SAVING THE GENE POOL:

GENEBANKS AND THE POLITICAL ECONOMY OF CROP GERMPLASM CONSERVATION

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Thesis submitted in fulfilment of the requirements for the degree of Doctor of Philosophy

2016

I, Sara Marques Mano Ivo Peres, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

For my family: Ivo, Graca, Raquel, and Ines.

ABSTRACT

In the 1970s, concerns about the erosion of genetic diversity of crops led to the establishment of genebanks, repositories for the conservation of plant genetic material, which raise interesting questions about the ways in which biobanking constructs and shapes bioeconomies. Past theorizations have shown that biobanks are part of new bioeconomies that complicate distinctions between social and economic values, and play essential role by managing the different values and priorities

In this thesis, I extend this approach to the conservation and use of crop germplasm. Plant genetic resources for food and agriculture circulate internationally in what I term the ‘germplasm economy’: a complex arrangement that is notable for including a novel multilateral system of mutual facilitated access and benefit sharing. Thus, here I analyse the practices and organisation of genebanks, as a means to explore their role in that economy.

Based on an interpretive, discourse analysis of documents and 22 semi-structured, qualitative interviews (with actors involved in gene banking policy and practice in Europe), I argue that genebanks construct the shared pool of plant germplasm by constructing ‘genetic resources’ from germplasm, therefore creating a gene pool that is technically and politically available for sharing in accordance with national and international germplasm policy. In so doing, they manage the different value(s) associated with germplasm in ways that enable and justify the international germplasm economy.

Hence, this work corroborates the perspective that biobanks of biological material manage and create the economies that they are part of. Yet, in addition, it suggests that genebanks themselves can be considered resources, and that this understanding is important in constructing the germplasm economy as one predicated on sharing Therefore, it suggests that analyses of biomaterial economies should take into consideration both studies of the bioeconomy and of the political economy of technoscience.

ACKNOWLEDGMENTS

This research would not be possible without the generosity of all those who kindly agreed to take part. Their insights make this work possible and I am very grateful to all of them for sharing their perspectives and considerable experience with me.

I am very grateful to my supervisors, past and present: Brian Balmer, Samuel Randalls and Gail Davies. Their insightful guidance, unwavering support, and enthusiasm for exploring this project was most appreciated. Their comments on the project and the resulting thesis have been essential in enabling me to carry out this project to its conclusion; any outstanding errors are my own. I am also indebted to Helen Curry for insightful feedback on the first chapter, along with fascinating discussions about a shared interest.

I would like to acknowledge the ESRC for the funding for this doctoral research; and the STS Department at UCL, FAPESP (Brazil) and the Society for Social Studies of Science for funding that enabled me to present this work at conferences. Many thanks are also due to all who, in various ways, aided me as I carried out this research: to the librarians at Bioversity International (Italy), Ben Emmett, and to Piero Valentini, Isabel Gomes, the Domingos and the Peres families for the shelter and good company during the various stages of this research.

I have always felt at home in UCL STS and could not have hoped for a more nurturing and rewarding department in which to carry out this work. I would like to thank all the departmental staff, especially Joe Cain, Chiara Ambrosio, Jon Agar, Simon Werrett, Jack Stilgoe, and Karen Bultitude. The PhD students have been the most wonderful colleagues and friends over the past years, and it’s been a pleasure to see the community grow to the point I cannot thank them all personally. Nonetheless, Tona Anzures, Yin Chung Au, Katherine Cecil, Jonathan Everett, Toby Friend, Hsiang-fu Huang, Elizabeth Jones, Oliver Marsh, Tom O’Donnell, Stephanie Radcliffe, Julia Sanchez Dorado, Melanie Smallman, Paul Smith, Erman Sozudogru, Raquel Velho, Samantha Vanderslott, and in particular Mat Paskins and Shana Vijayan provided endless inspiration and unforgettable times. Thank you.

Many others offered much joy and encouragement for the last four years, and I lucky to count them as friends. I'd like to thank all ex residents of Ainsworth Way, human and feline, for being brilliant housemates. In particular, I thank Ravi Sachdev for so many conversations about plants; and to Annie Hudspeth and especially Fred Carver for years of friendship and laughter. To Giles Barrett, for encouragement at the beginning. Thanks also to Nick Bannister, Dave Bishop, Perdita Jones, Harry and Sabrina McIntyre, Trudy Morgan, Andi Thomas, and everyone who has made Leytonstone feel like home from the start. To Claire Amos, Francesca Schiavone and all the STAMPEDE team. I'm grateful to Hafren Williams, for enjoyable LSE days library days. To Isabel Gomes, Marta Sobur, and Lara Verardo, who are never far from my mind. Heartfelt thanks to Preeta Datta, Imogen Lee, both doctoral inspirations and dear friends. I look forward to seeing you all soon.

I would like to dedicate this thesis to my family; Graca, Ivo, Ines and Raquel, with love. Our family history roots my current work in subtle ways. Obrigada.

The last few years have been challenging, exciting, and, above all, adventurous. It was a real pleasure to share them with Jon Emmett, whose amazing company, unwavering belief, and constant good humour (along with excellent proofreading skills) made this particular adventure so enjoyable. I look forward to our next one.

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ACRONYMS

AEGIS	A European Integrated Genebanking System
CBD	Convention on Biological Diversity, opened for signature in 1992
GCDT	Global Crop Diversity Trust, known as Crop Trust after 2015.
CIMMYT	International Maize and Wheat Improvement Center, Mexico; one of the IARCs of the CGIAR.
CGIAR	Consultative Group on International Agricultural Research
ECPGR	European Cooperative Programme on Plant Genetic Resources (previously, ECP/GR)
FAO	The United Nations' Food and Agriculture Organization
GPA	Global Plan of Action on Plant Genetic Resources for Food and Agriculture
IARC	International Agricultural Research Centre: research institutes of the CGIAR, often house large genebanks for the relevant crop.
IBPGR	International Board for Plant Genetic Resources. Established in 1974, later became known as IPGRI[1]

[1] http://www.bioversityinternational.org/about-us/who-we-are/history/. Accessed 10.08.16

IPGRI	International Plant Genetic Resources Institute. Successor to IBPGR, established in 1991. From 2006 onwards, this institution became known as Bioversity International.
IRRI	International Rice Research Institute, one of the IARCs of the CGIAR
ITPGRFA	International Treaty on Plant Genetic Resources for Food and Agriculture, opened for signature in 2001
MLS	Multilateral System of the ITPGRFA
PGRFA	Plant Genetic Resources for Food and Agriculture
SoWPGRFA	State of the World's Plant Genetic Resources for Food and Agriculture, published in 1996 and 2010 by FAO
WIEWS	World Information and Early Warning System on Plant Genetic Resources for Food and Agriculture

CHAPTER 1 INVESTIGATING THE GERMPLASM ECONOMY THROUGH GENE BANKS

1.1 Of seed vaults and genebanks: theorising conservation as part of the germplasm economy

In February 2008, the world's press descended on Svalbard, in the Arctic Circle, for the official opening of the Svalbard Global Seed Vault (SGSV) – also known in the media as 'the Doomsday Vault'. Since then, the SGSV 'has come to encapsulate the global imperative of conserving the biodiversity relating to the world's major food crops against the growing challenges resulting from rising human populations, lost [sic] of agricultural land and climate change' (Ambrose, 2010, p. 1). The Vault can house up to 4.5million seeds inside thick, reinforced concrete walls[2] and requires little active work. Indeed, it is designed to withstand impressive sea level rises due to climate change and the naturally low temperatures should be enough to preserve these seeds for centuries, should the artificial cooling fail. In other words, the Seed Vault could be said to invite a particular idea of genebanks as remote, relatively passive. From that perspective, places like the Vault can be portrayed as repositories for frozen seeds that are physically and metaphorically dormant and out of sight, kept as 'insurance' in response to a possibly apocalyptic future (Kera, 2013): a 'Noah's Ark for the world's seeds' (Qvenild, 2008).

Yet, although the Seed Vault at Svalbard is in all likelihood the most well-known of all genebanks, it is not a typical one: in contrast to the remote, mostly undisturbed Seed Vault, most genebanks are quite dynamic institutions that are engaged in accumulating, transforming, and re-circulating genetic resources. They are, in some sense, involved in a sort of 'germplasm

[2] http://web.archive.org/web/20100512065829/http://www.regjeringen.no/en/dep/lmd/campain/svalbard-global-seed-vault/description.html?id=464076 Accessed 18.07.16

economy' where actors across different institutions and countries manage the conservation of plant germplasm considered to be valuable, according to a particular imaginary of interdependence and public goods. Consequently, the real complexities and the most interesting questions about *ex situ* conservation (defined as conservation outside the original environment[3]) become apparent if we move our analytical focus away from the idea of banking as a one-off action – a deposit – to the idea of banking as an ongoing *process* that is relational and porous, as genebanks actively (re)produce both the genetic resources in their care and the germplasm economy of which they are part.

The fundamental argument of this thesis, consequently, is that studying the practices and organization of genebanks can provide helpful insights into the biomaterial bioeconomies they are part of (in this case, of plant germplasm), because following biobanks in practice provides empirical purchase on the way these repositories' activities create, accumulate, and distribute resources considered to be valuable. More specifically, focusing the analysis on biobanks, rather than on the use of genetic resources, brings into focus the relationship between the political economy of genetic resources and that of genebanking itself. I make this case by arguing that the contemporary germplasm economy, with its emphasis on cooperation and multilateral access (what I call a regime of sharing) is built on the idea that genebanking can only be at its most effective and sustainable only if actors agree to share the genepool *and* the responsibility for carrying out conservation of genetic resources. In that way, in the germplasm economy, the main priority is the continued 'flow' of germplasm, and the assurance of conservation into the future. The shared genepool and the germplasm economy are co-constructed in light of this rationale, where mutual access and cooperation are the stepping stones to the production of both social and economic values.

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[3] For published syntheses about the application of ex situ conservation to genetic resources for food and agriculture see for example (Hawkes, Maxted, & Ford-Lloyd, 2000; Engels, Rao, Brown, & Jackson, 2002)

The thesis is based on a study of the evolution of crop gene banking in the European region (with a focus in Portugal and the United Kingdom). Through interpretive analysis of a body of documents and 22 semi-structured, qualitative interviews with actors involved in gene banking policy and practice in Europe, I show that genebanks' role can be summarised as producing, maintaining, and disseminating *valuable* genetic resources. They play an important role in mediating the sharing of germplasm and data about germplasm, and people in the genebank community work cooperatively in conservation activities.

The findings in this study lead me to argue that genebanks permit the specific organisation of the germplasm economy. In that sense, they operate as the biobanks that Waldby and Mitchell (2006) analysed, such as the UK Stem Cell Bank. In that particular case, the authors note, the bank enables a novel sort of 'tissue economy' to emerge where *value and values* can coexist, because the bank takes on the work of ensuring the accumulation and circulation of embryonic cell lines. Genebanks enable the creation of genetic resources that are 'disentangled' and can be circulated in the multilateral system that characterises the germplasm economy. Therefore, genebanks enable and underpin the accumulation and re-circulation of resources (not germplasm, but also data and labour) in specific ways, which should be taken into account in our analyses of biomaterial economies.

Applying this conceptual approach to genebanks enables me to derive from the empirical data some insights about the contemporary developments in the workings of genebanks, namely, towards greater importance of facilitating use, towards the creation of regional databases for genebank data, and towards greater 'sharing of responsibility'. In so doing, I am contextualising conservation as part of a 'germplasm economy' through which germplasm and data circulate, and which bind together gene banks, users of germplasm, their producers, and others. In so doing, I aim to contribute to ongoing work in Science and Technology Studies and Geography about the circulation and accumulation of biomaterials in times of commodification (Hayden, 2003; Parry, 2004; Waldby & Mitchell, 2006).

This change in perspective from the idea of genebanking as depositing to genebanking as an ongoing process of value management bring to the fore some questions that are, I argue, inherently political economic, such as (a) what material should be conserved – or, in other words, what constitutes 'valuable enough' material; (b) how should the costs and benefits of conservation be distributed, and (c) under what terms should it be used or exchanged. Simultaneously, it opens these matters up for an STS analysis that takes into consideration the material practices of genebanks as well as the interpretation of the governance framework for genetic resources conservation.

Even though the Seed Vault is not part of my main empirical focus, it is a good place to begin this discussion because its existence leads to two important insights regarding genebanking and the germplasm economy, which orient the thesis. The first noteworthy aspect is that the Seed Vault is, as its official webpage points out, 'no ordinary gene bank, where scientists and others can apply directly to access seeds (…) [it] is a safety stock for these local deposits, which can be used to recreate valuable plant varieties whose seed collections in a local gene bank are lost'[4]. The SGSV was described as

> *'… the ultimate insurance policy for the world's food supply, offering options for future generations to overcome the challenges of climate change and population growth. It will secure, for centuries, millions of seeds representing every important crop variety available in the world today. It is the final backup.'5*

Having seeds at Svalbard ensures that the genetic material contained within is 'backed up' in the event of the loss of the 'original' material in other seed

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[4] https://www.regjeringen.no/en/topics/food-fisheries-and-agriculture/landbruk/svalbard-global-seed-vault/en-ekstra-beskyttelse/id2365112/ Accessed on 07.12.15

[5] https://www.croptrust.org/what-we-do/svalbard-global-seed-vault/ Accessed on 07.12.15.

banks. Duplicating stored genetic samples is recommended as good practice in genebank management (FAO, 2014, p. 57; SGRP CGIAR, n.d.) as a way to prevent loss of material, be it due to catastrophic losses or, as is often pointed out in the primary literature, as a result of rather more everyday losses (Fowler, 2008), such as those caused by equipment breakdown or staffing issues which can, and do, affect various collections. This insight is significant because it means that genebanks, although conservation measures, are, in some sense, vulnerable to the loss of genetic resources and need their own insurance. In turn, it raises questions – that are at once technical, social, and economic – about what genebanks are, and what it takes to keep a collection going.

Figure 1 'Svalbard Global Seed Vault' by Dag Terje Filip Endresen on flickr. Licensed by CC-BY-2.0. See footnote 6 for details.

Secondly, the very existence of the Seed Vault (depicted in Fig. 1[6], above) is explicitly related to the shift towards a recent arrangement of the germplasm economy, that follows what one might call the sharing rationale. The SGSV is an illustrative component of a complex economy of conservation and access to seeds that transcends borders but where conservation can be a global concern just as seeds are simultaneously resources under national sovereignty. Its operation demonstrates both the entanglements between conservation and use and between politics and pragmatism. International cooperation is emphasised, but simultaneously, the national sovereignty of countries with respect to their own genetic resources is enshrined in international treaties. It is because of this link that the SGSV was described as 'a global backstop' and 'a cornerstone in the global system' (Westengen et al, 2013) considered to be emerging after the negotiation of the International Seed Treaty in the early 21st century (Hodgkin, Demers and Frison, 2012). Its very existence can be understood as an enactment of the perceived interdependence (see section 1.3) between countries with respect to genetic resources. In that sense, it represents a continuity from the inception of structured programmes of genetic conservation by the International Biological Programme and FAO in the 1960s and 1970s, that were envisioned as a global endeavour (see eg Frankel, Bennett, & others, 1970; in Peres, 2016). Yet, as I will return to in section 1.3, the suggestion that conservation should be organised solely at the international level has been eroded considerably since then.

Given the relatively complex negotiations regarding the control over genetic resources, it is significant to hear proponents of the Seed Vault and the Multilateral System (established by the International Seed Treaty, whereby

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[6] 'Svalbard Global Seed Vault' by Dag Endresen on flickr (ctril+click link for image). CC-BY-2.0 license: https://creativecommons.org/licenses/by-nc-sa/2.0/legalcode .

countries agree to provide access to a subset of crops thought to be particularly important for food security) use concepts like ‘the world’s food supply’[7] and the creation of a ‘global system’ (Hodgkin, Demers and Frison, 2012). Clearly, they draw links between countries’ fears of expropriation and biopiracy, lack of collaboration between countries, and the fragility of genebanks:

> *‘…over the past 20 years, many countries have closed their borders to outgoing samples for fears of “biopiracy” (…) consequently, some of the world’s most important gene banks (…) have not provided a single sample to a foreigner in years, even though gene banks are highly dependent on crops and crop diversity that originate elsewhere. The jealous guarding of such collections has rarely been matched by funding adequate to their conservation. National gene banks have languished, and the biological diversity in their care has deteriorated or even been lost. Collections became victims to anaemic budgets and a reluctance to allow genetic resources out of their native country, even if only for safety duplication. This depressing background explains why a Plan B was desperately needed, yet almost impossible to imagine’ (Fowler, 2008, p. 190).*

Hence, the opening of the Svalbard Seed Vault is telling, because its very existence is only considered to be possible because of a shift in the international genetic resources policy framework; towards a more cooperative ‘Multilateral System’ of access and benefit-sharing. The principle of this system is that parties are exhorted to pool their resources and share the benefits, rather than operate through individual negotiations and bilateral agreements, as is the case with other biodiversity. However, that sharing rationale is rather contingent and ambiguous in parts, as reflected, again, in the very workings of the Seed Vault. That ‘Plan B’ was itself made more difficult by concerns about expropriation. The idea of setting up a global seed vault at Svalbard was first mooted in the 1980s, but only came to fruition in 2008, precisely because of fears by depositor countries of expropriation of

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[7] https://www.croptrust.org/our-work/svalbard-global-seed-vault/. Accessed on 01.03.17

’their’ germplasm. According to seed conservationists associated with the Crop Trust, ‘it took almost 20 years before the technical, legal and political context allowed the idea to be realized. The most important factors were the long, and at times politically polarized, international processes and negotiations regarding the conservation and sustainable use of PGRFA’ (Qvenild, 2008; Westengen, Jeppson, & Guarino, 2013) (or plant genetic resources for food and agriculture – a definition further discussed in 1.2.1).

So, the establishment of a global back-up was complicated by the need to provide reassurances that the material within would not be shared with others against the wishes of the depositors. In fact, the Vault operates a so-called ‘black box system’ whereby only the depositor can withdraw the seeds deposited. Paradoxically, for the vault to be global, the seeds within must remain effectively separated from other deposits in terms of access, in that only depositors can retrieve it. This story illustrates a tension between the conceptualization of PGRFA as resources under national sovereignty, but also resources that are said to be of ‘global concern’. If the Vault represents a ‘global backstop’, it must also ensure that the sovereignty of countries over ‘their’ material is respected, if it is to operate at all.

Svalbard matters for the broader discussion about genebanks because its existence is a sign of the contemporary situation with regards to the germplasm economy: genebanks are thought to have valuable material; yet they require a ‘backup’, and international cooperation is the way to ensure that genetic material can exist. In other words, the germplasm economy and its organisation is as much about the fragility of conservation as it is with its use. The emergence of the Seed Vault indicates that the ways in which crop seeds are conserved are bound with ideas about how biological material should be shared, with whom, and under what circumstances. Moreover, one might argue that the establishment of the Multilateral System as part of the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA, 2001) (further discussed in 1.3) appears to represent a new phase in conservation, where projects like the SGSV become possible. This shows how gene banks, far from being passive repositories for plant material frozen in time, are instead nodes in networks that include other gene banks, farmers, breeders, scientists, and policy actors; and through which 'flows' germplasm – that is, the material containing the inheritable material in plants. From this perspective, then, gene banks can be conceptualised as nodes in what I have termed the 'germplasm economy' of crop genetic diversity. In the sections that follow, these suggestions will be explored in greater detail, leading to a suggestion of an empirical and analytical approach to the investigation of this economy.

For the rest of this chapter, then, I will develop the argument that this change in perspective is helpful in contributing to our understanding of how genebanking figures in the contemporary economies of plant genetic material. After introducing gene banking and discussing how it has been conceptualised in academic work thus far, in section 1.2; in section 1.3 I provide an overview of *ex situ* conservation in the context of the changes to genetic resources policy and argue that understanding genebanks requires attention to the double role of conservation and facilitation of use: it has long been shaped by concerns and ideas about how they should be distributed. So, in 1.4 I set out a different approach that instead focuses on the role of genebanks in germplasm economies, and present the research questions that drive this current research project; before outlining the remainder of the thesis in section 1.5.

1.2 Genebanks as sites for the (re)production of genetic resources: introduction and existing work

In this section, I define important concepts pertinent to genebanking and introduce the principles of genetic conservation. Concurrently, I present and discuss existing academic perspectives from the humanities and social sciences that begin to situate and interpret genebanking in different ways – and which presents several insights that illustrate the richness of genebanking as a topic for STS, despite its relatively scarce presence in the literature, especially as a main focus (but see Hebditch, 2009; Saraiva, 2013; Peres, 2016). This review leads me to argue that while these few publications make important contributions to our understanding of genebanks, there is thus far little specific attention to what happens within genebanks themselves. Yet, as I argue in this section, it is at these sites that plant material is (re)produced as plant genetic resources that are made mobile and shareable. This analysis requires empirical, qualitative analysis of genebanking that place them in a broader context: what I have called the 'germplasm economies' that genebanks are part of. Exploring the practices and organisation of genebanks would therefore provide an example of the 'germplasm economy' in action by considering the ways in which genebanks construct the shared gene pool.

In their broadest definition, gene banks are repositories for the preservation and maintenance of genetic material. Hence, the term can be applied to a variety of different organisms, as well as kinds of repositories and organisations. A gene bank can refer to a collection of genetic material from animals, plants or other organisms; but seems to be defined by the collection of genetic information in a material form – that is, as strands of DNA that may be free-floating or incorporated into the cells or tissues of particular organisms.

The genebanks that concern us here are those specifically targeted to crop plants. The *Dictionary of Plant Genetic Resources* defines genebanks as '1. A genetic resources centre where genotypes (as seeds, pollen or tissue culture) are stored.' (IBPGR, 1991, p. 70). By 2010, the definition of genebanks included DNA samples or sequences in libraries (see eg Engels & Fassil, 2011, p. 153) – although, in contrast to germplasm, DNA does not enable the self-replication of material. This indicates that the definition of a genebank has developed over time, with DNA banks becoming increasingly interesting to conservationists (Savolainen, 2006; Vicente & Andersson, 2006). This is significant, as it indicates that the perception of what counts as a possible 'source material' for preservation has changed with the development of different biotechnological techniques that have permitted the long-term storage of these materials. Genetic resources are conceptualised as biophysical *and* informational resources (Halewood, 2013), and that belief influences the ways in which they are accumulated and disseminated (Parry, 2004).

Genebanks, then, are repositories for the conservation of genetic diversity, but they act on the material basis of those alleles, or germplasm. The purpose of these collections is to conserve plant genetic diversity through 'genetic conservation', that is, 'the collection, maintenance and preservation of intra- and inter-specific *variation,* e.g. a representative sample of the genetic variation of a particular species' (IBPGR, 1991, p. 72). Plant conservationists undertake genetic conservation through the preservation of *germplasm*, or material containing functional units of heredity. It should be emphasised that the conservation of crop genetic diversity does not necessarily require genebanking. In fact, there are two main approaches; *in situ*, referring to the conservation of populations within their natural environment, and *ex situ*: outside its natural environment, in genebanks. *Ex situ* 'comprises methods which allow the maintenance of genetic integrity of collected germplasm samples outside their natural habitat' (Engels & Fassil, 2011, p. 145). In contrast, *in situ* conservation necessarily means caring for specific populations in their place of origin. *Ex situ* conservation was identified as the main priority for conserving valuable genetic resources (Frankel et al., 1970) and was the preferred method of conservation by most plant breeders, following Otto Frankel; however, since the 1990s, this situation has reversed, in that *in situ* is now understood as the most important approach with *ex situ* considered as a complementary method of conservation.[8]

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[8] Although this change is significant in its potential geopolitical implications, it remains relatively tangential to this particular work. In the current thesis, *in situ* conservation is discussed solely in relation to genebanking, as a means

We should consider the emergence of genebanks as part of the broader context of changes to agricultural research and development, and particularly plant breeding. There were quite significant changes to the organisation of the plant sciences and industry during the 20th century, from the development of plant breeding in light of Mendelian genetics (Palladino, 1993, 1996; Harwood, 2015), the shift towards the privatization of agricultural knowledge production, and its implications for agricultural research and policy (Byerlee, Echeverría, & others, 2002; Goldman, 1998), the Green Revolution (Perkins, 1997; Yapa, 1993) and the development of a food security discourse (Nally, 2015), and indeed the centralisation of the seed industry (the majority of seed sales are now sold by a handful of multi-national corporations.) Of particular relevance for understanding the case of genetic resources conservation are the changes to plant breeding. The paradigmatic case here is that of the Green Revolution. Up to the 20th century, crops were 'narrowly' adapted to particular environments, and were derived from endogenous varieties that had evolved in those environments. Yet, with the development of new, scientifically bred varieties (Yapa, 1993) that were designed to be used in a variety of different environments, there was a progressive homogenization of the crop varieties used worldwide, including in genetically diverse areas. As a result, these old crops were being used less often in favour of newer, higher-yielding varieties; leading to 'genetic erosion' of the intra-specific diversity within important crop species.

According to Otto Frankel and J. G. Hawkes, both important actors in the establishment of the 'plant genetic resources movement', the 1960s saw both a 'rapidly growing interest in the primitive cultivars and the immense range of

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to delimit the scope of the research. For further work on *in situ* conservation readers are referred to, among others, (Brush, 1991; Zimmerer & Douches, 1991; Brush, 1995; Graddy, 2013, 2014). However, it is important to emphasise that 'in situ' and 'ex situ' are actors' categories, and other analysts have interrogated their purpose. Specifically, Braverman (2014) argued that the dichotomy of in and ex situ conservation is, in any case, restrictive and 'incompatible with ideas of naturecultures and multinatures'; however, in my research it maintains its relevance as an actors' category variation they contain, and in the wild relatives of economic species, many as yet scarcely explored and exploited' and increasing warnings of a 'greatly accelerated rate of displacement of primitive crop varieties by locally selected or introduced cultivars' (Frankel & Hawkes, 1975, p. 1). Engels and Fassil, too, suggest that the recognition of the value of genetic diversity came from the disappearance of genetic diversity coupled with the breeders narrowing the genetic base of crops (2011, p. 146). So, domestication and agricultural practices mean that only a very small part of the potential 'genetic base' has been utilised in breeding: 'this focus [of breeders] on a relatively small number of genotypes with desirable traits meant that a large amount of potentially useful genetic variability was excluded from breeding programs' (idem).

Metaphors such as that of the 'treasure chest' (FAO, 2010, see Figure 2 below) are, I would argue, used to convey the value of genetic resources – and, *qua* metaphors, these concepts structure how actors deal with, and apply meaning to, genetic resources and their conservation (Lakoff & Johnson, 2003 [1980]). Plucknett et al. (1987, p. 3) claim that

> *'Boosting and sustaining agricultural productivity, the sane alternative to a further deterioration of remaining wild areas and marginal zones, embraces scientific, social and political concerns (…) Plant breeding, an outgrowth of genetics, has a central role in the worldwide effort to improve agricultural output, and breeders rely on genetic resources to produce better-adapted and higher-yielding varieties. Maintaining the genetic diversity of crops as well as conserving wild plants and animals has thus become a central principle in strategies for sustainable agricultural development.'*

Altogether, then, the situation with respect to genetic resources firmly ties their conservation with their characterisation as a source of potential value, a 'treasure chest' that consequently deserves protection and inspection – but whose value, necessarily, depends on its use. Genebanks, like botanic gardens, are a form of *ex situ* conservation, that is, where the material is kept outside the environment in which it was evolved. For that reason, they are also considered (with the exception of field gene banks) to be an evolutionarily ‘static’ form of conservation, in the sense that the biological material is not continuing to evolve in response to the evolutionary pressures of its original habitat. Often, they store the genetic diversity at the intra-specific level (rather than at the species level).

> **“While genetic diversity represents a ‘treasure chest’ of potentially valuable traits…, it is under threat and special efforts are needed to conserve it both *in situ* and *ex situ*, as well as to develop a strong capacity to use it, especially in the developing world”.**
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> **FAO. 2010.** *The Second Report on the State of the World’s Plant Genetic Resources for Food and Agriculture.* Chap. 8, The Contribution of PGRFA to Food Security and Sustainable Agricultural Development. pp.184–185. FAO. Rome, Italy.

Figure 2. An example of the use of value metaphors in describing the conservation and use of genetic resources. Source: Food and Agriculture Organization of the United Nations, 2010[9], p. 12. Reproduced with permission

Entries in genebanks are known as *accessions.* They represent the ‘sample, cultivated variety, strain, or bulk population maintained at a genetic resources centre or in a plant breeding programme, for conservation or use (…) which is held in storage’ (IBPGR, 1991, p. 1). They must be representative of the genetic diversity within a particular population. Hence, the number of individuals represented within an accession depends on the type of reproduction of the crop in question (when they are clonal, one accession might be material from one individual; but for open-pollinated plants it might be the collected gametes from a few hundred to a few thousand).

Currently, there are over 1750 genebanks around the world (FAO, 2010, p. 55). These repositories can (and do) vary considerably in terms of scope,

[9] The Second Report on the State of the World’s Plant Genetic Resources for Food and Agriculture in brief. Available at http://www.fao.org/docrep/013/i1500e/i1500e_brief.pdf

specialising in one or in multiple crops, and storage capacity. For instance, the largest public genebanks are those established within the agricultural research institutes of the Consultative Group on International Agricultural Research (now CGIAR); such as the rice collection at the International Rice Research Institute (IRRI, Philippines, with 131,863 rice accessions, the largest in the world) and wheat and maize at the International Centre for the Improvement of Wheat and Maize (CIMMYT, Mexico), which stores 164,320 samples of maize and corn (in beige in Figure 3, below).

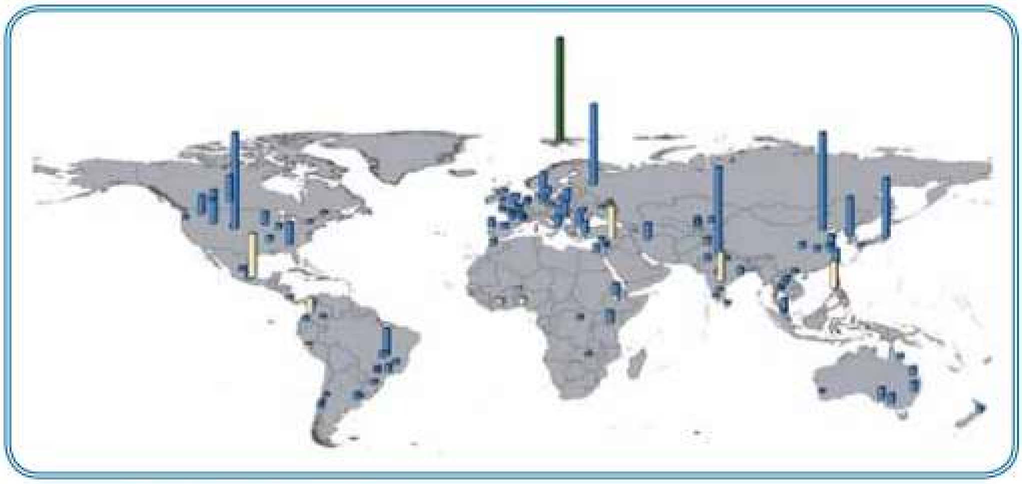

Figure 3. The geographical distribution of genebanks with >10,000 accessions. Here, the Seed Vault is green, national or regional genebanks are blue (beige corresponds to CGIAR genebanks). Source: Food and Agriculture Organization of the United Nations, 2010[10], p. 56. Reproduced with permission.

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Genebanks can contain many hundreds of thousands of samples, and are dedicated to one or a few crops. The largest national genebank collections

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[10] The Second Report on the State of the World's Plant Genetic Resources for Food and Agriculture. Available at http://www.fao.org/docrep/013/i1500e/i1500e.pdf

are situated in China (Institute of Crop Science, Chinese Academy of Agricultural Sciences, 391,919 accessions), India (National Bureau of Plant Genetic Resources, 376,238 accessions) and the USA (384,876 accessions at the National Center for Genetic Resources Preservation)[11]. Yet other genebanks can be considerably smaller, with tens or hundreds of samples. Hence, the institutions that are carrying out genetic conservation as part of the same germplasm economy can have rather different capacities or practices.

1.2.1 Plant germplasm as 'genetic resources': conserving what?

Ex situ conservation in genebanks involves the preservation of the germplasm in plant material. This can exist in many different formats – from seeds to in vitro cultures, in field gene banks, or – increasingly – DNA banks. With respect to crop plants this can refer to *seeds* (that make up the vast majority of genebank holdings, at over 90%), whole plants/trees, cultured tissues, or even embryos in the case of coconuts. Even though genebanking techniques involve the preservation of plant *material*, the objective is the conservation of the DNA within – and, consequently, of the alleles and genotypes found in different populations.

So, in fact, seeds are figured as 'primarily a convenient form of gene storage': *proxies* (van Dooren, 2009, p. 391). This concept was developed by Parry (2004) in her analysis of the ways in which biotechnology and the information sciences come to bear on the circulation and commodification of biomaterial. The introduction of biotechnological and information technologies in the 1970s permitted the creation of increasingly 'decorporealized' *bio-informational proxies* which make their genetic or biochemical characteristics

[11] This data is available through FAO's WIEWS (World Information and Early Warning System on Plant Genetic Resources for Food and Agriculture) http://www.fao.org/wiews/map-test/en/. Accessed 18.07.16

easy to isolate and manipulate (idem, p. 65). These can have a material expression; for instance in the case of cell cultures or cryogenically frozen specimens; or be fully digitalized, as in the case of DNA or protein sequences (idem, p. 68). Parry and van Dooren characterise a seed as a proxy for a plant, so that it reduces the organism to some essential characteristics, losing some of its corporeality and much of its context.

Figure 4. 'Inside the cold store' by Luigi Guarino on flickr[12]. Photograph of the cold store of the USDA genebank at Ames, Iowa. Licensed under CC-BY-2.0.

Genebanks' focus on the utilitarian, informational aspects of banked material has led van Dooren to critique them as limited conservation tools. Writing from an environmental philosophical perspective, he notes the reductionist nature of genebanks, where what can be kept is only a 'unique kind of

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[12] 'Inside the cold store by Luigi Guarino on flickr (ctrl+click for image). License: https://creativecommons.org/licenses/by/2.0/legalcode.

instrumentalised genetic life' (van Dooren, 2009, p. 375).[13] 'Genetic diversity' is but a small proportion of biocultural diversity, broadly understood. They are geared primarily towards the conservation of the rather less tangible 'genetic resources'. Hence, a genebank is limited as a conservation tool. A genebank is utilitarian and geared towards the needs of few groups (he identifies plant breeders). Moreover,

> *'Through its use of seed as a conservation-proxy it fails to contribute to the maintenance of existing biosocial natures, it fails to adequately conserve and value the other diversities that are still vulnerable (both 'biological' and 'cultural') when genes are banked, and so sees no necessity in a broader sharing that keeps plants growing and their seeds moving in environments and amongst people.' (van Dooren, 2009, p. 387)*

It is clear that while genebanks store *material*, they are not necessarily keeping all plant biodiversity; instead, what is banked is there because it is valuable. As defined in plant genetic resources-related scientific literature 'genetic resources' are 'germplasm of plants, animals or other organisms containing useful characters[14] of actual or potential value. In a domesticated species, it is the sum of all the genetic combinations produced in the process of evolution' (IBPGR, 1991, p. 74). However, since then this concept has also

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13 Yet, this is not to say that van Dooren thinks we should not have genebanks, Rather, it is a matter of deciding what it means to (using Derrida) 'bank well'. Again, this suggests that there is something interesting about ex situ conservation in that it can unfold in many different ways; therefore, the way in which it is constituted tells us much about the priorities, the needs, and the preoccupations of the actors who are driving forward genebanking.

[14] Characters refers to 'the phenotypic expression, as a structural or functional attribute of an organism, resulting from an interaction of a gene or group of genes with the environment.' (IBPGR, 1991: 26). In contrast, specifically genetic characters are 'any observable trait in the development of an individual. Each developmental step may be governed by different genes which provide the potential for a character to be expressed. The actual expression is, however, also dependent on the genetic and external environments.' (IBPGR, 1991, p. 72).

become a *legal* definition that applies to plant material of actual or potential value for the purposes of food or agriculture (CBD, 1992; ITPGRFA, 2001).

This definition raises two interesting points: firstly, that it applies to only a subset of all plant life: that which is considered valuable or useful to actors (especially plant breeders or other scientists, but also increasingly other groups such as farmers), generally because it is economically valuable or rare. Secondly, the encompassing of *potential* value as well as actual value means that the concept of plant genetic resource can apply to samples which are not currently in use, but which could have use value in the future. Hence, the value of genetic resources is articulated in terms of their utility – but, given that future needs are unknowable, actors consider it valuable to maintain a diverse set of germplasm.

Although van Dooren identifies and comments on the conservation of only a subset of biodiversity, as well as noting that the value of plants is reduced to 'use value' for plant breeders, his work does not consider how these seeds might be made into genetic resources in the first place. And yet, as Hamilton (2008) has suggested, the transformation of natural seeds to 'genetic resources' makes

> *'…nature thinkable in new ways. What sets this new concept of resources apart is that it relates specifically to the genetic aspect of these resources, something which creates a dramatic new category in our understanding of our environment. No longer, it would seem, are issues of resources limited by the tangibility or even corporeality of resources. Thus, genetic resources become thinkable and contestable: in a word, they become governable' (Hamilton, 2008, p. 1754)*

So, in what ways is the genebank transforming the germplasm into a genetic resource of actual or potential value? How is that, in turn, related to the organisation of the germplasm system itself? Here, an STS approach would be able to go further in interrogating the relation between seeds and genetic resources. It is my suggestion that such a move between germplasm and genetic resource is likely to illuminate what is considered to be valuable, and to whom. Doing so will, I argue, require a careful exploration of how plant material is treated, evaluated, and conceptualised once it is in the genebank.

1.2.2 Genebanks as archives: managing the conservation and use of genetic diversity

One particularly interesting aspect of genebanks is their objective of ensuring that material is preserved for the future. It is to that end that material is preserved in different ways to extend its lifespan. Seeds, for instance, make up the vast proportion of banked materials (FAO, 2010). This approach is 'the best researched, most widely used and most convenient method of *ex situ* conservation' (Engels & Visser, 2003, p. 65). Protocols for seed conservation involve the reduction of the moisture content of seeds and storage at low temperatures (FAO, 2014; Harrington, 1970). In the case of seed banks, the materiality of seeds was exploited in order to increase the longevity of the seeds through technological means. The storage of seeds in banks aims at lengthening their 'natural' longevity: for example, an encyclopedia entry on genebanks by Ambrose (2010) states that 'seed longevity and their ability to withstand severe environmental stresses enable *seeds to persist as a natural seed bank in the soil*' (my italics): statements of this sort draw a continuity between the 'natural' physiology of seeds and their preservation through drying and cold storage. Yet other approaches exist, and these can be more technologically intensive: genetic material can be kept in cryogenic storage, tissue culture, or trees in the case of clonal species. Again, the aim is to ensure that genes would not be lost due to the non-cultivation of material in other places.

Other scholars have noted that genebanking is an example of the drive to 'archive nature' which has become increasingly feasible (and desirable for some actors) with the development of biotechnology and digital technologies in the 21st century (Bowker, 2005, p. 1102; Waterton, Ellis, & Wynne, 2013, p. 122). They present a critique of genebanking that shares common ground with van Dooren's. Drawing from Derrida's work in *Archive Fever* (Derrida & Prenowitz, 1995) they argue that these repositories may suggest the possibility of creating a total archive of biodiversity, but that is illusory – what is kept will necessarily be a pared-down *representation* of diversity, even as it seems to contain the richness of biodiversity.

This suggestion, thus, again points to the potential issues with conflating genes with plant life; and makes evident the issues with *ex situ* conservation – but it too starts from the assumption that genebanks should be framed as mainly projects of conservation, comparable to, say, a zoo or protected area. And doing so omits some other interesting questions about what it means to conserve genetic material for the future in these circumstances. I have previously argued that the purpose of gene banks is to enable recall, that is, the retrieval of 'old' (that is, non-modern) crop varieties from an archive, where they are kept as representatives of the past (Peres, 2016). The purpose of seed banking hinges on the idea that it is possible to maintain, to a considerable extent, the 'genetic integrity' of accessions when they are in storage.

In the Foreword to the most recent State of the World's PGRFA Report, the Director-General of FAO reiterated that

> *'the need to conserve and sustainably use the world's plant genetic diversity is more critical than ever (…) The continuing loss of plant genetic resources for food and agriculture greatly reduces our options, and the options of future generations, or adapting to these changes and ensuring food security, economic development, and world peace'.*

He emphasised that delay in doing so would be risky for people and for the environment, and that it was

> *'both sound economic management and a moral imperative to conserve the resources that millions of years of evolution and thousands of generations of farmers all over the world have given us, and use them sustainably and profitably, to*

ensure that we can feed the generations to come' (FAO, 2010, para. 3 of the Foreword)

As this argument demonstrates, the conservation of genetic resources is very firmly embedded in broader narratives about the need to protect material because it is *valuable for the future*. Hence, genebanking emerges as the right thing to do in the sense that it fulfils both a social good and is potentially economically valuable – in that it is the basis for the future of agriculture. Yet, it is also clear that there is an intense future-orientation to these projects of genebanking, which recall those of other archives of science, such as astronomical observations (Daston, 2012). Importantly, the conservation of material is done prospectively, that is, present observations are kept for an imagined community of future users. However, I would argue that genebanks are effectively an *a priori* collection of material whose use is largely *under*determined, in the sense that it is unpredictable when or where they might be useful – or for whom.

This insight is particularly interesting because seeds are artefacts, whose constitution is very much hybrid and biocultural - a theme which is commonly remarked by authors writing about germplasm conservation; (Busch et al., 1995; Van Dooren, 2007), (Bonneuil, Foyer, & Wynne, 2014). As Busch et al (1995, p. 6) note, nature is socially constructed - and 'by making nature, particularly in the production of food and fiber, we produce and reproduce ourselves as well'. This volume, albeit constuctionist in nature, makes the important point that the growing homogeneity in human culture is mirrored in that of its crops.

'Cultivated plants and farm animals are as much cultural artifacts as are machines. Their cultivation is dependent upon and intertwined with a host of other cultural artifacts, including institutions. Domesticated plants and animals are only the most visible material aspects of social decisions and social structure. Hence, plants and animals fade into nonuse, even oblivion (as is the case for many landraces that are no longer cultivated), as soon as we cease to care for them, as soon as the social structures of which they form a part change.' (Busch et al., 1995, p. 6)

The idea that we reproduce ourselves and our cultures with our seeds is a pertinent one: it means that we do this reproduction along specific lines and not others, but these directions are multiple and contingent. As Donna Haraway puts it, seeds are iterations of the 'material-semiotic offspring of the mutated space-time regime of technobiopower, along with fetuses, databases, genes, brains, ecosystems' (Haraway, 1997, p. 11). In so doing, she emphasises their (material-semiotic) *malleability* in a time of biotechnological applications, and their hybridity, in that they simultaneously incorporate, and are constructed through, cultural practices (be they scientific or not),:

> *'A seed contains inside its coat the history of practices such as collecting, breeding, marketing, taxonomising, patenting, biochemically analysing, advertising, eating, cultivating, harvesting, celebrating, and starving. A seed produced in the biotechnological institutions now spread around the world contains the specifications for labor systems, planting calendars, pest-control procedures, marketing, land-holding, and beliefs about hunger and well-being' (Haraway, 1997, p. 129).*

This is particularly the case with domesticated seeds, where each generation replicates/represents the choices of the people who cared before, and the environment where people and plants interacted. In this way, the genome of domesticated plants could be said to contain the story of its evolution within a particular environment and culture: in fact, one could argue that it is for that very reason that seeds are being preserved in the first place. In other words, if seeds are proxies for genetic resources, one might also argue conversely that genetic resources are proxies for the evolutionary history of specific crop population: in other words, they are there as a means of preserving traits. Hence, *ex situ* conservation is presented as form of 'insurance' for the future (Li & Pritchard, 2009) and the material they contain is described of being 'of actual or potential value' but is kept without a particular knowledge of when/where it might be used.

This particular characteristic is highly significant, because it means that the *decisions* made about how to organise, maintain, or manage the collections of germplasm in genebanks must be done by recourse to a particular future-orientation, as well as present concerns or characteristics. The value of a particular genetic resource is not known in advance, because its usefulness (or potential user) has not necessarily yet been determined. One might argue that this is not, per se, significant: after all, the point is to conserve material *so that* it is possible to make use of that material in the future. As Radin (2015) has shown, other archives have been faced with this question and sought to develop strategies for the organisation of their collections that would match the requirements of future users (ie planned hindsight). So, genebanks not only have to carry out preservation of material, but also to do so in a way that ensures it is available for future use. In other words, material has to be kept in such a way as to make it available for 'recall' out of the genebank.

The collection and deposition of material in a collection is just a part of the process of conservation. There are, in addition, posterior steps that matter: these include the registration, characterisation *and evaluation* of plant materials (Villalobos & Engelmann, 1995; J. Engels & Visser, 2003; Upadhyaya, Gowda, & Sastry, 2008) , or circulated in the future. Hence, we should think about what it takes to maintain these collections, not just create them. This means extending the analysis of genebanking away from the idea of depositing material – one event, at one time – to that of maintenance – which requires a longer perspective. Thinking about what it takes to maintain collections is important because it makes visible the ongoing work/costs of conservation, which should be part of analyses of the organisation and practices of genebanking. This is particularly significant because what is being kept is not data, but genetic material, and the maintenance of the genetic integrity of samples is tricky, given that it involves preserving material without disturbing the invisible distribution of alleles in the sample. This is particularly significant because what is being kept is not data, but genetic material, and the maintenance of the genetic integrity of samples is tricky, given that it involves preserving material without disturbing the invisible distribution of alleles in the sample.

Bowker's work on the large biodiversity data archives is important here. He develops an account of the creation of increasingly 'global' archives of data about biodiversity, noting that the process of creating these involves a deterritorialization and a-temporalization which produce apparently objective data (Bowker, 2005) and makes quite a specific analogy to genebanks. Germplasm becomes, through conservation, 'de-territorialised' and mobilised so it can be used in the future, anywhere in the world and in under any circumstances (Whatmore, 2002, pp. 91–116). This approach leads to important questions about the role of archiving practices themselves in the creation or transformation of the value of genetic resources. This means that we need more accounts of how genebanks work in practice, and how this germplasm is made visible, mobile, and valuable through the work of the genebank itself.

1.2.3 Genebanks as banks: bioprospecting- and value

Elsewhere, I have suggested that seed banks enabled the preservation of seeds from different regions in the same place, thus enabling the creation of 'globalized' collections (in contrast to more locally situated, *in situ* collections) (Peres, 2016). Changes toward broad-adaptation high-yield varieties internationalized the value of genetic resources, as, for instance, genes from Japanese varieties made their way into wheats bred in Mexico and eventually grown across different regions. So, the material in a gene bank is kept so as to be disseminated out again, and this is a considerable part of the activities of the genebank itself. It is therefore important that these activities figure in our analyses of genebanking practices.

The spatial distribution of genebanks around the world is not even – nor does it map onto the distribution of genetic diversity worldwide. Vavilov's work on the evolution and distribution of plants posited that the greatest amount of crop variation was to be found within 'centres of

origin' (Vavilov, n.d.), many of which are in developing countries. Yet, many genebanks are situated in developed countries and therefore there has long been a 'flow' of genetic resources from their countries of origin to other places when they are deposited in genebanks. For illustration, the table in Figure 5. Number and percentage of indigenous accessions in genebanks from that country. Source: Food and Agriculture Organization of the United Nations, 2010, p 69. Reproduced with permission.

(below) demonstrates the relative proportions of endogamous material held in genebanks in different regions.

Region	Subregion	Number of indigenous accesions	Total number of accessions (*)	% of indigenous accessions
Africa	West Africa	32 733	40 677	80
Africa	Central Africa	934	18 829	5
Africa	Eastern Africa	100 125	119 676	84
Africa	Sourthern Africa	40 853	41 171	99
Africa	Indian Ocean Islands	131	273	48
America	South America	145 242	180 604	80
America	Central America and Mexico	41 370	51 513	80
America	Caribbean	13 746	23 671	58
America	North America	114 334	521 698	22
Asia and the Pacific	East Asia	179 055	255 673	70
Asia and the Pacific	South Asia	420 019	443 573	95
Asia and the Pacific	Southeast Asia	74 466	137 763	54
Asia and the Pacific	Pacific	42 649	188 988	23
Europe	Europe	354 015	939 620	38
Near East	South/East Mediterranean	66 363	73 428	90
Near East	West Asia	54 735	55 255	99
Near East	Central Asia	20 375	25 283	81
World		**1 701 145**	**3 117 695**	**55**

* Total number of accessions whose country of origin is reported.
Source: WIEWS 2009

Figure 5. Number and percentage of indigenous accessions in genebanks from that country. Source: Food and Agriculture Organization of the United Nations, 2010[15], p 69. Reproduced with permission.

15 The Second Report on the State of the World's Plant Genetic Resources for Food and Agriculture. Available at http://www.fao.org/docrep/013/i1500e/i1500e.pdf

Genebanks, like botanic gardens before them, enabled the preservation of genetic resources in places that were not their country of origin – contributing to their circulation and accumulation in different places. Figure 5 (above) demonstrates the distribution of the largest genebanks worldwide. This has been remarked on by activists involved in campaigns against what they see as the expropriation of valuable genetic resources from the Global South. As the quote below indicates, the process of genebanking involves a movement away from the places of origin of these populations and towards genebanks; where they are physically and metaphorically set apart from their places of origin.

> *'Since antiquity, farmers have been the custodians of crop genetic resources, but today crop germplasm is increasingly being preserved in gene banks. It is this radical departure from tradition that is partly responsible for some of the controversy over the preservation and use of crop genetic diversity. Gene banks contain germplasm samples within easy reach of plant breeders. Scientists need well preserved and evaluated materials at and so that they can confront the many threats to agricultural productivity. (Plucknett et al., 1987, pp. 3–4).*

Kloppenburg's (2004 [1988]) influential, and well-considered, Marxist analysis of the political economy of *plant biotechnology* is a significant precedent to this present study because he emphasises the role of the commodification of germplasm in this history (Kloppenburg, 2004, p. 335). It therefore merits careful consideration. He focuses on germplasm as 'raw material' that is entwined in global circuits of production and capital accumulation: indeed, he notes that the role of developing countries as producers of germplasm exemplifies the typical position of such countries in the 'international division of labor' as exporters of primary or raw materials (Kloppenburg, 2004 [1988], p. 14). Kloppenburg argues that public plant breeding science in the USA and at the centres of the Green Revolution were grounded on the traffic of exotic germplasm (the 'raw material of the plant breeder') away from 'gene-rich' peripheries to the 'gene-poor' centres of agricultural research.

He describes this movement as quantitatively and qualitatively ‘asymmetric’, in that genetic material tended to flow from ‘Third World’ (sic) countries to Western nations. Moreover, this material had ‘very different social characters depending on the direction in which it is moving’: what was considered a free good at exit would return as part of commodities, that is, plant varieties produced in the context of the seed industries, available for sale (Kloppenburg, 2004, pp. 14–15). In other words, he appears to be describing the political economic ‘moves’ of capital - primitive accumulation (where the means of production are dissociated from labour) and of commodification. For Kloppenburg, the establishment of the IBPGR

> *‘has further institutionalized the historically asymmetric flow of genetic resources between the Third World and the capitalist societies of the Northern Hemisphere. Coupled with the continuing failure to stem the process of genetic erosion, this asymmetry has potentially ominous implications. As the well-known economic botanist Garrison Wilkes (1983, p, 173) points out, “The centers of diversity are moving from natural systems and primitive agriculture to gene banks and breeders’ working collections with the liabilities that a concentration of resource (power) implies”’ (Kloppenburg, 2004 [1988], p. 166)*

So, as this quote illustrates, genebanks played a role in the accumulation and the distribution of genetic resources; and the way in which they ‘flow’ around the world is a highly political matter, given that there are various examples of biological resources (both wild and domesticated) found in the South entering circuits of the global economy as a ‘raw material’ for technoscientific projects from which valuable products (for instance, new pharmaceuticals or proprietary seed varieties) are created without subsequent recompense to the farmers and the country from whence it originates - the paradigmatic case here is the production of chemotherapy drugs vincristine and vinblastine from the rosy periwinkle (*Catharanthus roseus*) by Eli Lilly in the 1980s

(Karasov, 2001)[16]. However, again, Kloppenburg's focus is not the conservation per se, but rather the political economy of biotechnology; so that there is a place for further attention to what happens within genebanks, and their role in the dissemination of germplasm. This is particularly important because access to, and control of, plant genetic resources for food and agriculture present a different case to other kinds of biodiversity: in this case, the configurations of market forces, open access, and sovereignty have changed over time. This is the subject of the next section, in which I overview the evolution of this economy of genetic material and point to particularly interesting questions for STS scholars that emerge from it.

In summary, academic critiques of genebanking have thus far emphasised their limitations as *conservation* tools (van Dooren, 2009). However, this tells us little about the ways in which genebanks are involved in the production, accumulation and distribution of valuable materials. In addition, this could be very important because genebanks are effectively a form of technoscientific intervention – a biobank – and as such their practices and their organisation both reflect and construct society. In this section I have demonstrated how genebanking is seen, in effect, as the preservation of genetic material so that it can be used in the future - that is, their role is both conservation and facilitation of use (see for example Anishetty, 1994; FAO, n.d.; Engels, et al, 2002), but simultaneously the activities of genebanks have long been part of a broader debate about the commodification of biological resources and their derivatives, which means that they are part of certain economies that connect plant germplasm with 'users' and, in some cases, developers that might extract from them both use value and/or exchange value .In that way, the

[16] Although, as Curry (2012) shows, the rosy periwinkle has a longer history as an ornamental plant before its re-valuation as a biological resource. This work reminds us of the contingency of narratives that cast plants as exotic or endogenous, endangered or plentiful. This point, although not developed further in this particular thesis, can fruitfully be applied to crops; suggesting that any histories of crop varieties, especially from a conservation angle, would benefit from attention to these dynamics as plants travel through their geographical range.

conservation of genetic resources is folded into broader concerns about politics, commercialisation, and the direction of agriculture in the 20th century.

Genebanks, then, are far from passive – indeed, we see actors expressing this view by stating that genebanks should not be considered musea:

> *'A gene bank should not be regarded as a plant museum where relics of the past are merely preserved or displayed. Accessions should be used, and breeders need to know what packets or bottles of seed on the shelves contain.' (Plucknett et al., 1987, p. 74).*

Their activities and organisation hence deserve closer academic attention, in order to explore how they play into ongoing debates about the conservation and use of genetic resources. This is particularly interesting in light of the current governance of genetic resources conservation and use, as the ownership status of genetic resources has itself shifted over time. These developments are the subject of the next section.

1.3 Interdependence: policy, conservation, and the flow of genetic resources

In this section I overview the international policy framework that regulates access to genetic resources for food and agriculture, showing how changes in the international governance framework regulating access to genetic resources and their property status influenced genebanking: the *ex situ* conservation of crop diversity has always been entangled with particular ideas about how these resources should be accessed. There was from the start an influential discourse of *interdependence* specific to crop genetic diversity which underpinned the imaginary of the conservation of plant genetic resources as an international, cooperative, efficient, rational system that could provide genetic 'raw material' for future crops, capable of dealing with the twin challenges of sustainability and productivity. These linkages are arguably specific to genetic resources for food and agriculture – indeed, to the extent that a whole separate international treaty, the International Treaty on Genetic Resources for Food and Agriculture, was developed to account for the issues that set it apart from 'wild' biodiversity, its conservation, and sustainable use.

I argue that there has long been a tension between the enclosure of genetic resources and what genebanking actors see as the requirement for free flow of genetic resources. As a result, the development of the current germplasm economy, which began with the International Treaty for PGRFA in 2003, was grounded on the suggestion that countries should cooperate, while simultaneously maintaining their entitlement to national sovereignty over genetic resources. This policy suggests that the ability to accumulate and circulate germplasm was inevitably shaped by political concerns about access, control over germplasm, and the extraction of value from this genetic material: these questions therefore come to matter for the conservation of genetic material in genebanks as well. Germplasm conservation was, from its inception, part of a system where the international exchange of germplasm was considered to be the norm. In addition, conservation was arranged internationally; as no country individually would be fulfilling its own needs – given that plant breeding relied on the use of germplasm that originated in other places. Throughout time, the idea of interdependence was powerful enough for it to be a fundamental right, protectable by international treaty; to the point that it involved the negotiation of a whole new treaty, the ITPGRFA, so that facilitated access could be accommodated within the property rights paradigm of the CBD.

Currently, there is a sparse, but growing historical literature that details the beginnings of the conservation of crop genetic resources, and of *ex situ* conservation more specifically (Pistorius, 1997; Pistorius & van Wijk, 1999; Saraiva, 2013; Peres, 2016); as well as some accounts by historical actors (see for instance Bommer, 1991; Scarascia-Mugnozza & Perrino, 2002). Pistorius's historical analysis of the beginning of the global efforts of conservation (1997) shows how international cooperation was invoked in the construction of international conservation efforts, and takes a historical approach to understanding the conflict over the control of genetic resources (Pistorius, 1997; Pistorius & van Wijk, 1999).

The conservation of genetic resources in *ex situ* genebanks was, at its start in the 1960s and 1970s, envisioned as an *international* effort. Yet by the 1980s, there were heated debates at fora such as the FAO about access to PGRFA and the potential for expropriation. There are concerns over the expropriation of genetic resources, and it is framed sometimes as a North-vs-South issue, or of biopiracy. Until 1983, there was no international legislation governing the conservation of 'genetic resources' per se, so that access to material was unregulated (although this does not exclude the possibility that people were taking action to protect or prevent the spread of genetic resources). Yet, actors working in genetic resources conservation did appear to take a quite globalist approach to germplasm, with the suggestion that free flow and access should be the norm, along with a communal conservation approach. This stance was reflected in the signing, in 1983, of the International Undertaking on Plant Genetic Resources. According to this *non-binding* document, plant genetic resources were part of the 'common heritage of mankind'[17] and, as such, belonged to everyone and should be freely accessible. However, different countries contested this situation on the grounds that bringing 'commercial' germplasm under the definition of common heritage of mankind impinged on owners' property rights. On the

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[17] As a concept, 'the commons' was originally introduced by ecologist Garret Hardin in his seminal essay (Hardin, 1968) where the overgrazing of a putative commons, defined as 'a tragedy', is presented as evidence of the problems associated with the lack of property rights over natural resources for their management. In a commons, costs and benefits are unequally distributed (ie an extra head of cattle benefits one farmer to the detriment of the commons; so if all act in a way that maximises benefit the commons will be destroyed.) Yet this perspective has, rightly, been critiqued for relying on the assumption that each herder would act in a 'rational'' (I.e., self-interested) way, in a common with no rules regarding individuals' behaviour. Yet, as Ostrom demonstrated, common pool resources were managed in accordance with a set of social rules; while people''s behaviour and choices consistently deviate from the sorts of economic rationalities that are inputted to them (Ostrom, 1990, 1999).

other hand, political representatives of countries ‘rich’ in germplasm, too, objected to what they saw as expropriative behaviour in the form of the movement of germplasm from their origin in ‘gene-rich, resource-poor’ countries to genebanks in the North (Kloppenburg, 2004 [1988]: 14-15). This was contested by actors on grounds of exploitation, or a new form of biocolonialism (a critique exemplified by Shiva, 1997). Accordingly, members of the FAO signed Resolution 8/83, which affirmed the status of plant genetic resources as ‘heritage of mankind [that] consequently should be available without restriction’ (FAO, 1983) and set out the International Undertaking on Plant Genetic Resources, according to which the conservation of genetic resources should be encouraged to operate at an international level, suggesting that governments take steps to set out a Global System (Silva Repeto & Cavalcanti, n.d.). However, countries with private seed industries contested the fact that breeders’ lines, too, would be considered ‘common heritage’, while other political representatives of countries ‘rich’ in germplasm objected to any attempts to create an exception for protected material (Kloppenburg & Kleinman, 1988). Many actors noted the interdependence between different parts of the globe enacted in a flow of germplasm from its origin in ‘gene-rich, resource-poor’ countries to genebanks in the North (Kloppenburg, 2004 [1988], pp. 14–15). Accordingly, campaigners made the case both for the need to conserve genetic resources, but also for ensuring that the ability to control their genetic resources should remain with the countries of origin and with farmers (Kloppenburg & Kleinman, 1988; Mooney, 1980). For Kloppenburg, for instance, national sovereignty was the solution to ensure that this was the case.

The Convention on Biological Diversity, which was open for signature to Parties on the 5th of June 1993, changed the status of genetic resources into resources under the national sovereignty of the countries in which they are found. According to the CBD, before a genetic resource can be accessed consent needs to be sought from the provider of the genetic resources and appropriate benefits paid (Dutfield, 2000; Glowka, Burhenne-Guilmin, Synge, McNeely, & Gundling, 1994). Beforehand, there was no requirement to seek permission nor to pay benefits for genetic resources *per se* - although intellectual property restrictions applied to commercial material. In summary, then, the first phase demonstrates the characterisation of genetic resources as ‘open access’ goods, I suggest that one can identify a second phase where international governance becomes binding and genetic resources are no longer freely available.

Interestingly, the CBD considered all biological diversity equally, so that specifically crop-related material that was kept in genebanks was covered by the stipulations of the convention too. Hence, there were no specific arrangements for the material that had already been accumulated in the CGIAR collections in the preceding decades, which actors at the time argued required specific attention (CGIAR Genetic Resources Genetic Committee, 1995). According to policy actors, the CBD had a significant impact on the flow of PGRFA along the conservation networks: specifically, sharing of PGRFA went down, and the creation of national collections went up (Fowler & Hodgkin, 2004; Lopez-Noriega et al., 2012), especially as there was no specific mention of what was the status or the fate of the material that had already been accumulated in the CGIAR collections in the preceding decades.

However, as the next step in the story shows, the idea of interdependence was central to actors engaged with the construction of the Global System, who argued for the need to ensure a continued flow of genetic resources regardless of the ownership status of PGRFA. Falcon and Fowler (2002, p. 210) state that the genebanks of the CGIAR saw a decrease in the number of collections from 9782 per annum, on average, for the 5 years that preceded the coming into force of the CBD. By comparison, they say, the number for 1997 was 563, with a decline in the number of collecting missions, too, from hundreds to tens. They go on to report stories of genetic populations *in situ* being lost because collection for purposes of conservation was stopped because of fears of biopiracy. The authors thus argued that the ‘greater good’ of conserving this valuable material is being limited in order to facilitate control over potentially valuable genetic resources. Although the authors are not unsympathetic to the position of developing countries, what seems to concern them most is that such ‘sovereignty’ arguments curbed cooperation and could lead to the loss of more genetic material, which would be damaging to all because of what they saw as global interdependence with respect to genetic resources.

Simultaneously, the publication of the first State of the World’s Report on Plant Genetic Resources in 1996 (FAO, 1997) highlighted concerns about the state of genebanked material worldwide: little information was available about the material that was stored, and in several cases, there were questions about the conditions of conservation, and about the rates of regeneration required to maintain viability. Hence, the possibility of ensuring the conservation of genetic resources through genebanking was being queried in some quarters. However much some actors lauded the activity of IBPGR and the establishment of gene banks, concerns were also put forwards about the cost and the potential vulnerability of such collections, especially in light of cases where collections were threatened or lost. These include the losses, quoted by Mooney[18] (1983:, p. 29) of ‘a major Peruvian corn germ plasm collection’ due to refrigeration failure, while other corn was lost during the reorganisation of a seed bank in Mexico. Such lack of security was also reflected in funding problems, which were seen to threaten collections, including in wealthy countries. This led activists and other commentators to ask about the wisdom of ‘putting all the eggs in one basket’ (Cary Fowler & Mooney, 1990) by privileging the conservation of genetic diversity in *ex situ* genebanks, as opposed to maintaining some examples of these crop varieties *in situ,* in their own environment. So, *in situ* conservation became the primary means of conservation, just as countries were seeking to assert their control, and sovereignty, over genetic resources.

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[18] Pat Mooney has been an activist involved in questions of access and control of genetic resources for decades, founding Rural Advancement Foundation International (RAFI, now ETC Group). Interestingly, he co-wrote ‘The Threatened Gene: Food, Politics and the Loss of Genetic Diversity’ with Cary Fowler, who went on to lead the Global Crop Diversity Trust (now known as the Crop Trust) between its inception and 2013.

Around this time, too, intellectual property laws were becoming increasingly restrictive. Saraiva (2013) refers to the history of the UPOV to make the case that – in Europe at least – the intellectual property protection over crop varieties *was* designed in such a way as to maintain an 'open-access commons of genetic resources' by incorporating a 'breeder's exemption' so that breeders are entitled to use protected varieties in breeding further varieties; as well as protecting farmers' rights to their own seed. However, those liberties were considerably restricted with the 1991 updates to UPOV. He suggests that these changes also affected the role of genebanks: it was 'no longer to feed the egalitarian republic of breeders working at national institutes or international centres for development aid, but instead to shower biotech corporations with genetic resources' (Saraiva, 2013, p. 204): the author therefore suggests that genebanks are being called upon to help such companies to realise the commercial value of genetic resources.

The problems raised by the CBD for the 'flow' of germplasm meant that, soon after the CBD was signed, work began on the negotiations for a new, independent treaty that would 'harmonise' with the CBD but not require bilateral negotiations for genetic resources thought to be important for the purposes of food and agriculture. The resulting legislation was the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA), signed in 2001 and entered into force on the 29th of June 2004. There are currently 139 Parties to this treaty[19]. This new legislation maintains the ownership status of genetic resources set by the CBD as belonging to individual countries, but seeks to encourage mutual, facilitated access to material. The method it uses to do this is the creation of a 'Multilateral System' for genetic resources, whereby countries agree to facilitate access to a subset of genetic resources that are considered to be important for food

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[19] A regularly updated list of the signatories to the ITPGRFA is available online at http://www.fao.org/fileadmin/user_upload/legal/docs/033s-e.pdf This version was updated on 01.04.16 and accessed on 19.07.16

and agriculture purposes. This system sets up ‘a pool of genetic resources that are available to everyone’[20] comprising 64 crops considered to be the most important because they account for 80% of human consumption. This list, known as Annex 1, is reproduced in Appendix 1. By ratifying the treaty, Parties agree to make the genetic diversity pertaining to these crops, and available information about them, accessible ‘to all’. Users receive these genetic resources under the Standard Material Transfer Agreement (SMTA), according to which they will agree to make any derived products fully available under the same conditions, or pay a percentage of any commercial benefits to a common fund that is in turn allocated towards conservation or agricultural development projects in the developing world.

In other words, I argue that it encourages countries to share genetic resources internationally. Here, I use the concept of sharing to describe the organising principle of current genetic resources policy: it attempts to bridge the tension between the principle of national sovereignty (enshrined in the CBD, 1993) and the vision of these resources as a global concern (and, before the CBD, ‘common heritage of mankind’ materials) the proposed solution to resolve the problem of blockages in the flow of genetic resources and therefore is the proposed solution to resolve the problem of blockages in the ‘flow’ of genetic resources. For some, the presence of these instruments is already bearing fruit:

> *‘Even in their infancy, the stability that these instruments have brought to this sector is enabling better longer term planning and interregional cooperation and the development of global crop conservation strategies and systems. This is exemplified through [among other things] the iconic international project of the Svalbard Global Seed Vault to act as a safety back up to the world’s gene bank community which has accepted 430 000 samples representing 3200 species in the first 21 months of operation’ (Ambrose, 2010, p. 4)*

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[20] ‘What is the Multilateral System?’ http://www.planttreaty.org/content/what-multilateral-system Accessed 19.07.16

So, the Seed Treaty and other genetic resources policy documents might set out requirements for how access to germplasm should be carried out – that is, how and under what circumstances countries should share germplasm – but, importantly to the case at hand, they *also* include a vision for the most appropriate way to undertake conservation: these are the behaviours and activities necessary to ensure the survival of the *ex situ* collections that exist already. Again, then, these documents entangle the idea of *conservation and use* as two sides of the same coin: that is to say, successful conservation of genetic resources is ensuring that it is used, over and above the maintenance of accessions in freezers. Such a definition is, I argue, at least in part based on the need to ensure that the material which has been preserved in genebanks is, in fact, being used – and therefore, its value is being realised.

What is very interesting about the case of PGRFA (as opposed to other genetic resources) is how there is a very explicit definition of germplasm as resources and public goods which should not be 'removed' from the public domain, but need to be protected (Dedeurwaerdere, 2010). In the case of the MLS, the material is accessible as if it was common heritage, although there is national sovereignty – if only to a certain extent. While the contents of the commons are free from IP, any *progeny* derived from them can either be part of the commons too *or* a share of the benefits can be returned in its stead; a 3% royalty payment to the Fund of the Seed Treaty. This has led some scholars to suggest that a sort of General Public License be instituted which would make it more difficult to extract IP by virtue of (not overly defined) future payments should there be a profit (Aoki & Luvai, 2007; Kloppenburg, 2010). It concurs with the view that a commons does not serve to exclude all appropriation, but rather to reach a compromise between individual claims (in our case, over progeny derived from the global gene pool) and the collective's access to non-rivalrous information (idem, p. 142).

This overview of the changes in access to genetic resources and concurrent growth in genebanks tells us two important things: firstly, that there was a vision for a global outlook to the conservation system from its inception in the

1960s-1970s. Moreover, it suggests that there are links between what was considered to be good practice on the conservation of genetic resources (e.g. safety duplication, sending out material, creating big collections) and specific ideas about access. In this case, the policy is that it is in the best interests of everyone to share in both the benefits and the costs of conservation. The aim, as expressed in the documents produced at the international level, is to encourage the sharing of seeds and of responsibility for conservation. Moreover, the free flow of genetic resources is seen as the way to maximise their usefulness. Nowadays, the circa 1750, collections in the world contain around 7m samples, of which 1.5 to 2m are expected to be genetically unique. This is an important idea, as it suggests that there has been much duplication and circulation of the same samples within genebanks (although, as I will argue in the empirical chapters, the question of what constitutes a unique sample is a complex one, that depends on 'scientific' and 'social' assessments simultaneously).

1.4 Understanding the germplasm economy through the study of genebanks: approach and research questions

Thus far, I have introduced the topic of crop genetic resources conservation and sought to demonstrate that there is scope for work that takes as its focus what happens *after* a seed is collected for the first time that really matters – in other words, that takes as its analytical site the genebank. In order to make sense of gene banking we must turn our attention to their practices, and their organisation, over time. These practices should also be understood in context, in light of wider social, political and economic developments. STS and Geography can contribute positively here by providing the theoretical tools with which to make sense of this case (discussed further in the next chapter, where I provide a literature review). Given the mutual imbrications of genebanking and the flow of genetic resources that I have begun to outline in this chapter, it is my suggestion that we consider genebanks *as* part of the shared gene pool, and thus as co-productions (Jasanoff, 2004) of the natural and the social, the gene pool and the seed economy. Understanding the way in which genetic resources are produced and circulated in this germplasm economy requires that we take into account the processes and practices of genebanking, as much as the legal requirements of the new Multilateral System. In other words, defining what is meant by a shared gene pool is a question that is as much about the practices of genebanks as it is about the definition of the germplasm economy.

Conversely, the germplasm economy is constituted by the sociotechnical networks that connect genebanks, their users, and the producers of genetic resources (including farmers, research scientists or breeders that work with or produce plant varieties). These networks include, and are mediated, via technological artefacts (eg., freezers, labels, databases, transfer agreements). As in the tissue economy described by Waldby and Mitchell (2006, p. 33), this is a political economy in that it presupposes and constitutes certain social relations between genebanks, users and countries. The use of the term germplasm economy is helpful because it brings to the fore the roles that value(s) play in organising genebanking.

Waldby and Mitchell (2006) use the term ‘tissue economies’ to mean ‘a system for maximising [the productivity of human tissues], through strategies of circulation, leverage, diversification and recuperation’ which is also a way of ‘hierarchizing the values associated with tissue productivity’ (2006, p. 31). In summary, they are ‘at base about the way the biological capacities of the human body contribute to social, economic, and political systems of productivity and power’ (2006, p. 187). This definition can be easily applied to the case of agricultural productivity and the role of genetic resources therein. From that perspective, conservation in genebanks is a means of maximising the productivity of future agriculture through strategies of accumulation, conservation, and dissemination of genetic resources for food and agriculture. As I demonstrate throughout the thesis, genebanks engage actively in the construction of the value of genetic resources: over time, their activities and organisation are increasingly geared towards the maximisation of productivity out of potentially valuable material. Thus, the value of genetic resources is underdetermined, malleable, and requires considerable work on the part of genebanks. Indeed, if we look at how this germplasm economy is organised, we see which value*s* are privileged at which turn, that is to say, what is considered most important to the actors as they go about making choices about the best way to carry out their job. These strategies become visible when we ask actors about the role of genebanks, and how they carry out their functions of conservation and facilitation of use. Hence, I suggest the following three research questions to begin addressing these aims within this thesis:

1) How do gene banks transform germplasm into genetic resources?

By definition, genetic resources are considered to have *actual or potential value* (CBD, 1992, ITPGRFA, 2001). Starting from the suggestion that the material in genebanks are proxies (Parry, 2004; van Dooren, 2009), I aim to follow how the processes of genebanking are constitutive of the value of genetic resources. The objective of this question is to open up for analysis how value is shaped by genebanking (eg, how and under what conditions materials are kept), rather than presuming that the value of genetic resources is fixed and independent of the context.

2) How is the shared gene pool constructed in/through the practices and organisation of gene banks through which they accumulate, disseminate and exchange genetic resources?

Following on from the previous question, I aim to investigate how genebanks produce some genetic resources as part of a common, shareable genepool. Here, I draw on the concept of a species' gene pool for crop breeding set out by Harlan and de Wet (1971) where they differentiate between primary, secondary and tertiary genepools as a relational method of classifying species. Primary genepools are capable of crossing easily, whereas secondary genepool members can cross-fertilise and produce some fertile hybrids. Tertiary genepool members can only be crossed with specific biotechnological interventions, such as polyploidy. My choice of terminology was led by three reasons: firstly, it conveys the pooling of resources into a communal group; secondly, it mirrors the concept that genetic resources of the same species that may be kept in different genebanks are, relationally speaking, in the same genepool in relation to each other, regardless of physical distance – as is expressed by the classifications acquired in genebanks. Finally, my use of 'shared genepool' also harks back to actors' terms, where people refer to the material in the multilateral system, with references to the 'world's gene pool' by FAO as the 'global gene pool'[21].

3) What can we learn about the organisation of the germplasm economy (that is, the strategies in place to organise the accumulation and dissemination of genetic resources) by studying the practices of genebanks? What role do they play in constructing the germplasm economy?

The last question relates the answers to the previous two to an analysis of the germplasm economy. It seeks to tease out how genebanks are engaged in the production of the germplasm economy by creating the shared genepool and managing the value of genetic resources. Because it considers the relation between the germplasm economy and the way genebanks themselves have developed over time, it can contribute to extending our analytical grasp of the implications of the Seed Treaty-era policies in the genebank, and conversely, how activities there reflect the broader context in terms of genetic resources use and exchange.

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[21] FAO (2013) 'World's gene pool crucial for survival' http://www.fao.org/news/story/en/item/174330/icode/, accessed 14.07.2016

1.5 Thesis outline

This thesis is composed of eight chapters. In Chapter 2 I review previous work on the study of biobanks and of bioeconomies. I argue here that there is a role for the study of the political economy of biobanks in order to understand bioeconomies; given that applying this theoretical approach to the germplasm economy brings into the analysis the ways in which genebanks must operate in order to continue their own work. Chapter 3 describes the methods of research and data analysis and sets out the methodology that underpins this work. I argue for a dual approach, where I examine genebanking and its role in the germplasm economy both in theory (as it is portrayed in policy documents) and in practice, that is, actors' experiences and perspectives.

The four empirical chapters that follow (chapters 4 – 7) are dedicated to the analysis and discussion of the empirical data gathered during the course of this research. Chapters 4 - 6 are dedicated to understanding the role that genebanks play in managing the 'flow' of a particular resource considered to be valuable. In Chapter 4, I show how genebanks are involved in the preservation of valuable germplasm, and their role has been increasingly dedicated to ensuring that the flow of genetic resources is not impeded. Chapter 5 is dedicated to an analysis of the flow of data, and I demonstrate again that genebanks are engaged in a project of building the value of the shared genepool. Here, the role of genebanks in demarcating between public and private material comes to the fore. In Chapter 6 I show that the work of genebanks in demonstrating the value of their collection is at least partially due to the need to maintain their own collections by demonstrating their impact for funding, in order to ensure the flow of funding for their own collections. Finally, in Chapter 7 I explore the germplasm economy through an analysis of what cooperation is for, and I argue that the sharing rationale that characterises the current germplasm economy is the result of an appeal to the idea of both value and values: interdependence is, at once, an economic and social relation that is used to justify the current organisation of genebanking as beneficial to all.

The implications of these analysis and the next steps are discussed in the concluding Chapter 8, where I argue that the findings in these chapters show how the germplasm economy is oriented around a regime of sharing that is as much about the organisation of the genebanking system as it is about the sharing of genetic resources. Therefore, I conclude by suggesting that analyses of biomaterial economies should encompass also a theorization of biobanking itself as a resource, with its own particular political economy.

CHAPTER 2 BIOBANKS - BETWEEN THE BIOECONOMY AND THE POLITICAL ECONOMY OF TECHNOSCIENCE?

The proliferation of 'banks' for the storage of material and data is a notable development of science, technology and medicine in the 19th and 20th centuries, from the banking of blood, milk, or semen in medical contexts (see for instance Swanson, 2011; Starr, 2012 for historical perspectives) to the collection of blood and tissue samples for research from human populations worldwide (Anderson, 2000; Radin, 2013; Kowal & Radin, 2015) to the development of protein sequence databases such as GenBank (Strasser, 2008; 2010; 2011) and large-scale biodiversity data banks, like the Global Biodiversity Information Facility (GBIF) (Bowker, 2000; 2005). By nature – and name – they suggest the accumulation of particular objects of value in order to have them available for the future. Naming these institutions 'banks' is indicative that their contents are seen to be valuable goods, or resources, and reflects the idea of ongoing deposits and withdrawals (Starr, 2001, p. 120; 2012). These repositories are very interesting sites for the study of the relationship between science and values: investigating the biobanks, data banks and other repositories for the storage of 'resources' such as seeds, tissues, organs, cells, or data enables us to think about how value(s) are articulated. Moreover, it makes no sense to think about banks (scientific or financial) without their context; that is, the economy that they are part of and which determines the ways in which resources flow. Hence, looking into the activities of banks is a way to develop accounts about what is value, and how science and technology contribute to the development of economies in which circulate different kinds of resources, exchanged in particular ways (e.g. as gifts or as commodities, within a market or a commons).

Such is my approach here to conceptualising genebanks; and an interdisciplinary approach that combines the interests of STS and Geography is well suited to this topic. From an STS perspective, it is important to think about the interpenetration of technoscientific elements (e.g. new methods of freezing seeds) and socio-economic ones (such as the new regulatory framework for the conservation and use of plant genetic resources). In addition, genetic diversity and its governance, agriculture, and plant technosciences all have their own spatial distributions, as noted in section 1.3. Hence, particular attention should be paid to scale, and to the setting up of geographies of conservation and access to plant genetic diversity that construct it as a 'global' concern and resource. Therefore, both disciplines contribute to the conceptualising of genebanks as constituent parts of a germplasm economy, in ways that I discuss in this chapter.

In this literature review I suggest that studying genebanks can provide insights about the political economies of genetic resources. An approach that focuses on banks (as opposed to the practices of collecting or extracting from the genebank) enables analysts to explore how these repositories are engaged in the production, maintenance and maximisation of genetic resources and, consequently, on the construction of their value and of the political economy in which genetic resources circulate. I shall focus particularly on the theorisation of the role of (bio)banks in broader economies by reviewing scholarship from STS and human geography for what it can contribute to our understanding of banks. After reviewing existing work STS work about the bioeconomy – that is, the interrelation between capitalism and biotechnology - I go on to suggest that there is a need to consider in greater detail the ways in which biobanks themselves have their own political economies, which must be taken into account in order to develop a more multi-faceted analysis of the organisation of particular tissue economies. Conversely, studying these particular sites is a way into avoiding economic determinism and instead empirically exploring the ways in which actors in genebanks work within and without their economic constraints. By using the germplasm economy as an example, I will demonstrate that suggestion throughout the empirical chapters and conclusions. I will begin, however, by situating the present thesis in broader questions about the relationship between science and economies.

If science and technology are necessarily *social* endeavours, as Science and Technology Studies work has demonstrated since its inception (Kuhn, 1970;

Shapin & Schaffer, 1985; Bijker, Hughes, & Pinch, 1987; Latour & Woolgar, 1986; Latour, 1987; Woolgar, 1988; Jasanoff, Markle, Petersen, & Pinch, 1995 for an overview of the field ; Barnes, Bloor, & Henry, 1996) it comes as no surprise that science and technology play a significant role in economic processes and should be studied as such. The production and distribution of goods and services – quintessential economic processes – relies on (increasingly complex) technologies. Technoscientific developments can transform economic processes, as is evident with respect to past economic 'revolutions' – most notably, the industrial revolution of the 19th century, or the development of the information economy in the 20th. However, STS work also argues against thinking of science and technology as being set apart from, and 'impacting on', society: instead, both are inescapably social, and thus should be understood as part of the same system (Latour, 1987; Jasanoff, 2004). Indeed, as these authors have argued, science and society are co-produced. For Latour, the boundary between nature and culture is artificial, and its construction a typical characteristic of modernity (Latour, 1987). Jasanoff suggests that, because science and society are co-produced, changes to the social order will require changes to the natural order too (and vice-versa). Her co-production idiom suggests that 'the ways in which we know and represent the world are inseparable from the ways in which we choose to live in it' (Jasanoff, 2004, p. 2). Therefore, they should not be analytically separated. Consequently, one might also expect that the production of scientific knowledge and/or technological artefacts will be contingent and incorporate social, political - and, indeed, economic - factors into its development. Hence, there is no obvious separation between science and 'the market' (Callon, 1994). Discussions of this incorporation can be found on two rather different perspectives, proposed by Callon (as above) and by Mirowski and Sent (2002).

Considering what it means for science to be a 'public good', Callon argued against the idea that that science a non-rivalrous and non-appropriable good that is essentially separate from the market (that is, according to the traditional economist meaning of the term). Instead, he calls for a 'complete reversal of our habitual ways of thinking about public goods and a new definition of them' (Callon, 1994, p. 397), by focusing on the idea of science *for* the public good. For Callon, this means science that supports and maintains diversity in terms of the practices and structures it can encompass, the social needs it can fulfil, and in the social networks that encompass funders, users, and producers.[22].

In contrast, Mirowski and Sent's 'New Economics of Science' approach to the study of the commercialisation of science (2008; P. Mirowski & Sent, 2002) suggests that both the practices and the outputs of scientific research are shaped by different approaches to its commercialisation (Birch, 2013), so different economic regimes influence the kind of science that is produced. Importantly, commercialisation too should not be reduced to a simple or uniform process: instead, it must be understood as heterogeneous and evolving. Thus, rather than speaking of 'commercialisation', they identify different periods during the 20th century; showing that what 'commercialisation' consisted of in the 1990s differed substantially from its 1930s counterpart because of socio-economic differences.

These approaches demonstrate how the creation of economic value from technoscience has the capacity to shape the direction of science. These findings therefore complicate the Mertonian perspective that scientists' work is built on communalism and disinterest (Merton & Storer, 1973). Yet I would argue that they open up to analysis a very important question: what are science and technology for? Or, more specifically, what value/s are science and technology producing, and in what ways? Finally, is the commercialisation of science incompatible with the production of the public good? This work therefore opens up for analysis the relationship between science and values, including economic value.

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22 Stengel et al (2009) applied this model in order to understand what it means in the context of plant sciences research in the UK between 2003 and 2006, and concurred with the perspective proposed by Callon.

Such work is particularly welcome at a time when we've seen such dramatic changes in the economic arena, with the development of the neoliberal regime that has had such wide-ranging implications for society; including for science (Birch, Levidow, & Papaioannou, 2010; Lave, Mirowski, & Randalls, 2010; Randalls, 2010; Lave, 2012; Levidow, Papaioannou, & Birch, 2012), the environment and understandings of biological material (see for instance McAfee, 2003; Cooper, 2008; Braun, 2015). Despite the establishment of this stream of research, neoliberalism remains, for some, a surprisingly underexplored area within STS (Birch, 2013). The implications of neoliberalism for science include the roll-back of state funding and services, and the stepping in of private funding and interests in the carrying out of basic and applied research, as well as services.

And yet, there are cases that appear to buck that trend. The study of conservation of crop germplasm in particular[23] is interesting because there is a move *away from* the standard narrative of commodification and trade; instead, it has a focus on mutual access and cooperation. The preservation of valuable biological material is underwritten by the state, despite the ongoing costs of that endeavour and against the changing status of PGRFA as resources. This results in the periodic reiteration of what is valuable about the materials (therefore justifying the costs), and – more practically speaking – on everyday value judgements, undertaken when managing conservation collections (what should be kept, and what should not?).

Consequently, understanding why the germplasm economy is organised as it is, and how that can be contextualised in the relevant sociotechnical networks of plant breeding and research, can be very instructive in terms of exploring how to think about science and economies without resorting to

[23] Which poses very different questions than the conservation of 'wild' biodiversity, as discussed in Chapter 1. The conservation of plant genetic resources for food and agriculture is framed as a way to avoid losing genetic diversity among plants that are economically important or otherwise useful to humans.

essentialising, or taking for granted, the role of ‘the market’, or of collapsing different kinds of value (social and economic, actual and potential) to economic value alone. Values are, of course, significant concerns for STS as a whole, yet it appears that their role in the development of the economies of science, technology, and nature/conservation could be theorized further.

If, as Cori Hayden puts it, we can variously think of biodiversity as ‘an ecological workhorse, essential raw material for evolution, a sustainable economic resource, the source of aesthetic and ecological value, of option and existence value, a global heritage, genetic capital, the key to the survival of life itself’ (Hayden, 2003, p. 52) how are these overlapping conceptions reflected - or indeed, *a*ffected - by the practices of collecting, storing, managing and disseminating seeds? Conversely, what does the governance framework and the envisioned organisation of genebanking (as expressed through legal, strategy and other documents) convey about the valuing of germplasm? In analysing actors’ perspectives on genebanking and its governance we can begin to grasp how genebanks are intended to ‘preserve value’, and through these, the values that underpin the regime structuring the multilateral germplasm economy. Doing so brings into analytical focus how *practices* of conservation matter in structuring the germplasm economy, as well as how it is arranged in a way that enables the production of particular values. The conservation system and its collection are, in effect, co-produced. Studying the economy by training the analysis on banks is a convenient way of following this process over some time.

Interestingly, another group of scholars in STS have been grappling with the issue of how to avoid economic determinism when studying the capitalization of the life sciences – and, more specifically, what might be the use of co-production for this purpose. For instance, Sunder Rajan (2012) asks

> *‘How might we think causally about the trajectory of the capitalization of the life sciences? How might co-production, or Marxian analytics, or indeed any other kind of conceptual frameworks, help work through the problem (…) concerning a particular political economic and epistemological trajectory that, over space and time, indicates a process of*

> *capitalization, but where the norms and forms of capitalization are complicated, and where falling prey to economic determinism would be an impoverished analytic move?' (Rajan, 2012, p. 9)*

This question is both thorny and important; as such, it is at the heart of this present review, even if it can only begin to open such a question up for reflection. Nonetheless, taking into account the emergent research agenda in STS, I hope to develop it in a modest way by suggesting that:

a) Empirical studies are central to the endeavour of avoiding economic determinism;
b) It is productive to seek out case studies where the narrative of progressive enclosure/privatization/commodification is disrupted, as is the case with germplasm conservation (as discussed in Chapter 1), or certain examples of tissue economies. Cases such as these make more visible the multiplicity of values at stake, and can therefore make clearer how it is that particular arrangements come to prevail over others.

This thesis, and the present review, is grounded on the argument that STS should produce analyses that can make sense of the ways in which sociotechnical constructs like genebanks are embedded, and contribute to, certain socio-economic contexts where concepts such as 'genetic resources' are imbued with ideas about what constitutes value. Specifically, we should think about the relationship between contemporary technoscientific projects such as contemporary *ex situ* conservation and the rationalities, world-views, and priorities that are applied – and how these are themselves an expression of broader political economic perspectives. Hence, observing genebanking practices on the management of germplasm, data, funding as they are effectively issues of value management makes clear that genebanking has been shaped by political-economic concerns about the most appropriate way to disseminate that value, as I argue in the empirical chapters that follow.

In other words, this research seeks to make sense of the way actors across the world have organised the germplasm economy without neglecting the political economic aspects of technoscience itself. In so doing, I follow the call to bring studies of political economy more closely into contact with STS (Birch, 2013; Birch & Tyfield, 2013) that take as its object technoscience itself[24].

> *'the ways that the economy is ethically, socially, and politically organised and configured and how this shapes technoscience and is constituted by technoscience in turn. Classical political economy concerns the social and political context in which the production, consumption and distribution of goods, services and wealth happens. By contemporary political economy I mean to include the growing literature on subjectivities, moral discourses, institutions, knowledge and innovation dynamics, and natural ecologies that constitute and are constituted by the social and political context of economic activity (Birch, 2013: 49-50)*

This contemporary meaning is relatively broad, at least in relation to its comparator of 'classical political economy', which was itself foundational to the social sciences through the work of Marx and Weber.

Ultimately, I seek to contribute to contemporary debates in STS about how best to develop analyses of the political economies of technoscience (Birch, 2013), as well as exploring how biodiversity is understood as a source of value in this particular context. However, other scholars critique these as too structuralist, essentialising ideas such as that of a market economy. Instead, they argue for the need to understand the political, social and organisational context of the particular economy/phenomena/concept that is of interest;

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[24] Birch (2013) makes the case that STS has to move beyond the 'economic turn' exemplified by Mackenzie's (for instance, MacKenzie, 2006) work where the tools of actor-network theory were applied to particular socio-technical systems in the research area designated as 'Social Studies of Finance'. This could be a methodological issue: after all, some have suggested that ANT, with its view of science as a 'marketplace of ideas', would itself reproduce neoliberal tenets and thus essentialise the social order aspect of the equation.

since this heterogeneity implies that concepts such as ‘public’ and ‘private’ should not be seen as essential or atemporal. An example here is Gibson-Graham’s (1996) critique of approaches where ‘capitalism’ and market economies are unexamined, their existence ossified and naturalised. Therefore, new approaches to the understanding of the political economies of technoscience suggest that attention has to be paid to the way in which such economies (and consequently, the meanings of concepts like ‘the economy’, the ‘public domain’, and ‘sharing’) are constructed in practice.

In summary, STS and Geography scholars have sought to theorise the interrelation of scientific knowledge and technology and markets or economies, especially in the context of the changing economic structures of the late 20th century. One particularly pertinent question in this context is how to provide analyses that can productively understand economic factors without reifying or essentializing specific concepts, such as capitalism or neoliberalism. I have suggested that one means of addressing this problem empirically might be to seek out particular examples where the trend of progressive enclosure and commodification is contested, in order to explore how actors both work within and resist specific arrangements. The case of genebanking therefore provides a suitable topic, as I argued in the previous chapter. More specifically, turning our analytical focus to genebanks themselves as sites of value accumulation can provide some analytical purchase on the ways in which biobanks shape, and are shaped by, the economies they are part of.

2.1 Banking in the economy: accumulating material and data

The introduction to genebanks has shown that they contain collections of crop germplasm that are perceived as *resources,* and are therefore involved in the manipulation and management of these materials so as to maintain their value, in accordance with the values, priorities and requirements of the present and future users of genetic resources.

In this section I review work from STS and related areas that suggests how we might productively interrogate collections of biological material and/or data to explore the production, maintenance and circulation of valuable materials. These include *biobanks* of different tissues and organs that may be collected for the purposes of research and/or therapy, and *databases* for DNA/protein sequences or biodiversity data, where they have a particular 'economic' focus. Finally, I introduce work about natural history collections and other collections for conservation purposes.

Biobanks have been a focus of studies from STS and allied perspectives. The first major point of interest was the ethics of biobanking, especially when allied with the potential for the commercialisation of the biological material and information collected. Of particular interest here - because the impetus for conservation is the preservation of valuable resources - is what they can tell us about the accumulation, storage and dissemination of material, and ideas about the value of these materials. This applies to different biological materials such as umbilical cord blood (Martin, Brown, & Kraft, 2008) or DNA samples for medical research (Mitchell & Waldby, 2010). Yet another, still smaller body of literature, focuses on the economics of biobanks rather than ethical issues. Turner et al's paper (2013) is an example here: the authors suggest that although it *is* important to analyse the economic role of biobanks, it is important to develop an alternative conception 'beyond the logics of commodification', and framing the economics of biobanks solely 'in terms of participants and their bodily tissue' could reproduce the very commodification of science that these scholars critique (Turner et al, 2013). This insight is important in the case of the germplasm economy, as it illustrates my argument that we should not presume that economies are organised around straightforward commodification or market exchanges.

These banks are sites for the *accumulation of* value, and are essential in the creation of 'resources' out of the biomaterials that are traded. Indeed, the literature on biomedical economies (which will be outlined further in the next section) suggests the role that biobanks can play in setting up these economies. Waldby and Mitchell (2006) suggest that banks are

> *'site[s] for accumulating valuable tissues, but (…) the value of human tissue is complex and overdetermined by considerations of ontological status, clinical efficacy, knowledge production, social relationships and market forces. The management of tissue banks may involve mediating between conflicting demands arising from these values. Tissue banks may find themselves abruptly enmeshed in a complex biopolitical field' (Waldby & Mitchell, 2006, p. 37).*

It is for that reason that biobanks can be essential in setting up flows of resources that are not straightforwardly commodities or gifts. They can be important in 'disentangling' material into commodifiable resources, as is the case with the creation of stem cell lines from embryonic material through the UK Stem Cell Bank.

An empirical study of genebanks' activities and their relationship to value can be productive in extending this approach beyond 'red' biomedicine, thus providing a comparative angle, and considering in greater detail the biopolitics of agricultural development. This conceptual framework is essential in order to make sense of the role of genebanks in the germplasm economy since there are significant parallels with the case of the Stem Cell Bank: hence, their approach provides a means to understand the complex situation that is in place in the case of seed banks. In both cases, banks are responsible for maintaining the value of their 'deposits', and ensure that it is distributed in accordance with particular rules.

Particularly interestingly, in both cases the banks are meant to make their resources flow in ways that are seen to be socially productive, or that encourage social goods and innovation over and above 'narrow' economic interest. However, there are also some important differences between the organisation of genebanks and the case of embryonic stem cell lines, not least in terms of the demand for these lines; these differences will be further discussed in line of the empirical evidence.

Perhaps unsurprisingly, banks are also places where the material collected can gain in value (including economic value). Drawing on the work of Waldby and of Cooper, Nadine Ehlers (2015) describes how ‘waste’ fat becomes a source of biovalue in ‘bioprospecting for gold’ - or rather, adult stem cells whose regenerative potential is imbued with promise for overcoming the limits of the body. She seeks to understand the conditions under which fat is seen as ‘endlessly malleable’ and promising, and biovalue can be created, banked, and extracted. She shows that corporations can monetise fat into economic surplus: in so doing, they transform waste material into a commodity. Therefore, fat banking is ‘a future-oriented storing of promise’ that is ‘spectacularly financialised’ (Ehlers, 2015, p. 267) – and it is the process of banking that permits that increased valuation.

In Parry’s (2004) work, collections are understood as new ‘centres of calculation’ (Latour, 1987) from where valuable biological ‘proxies’ (seeds, tissues, DNA and others) are ‘circulated as commodities around the networks of exchange that underpin this new resource economy’ (Parry, 2004, p. 151). This perspective emphasises the accumulative process of information and hence leads me to suggest that we might look for what the process of genebanking itself might mean for the way we perceive individual accessions – and the collective gene pool.

Drawing on Parry (2004), Van Dooren (2009) suggested that banked seeds are an example of proxies, ‘standing in’ for more complex kinds of agrobiodiversity because they are the ‘kinds of diversity that matter’ for future research and breeding. Consequently, genebanking projects cannot conserve diversity in its all its biosocial complexity, instead preserving and making ‘readily available for use a unique kind of instrumentalised genetic life’ (van Dooren, 2009, p. 375). His work therefore suggests that the kinds of biological life that are kept represent a narrow range of value(s), because what is kept is that which is valuable to a narrow group of people - the plant breeders. Moreover, van Dooren articulates value in relation to access and distance: that is, the material in seed banks is ‘far away’ (both geographically and figuratively) from farmers who might make use of it.

Van Dooren writes from an environmental humanities perspective, pointing out the limitations of contemporary genebanking systems and discussing what it might look like to 'bank well' (after Derrida). Importantly, he recognises a role for genebanks – but argues for increased 'proximity' to farmers and greater openness so that these collections become better integrated 'nodes' on networks of circulation and exchange of seeds, rather than frozen collections that are out of reach. Here, it is not in question that seeds are valuable, but what is also important is that the multiplicity of values and their meaning to different groups (farmers, plant breeders, others) are recognised and taken into account.

Work on banks or collections shows us that these are *future-oriented.* Their operations are dedicated to the accumulation of resources for retrieval, and the practices of, and discourses about, biobanks often reflect this, as is evident in Martin and Brown's work on capitalising hope (Martin, Brown, & Turner, 2008). They are, effectively, part of what Waldby and Mitchell (2006) call *speculative economies*, as they demonstrate through a case study of private cord blood banking (Waldby & Mitchell, 2006, pp. 110–130).

This literature has been successful in accounting for the creation of (economic) value from the hopes and fears of parents, patients or other donors, who can be engaged by making appeals to preparedness and care. Yet, I suggest that the attention to the creation of collections should be supplemented with research into their maintenance – and, in some cases, its disappearance. Such focus is less commonly seen, but what work there is suggests that it is analytically important because it shows that there is a need for taking time into account. The contents of a collection are dynamic – they grow or contract, material becomes more or less valuable. These changes are important for understanding not just collections; but are also an important means of connecting the collections to the broader economies that they are inserted into. An example here comes from the work of Kowal (2013). She studied what happens to collections of DNA from indigenous peoples as the scientists who originally collected them retire. She argues that their value encompasses not only scientific or exchange value (in that they are resources that enable collaboration between scientists), but also *ethical* biovalue. This means that for them to have any other kinds of value, their ethical credentials must be clear, and ongoing, but the data on what scientists see as ‘valuable resources’, suggesting that ‘ethical biovalue, scientific value, exchange value and biocapital (at least in its pastoral forms) are all mutually reinforcing’ (Kowal, 2013, p. 586) Without ethical biovalue, for instance, that guarantees their provenance and ethical credentials, their use value for scientists is much diminished.

As Cooper (2015) states, following Landecker (2005), biotechnology developed, in the 20th century, the ability to ‘disrupt the temporality of living matter’ (Cooper, 2015, p. 259). Therefore, the availability of these means to manipulate rates of growth, and loss, of living material provided a new capacity to accumulate – and indeed, circulate – it new ways. Therefore, it is helpful to think about the role of biobanks as places where biological materials can be accumulated and preserved through the use of biotechnologies.

Cooper suggests that such temporal disruption gives rise to questions about the temporality of *value*, because increasingly the privatised life sciences adapt to the demands of investors, while ‘long-established areas of biological accumulation such as factory farming and agriculture were subject to the imperatives of just-in-time production’’ (Cooper, 2015, p. 257). This insight is applicable to genetic resources and genebanks too, as it suggests that the use value of material in genebanks can be a function of the external context (that is, the kinds of plant breeding that are currently happening and the pressures and objectives in place). In this way, it is productive to think about the implications of commercial pressures and what Cooper calls the ‘the growing entanglement of life science research and market economies’ because it ‘unsettles the established categories of political economy and poses far-reaching question about the relationship between the temporality of biological life and the temporality of value’ (Cooper, 2015, p. 257).

So, we can conceptualise banks as places that accumulate and maintain valuable material, even though the value of that material is in fact dependent on factors like the ability to ‘freeze’ material in time, but also the techno-economic context under which that material might be used. Another such factor that is important is the way in which material is organised in relation to the future. As Radin (2015) shows, the effort required for the maintenance of collections of frozen tissues gains legitimacy by promising to organise the material in a way that would appeal to future users, once it becomes apparent that it is possible to use such tissues for reasons other than those they were collected for. Yet to create and maintain such collections required not only the collection of such materials, but also a project of coordination of different collections, and their organisation so as to optimise them for future use (Radin, 2015, p. 363).

This work, too, underlines the importance of paying attention to temporality when studying collections, particularly how it relates to value. Radin’s work suggests that the acts and organisation of banks are significant in thinking about the value of biological materials, in that actors believe that the curation of material in specific ways makes it more or less valuable.

Yet there is another level at which we can develop a temporalized account of value and conservation. Bowker suggests that the development of large biodiversity information databases is part of a discourse where the present is to be ‘rendered eternal’, therefore

> *‘removing ourselves and our planet out of the flow of history. (…) [t]he background (our canvas) should stay stable while the foreground (human attainment of perfection) should be changing rapidly (…). The nec plus ultra is the cloning movement. Thus a company in San Diego offers gene banking by holding out the possibility of pet cloning (…). Indeed, one vision (popularised in the film Jurassic Park) is that we can preserve biodiversity by banking gene sequences and rolling out diversity when we need it.’ (Bowker, 2005, p. 209)*

This is an interesting question, as it is possible to read the purpose of genebanking in this way; however, the storage of diverse genetic material for its ‘option value’ can also be understood as a means to preserve diversity in order to maintain the generative potential of agriculture, thus combatting the homogenisation of genetic lineages.

The conservation of genetic resources brings up important questions regarding what it means to maintain value for the future. In this sense, too, it sits between the work on the economies of tissues and those of ‘bioinformation’, because here, ensuring that the genetic information is not lost ‘require[s] marshalling and oversight, economy in the archaic sense of ‘husbandry’’ (Waldby & Mitchell, 2006, p. 33) of the material basis, that is, the seeds and other plant materials. In this way, it differs from the curation of information that is kept digitally. However, they are *unlike* therapeutic tissues in that, in theory at least, germplasm is not an exhaustible resource.

The conservation of genetic resources therefore brings up important questions regarding what it means to maintain value for the future, and studying genebanks (that have a conservation function and have existed for a while) provides a great opportunity to grasp the work that goes into maintaining these materials ‘in the present’, instead of taking it as a given. Hence, we can think about how these banks/collections are seen as sites for the maintenance and accumulation of valuable material. In particular, as discussed, they bring up interesting questions about how value is constructed through collection practices: an issue that deserves further consideration in the case of the germplasm economy.

2.2 Studying ‘bioeconomies’

Having discussed biobanks and their role in the management of the value of biological resources, I now turn to studies of the broader economies that such biobanks can be part of. In this section, then, I review work that seeks to theorise the relationship between biotechnology and biological organisms (or parts thereof) and the practices of contemporary, capitalist sociotechnical systems, turning to ideas that help us to understand the conservation of germplasm in banks as matters of value. I start with older work about commodification of biological organisms (or parts thereof), which focuses on the implications of commodification of biotechnological artefacts into economic networks/regimes, but where the latter remain unchanged by the process. I then turn to more recent analyses of bioeconomies and associated concepts that suggest that simultaneous changes occur in these economies *as a result of* the technoscience (Lemke, 2011).

There is, of course, a long history of humans exploiting a variety of valuable characteristics in living organisms in different ways, leading to the co-evolution of domesticated plants and animals with particular social groups and environments. The movement of plants and animals to different regions played a significant part in processes of colonisation, and as a means to extract economic value and/or commodities. For instance, lucrative trade was established by colonial powers through the control of the production of commodities such as rubber, tea, tobacco and coffee - all plants that were introduced into colonies and became integral parts of plantation economies, as well as important resources for their owners. Institutions that enabled and coordinated the collection and circulation of plant materials, such as the Royal Botanical Gardens at Kew, came to be significant in empire-building in the 18th and 19th centuries (Brockway, 1979, 2002), demonstrating that the ability to successfully carry out the transfer of plants to new places was a necessary step in creating new productive sources of value for the Empire.

During the 20th century (particularly in its latter half), developments occurred both on technological and legal realms that enabled organisms or their constituent parts to become valuable for research, innovation or therapy; and often also alienated (in a Marxian sense) from their places/owners of origin. Examples include the HeLa cell lines (Landecker, 2007), organs (Waldby & Mitchell, 2006), tissues – such as in the John Moore case (discussed for instance in Jasanoff, 2012) and embryos (Franklin, 2006a). Callon (1998) would perhaps consider the development of these collections to be a form of *detachment* of these materials from their owners. Indeed, Waldby and Mitchell (2006) utilise detachment to explain how certain biobanks can be places where biological fragments can be dissociated (and therefore become ownable) as donors 'give away' their rights to these materials through, for instance, informed consent procedures.

Consequently, researchers in both STS and Geography started producing analyses that sought to explain the emergence of a trade in biological fragments along with the biotechnological capacity to preserve and move such fragments ever more widely. One approach (Nelkin & Andrews, 1998) considered it a process of *commodification* of biological material, that is, its transformation into commodities, or 'objects produced for sale on the market' for which there is not only (practical) *use value*, but also *exchange value* (Polanyi, 1985). These literatures can be parsed into two main strands: the commodification of (1) human tissue, and (2) non-human organisms. There are significant differences between the way we theorise the circulation, exchange and valuing of human and non-human tissue; especially predicated on the greater acceptability of ownership of non-human life forms. Hence, they raise different questions/arguments. The former bring up a set of questions about ethics, policy, or justice that often build on arguments about human dignity and individual autonomy.

Another set of literature has focused on green biotechnology and food systems and has sought to trace the 'implo[sion]' of genetics, the market and the law 'to produce novel forms of life, death and property all inseparably bound up with each other' (Van Dooren, 2007, p. 75). Since these are significant differences, the economies of human-derived tissue and non-human organisms (or fragments) are discussed in different sections. However, both strands are worth reviewing because some of the concepts and arguments developed are transferable from 'red' to 'green' biotech. For this reason, in the next section I turn to existing work on the commodification of non-human organisms; before returning to work on the economies of tissues and organs in 2.2.2.

2.2.1 *Economies of non-human materials and the construction of nature as resource*

In contrast to the biomedical tissue economies involving human tissue, the literature on the circulation and exchange of non-human nature is focused less on the ethical/dignity issues regarding the instrumentalization of people, and more on the political issues that emerge with the rise of intellectual protection and bioprospecting/biopiracy (Hayden, 2003; Merson, 2000; Parry, 2004; Reid et al., 1993; Svarstad, 2002). For instance, work of this kind tends to focus on the implications for the collective, since it often focuses on the rights of particular groups (often indigenous peoples) to manage or control the biological or genetic 'resources'[3] - and the 'traditional' knowledge about their uses - of which they are legally defined as the 'custodians'. Existing scholarship on that topic has shown how bioprospecting projects tend to involve actors from different countries and where, very often, there is an uneven distribution of what might be construed as valuable resources – both biological (that is, biodiversity framed as economically and socially valuable) and in terms of funding, research and development capacity, and so on. Since bioprospecting generally involved the exploration of less developed, but 'biologically rich' countries for industries sited elsewhere (see for instance Hokkanen, 2012) (especially before the Convention on Biological Diversity came into force in 1993) there is a clear spatial dimension to the study of commodification of non-human natures[4] (see e.g. Merson 2000; on the

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[3] Although there is a parallel with themes of consent on the STS literature on the human genome diversity project (Reardon, 2001) and post-colonial STS (e.g. Kowal, 2013; Radin 2013) which shows how indigenous *groups*, are gaining control over their own blood and other bodily fragments when they were collected and kept as research resources.

4 This is not to say that it is absent from the first, as seen for instance in Sunder Rajan's (2006) analysis of the exploitation of bodies in the Indian subcontinent for the creation of medicines to be used in the West.

implications of biodiversity governance in the context of ongoing inequality between ex-colonies and colonial powers).

According to Mulvaney and Wells (2004, p. 35), 'bioprospecting turns on the notion that biological diversity is a public good everyone depends on and therefore the "price" the good bears on the market does not represent its value.' Such biological diversity can therefore be said to encompass a multiplicity of values, not just exchange value. These values can be somewhat underdetermined, however, and raise questions about what constitutes an appropriate way of exchanging, acquiring and using biodiversity. In that sense, these are fundamentally political economic matters. Yet this literature has also shown how extending Western political economic constructs (like 'intellectual property' as pertaining to an individual) to other sociocultural arrangements (through global governance of biodiversity) has meant that those actors who are imbued with the right of ownership or consent are not easily identified by bioprospectors (see also Hayden, 2003). Questions such as who has the right to provide consent, what counts as a 'fair' benefit, and whose responsibility is it to decide in matters pertaining to the commodification of biological resources are controversial because there are different political and cultural conceptions of ownership between supporters and opponents of bioprospecting.

The literature on bioprospecting is applicable to thinking about the *ex situ* conservation of agricultural genetic resources. Firstly, there is the matter of governance: agricultural biodiversity is a subset of biodiversity altogether and, as such, is also covered by the CBD. Moreover, this case can be productively compared to the bioprospecting of 'wild' biodiversity. Both 'wild' and domesticated biodiversity have been disappearing at speed during the 20th century, albeit for different reasons, and both are 'bioprospectable' *resources* from whence valuable biochemical or genetic components can be drawn, rather than as 'raw materials' in the exhaustible, embodied sense of the word. This is important because it makes them non-exhaustible resources which are extracted/synthesized/bred into the final product. In this sense, they are understood as quasi-informational resources (Halewood, Noriega, & Louafi, 2012a). Like medicines, crop varieties too can be ‘‘protected’ and licensed, similar issues emerge about access to, control over genetic resources and what constitutes ‘benefit sharing’. Of course, the differences between the pharmaceutical and agricultural sectors (regarding for example materiality, modes of production (farmers have long bred their own, roles/spaces occupied by the pharmaceutical and agricultural industries) mean that they are not identical - and, as mentioned in the previous chapter, the Seed Treaty mandates ‘facilitated access’ to plant genetic resources specifically for the purposes of food and agriculture, unlike the CBD (even if the Multilateral system is rather partial). Nonetheless, writers working on the study of bioprospecting have identified significant questions about the characterisation of biological material as valuable resources, and what this means for the way they are utilized and protected.

As geographers have suggested, ‘resources’ have some kind of use value for humans, which means that they are part of broader economies of use and exchange. For example, Bridge (2009) defined natural resources as ‘parts of the non-human world to which value is attached’. It is relevant for this research that he identifies a series of paradoxes between the production and consumption of resources, and suggests these shape the geographical and historical dynamics of this configuration he calls the ‘material economy’.

One of the trends in privatization is the ‘extension of the property relation to *new* forms of nature, particularly genetic information and biological processes’ (Mansfield, 2007, p. 200). The interesting thing about seeds, in this instance, is that they straddle both ‘old’ and ‘new’ forms of nature. Although they have long been valued, the development of biotechnologies and new methods of breeding has meant that they could presently be *appreciated* (root word: price) as gene donors. And thus, they can be seen to operate as boundary objects (Star & Griesemer, 1989; Whatmore, 2002) between farmer communities, plant breeders, and conservationists, not to mention policymakers and publics.

The net effect is one of multiplying interests and, therefore, a potential for globalization of these value(s) and economies, in line with the broader bioprospecting story. Braun describes a globalization of the human and non-human collectives that ‘has more to do with technoscientific rather than political-economic practices, although the two are intimately connected’ (Braun, 2006, p. 650). He points to Franklin’s (2005) argument that stem cells are ‘global’ both in the sense that an international and competitive industry is emerging, but also in the sense that ‘they “offer the prospect of downloading genomics into a wealth of applications (p.60)” such that ‘life itself’ is now imagined in terms of its recombinant outcomes (Haraway, 1997; Rose, 2001)’.

The concept of ‘genetic resource’ itself remains underexplored in STS; although Parry’s and Hayden’s work is a fundamental starting point for understanding how the conservation of germplasm is organised along particular ideas about the value of nature and how to maintain it. Hayden

(2003) and Parry (2004) have produced empirical studies that focus on ‘how new ‘biologicals’ are being stabilized, denominated, stored, accumulated, distributed and turned into new forms of property’ (Franklin, 2006b). Hayden’s is an anthropological study of bioprospecting in Mexico. Parry’s (2004) work is an analysis of the social and spatial dynamics that make contemporary biological resource collections such as that of the US National Seed Laboratory at Fort Collins. Both these works are also, in different ways, attentive to the geographies of bioprospecting. Hayden suggests that *movement* – of prospectors, of biological material itself, of knowledge - is essential, as it is through it that a plant extract can be ‘reanimated as a commercial product’ by ‘being given new kinds of ‘connection’ (Franklin, 2006b, p. 302). Parry, on the other hand, is interested in the ‘dynamics’ of collecting and their relation to the *format* of what is being kept. Both authors examine the movements of biological and informational resources in an international economy, and identify the complexities that such fluidity creates for the governance of the use of genetic resources. This is an important insight, and in my empirical chapters I show that they exist also in the workings of genebanks.

One of the most prevalent ideas in theorising the value of genetic resources is that it hinges on being conceptualised as valuable information. Hayden tells us that ‘the actualisation of this value depended on the realisation that this was an informational good; a ‘storehouse of information not yet catalogued’ (Hayden, 2003, p. 58). Saying it is information which is valuable is important, since it means that this is a resource that is replicable and ‘non-rivalrous’, that is, where use by a given user will not impinge on the use of another (unlike other physical natural resources, like water, that are exhaustible). Moreover, it has practical implications. For instance, Waldby and Mitchell tell us that ‘the elasticity and recombinatorial promise of ‘information’ underwrites the conceptual power and promise of calls for the protection of biodiversity, for advocates suggest that’ it doesn’t depend on large-scale harvests of raw materials (Waldby & Mitchell, 2006, p. 140).

Parry (2004) suggests that biotechnologies could, like other informational technologies, ‘enable biological material to be stripped down, or rendered, in new more artefactual or even purely informational forms: as cryogenically stored tissue samples, as extracted DNA, as cell lines, MRI scans, or sequenced DNA coded into databases.’ (Parry, 2004: xx) This is termed ‘bioinformation, and these changes make it easier to transmit, copy, or manipulate it - therefore, ‘new and potentially lucrative markets are beginning to emerge in such bioinformation. Parry identifies this move towards the informational as a consequence of the advent of biotechnological/DNA techniques, which ‘enabled components that had been previously unknown, inaccessible or unstable to be efficiently maintained and utilised independently of the organisms in which they were originally produced. These biological derivatives have consequently come to be constituted as ‘resources’ in the classical sense, as ‘a stock or reserve upon which one can draw’’ (Parry, 2004, p. 49). She bases the idea that biotechnology can be re-conceptualised as information technology from Manuel Castells and others, stating that it has ‘the ability to decode and reprogram the information embodied. New biotechnologies enable us, in other words, to extract genetic or biochemical information from living organisms, to process it in some way (…) and, in so doing, to produce from it other combinations (…) that might themselves prove marketable and commodifiable.' (Parry, 2004, p. 50).

She notes that new biotechnological techniques enable the 'purification' of particular aspects of whole organisms (generally, their genetic or biochemical composition) in a process that leads to the creation of new, more fungible, accessible and portable *proxies* for the same organisms. In so doing, proxies lose some (and at times, all) their corporeality. Therefore, the bioinformational proxy can be increasingly decontextualized, while the valuable informational sequence itself becomes more accessible.

For Parry, resolving questions such as who 'owns' bioinformation and who should profit from their commercialisation (live questions still) requires firstly that we find out more about how this 'emerging resource economy in bio-information actually functions' especially since it has the potential of creating 'new *dynamics* of resource exploitation, and new *geographies* of (in)justice' (Parry, 2004: xx). This argument is applicable to the germplasm economy, itself a (genetic) resource economy; studying its organisation in practice by exploring in greater detail the workings of genebanks is a step towards reflecting on the implications of the current geographies of conservation and use of genetic resources.

Braun suggests that both Hayden's and Parry's work analyses the spatial and socioecological networks that have resulted from the changes that took place (genomic) sciences, global governance, and new economic arrangements. It is in this context that nature can be seen simultaneously as a 'global 'storehouse' of valuable genetic resources and a 'workhorse' that produces novel genetic forms. Precisely because nature is increasingly viewed as consisting of the 'essential raw materials' necessary for ongoing evolution (ie, 'genetic diversity'), conservationists and capitalists alike have come together with a shared interest in 'sustaining' genetic resources as an investment in the future. Not only has this wed sustainability to capitalism, a process enhanced through TRIPS agreements, it has also displaced 'local' natures into 'global' arenas, authorising actions that protect a 'global heritage' from 'local threats' ' (Braun, 2006, p. 650). Yet interestingly, perhaps that argument can be extended further back historically, at least in the case of germplasm. I have argued elsewhere (Peres, 2016) that genebanking is established as a conservation approach in the 1970s as an *international* project from the outset, and it is interesting to note that the same themes of common heritage and nature as workhouse are present.

In that sense, the study of a germplasm economy is interesting, too, as a contribution to ongoing work within geography to develop a critique of neoliberal biodiversity conservation (Büscher, Sullivan, Neves, Igoe, & Brockington, 2012) which, following McAffee (1999), the authors define as 'an amalgamation of *ideology* and *techniques* informed by the premise that natures can only be "saved" through their submission to capital and its subsequent revaluation in capitalist terms' (Büscher et al., 2012, p. 4). In so doing, this concept expands on the ongoing debate regarding the concept of neoliberal *natures* (Bakker, 2010; Castree, 2008; Heynen & Robbins, 2005; Himley, 2008), although this particular literature remains largely outside of the remit of this thesis, which focuses on repositories, rather than the more usual topics of environmental services, ecotourism, or debt for nature swaps. Instead, the case of genetic resources conservation appears to have more in common with the study of tissue economies (as I turn to in the next section). As I will show in light of empirical evidence, the germplasm economy cannot be easily described as an example of a case of neoliberal governance of nature; while at the same time there are definite examples of economic imperatives shaping the activities of genebanks, suggesting that, with respect to PGRFA at least, there is a complex economy at play – and one that genebanks construct through their practices.

In summary, then, the literature reviewed here demonstrates how living organisms - and, of late, their constituent parts – have been transformed/construed as *resources* that are integrated into economies. In addition, it has shown how a process that should be contextualised within broader trends of globalization and the emergence of technologies that enable the circulation and accumulation of biomaterials. One of the themes in this literature is the decontextualization of such 'resources': what is valuable is extractable from its environment, and constructed in scientific terms. Moreover, as Parry's work demonstrates, the shift towards less corporeal/more informational proxies has implications for the distribution and the regulation of these materials. Finally, and in a related way, we note how these developments are increasingly thought about at the 'global scale'. Resources flow from some parts of the world to others; setting up particular spatial dynamics between 'countries of origin' and 'users' of resources. This work, generally based on empirical case studies, is valuable in providing both a critique and a model for thinking about the circulation and exchange of biodiversity and its interaction with matters of value. Yet there is scope for greater attention to the collections themselves and the role that they play in making biological materials into valuable resources, and in shaping the sorts of economies that they circulate in. Therefore, in the empirical chapters that follow I take into consideration the ways in which genetic resources, data, and funding flow through genebanks and how they become increasingly mobile as they do so. As I began to argue in Chapter 1, sites like genebanks (and biobanks more broadly speaking) should not be considered as passive sites that have little effect on the economies that they are part of. Hence, in this thesis I sought to develop an account of the role of genebanks in the construction of genetic resources and the germplasm economy. In the next section, I focus on existing work on biomedical tissue economies because they provide ways of thinking empirically about the articulation of biological materials or fragments as resources with different kinds of value, and to explore the economies that emerge around them.

2.2.2 Theorising human tissue economies

'Biocapital' is a concept used several times in the STS literature by different people, with overlapping but distinct meanings – which Helmreich (2008) looks into at length in his paper *Species of Biocapital.* One iteration comes from Franklin and Lock's work (2003) and is defined as 'reproductive technologies generative of surplus value' (Helmreich, 2008, p. 127). Franklin and Lock's work is anthropological and feminist. In contrast, Sunder Rajan's definition of biocapital encompasses both the (re)generative potential of biotechnologies and the market potential of bioproducts (idem). Building on the work of Foucault and Rose, he describes biocapital as infused with evaluations of speculative potential of visions, hype and promise (Rajan, 2006, p. 18). Similarly, Cooper identifies a common belief in the ability to overcome limits to growth, shared between neoliberal economic thought and biotechnological reformulations of living organisms (Cooper, 2008). Hence, the operative word for this strand is, clearly, *potential.* That this is the case is indicative of the future-orientation that permeates contemporary economies. I begin this section by describing the two different iterations of biocapital – which Helmreich names 'Marxist-feminist' and 'Marxist-Foucauldian' (Helmreich, 2008) – as a means to introduce the approaches that are reviewed in the present section; all are perspectives that seek to illustrate the changing relationship between capitalism and the life sciences and could be said to study the 'bioeconomy'[25], but do so from different perspectives. Scholars working in this field take as a starting point the view that economies are forms of social relationship, and the ways in which resources are

[25] What is meant by 'the bioeconomy' is very much context-dependent. The OECD's definition in their project 'The Bioeconomy to 2030' (quoted by Hamilton (2008)],) is "*the aggregate set of economic operations in a society that uses the latent value incumbent in biological products and processes to capture new growth and welfare benefits for citizens and nations*". Lemke notes that, for the OECD, the 'bioeconomy' means an extension of existing structures and markets so that it is possible to capitalise on the products and services that emerge from the biosciences. Yet for scholars who study the bioeconomy (whose work is discussed above), the definition means rather a 'fundamental realignment of the economy' (Lemke, 2011, p.: 112) enabled by the new biotechnological capabilities; that is, the new emergent economy that is made possible by biotechnology.

exchanged are constitutive of the ‘social fabric’ (Titmuss, 1997; Waldby & Mitchell, 2006, p. 33).

Exponents of the Marxist-feminist strand whose exponents critique Marx for side-lining *re*production, or the replication of the labour force, while focusing on production: it is ‘wrongly marginalised in accounts of economic change and development’ (Franklin & Lock, 2003). These works have yielded important analyses of the ways biotechnologies have led to changes in the way we consider reproduction and kinship. However, the second, Marxist-Foucauldian strand of work is more directly relevant here. It is grounded in concepts from Marxian political economy, as expressed in concepts - like ‘biovalue’ (Waldby, 2000, 2002) and ‘biocapital’ (Rajan, 2006) - that draw from the labour theory of value[26]. These suggest that biotechnology has facilitated the extraction of surplus value from biological fragments, therefore in ways that go hand in hand with the contemporary arrangements of capitalism; which is itself transformed into a new ‘biocapitalist’ phase. That is its central assumption: that there is a synergy between the life sciences and the economy to the point that the former herald a new form of capitalism. Sunder Rajan explains the substance of this link as follows:

> *‘One can trace the epistemic milieu in which both economics/capitalism and the life sciences/biotechnology are undergoing radical transformation and dealing with apparently similar types of problem-spaces (such as, for instance, the understanding and management of complex systems of risk) at similar moments in time, and often drawing on one another for metaphoric or epistemic sustenance’ (Rajan, 2012, p. 7).*

[26] There seems to be an open question over the kinds of labour that produce biovalue. For instance, Mitchell (2011) emphasises the importance of what he calls *clinical labour* or ‘the regularised, embodied work that members of the national populations are expected to perform in their roles as biobank participants’ in the creation of biovalue (see also Waldby and Mitchell, 2010).

So, this approach is considerably co-productive in nature. For a historical example, we turn to Cooper's (2008) argument. She suggests that the 1980s were transformative for both the life sciences and various aspects of the social sphere - the 'neoliberal revolution'. She argues that 'the project of U.S. neoliberalism is 'crucially concerned with the emergent possibilities of the life sciences and related disciplines' (Cooper, 2008, p. 3). Hence, hers is an explicitly co-productive approach and she maintains that 'now, more than ever, we need to be responsive to the intensive traffic between the biological and the economic spheres, without reducing one to the other or immobilizing one for the sake of the other' (Cooper, 2008, p. 3).

Cooper argues that the biotech industry and neoliberalism 'share a common ambition to overcome the ecological and economic limits to growth associated with the end of industrial production, through a speculative reinvention of the future' (Cooper, 2008, p. 3). This attention to the creation of futures that are inexorably informed by technoscience as well as the unfolding changes in the economic context (in the form of commercialisation or the infiltration of the 'speculative logic of capital' into the life sciences) is what makes Cooper's work interesting in this case. For her, 'neoliberalism installs speculation at the very core of production' and therefore 'profoundly reconfigures the relationship between debt and life (…) in productive dialogue with the life sciences, where notions of biological regeneration are being similarly pushed to the limit' (Cooper, 2008, p. 3).

She does agree with Foucault that neoliberalism 'reworks the value of life as established in the welfare state and New Deal model of social reproduction'. Its difference lies in its intent to efface the boundaries between the spheres of production and reproduction, labor and life, the market and living tissues - the very boundaries that were constitutive of welfare state politics and human rights discourse' (Cooper, 2008, p. 3). But she qualifies his argument, suggesting that the aim of neoliberalism is

> *'not the commodification of daily life - the reduction of the extraeconomic to the demands of exchange value - as its financialisation. Its imperative is not so much the*

> *measurement of biological time as its incorporation into the nonmeasurable, achronological temporality of financial capital accumulation.'*

Where Cooper's work is concerned with the interrelation of neoliberalism and science, Waldby's work is one of the early conceptualisations of the interrelations between capitalism and the life sciences (Birch & Tyfield, 2013, p. 5). She uses the concept of *biovalue* (in Waldby, 2000), defined as 'the yield of vitality produced by the biotechnical reformulation of living processes, in order to explain how biological material is transformed and revalorized in contemporary bioeconomies:

> *'Biovalue refers to the yield of vitality produced by the biotechnical reformulation of living processes. Biotechnology tries to gain traction in living processes, to induce them to increase or change their productivity along specified lines, intensify their self-reproducing and self-maintaining capacities. This intensification or leveraging of living process typically takes place not at the level of the body as a macro-anatomical system but at the level of the cellular or molecular fragment, the mRNA, the bacterium, the oocyte, the stem cell. Moreover it takes place not in vivo but in vitro, a vitality engineered in the laboratory' (Waldby, 2002, p. 310)*

Some researchers have noted the parallels between the speculative nature of the contemporary bioeconomy (Cooper, 2008), so that it is the very 'potentiality' of these cells which is opened up for exploration (Hamilton, 2008): 'the fact that much of the value that may be contained among the diversity of flora or fauna is unknown, or more appropriately seen as *incumbent*, is what gives it, to give it its "promissory value"' (Hamilton, 2008, p. 4). Yet, at the same time the extraction of 'surplus value' results from 'setting up certain kinds of hierarchies in which the marginal forms of vitality – the foetal, cadaverous and extracted tissue, as well as bodies and body parts of the socially marginal – are transformed into technologies to aid the intensification of vitality for other living beings' (Waldby, 2000, p. 19).

The study of the organisation of what Waldby and Mitchell call 'tissue economies' exemplifies this approach to the study of the circulation of various biomedical tissues as a sort of *political economy,* in the sense that 'the forms of circulation characteristic of any tissue economy both presuppose and constitute certain kinds of social relations, and indeed power relations' (Waldby, 2000, p. 19). Their aim is to understand 'what [it means] to give blood and human tissues today, and what [it means] to receive them [and] what values and what kinds of embodied power relations are constituted by the exchange of human tissues, and what kind of social space does their circulation describe' (Waldby & Mitchell, 2006, p. 181). In so doing, they show that there is no clear distinction between a gift and a commodity economy, complicating the neat distinction made by Titmuss (1997) with respect to blood donation and his proscription of commodification as the source of the problem. For him, this clear separation between the market and social economies means that there is no possible overlap between values and economic value: a market system therefore chips away at the social ties that bind people together in a system where blood is donated.

They critique the conclusions of Richard Titmuss's comparative work on blood banking in the UK and the US, where he concludes that the commodification of blood in the US puts at risk the social relations/values that underpin the use of donated blood. They follow Appadurai (1986, p. 57) in suggesting that in the circulation of tissues too we see that there are multiple (and sometimes competing) values that can be ascribed to particular objects in this economy, and therefore it is social arrangements that define what constitutes a fair exchange or desirable outcome; and who is in the position to make demands. 'All these values remain implicit and potential until they are ordered into an economy. Different forms of circulation (giving, lending, buying) constitute and hierarchize these values (…) in different ways, and produce different social, ethical and health outcomes' (Waldby & Mitchell, 2006, p. 32).

So, if the circulation of tissues – especially in contemporary economies – cannot be considered 'pure' gift economies or commodity economies, Waldby and Mitchell (2006) seek to understand the ways in which modern tissue economies do, in fact, incorporate into their construction concerns about both economic value and social values; which shape and circulate within these. That insight is particularly relevant for the interpretation of the empirical work which follows: when considering the germplasm economy and the role that collections play in their organisation, we should bear in mind that this economy seeks to encapsulate both social ties and economic ones, and preserve in the genebank materials that have not only economic, but other values. Callon (1998) argues that in contemporary economies, gifts and commodities are increasingly mingling - as Waldby and Mitchell put it, they 'cannot maintain mutually exclusive forms of social space or spheres of relationship' (Waldby & Mitchell, 2006, p. 32). The circulation of such materials sometimes involves a change in status - for instance, in terms of 'ownership' from the individual who provided the tissue to other organisations (e.g. research institutes or hospitals), from 'waste' to precious research tissue, and sometimes from 'gift' to commodity. So, the commodity 'is not one kind of thing (…) but one phase in the life of some things' (Appadurai, 1986, p. 17).

Waldby and Mitchell argue – chiming with Parry – that technologies are transforming the capacity to extract, differentiate, and transform tissues so that they can pass through stages of being both gift and commodity. That is, tissues have different 'technicities' (Waldby and Mitchell, 2006, p. 182). This technicity is, according to them, a 'key feature': 'their overall shape is described at the intersection of material qualities of tissues (…) with the kinds of technology available to procure, potentiate, store, and distribute them (Waldby & Mitchell, 2006, p. 32). Consequently, technicity 'mediates the value and relations associated with particular kinds of tissues' (p.182). An example of varying technicity is the ability to 'disentangle' a tissue, in the sense of making it accessible, storable; standardised: or in other words, the ability for such tissue to mimic *currency*. Again, one might draw a link between their work and that of McAffee, who argues that only the kinds of nature that are capable of entering/being visible in global markets (through their standardisation etc.) can be seen to be valuable (and therefore, her argument goes, worthy of protection in 'green developmentalist' terms) (McAfee, 1999).

Yet, the Marxian-inspired STS concepts described above have been critiqued by other scholars who suggest that more attention is required to address the political economic aspects of these bioeconomies (Kean Birch, 2013, 2016; K. Birch & Tyfield, 2013; Tyfield, 2009). In their view, STS scholars have not yet fully engaged with the political economy theories from which they borrow certain terminology (especially Marxian terms, such as surplus value). As a result, they argue, there may be a 'fetishisation' of the 'bio' in current STS understandings of how specific biological entities come to be construed as valuable (K. Birch & Tyfield, 2013, p. 3). Their main message is that a deeper appreciation and engagement with the Marxian theories that STS bio-concepts draw upon (and more recent developments in this area) is required, since 'because of their particular technoscientific focus, these STS theorists have posited a transformation of modern capitalism without due attention to *the transformation of economic and financial processes in modern capitalism*' (Birch & Tyfield, 2013, p. 3). Perhaps, a step in the direction of addressing this critique, would be to pay more attention to the interplay between the transformations in the economy *and* the materials themselves - a sort of co-production.

Hence, and taking this critique into account, understanding the political economy of gene banking itself must be part of the task of investigating how the practices and organisation of genebanks operate in terms of (e)valuative practices. This means engaging with the maintenance of genebank collections as dependent also on the broader political-economic environments of agricultural R&D, by being attentive to the social, normative and political context that these 'economies' operate in. One way of doing so is to take a more historical approach that can make visible its temporal dynamics and implications for germplasm conservation. Doing so certainly requires a methodology that can take into account the larger scale since, as Tyfield (2009) emphasises, the potential problems that make typical STS work less amenable to the study of political economies, namely, the 'social interactionist ontology' that tends to ignore structural factors, while the detailed empirical work at small scales means that more 'macro' scale spheres/events - such as (political) economic ones - can sometimes be absent from the analysis.

2.3 Conclusion

Genebanks are, one could argue, *nodes* in an 'economy' of plant genetic resources: they are repositories for the storage of seeds, but their purpose is the conservation of the potentially valuable 'genetic resources' within, whose value can be extracted through use in future plant breeding or research. Seed banks thus serve to preserve such resources in such a way that their value is maintained, and also to disseminate valuable germplasm (according to demand and to the possibilities of the genebank itself). Hence, genebanking could be understood with the theoretical frameworks and approaches that consider the exchange and circulation of biological organisms as an economy. These scholars undertake to study what Lemke (2011) has called the 'economization' of life: the transformation of the economy to a bioeconomy.

The work surveyed here demonstrates how work on the commodification of nature has contributed to our understanding of how biological organisms are 'enclosed' and how such a process involves the setting up of particular social arrangements (into economies), as much as it does the creation of 'products' themselves – hence, nature becomes liable to be imagined, and consequently treated as, a valuable resource. Yet I have argued that such work could be extended to the study of the role of sites such as genebanks, enquiring about the role that they could play in the construction of particular organisms/fragments as valuable. A second relevant question here is what sorts of value(s) are identified in STS and other accounts: how are we to analyse the different kinds of value(s) that are seen to be present in these resources and these sites? As work in STS moves towards increasingly sophisticated theories of biological resource economies that identify heterogeneity (by which I mean, combine 'gift' and 'commodity' in different ways) and the coexistence between value and values, this question is theoretically important.

Here, the study of the germplasm economy can be helpful, given the multiplicity of values that can be encompassed within the umbrella of ‘genetic resource’: it provides a suitable empirical case study where the germplasm economy can be explored empirically and understood as a complex network that cannot be described wholly as a market nor as a gift economy: rather, it is a situation where both economic and social values are prized. In this situation, genebanks can hold a particularly significant role as the sites where these different values can be managed in ways that permit particular arrangements of the germplasm economy to function as they do.

Studying the exchange and the accumulation of biological organisms as economies is advantageous: it means we can think about the way scientific activity too is a source of not just social, but economic value. It also means we can look to the concomitant changes in economic (or political-economic context); for instance, in the shift towards greater future orientation, or performativity of imaginaries in a time where promissory value becomes increasingly important. Yet, more attention could be paid to how these economies are actually constructed in practice; that is, through artefacts and practices. Such a step is essential in developing an understanding of how, precisely, evaluation/ideas about value and its circulation/distribution might be performative. As mentioned in the introduction to the chapter, one way to do this is by paying attention to what happens in germplasm *banks.* Doing so, we can bring into the analysis what happens to the material when it enters these banks so that it becomes part of broader economies or circuits of exchange. In the next section, then, we turn to what people have had to say about biological *collections* and examine what that has to tell us about the construction of value.

Finally, the Foucauldian-Marxist approach to the bioeconomy clearly recognises, and seeks to define/expand on, its ‘speculative nature’. Consequently, this literature demonstrates how statements about the promissory value of biological material themselves matter – and, indeed, how that meshes with the rationalities of capitalism (with respect to ideas of continual economic growth). However, I suggest that we need to be attentive not only to the future (and the performativity of future-oriented statements) and present, but also to the past when we seek to understand the working of these bio-economies. This means two different things. Firstly, that we can take into account the idea that the biological material which is present in the bioeconomy has a past – a history, if you will – and that this past shapes the way in which such material is valued. Secondly, it suggests that a historical approach is helpful in terms of thinking about the 'life' of these future visions. My suggestion for resolving this tension is to focus the study on banks. These are, of course, a part of these economies; and by analysing their practices in tandem with external political economic factors as they go about accumulating, creating, and disseminating 'resources', I aim to follow the co-production of the gene pool and the gene bank.

CHAPTER 3 METHODS AND METHODOLOGY

In order to develop an account of genebanking as part of a germplasm economy, I undertook an interpretive, qualitative analysis of material (interviews and documents) through which I could follow how particular political economic themes were found in genebanking organisation and practices such as genebank management, genetic resources policy, the evolution of ex situ conservation over time, and the organisation of genetic resources networks and groups. This chapter is dedicated to a discussion of the methods and methodology used to develop the data corpus for this research. The source material comprised documents (policy, scientific, communication material such as newsletters, and media reports); along with interview transcripts from actors involved in genetic resources conservation policy and/or practice in the European region. I analysed semi-structured interviews (with 23 genebank staff, users, researchers and people working in policy, from the UK, Portugal, Italy and Germany) and documents in order to determine actors' perspectives and meanings of genebanking, its practices, and its organisation.

This was a qualitative study, as it sought to develop an account from the point of view of the actor (which Bryman, 1984, p. 77 describes as its 'sine qua non'), and where I attempted to understand actors' views about the practices and policies of genetic conservation. Because of the geographic distribution of both genetic resources and users, it is important to be mindful of the different situated perspectives on conservation. Therefore, I focus on people involved in seed banks in different positions and different geographic locations. The diversity between seed banking institutions and the decision to have a comparative angle at different levels steered me away from a straightforwardly ethnographic project, although this remains a distinctively worthwhile research avenue for future work. However, there remains an ethnographic bent to this work, since I have sought – especially with the interviews - to take an ethnographer's stance in asking about actors' worldviews, so that they help me to understand their perspective on the organisation of genetic resources (both in terms of how it is and how it should be).

In offering an STS/geographical perspective on genetic conservation, I intended to contribute to our understanding of the conservation of genetic resources as part of a broader germplasm economy where a multitude of interests, priorities and values are in evidence (instead of as a matter of politics-versus-science, or a story about the commodification of life and traditional knowledge). My aim was not to provide an evaluation of *ex situ* conservation. Instead, I meant to understand how genebanking practices and the germplasm economy more broadly are infused with ideas about what counts as valuable (enough) and what it means to conserve well. Thus, I intend for this project to be engaged both with the subject matter and with the ethico-political implications of STS work. Puig de la Bellacasa (2011) (building on Latour's (2004) concept of 'matters of concern') suggests that that we, as analysts, attend to 'matters of care'. That means being aware of, and open to, the ethical-political engagements that arise in the course of doing STS; which in turn involves being mindful of the implications of STS critique by recognising that it has effects in the world and that our objects of study can also be vulnerable and deserve our care (de la Bellacasa, 2011; A. Martin, Myers, & Viseu, 2015). I sought to develop this awareness in the undertaking of the research through reflexive consideration of the implications of research outcomes and my own involvement as a scholar (for instance, keeping in mind how pre-existing ideas and values relate to the research project). Such work is ultimately helpful, as it brings into view the ways in which epistemology, researchers' positionality, and ethics are tied into the developing research project. This exercise is particularly important as we continue to develop ways of doing engaged STS (Sismondo, 2008).

More specifically, I sought to attend to diversity, both at the level of the subject matter its theoretical treatment. By this I mean, firstly, that I subscribe to the need to preserve plant genetic diversity, inclusively in genebanks. In that, I echo van Dooren's (2009) suggestion that we 'bank well'. I suggest that understanding of what factors shape genebanks (and policy) into their contemporary contours, thus taking them to be contingent, rather than natural outcomes of international action to preserve plant germplasm, is a means to understand what it might mean to have a conservation system where diversity can flourish, and to bring into my analysis the genebank both as a site of value accumulation and as a site of care. It means being open to the ways in which multiple forms of valuing, working, and organising economies can (co)exist within projects like *ex situ* conservation. In this, I follow Gibson-Graham's (1996) perspective that we do not unwittingly gloss over the other economies that can exist in overlap with the market; it means, straightforwardly, that I aim to highlight a subject – genebanking – that overlaps with more common topics of STS study, such as the production of knowledge (see for instance Latour & Woolgar, 1986) or of technologies (Bijker et al., 1987), but that focuses on a sociotechnical system, the genebank, that is neither normally a site for basic research nor a particularly complex technology. Instead, studying the role of genebanks in the germplasm economy is a way to reflect on the relationship between value and values in the contemporary circulation and accumulation of biological materials as resources. Doing so therefore requires a methodology that provides qualitative data about actors' perspectives on genebanking practices and policies; these are discussed in the sections that follow, along with the methods used to develop and analyse the corpus of data. Section 3.1 provides details the interviews, while the process of documentary selection and discourse analysis is described in section 3.2 and data analysis is the subject of section 3.3.

3.1 Interviews with actors involved in genebanking

The first strand of this research involved gathering perspectives of actors that are involved in *ex situ* conservation and therefore have first-hand experience and theoretical knowledge of the subject. To gather these views, I undertook 22 qualitative, semi-structured interviews, in the UK, Portugal, Italy and Germany with 23 participants (including one interview with two participants).

In this section, I describe how interviews were carried out and discuss their fit with the project aims. I begin by introducing the use of interviews as a fundamental method of data collection in the social sciences and describe their value as a method of data collection for this particular research project (section 3.1.1). Then, I describe the methodological choices regarding the choice of interviewees (3.1.2), and in section 3.1.3 I describe and discuss the interviews process.

A qualitative interview is, at heart, a guided conversation where the researcher aims to ‘hear the meaning’ that is being conveyed by the participant (Rubin & Rubin, 2012, see also Kvale, 1996) Interviewing is described in contemporary research methods literature as a foundational method for the social sciences, where ‘conversational practice where knowledge is produced through the interaction between an interviewer and an interviewee’, but whose history could be argued to go back to Plato’s dialectical methods (Brinkmann, 2008). Interviews are important sources for social scientists in that they provide data on several levels: firstly, they can provide information about particular events; secondly, they reveal interviewees’ perspectives on the topics under discussion; and finally, the discursive practices through which participants communicate are also made available for analysis (Atkinson & Hammersley, 1994) and are therefore useful for a great variety of purposes, including oral histories and surveys, interpretive policy analysis, and other aspects of social research. The interview is therefore well-suited to grasp the experientially based perspectives of specific individuals (Kvale, 2008; Seidman, 2013), be they personal or professional (as with this research). It enables the interviewer to enquire about specific topics of interest and to go into greater depth as required, even without knowing what themes will be important in advance. The interview is thus a suitable method for inductive, in-depth qualitative research, where the interviewer seeks to develop a ‘bridge’ between their own subjectivity and that of their subjects which might allow the interviewer to ‘imaginatively share’ in the lived experience of the respondent (Bloor & Wood, 2006, pp. 105–109).

Interviews have been used widely within STS as a way of understanding the beliefs and discourses of scientists, their relationships with other scientists or groups/stakeholders such as the public and policy actors (see for example Gilbert & Mulkay, 1984; Balmer, 1996; Guston, 1999; Milne, 2012). I elected to carry out interviews - rather than questionnaires or in-depth observation of a limited number of sites - because this approach provided a suitable balance between gathering actors' perspectives and developing a data corpus that was relatively diverse. This method enabled me to collate a variety of perspectives from different actors within the practical limits to time and resources that exist in all research projects.

There is a gradient of structure regarding interviews, from the very structured survey interview, where the responses are restricted in advance by the shape of the questions, to unstructured interviews which more closely resemble everyday conversations. Such diversity of methods reflects very different perspectives on the purpose of the interview and the knowledge that can be derived from them (Bryman, 2015). Highly structured interviews, such as those used for surveys and market research, aim for the comparability and objectivity of the social sciences. In abstracting the interviewer from the situation and standardising interviews, the aim of undertaking structured interviews is to develop corpuses of data that is comparable. The possible subjective influence of the interviewer is to be avoided as much as possible through the standardisation of questions and prompts. At the other end of the scale are unstructured interviews, where there is least pre-emptive direction on the part of the interviewer; and which are generally found in the context of ethnographies (Fielding, 2006). Human interaction is at the centre of the ethnographic interview, where the knowledge that results is constructed, co-produced in the situation between the participant and the interviewer. Consequently, it is not possible to abstract the person(al) from the interview situation nor the knowledge produced by it. In-depth, semi-structured interviews occupy a middle ground between the two previous examples. The semi-structured interview seeks to maintain a degree of comparability between the different actors interviewed, but follows the epistemological tenets of the ethnographic interview. Rather than seeking to remove the interviewer from the situation in order to maintain the objectivity of the data, it is the very interaction between interviewer and participant that lead to the creation of knowledge.

One might argue that, since talking is a pervasive part of social interaction, there is little to distinguish interviewing as a method from either conversations or from being present in almost all kinds of social research (bar documentary analysis). Yet, it enables the canvassing of the views of people that would not be amenable to the more involved, longer-term forms of contact that emerge from ethnographic studies, for instance. Similarly, the interaction between the participant and interviewer could be understood as being less involved in pre-existing social relations. They also provide a more personal engagement with each participant than focus groups, which means that different sorts of information can emerge; given that the lack of other people permits a degree of openness that is not afforded in a group situation. The ability to provide a greater level of anonymity and, importantly, the lack of other people whose presence might induce the participant to shape their responses in whichever way, means that the individual interview has the potential to elicit observations that a participant would not feel comfortable disclosing in a group situation.

On the other hand, interviewing is not straightforward; and is actually 'one of the most widely used and abused research methods' (Leonard, 2003). Their apparent simplicity belies the difficulty of carrying out interviews, and the various epistemological and practical issues that can result from these. Firstly, interviewing is far from easy – even though it might be perceived as such (Leonard, 2003). The development of such 'conversations with a purpose' (Burgess, 1988) requires that the interviewer be attentive to its development on several levels, from interpreting what is being said (including non-verbally), contextualising it internally, and managing the developing relationship with the participant at that time – unsurprisingly, then, that interviewing technique develops with increasing interviewer experience. Secondly, there is criticism related to 'the vagaries of memory, selectivity, and deception in interviewees' accounts' (May, 2002, p. 237).

Interviews were a fundamental part of the research, as my objective was to explore actors' perspectives on the organisation of genebanking, policy, and practices. In so doing, I aimed to look for both what they had to say about them but also, particularly, how they understood them. In this way, the interpretive repertoire (Gilbert & Mulkay, 1984) was as important as the information provided about specific places. Talk with actors was always going to be essential; I aimed to investigate (a) how interviewees make sense of the genebanking project and how it fits into the broader context of contemporary agriculture and plant sciences research and (b) what concepts and words they use to explain it and (c) what concepts they associate with others. To develop these, I undertook 22 in-depth, qualitative interviews with 23 actors with different roles, in different European countries (see Table 1, p. 106). With these interviews I intended to use the posture that Spradley (1979, p. 34) characterised as 'I want to know what you know in the way that you know it… Will you become my teacher and help me understand?'. In that sense, they were ethnographically inspired; but they differ from them in that they were not grounded on a long-term rapport with the participants, gathered during extensive fieldwork (Atkinson & Hammersley, 1994; Fielding, 2006). Instead, these were semi-structured interviews, in order to provide a degree of comparability, and the canvassing of a broader spread of perspectives.

3.1.1 Interviewing experts in different countries: why these interviews

Since the starting point for this research was an interest in the tension between common and private goods, or between the concept of genetic resources as a common concern and a resource under national sovereignty, its scope should be international, so as to permit me to explore both the aspects of genebanking that are defined at the international level, such as the Seed Treaty, while also having a means to explore local and national contexts of genebanking. The study of the same genebanking project in different locations was important in developing an awareness of the geographies of genebanking, especially as they are imagined and constructed by actors themselves. These were interviews with experts, in that participants had specific professional skills and roles (be they as staff working in genebanks, or plant scientists that used genebank materials, or others involved in the coordination of *ex situ* conservation projects); a common occurrence in the field of STS due to its disciplinary focus (see for example Collins, 1992). As Littig (2009) points out, these have parallels with interviews with elites in that I was communicating with participants that have positions of responsibility and long careers in this area; and who had in some cases contributed to international policy-making in the field of genetic resources conservation. Thus, I would argue that, in some cases at least, they were at the ''top' of [the] stratification system' (Moyser, 2006, p. 85)'. One of the reasons for interviewing elites is in order to explore their unique experiences as 'insiders' (idem), in this case, to the development of genebanking practices and policy. This methodology has particular implications for practice, which I discuss further in section below. The position of power with elites is derived from their specific insight into the topic which is being researched. Social scientists have written about the issue of power in elite interviews (Mikecz, 2012), highlighting the importance of preparation and the development of a rapport in order to achieve success from such an approach. I intended to draw together interpretive/ethnographically inspired positions with expert, sometimes elite, interviews, so as to develop an understanding of the ways in which genebanking practices are conceptualised by internal actors and users; how participants see the role of genebanks within broader developments in the conservation and access to plant genetic resources, and how they make sense of the relationships between the work that genebanks do and the ways in which genetic resources are valued and used.

In interviewing actors with different professions and geographical locations, I wanted to gather different views about how they saw this germplasm economy, and how they thought the costs and benefits of conservation were distributed. This evidence will be taken together with the frame/narrative analysis of documents relating to the organisation of *ex situ* conservation, which is discussed in section 3.2. Given the geographical spread of the interviewees and the financial constraints on the project, the possibility of undertaking some interviews via Skype, the voice-over internet protocol (VOIP) software, was explored. Although Skype restricts the kinds of interaction that are possible (relatively to an in-person interaction) (see section 3.1.3 for a description and assessment of the Skype interviews), this was felt to be a justifiable, as it enabled the opening of the pool of interviewees further.

3.1.2 Recruitment: selecting interviewees from the European region

This study is about the European region, as a means of developing an account of the international genebanking broadly speaking. Yet, in order to have some more focused attention to the national scale, most of the interviews (18) took place in two countries, Portugal and the United Kingdom (UK). In addition to the contacts in the two main study countries, other interviews were done with actors with first-hand experience of working on the regional level organisation of genebanking, particularly, in projects with the objective of increasing in international cooperation on genetic resources conservation. These two countries make interesting cases for the present study given their differences with respect to genetic resources conservation: in the UK, there is a relatively decentralised system of genebanking, with different genebanks being responsible for different parts of the collection. In some cases, these genebanks are associated with a particular university; in others, with independent research institutes. In contrast, the Portuguese germplasm collection is mostly held at one genebank that contains 71.3% of all accessions, while other smaller collections exist for tree crops where needed. With respect to the germplasm holdings, too, these countries provide a useful contrast. The UK has 800,358 accessions in its National

Inventory[27], in contrast to Portugal's 45,375 (INRB, 2008). Altogether, these differences both in terms of the countries' genebanks and geopolitical/economic differences made them useful starting points for the thesis. However, four other interviews were undertaken with interviewees in Germany and Italy, in order to contribute contrasting views and expand the data set with respect to the European-level organisation. Other countries also feature in the data analysis 'by proxy', where interviewees referred to them (more detail on this is available in section 3.3, data analysis).

With these interviews, valuable perspectives were added to the database which represented different ways of thinking and organising genebanking. These were decisions taken on a case-by-case basis, and in response to my evolving understanding as it was informed by the data gathered. My research involved contacting people that would have particular insights, or interest, in the strategies of genetic conservation, as well as how it is carried out in practice. So, after a period of familiarisation with the organisation of genetic resources networks in Europe, I decided to undertake the identification of different actors involved in genetic conservation by scoping two main 'arenas' of genetic conservation: the representation of each country in the State of the World's Genetic Resources report (FAO, 2010) and members involved in the European Cooperative Programme on Genetic Resources, or ECPGR. By using the structures of genetic conservation as they were represented through these networks and their documents, I intended to reach the people who were involved in, or at the very least were aware of, the organisation of genetic resources conservation at either the national or European level, or often both. Such participants could tell me about how genebanking was organised, how they wished it were organised, and why – along with providing me with information about the collections/organisations where they

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[27] 'Accessions in EURISCO' http://eurisco.ipk-gatersleben.de/apex/f?p=103:1 Accessed 20.08.16

worked. To find them, I proceeded to map the collections available in each country by making reference to the Second State of the World's Report on PGRFA (CGRFA, 2011), to which each country contributes a report, and cross-checking with the online database WIEWS[28]. This provided an official count of the genetic resources available as of the decade 2000-2010 which pinpointed the collections that are 'public' (documents like this are also an important source for analysis of the 'public message' which is being put out to the world about each particular country – see 3.2). In addition to this collection-based search, I was interested in recruiting people who were involved with the ECPGR, as a European-level network for cooperation on genetic resources. Therefore, I listed actors involved in the ECPGR Working Groups for the two countries and invited them to participate. These documents allowed me to identify potential participants that worked in genebanks, users, and genetic conservation policy, both at the national and European levels. Invitation to participate was done via e-mail, as this is a common and appropriate method for professional communication. The initial emails sent out are found in Appendix 2, and this communication included a Participant Information leaflet about the project, available in Appendix 3, along with a link to my departmental webpage and contact details. Where no response was received a follow-up email was sent (no earlier than 7 days after the initial email). On a few occasions, a telephone call was made as a follow-up when the email yielded no response.

The social network of people involved in genetic conservation is small. This factor was fundamental in shaping the progression of my research, and it is at this point that methodological decisions taken at the beginning of the

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[28] The World Information and Early Warning System on PGRFA (http://www.fao.org/wiews/) is a 'global information system' maintained by FAO with the stated purpose of 'facilitating information exchange [and] periodic assessments of the state of the world's PGRFA' (http://www.fao.org/wiews/background/en/). It is interesting as an example of the importance placed on the monitoring and accessibility of data about genetic resources in the context of international governance of conservation efforts, expressed in documents like the Global Plan of Action (CGRFA, 2011) and which are discussed in CHAPTER 5

research set a path which would prove limiting in the long run. The scarcity of people working in the area made finding out who to recruit for this research into a task at once easy and complex. The simple aspect came with identifying the appropriate people that were responsible for each of the genebanks and were involved in policy making in different countries. However, complexity arose as the small number of people – and their awareness of peers in their professional networks - became an issue in tension with a commitment to maintaining the anonymity of participants, which meant that I did not make full use of the snowball technique (further information is provided in the paragraph on research ethics, below). The sample of people interviewed is, therefore, not representative in the sense of aiming for a total or 'balanced' representation; for instance, there is a preponderance of people who work in *ex situ* conservation over those who use the seed bank. My intention was to speak to people who are familiar with genetic conservation policy, rather than to develop a comprehensive account of perspectives about genebanks, or compare users' views with those of genebank managers. Instead, the aim is to develop an account of the local interpretations and positions *vis a vis* the sharing discourse that is represented in the newest regulatory framework. Consequently, even though these identities are not separable and are taken into account in the analysis, the focus is on the role of genebanks as institutions that operate within this germplasm economy. Although it was relatively unproblematic to identify the participants, it was sometimes the case that the information was out of date - there had been changes, and specific roles were not filled, meaning that a role-by-role comparison between the UK and Portuguese cases was not always possible.

Before any interviewees were approached, the research project was granted ethical approval under the 'minimal risk' category. The research was presented as a social science project with which I intended to explore genebanking practices and organisation; translated mainly into three broad themes – conservation, use, and relationships with other groups and organisations. Forty requests for interview were sent out, from which 22 interviews were arranged with 23 interviewees (two were interviewed together). In several cases, potential participants were contacted and after a conversation, decided that their expertise was not relevant to the aims of the project. Despite this, the rate of recruitment was fairly positive. Although it is not possible to make concrete statements about the motives for this uptake, there was some evidence that some of the participants considered the topic to be pertinent or interesting, particularly in light of the timing, a decade after the Seed Treaty came into force. Having made contact with interviewees, I began to undertake interviews in September 2013 while the recruitment process continued. In the next section, I describe how these interviews were carried out, and discuss the importance of being reflexive and aware of positionality when carrying out research projects such as this, where different places are being compared and where the researcher might be perceived differently.

3.1.3 Talking about genebanks: interviews and situated perspectives

Altogether, 22 interviews were undertaken with 23 interviewees, of which 16 were conducted in English and 6 in Portuguese (see Table 1 for a cumulative description of the interviews and Appendix 5 for a breakdown per interview). These interviews took place between September 2013 and September 2014 with an average length of 1 hour and 9 minutes (ranging between 02h11m and 24 minutes). The interviewees can be described according to their location but also their role – or in some case, multiple roles - within genetic resources conservation. I have articulated these as six broad categories, summarised here and described in Table 1. 'Genebank staff' applies to interviewees who work in genebanks – for instance, as curators or technicians. Ex situ conservation coordinator refers to individuals whose work involves the coordination of networks or projects involving several genebanks in different countries. Those who hold a university post and carry out basic research into genetic resources are categorised as 'researchers', whereas 'database coordinators' have responsibilities for curating germplasm databases. 'Policy' refers to interviewees with official policy roles at the national level, and plant breeders are interviewees who utilise genetic resources, as well as having first hand experience of the conservation system by working in institutions with germplasm collections.

Table 1. Cumulative information about interviews. The characteristics detailed here are the classification of participants according to professional role, and of interviews according to language and interview format. Information about individual interviews is provided in Appendix 5.

Characteristic		Number of interviewees	Total
Roles carried out by interviewees	Genebank staff: people who work in genebanks in any capacity (curators, assistant curators, etc)	14	27 (5 interviewees were assigned to two different roles)
	Ex situ conservation coordinator: Interviewees who work for international organizations with a coordinating and networking role within *ex situ* conservation	4	
	Researchers: interviewees involved in basic research into genetic resources/plant biodiversity	3	
	Database coordinators: responsible for running germplasm databases or coordinating biodiversity databases. Includes one National Focal Point.	3	
	Policy: interviewees with official policy roles in genetic resources policy at the national level	2	
	Plant breeders: interviewees utilising genetic resources from genebanks, who also have experience of *ex situ* conservation	2	
Language of interview	English	16	22 (one interview was conducted with two participants simultaneously)
	Portuguese	6	
Interview format	Face to face	18	22
	Skype	22	

Before each interview, I prepared by reading about the projects and institutions that each interviewee was involved with, so as to be familiar with their work and professional interests and expertise. This step is important when carrying out elite interviews; where issues of status and time limitations come into play. Specifically, interviewees may not welcome requests for information that they feel could be accessed through other means, especially if they feel that there are many demands on their time (Mikecz, 2012; Moyser, 2006). So, Mikecz emphasises that thorough research ahead of the meeting is a crucial step: increasing the knowledgeability of the interviewees can help in gaining access (this was not particularly important for my case) but, especially, in establishing a rapport and 'decreas[ing] the status imbalance between researcher and researched' (Mikecz, 2012, p. 491). He states that 'the researcher's positionality is central to successful elite interviewing. It is not determined on an insider/outsider dichotomy but is on an "insider-outsider" continuum that can be positively influenced by the researcher through preparation. Positionality is dynamic; it evolves during the course of data collection and becomes a key determinant of the research's success' (Mikecz, 2012, p. 492). In practice, this argument was borne out to a certain extent, in that the pre-interview research was fundamental in identifying potentially important lines of questioning.

Preparation was therefore done before each interview in order to gather context-specific information, specifically regarding the work carried out at each site and/or the projects that the time allocated to preparing for each interview was thought to be worthwhile. Firstly, during the interview itself it enabled me to contextualise what was being said and, in some specific instances, to ask questions that could lead the conversation towards productive ends. However, the use of this prior knowledge was balanced against the need to record how interviewees described their own activities and concepts. In addition, it was helpful at points where I intended to demonstrate knowledge of the subject so as to dispel - or at least ameliorate - first impressions regarding my status (as young, female, social scientist –

more on this issue below). In addition, reading and making notes regarding the work of the interviewee and their organisation was needed in order to prepare interview schedules (see Appendix 6 for a sample interview schedule).

Before turning to the practical aspects of the interview, I will detail the question arrangement. Although the original interview guide was a sequential list of questions, I later developed a 'fractal interview guide', depicted in Appendix 6, where the themes or questions were organised relationally, rather than purely sequentially. This straightforward method of arranging the themes to be covered provided a way to follow interviewees' own raising of issues. The sequential approach was somewhat restrictive, in that the different themes of the interviews would often be linked (eg conservation and use). In that way, the answers were better suited to a more flexible arrangement of the interview questions. The tree guide facilitated the flow of the interview, in that I could follow the themes and ensure that the questions were put to the participant with a minimum of repetition. Moreover, these schedules were flexible, enabling me to adapt the questions to the particular work of the participant. In addition, my understanding of the project, too, was evolving: as a result, questions became more focused during its life cycle. At the beginning, questions were broadly set around the practices of genebanks (conservation, use, participation in networks). Then, as the project progressed, questions became more explicitly focused on issues around sharing.

The opening question concerned the career and experiences of the participant, along with the history of the institution they worked for. This enabled me to understand their involvement with genetic resources and their history up to their current role. This often brought up interesting ideas about the past versus the present of genetic resources conservation; as it was often the case that there had been important changes to the institutions, such as privatisation. Other questions were arranged around the themes of conservation and use of genetic resources; asking for details about the way in which material was shared and how it was used. Another topic was the relationship between that particular institution and others, especially at the European level. As questions differed depending on interviewees, those in policy positions were asked more questions about the policy domain rather than activities within genebanks. Similarly, users contributed information about the practices of searching through and acquiring material from genebanks. Finally, each interviewee was asked at the end whether there was anything else they would like to add, or that they thought should be part of the discussion: this, too, was an instructive way to know what they thought was important, even if it is unlikely that an interview could ever cover all the possibly relevant issues. However, it was not always successful: despite my interest in a dialogue in order to identify what participants thought was important, in a handful of cases I was told that it was the researcher's, rather than participant's, task to identify interesting topics for discussion. The objective of these interviews was to elicit from participants their views on what genebanking was and how that related to the contemporary policy framework on genetic resources, by asking them to describe the practices of conservation and dissemination of germplasm, and to talk about how different institutions, repositories, and/or people interacted to make these happen. One interesting aspect that became a valuable strategy to achieve this was to steer the interview towards the past, present and future, because this encouraged reflection on how things should be, how they had been, what was preventing them from reaching this envisioned end.

As discussed, the interviewing process is a matter of co-constructing a meaning between the interviewee and interviewer, rather than a matter of 'mining' for information or reaching any kind of objective truth. This is to say, it is a dialectical process. I attempted to engage productively in this process with participants by making my thinking process open, rather than guarded or occluded from them. This meant, for instance, engaging with their answers in a way that sought to encourage the development of a meaning from them: it invited a direct response on the issue, while attempting to be non-directive. So, for instance, an interviewee might be asked to respond to a possible interpretation which developed for me during the course of the interview:

'So, is it… does it mean that, in a way, it's perhaps actually a little bit complicated to count, to get a sense for genetic diversity (…) unless you are going to genotype them in some way?'

With this approach I sought to give the interviewee an opportunity to disagree or agree, and provide further information. In either case, this would be informative and work as a way to produce knowledge (ie, would work as a kind of validation of the ideas that were being developed). Scholars who subscribe to a more structured approach that prioritises the minimisation of potential bias might argue that this approach could be leading, inviting specific answers. However, it was productive in the context of this research, where participants were in the position of experts who were being asked to help me to understand what was going on. In this case, it is more likely that they feel in a position to make their own views clear, 'correcting' interpretations that they see as not valid. This is worthwhile, or epistemologically productive, without me taking what participants say at face value. Yet, it provides me with a way of knowing what *they* see as true, or correct, which is helpful when it can be compared to other people's views on the subject.

Interviews were either carried out in person or, in four occasions, via Skype. Next, I describe the interview procedure for both of these settings, in turn. Where the interviews were carried out at interviewees' work places, the first step was the consenting process. The participant information sheet was used as a guide for the discussion was used in order to ensure that the main points were discussed; and participants were given the opportunity to ask questions. Informed consent was recorded by signature of the form (Appendix 4) which would be kept by both. Then, the tape recording began and the interview proper took place. In-person interviews also led to the opportunity to visit four collections (two seed banks, one field gene bank, one herbarium) in two different countries. The day after the interview, a brief email was sent to thank the interviewee and reiterate that I was available for any further discussion or questions.

When interviews were done via Skype, a short, preliminary call took place to explain the project, after which participants were asked to complete and send me a consent form, which I countersigned and sent to them. During the interview itself, the call was recorded using software (MP3 recorder) and brief notes were taken at the same time. After the interviews were concluded, notes were recorded in memos for future reference. This method was a helpful way to deal with the issue of geographical distance. It enabled me to carry out interviews without being physically present, and in one occasion it meant that the interview did not have to be cut short, instead taking place over two sessions. It was a worthwhile decision, and I believe that it worked particularly well because the interviewees themselves were familiar with the technology and comfortable with using it for work. It is also possible that the offer of a Skype interview might have been attractive to some interviewees, enabling them to fit it into a day where they were not in their working environment, as happened in one occasion. Nonetheless, this method has clear drawbacks that must be taken into consideration. Firstly, the absence of face-to-face contact means that one level of communication is missing from these interactions. Consequently, the interpretation of what the interviewee is saying will necessarily be restricted. However, this problem can be overcome, at least partially, by the use of the video call option. This option was put to the interviewee and taken up in one of the occasions, with considerable success. Equally, this can lead to awkwardness during the interview itself, when people talk over each other. This did happen on one or two occasions during the interviews. Yet, in these circumstances, it is possible to adapt the way the interview is being done; in this case, the corrective action simply involved leaving more 'space' (time, really) for the interviewee to think and respond. Another, perhaps more significant issue is the potential for glitches and problems with the call itself. The lack of reliability of software was the biggest stumbling block to the use of this approach: two (of five) interviews were interrupted by problems with the line. In addition, one attempt straight out did not work. Fortunately, the interviewee in question was very accommodating and the interview was re-arranged. Given that this was a predictable risk, the preparation for the interview involved me suggesting to the interviewees that this could happen and if it did, how we would deal with it (I would call them back). Overall, then, my experience was that the problems with the use of Skype were offset by the increase in coverage gained by using it. This can be a productive means of gathering interview data which would be appropriate in cases where the participants themselves make use of this technology for work purposes.

The interviewing I undertook had features from two approaches (in-depth interviews with an ethnographic bend; and elite interviews) that generally imply different kinds of positionality. Although these can be said to be in tension, this is not unprecedented[29]. For this research project, the objective of drawing from both approaches was to develop a more situated understanding of the situation from the perspective of these interviewees which relies on some kind of shared ground or experience. In the case of my research, such shared experience was present, albeit in two different ways. With the group of interviewees in the UK, I could draw upon my own, limited, professional experience managing a research tissue bank, along with academic grounding in genetics. With the group of interviewees in Portugal, common ground included also a shared nationality, which did figure in the interviews. Such positionality was an important concern, and an interesting point of reflection, during the data collection process. The diversity of interviewees, and the cultural differences between the various sites, meant that I had a variety of experiences during interviews.

In summary, I undertook semi-structured interviews undertaken with a variety of participants, which articulated actors' perceptions and representations of germplasm conservation from different sectors (policy/practice) and countries. As I turn to next, the data from these interviews was analysed with a variety of documents, including policy and media, which also served to describe and make arguments for particular ways of organising conservation:

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[29] For example, other scholars have suggested that the application of feminist methodological approaches to the study of elites can be helpful in navigating some of the issues around authority and power (Conti & O'Neil, 2007; see also Kezar, 2003 for an example of a different approach).

here, the sociotechnical imaginaries of seed banks were laid out in a variety of different ways, and for different audiences. The next section describes their selection and analysis, focusing on the use of discourse analytical approaches.

3.2 Thematic and discourse analysis of documents

While the interviews with actors were essential for the task of developing an account of genebanking, they made up only a part of the data: other helpful sources were available in the form of documents of different kinds produced about *ex situ* conservation. These represented an official record of actors' and institutions' perspectives that could be mined for identifiable themes (that process is discussed further in section 3.3). Additionally, documents were important because they provided insight into the ways actors communicate about genebanking and its role in the broader context of *ex situ* conservation and use; laying out the arguments, metaphors and that are associated with genebanking and genetic resources. In these documents one can find actors' assessments of the practices of genebanks, the policies governing PGRFA conservation, and the myriad factors (political, technical, economic, social) that are identified as significant in shaping genebanking. Consequently, these documents, too, can be seen as similar 'to an anthropologist's informant or a sociologist's interviewee' (Prior, 2008). This does not mean, of course, that they should be taken uncritically: rather, and much like with interview data, they should be interpreted, taking into consideration the context and positionality of the actors who are doing the act of communicating. Hence, in this research, interviews and documents alike served both as *resource* (providing information about the subject) and *topic* (in that it shows how genebanking is presented and re-presented). This distinction, first elaborated by Zimmerman and Pollner (2013[1970], p. 33-34) is useful because it emphasises that the text itself can be a source of information, if it is analysed accordingly.

In this context, I was particularly interested in the interpretive repertoires (Gilbert and Mulkay, 1984) rhetorical devices (Mulkay, 1993), and the metaphors (Lakoff & Johnson, 2003) that actors used in order to explain the role of genebanks and how they operate within the broader context of PGRFA conservation policy. Wetherell and Potter (1988) define repertoires as 'building blocks speakers use for constructing versions of actions, cognitive processes, and other phenomena' and which are 'constructed out of a restricted range of terms used in a specific stylistic and grammatical fashion. Commonly these terms are derived from one or more key metaphors and the presence of a repertoire will often be signalled by certain tropes and figures of speech' (Wetherell & Potter, 1988, p. 172). It is this attentiveness to the deployment of particular metaphors to convey meaning that made this particular approach helpful when analysing this corpus: it provided a means to identify how actors talked about the activities of genebanks while encompassing particular recurring concepts like 'rationalization' or 'adding value'. The concept of interpretive repertoire was used by Gilbert and Mulkay in their work to examine how scientific discourse was constructed: they found that scientists utilised two different repertoires, empiricist and contingent, in order to communicate about scientific practice (Gilbert and Mulkay, 1984). This approach was also utilised to good effect by Jasanoff and Kim (2009), who analyse the discourse of policy documents and speeches to characterise the sociotechnical imaginaries of the USA and South Korea. In so doing, they are looking for specific metaphors, rhetoric, and arguments that contribute to their construction, to identify interpretive repertoires through which these imaginaries are created and transmitted. 'Discourse analysis' is a term with different definitions, depending on the perspective of the analyst; although all share the view that talk is an important way of constituting the social world; that is, discourse is constitutive. Hence, discourse analysis is a very broad and adaptable definition, and a particular approach must be chosen in accordance with the requirements of the research questions that drive forward the research. All kinds of discourse analysis have four 'core features', according to Antaki (2008, p. 432). The text must be 'naturally found', rather than invented. Interview data is not acceptable to all analysts, but I do consider it 'naturally found' because the answers provided cannot be predicted, nor am I trying to direct them. Secondly, the words ‘are to be understood in their co-text at least, and more distant context if that can be defended’ (which is arguably also dependent on the perspective of the analyst). Thirdly, the analyst should not exclude from the analysis the non-literal meaning of words - what Antaki calls their ‘force’. Finally, this analysis should ‘reveal the social actions and consequences achieved by the words’ use - as enjoyed by those responsible for the words, and suffered by their addressees, and the world at large’ (Antaki, 2008, p. 432).

Broadly speaking, one might split discourse analysis into the more linguistically oriented, ‘micro’, part; influenced by linguistics; where the analysis is focused on, for instance, ‘discourse that acts at the level of interaction, through conversationalists’ activities, realised in the allocation, organisation, and internal design of turns at talk’ (Antaki, 2008, p. 431). For this research, it is the broader level of discourse which is of interest: that which operates at ‘the overarching level of social regulation, operating through official and unofficial discourses like laws, media coverage or advertising texts’ (idem). Here, both those creating the discourse, and recipients of it, will be groups of actors - in the case of my research, the interest is on scientists, policymakers, and users of germplasm - hence the need to analyse these kinds of documents.

Scientific documents relevant to this thesis were identified through literature searches (using Web of Knowledge, Google Scholar, and CABI abstracts, as well as scanning the bibliographies of existing sources), while policy documents were drawn from the document repositories of the relevant organisations (e.g. the FAO). In addition to general terms such as ‘*ex situ* conservation’ or ‘gene banks’, searches were carried out about specific seed banks and individuals. Different documentary sources were selected for analysis; these included strategy and policy-related documents, meeting minutes, scientific journal articles, and media reports. They all shared a focus on *ex situ* conservation and its role in the world – particularly, they set out actors’ suggestions regarding what would constitute a successful genebanking system and set out the conditions under which it could happen, and the challenges to it.

Altogether, 106 documents were added to the corpus for CAQDAS analysis. The total number of words was estimated to be circa 1.2m, although not all parts of the text were equally relevant. The documents are summarised in Table 2, below. Next, I describe, in turn, their characteristics and what they contribute to the analysis. The first group of documents to be collected (Table 2, column A) were the set of policy documents produced at the level of FAO and which set out the 'global' vision of plant genetic resources. These set out the strategic plans for the conservation system in the terms that were agreed between different countries; and therefore are fundamental. The analysis of the Global Plans of Action (GPAs) was focused on the priorities which are particularly related to *ex situ* conservation. One notable characteristic of this material was their recurrence through time (1990s: CBD, first GPA, first State of the World; followed by second iterations in the 2000s) which made it possible to look for changes between the two periods; which was significant given the policy changes that occurred during this time (see section 1.3). Included in this group were any documents related to FAO's Global System, included the funding of collections by the Global Crop Diversity Trust.

A second, related group of documents were those produced by actors from within the genebanking world detailing the strategic vision for particular crops (e.g. cocoa) or specific geographic regions, namely, Europe. Also included here are reviews and other articles published in newsletters or peer-reviewed journals that deal with strategy. These documents detail the appropriate future for genetic resources conservation as it is 'charted' by those involved. They consequently provide important assessments of the current situation, as well as expectations about the future and, importantly, they often identify specific (political, technical or other) factors as important for future success. These documents therefore tell us what particular arrangements actors think are feasible in the future, and why.

The policy-related documents above can be compared to other documents that focus on conservation practices (Table 2, column B), that is, how policies are (or not) carried out, and why. They explain the technical requirements for successful conservation, often relating them to particular decisions in the policy domain. Under this rubric fall the State of the World Reports and generally available training materials; whereas at the regional level it is represented by newsletters and reports by the ECPR. Finally, the same information at the country level is provided by the State of World Country Reports and similar documents. Finally, the third tranche of the corpus (column C) is made of material aimed at the public, and which focuses on the three scales determined here: 'global', which refers to coverage of international organisations, repositories such as the SGSV; whereas the second group refers to actions or legislation at the European level; and finally, the National/local corpus refers to material about individual repositories (the majority) and to the national system where available.

Table 2. Categories of documents selected for discourse analysis in the corpus.

	Documents in the corpus		
	a. Policy	b. Practice	c. Public representations
International	Legislation Global Plan of Action reports Journal articles	State of the World reports Journal articles Training materials (eg Crop Knowledge Bank)	Reports about the SGSV the Seed Treaty
Regional network	ECPGR policy (regional strategy for Europe) European Commission reports regarding European	ECPGR Working Group reports IPGRI's Newsletter for Europe Journal articles	Reports on cooperative projects Reports on European legislation regarding PGRFA

	genetic resources policy		
National	National policies and legislation on genetic resources Commentaries on these policies	State of the World country reports Funding reports for PGRFA-related projects Minutes of national organisations Journal articles	Media reports about specific genebanks and PGRFA in general, where they have a specific national emphasis

These documents were collected over the life of the project, and their analysis commenced before, but continued contemporaneously with that of the interviews, so as to develop common frames of analysis. This process is described in the next section.

3.3 Data analysis

Having determined the most appropriate sources and collated data for the project, the next step was to describe the methods of data analysis. Interviews were recorded directly onto .mp3 format. Those done in person were recorded with a Marantz recorder, while the interviews done through Skype were recorded via MP3 recording software that worked with Skype. Transcriptions were then made of the interviews: 11 were undertaken by me, while another 10 were done by professional transcription services (Way With Words in the UK, and AP in Portugal) for practical reasons. The approach to transcription evolved during the life of the project: the first few transcripts included careful attention to the modulation of voice, self-corrections, and other signs that might aid interpretation of the message. The aim here was to keep this information in the transcript, which might be particularly helpful in aiding the interpretation, particularly in terms of seeing where people might have corrected their speech from one term to another, less sensitive one. Yet, this approach was too onerous (both in terms of the time it took to produce, and the lack of readability of the resulting text) and the potential gain too tenuous to warrant it; consequently it was simplified. Where the transcriptions were done by others, they were then cross-checked by me against the recording to correct any omissions, misheard words, and technical concepts. The transcripts were sent to interviewees for an opportunity to check them, except for one where the participant specifically requested it was not sent in full.

Systematic analysis of the data is a fundamental step in the development of the research, and needs to be undertaken carefully in order to develop a complete picture of the data. In addition, it helps to avoid the creation of unfounded conclusions onto the data (based on the prejudices of the researcher). The data collected was entered into the CAQDAS software NVivo for analysis. Analysis was done through simultaneous coding and writing (and thus continued through the period of drafting the analytical chapters). Codes are defined as ‘tags or labels for assigning units of meaning to the descriptive or inferential information compiled during a study’ (Miles & Huberman, 1994, p. 56). Coding is a crucial step of the interpretive analysis of qualitative data because it relates the data to the eventual findings of the research, since it is through this process that analytical thoughts develop and mature. And yet, it is a nebulous process of interpretation, where the knowledge, ability and values of the analyst are come into contact with the data. Hence, coding merits careful attention/reflection; however, the process of coding is often not set out in research papers (DeCuir-Gunby, Marshall, & McCulloch, 2011).

Scholars do differ in terms of their interest in and attention to coding. It is a very well-established methodology in the social sciences and, again, varies widely in accordance with the kind of work being done - and with the theoretical commitments of the researcher. For instance, the use of codes is essential for some researchers, but others find this breakdown to be artificial (Saldana, 2009). For the present research, coding is an important and welcome tool: it is a process of assigning labels to the data, but also of 'disassembling' the corpus into fragments; which precedes its reassembly into different themes, leading to findings (Yin, 2016). Its use works well with a methodology that does not aim to uncover a pre-existing truth – which, if it were possible, might involve 'true' and 'false' ways of disassembling the data. Instead, where the aim is instead to find particular imaginaries and their effects on social practice, coding is seen as a way to reach interpretations, and check these against the data (for instance, by looking at the number of times, and on which data, a code recurs). In so doing, it encourages a good fit between data and theorisation.

For the purpose of this project, coding was therefore a fundamental part of the engagement with the data. The iterative process of producing the codes, reviewing the transcripts, assigning codes to fragments of data, and reviewing the codes themselves, was the process of data analysis. To aid this process, I followed the approach suggested by Yin (2010) and Saldana (2009) of writing memos about the data; a method shared with grounded theory. Performing these two activities simultaneously was a means to develop the theorisation and coding system reciprocally (Saldaña, 2009, p. 33). This was extremely helpful as a way to engage with the data, and led to a set of memos that could serve as the basis for second-order, analytical codes – and could themselves be coded. Given this working process, the use of NVivo was an important advantage, as it enabled flexibility in the coding process and, equally importantly, it facilitated the keeping of records about the evolution of the coding process, especially in terms of their definition.

Yet if this process is to be fruitful, the approach to coding must itself be decided in light of the research questions. In this way, more descriptive projects, or grounded theory, are better suited to data-driven codes than the more theoretical ones which might be useful for deductive projects. Several different methods of coding are available to analysts (overviewed in Saldaña, 2009), from the more data-derived coding approaches utilised by grounded theorists (Strauss & Corbin, 1990) to a more structured approach where codes are produced a priori and applied to the data (detailed for instance in MacQueen & Guest, 2008). For example, structured interviews yield responses to the same questions, which are categorised with the appropriate code. Much like the different approaches to interview, these privilege different things, from comparability and structure, to maintaining the voice of the participants and their language: we can see how these are therefore related to the interview approach, from less to more ethnographic. Coding can and should be articulated in accordance with the research questions and the data collected. Therefore, it is important to become familiar with various different approaches to coding, and create a way of approaching the coding which is appropriate to the research questions. Thus, coding can be eclectic and 'made to order' so as to fulfil the brief of the project. What is important is that there is constant reflexive work to see how the codes match the data, and what is being left out.

In the case of this research project, it was important that these codes enabled the detection of both specific *themes* and *interpretive repertoires*. Hence, they required mostly data-derived 'descriptive' codes, with a subset being 'in vivo' codes, that is, which were extracted directly from the data and therefore captured the language used by the participants themselves (eg. 'germplasm flow', 'freedom to operate'). The first kind described the *topic* of the fragment of data being coded (Saldana, 2009, p. 70); they are very common in qualitative research. In vivo codes are often used as part of grounded theory work in order to ensure that theories are built from the data. A selective codebook is detailed in Appendix 7.

The coding process began with a period of 'pilot' coding: a set of transcripts were read in physical form, and particular themes were identified from recurring concepts. This evolved into the initial set of codes which was further developed as data analysis progressed, expanding to a list of circa 80 codes during this 'first order' coding (what Saldana [2009] calls 'elementary coding'). Throughout the analysis of the data, the codes were refined. I periodically returned to the definition of each code and considered the references within. For important analytical codes, I created ‘memos’ that set out the reflection about those codes at the time. This is effective because it provides an important way to track the reasoning behind particular choices, and follow it as required. It also requires an analytic engagement with the data that is conducive to interpretation. Through this approach, the set of codes that proved more influential across the data available became the focus of the analysis. The codes were used not only as a way to categorise the data but also to ‘reassemble’ it (Yin, 2016) (Yin, 2011). Therefore, the second round of coding more analytical codes were developed which re-assembled the data. Examples include NVivo codes such as ‘making value visible’, and were often based on the memos written as the data analysis was ongoing.

3.4 Conclusions

In conclusion, the analysis of the practices and organisation of genebanks as part of the germplasm economy is based on empirical data derived from a corpus of interviews (n=22) and documentary sources. Together, these materials provide a rich image of actors’ perspectives regarding the conservation and exchange of germplasm, particularly in Europe. Iterative coding led to the identification of specific themes and interpretive repertoires that are the grounding for the analysis of genebanking as a means to construct the germplasm economy and the shared genepool.

CHAPTER 4 GENEBANKS AND THE FLOW OF GENETIC RESOURCES

In this chapter, I explore the role of genebanks in managing 'germplasm flows' and draw links between these activities and the understandings actors have regarding how the germplasm economy should work. In their book *Tissue Economies*, Waldby and Mitchell show how blood banks and stem cell banks have a significant role in making decisions about competing interests (e.g. of the donor and the user) and in managing different *values* (Waldby & Mitchell, 2006, p. 33). Similarly, in this chapter I develop an account of the role of genebanks in the kind of economies that are established around the 'flows' of genetic resources. Specifically, I show how, post-Seed Treaty, an economy is envisaged by actors working in genebanks and genetic resources policy that considers mutual access to germplasm to be mutually beneficial; and genebanks are the source for the appropriately regulated germplasm. This shift in genebanking focus towards encouraging and ensuring the value of germplasm is simultaneously important to ensure the survival of the Multilateral System established by the Seed Treaty, and of the conservation system itself.

To explore how genebanks are involved in the management of germplasm (and of the germplasm economy) requires developing a concept of genetic *resources*, that is, as biological materials that are considered to have value. When van Dooren (2009) suggests that genetic resources are 'proxies' for the more corporeal, fleshy crop biodiversity (as introduced in Chapter 2), he is making a critical point about what he sees as the reductionism of genebanking, that can ever only preserve germplasm, rather than agrobiodiversity more broadly speaking. Yet, if we take genetic resources to be proxies preserved in the genebank, that assumption provides a way to theorize genebanking processes that is sensitive to political economic concerns about what it means to consider value.

I argue that the starting point to that approach is that genebanks create proxies in the sense that they *disentangle* germplasm (after Callon, 1998) into forms – accessions - that actors see as capable of existing outside of their original environment while maintaining their genetic integrity (and consequently, their phenotypic characteristics). Thus, genebanks make germplasm into valuable genetic resources that are *mobile*, and that can be conserved '*ex situ*' in genebanks. It is for this reason that they can be considered *proxies* that are perceived as being valuable in other places. Hence, they are very significant for the construction of a germplasm economy, because they enable the accumulation and dissemination of genetic resources both in a technical and a political sense. That is the focus of the present chapter, where I explore the parallels between conservation of genetic resources and the accumulation of value by analysing how germplasm is banked and disseminated. I then interpret these findings to show how we conceptualise genebanks as creators and managers of value in the germplasm economy.

4.1 Saving germplasm, maximising resources: genebanks as repositories for value

Asking what material is included in genebank collections, and under what terms, makes visible the processes and decisions involved in creating valuable proxies. The main empirical focus for this section is therefore on the steps that take *make* germplasm into genetic *resources* of actual or potential value. I discuss, in turn, three 'entry routes' for the inclusion of plant material (of different kinds) in genebanks: it might be collected directly from the field; it can be donated by individuals or research institutes; or it might come from other genebanks. For each of these cases, I show how actors consider the banked germplasm to be valuable in light of its *context*.

Perhaps the most obvious route for accessions is from its original habitat (*in situ*) to the genebank. In these cases, plant conservationists or scientists undertake specialist collecting expeditions during which they sample populations of landraces or crop wild relatives, from on-farm plant populations (or wild in the case of crop wild relatives), and in accordance with sampling and collection protocols (see for instance Guarino, 1995). As collectors gather germplasm and information about the varieties or populations at hand, the process is influenced by the sorts of relationship that are formed with the donors in question – often, farmers – who provide them (I20). In that sense, the work that goes into collecting genetic resources is social, as well as technical.

These collecting missions are, however, declining in number (Halewood et al., 2012a, pp. 99–120). There are different factors that might have potentially contributed to this decline, all of them significant from a political economy perspective. Firstly, IPGRI (now Bioversity) and FAO funded many in the 1970s and 80s but have scaled these back, and the expense means that existing collections do not necessarily undertake their own expeditions[30]. Secondly, some actors identified a problematic downturn on the number of permits granted for collecting missions after the CBD, which was used as an argument for the problematic nature of the bilateral model. Finally, the progressive accumulation of genetic diversity over time means that for some crops there is already a large amount of collected material (as seen, for instance, in rice).

Historically, collectors did not require consent to acquire samples when genetic resources were considered 'common heritage of mankind', that is, up until the CBD came into force. Since then, access requirements must be in place before collection is possible (see chapter 1). Such 'direct' collections of material are highly prized by genebanking actors because they yield genetically unique material. This link between genetic uniqueness and value points to one of the criteria that is used to determine what counts as valuable

[30] Even so, there is a recent example of a concerted effort of large scale collecting: that organised by the Millennium Seed Bank Partnership at RBG Kew (van Slageren, 2003).

material: its scarcity. As will be clear throughout the chapter, genetic uniqueness matters: material that is one of a kind is perceived as particularly important and, in contrast, duplicated material is less important (see section 6.2 for a discussion on this matter) – except where the duplication is intentional (for example, when it is done for the purpose of having a 'back up' accession, as is the case of the safety duplicates at the Svalbard Seed Vault). This example illustrates the hierarchies of accession value that can be established within genebank collections.

Another route through which genebanks acquire material are donations, often by breeders or by research institutes. These may have working collections, but no desire to keep material that has no use value. Hence, they might pass on to the genebank old breeding materials, or commercial varieties that are no longer sold. These genetic resources are, then, a gift - in the sense that the donor does not keep any particular rights over the material. In these cases, the genebank appears to serve as a means to 'save' material which is not immediately useful to the creator/research institute – perhaps one might say with little exchange or use value at the time - but which would be wasted otherwise. In this way, some kind of potential (bio)value is recognised which warrants its conservation in a genebank, even if the research institute don't see the value in maintaining the sample themselves.

Genebanks, then, are repositories for the conservation of the potentially valuable; they are 'insurance' collections as much as they are archives of heritage material. They are kept because they are perceived to have some potential use value, I would argue, rather than because they have intrinsic value. Like collections of cord blood or other biomedical materials that *could* potentially be useful, they are stored and managed in ways that permit their future use and maximise the value of the collection. They provide the means (and bear the cost for) the storage of material that have no clear economic value in their current incarnation. Hence, they occupy a particular place in the germplasm economy by preserving material that might have no obvious present value.

Yet, importantly, not all material that is entered into the genebank has to be a donation, or available under the same conditions. For example, some genebanks - especially when they are situated within larger plant science institutes - take on the responsibility of maintaining the material on behalf of other people. In this case, it might not be accessible under the same conditions as other publicly available material (I10). Thus, it is possible – at least in some collections – to have multiple levels of accessibility to the collection[31]. Genetic resources do not have to be donated to enter the genebank, necessarily. This finding suggests that genebanks have the potential to encompass material with different ownership ties, and develop multiple flows of genetic resources. They are, therefore, important in managing the flows of germplasm within the germplasm economy.

Finally, and interestingly because it speaks to the 'openness' of genetic resources and the concerns about efficiency, the third main route of germplasm access can be *other* genebanks. The fact that there are an estimated 1.5-2m 'unique' accessions out of circa 7m points to the high level of circulation/exchanges between *ex situ* collections. Of these, a proportion will be so-called 'safety duplications', undertaken so as to ensure that the material is not lost should there be damage to the original collection (this is exactly the purpose of the Seed Vault). In such cases, the material is often kept under a 'black box' arrangement where only the depositor is entitled to retrieve the material. Hence, in this case, material is kept in the genebank and not accessible. Safety duplications do not, however, account for all (or even a majority) of the duplication seen, given that safety duplication is a relatively cumbersome process which is not implemented everywhere). This means that a considerable amount of germplasm was/is requested from other collections for the sake of stocking/founding another collection. That this is the case indicates a strong openness to the dissemination of material. Clearly, then, the germplasm economy also depends on the reproduction and

[31]These can be mediated by different databases, for example: material can be made more or less accessible to different user groups depending on what catalogues/lists they are on. This theme is reprised in CHAPTER 5.

dissemination of material between genebanks, and not only on the storage of totally unique accessions in one collection alone.

Once in the genebank, genebanking staff split the samples, clean and dry them (if required), before storing the final accessions in the collection (the material is also described and classified in accordance with standard genebank practices; but this subject is discussed in Chapter 5). Seeded material can be entered into the *active* collection (for dissemination) and/or the *base* collection (which is generally in deep freeze storage, and from whence further material can be regenerated as needed). Where material is asexually reproduced, the system is different as a cutting, or a part of the cell culture, can be taken.

This overview of the routes onto the genebank demonstrates that the flow of germplasm into the genebank can occur in different ways; but it is already clear that material is treated as donations, and as material with potential value – that is the reason why it should be maintained. Next, I show that genebanks do not accept all potential material, and argue that the accumulation of material must be managed within the capacity of genebanks. Consequently, these repositories are responsible for managing their inputs in a way that maximises their available resources.

One of the hints that such a process takes place is the way that collection growth is dynamic, and currently thought to be decreasing (FAO, 2010; Halewood et al., 2012a). For illustration, Figure (below) illustrates the changing rate at which a subset of genebanks accumulated accessions between 1920 and 2007. This graph, which was part of the Second Report on the State of the World's PGRFA, illustrates a trend for progressive increases in genetic resource acquisition, with a noticeable uptick beginning in the 1970s – as international efforts to acquire germplasm were in full swing – and a decrease in the late 1980s-early 1990s, and a noticeably dynamic pattern since then.

Part of it could be cumulative - after all, there is thought to be good coverage for some of the most important crops (eg, rice). Yet another significant reason is that there is an interest in curbing unchecked growth of the collections, something which was also noted by the curators in interviews (I1, I3, I4, I10) Rather than indiscriminately accepting material, all seemed to have particular criteria which governed what was acceptable and what was not.

Source: 31 genebanks of the NPGS of USDA (source: GRIN, 2008); 234 genebanks from Europe (source: EURISCO, 2008); 12 genebanks from SADC (source: SDIS, 2007); NGBK (Kenya) (source: dir. info., 2008); INIAP/Departamento Nacional de Recursos Fitogenéticos y Biotecnología (DENAREF) (Ecuador) (source: dir. info., 2008); NBPGR (India) (source: dir. info., 2008); IRRI, ICARDA, ICRISAT and AVRDC (source: dir. info., 2008); CIP, CIMMYT, ICRAF, IITA, ILRI and WARDA (source: SINGER, 2008).

Figure 6. Number of accessions acquired per year in a subset of genebanks. Source: Food and Agriculture Organization of the United Nations, 2010[32], p. 57. Reproduced with permission

The crop classification, for instance, was nearly always a decisive factor: as collections in the UK are often specialised in a subset of crops, they would take that particular material. Another important factor was the likelihood of usefulness of the material – which was sometimes described as 'valuable'.

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[32] The Second Report on the State of the World's Plant Genetic Resources for Food and Agriculture in brief. Available at http://www.fao.org/docrep/013/i1500e/i1500e_brief.pdf

Hence, material that was known to be desirable by plant breeders, or for which there was associated data regarding its agronomic characteristics, was likely to be added (I3). Finally, the perceived *uniqueness* of a particular sample was a criterion for its inclusion in the genebank, according to the view of one British genebank staff member:

> *'…we've added accessions to the collection through that time but not(.) not as many as would have been the case in the past so I think the collections have moved on from a sort of active expansion to more of a management [ok] phase; we're still adding material, we're still interested in adding material. But we have to be, due to resource constraints, we have to be quite selective about what we add so I'm interested in gap filling, things like wild relatives of crop species are of particular interest; landraces are of particular interest; ah but generally anything that is offered to us that doesn't(.) replicate something that we already have would be potentially of- of interest here. (I4, UK genebank staff, lines 57-64)*

These requirements regarding what is included in collections are a very important insight into the contemporary status of genebank collections: they showed that there is no longer an interest in letting the collections grow unchecked. Although things might have been different in the 1970s and 1980s, when the emphasis was mostly on the collection of materials, curators are now making decisions about which germplasm should be added. Moreover, there is also a trend towards the differentiation of materials into different sub-collections:

> *'…they'll be maintained as discrete collections so that they have an identity; a clearer identity for the community [OK] rather than being subsumed [yeah] within the main collections. Actually that's a slight trend that you can pick up in other countries as well. So we're not going to see the great expansion of the main gene banks, we will see curation of specialist collections; that have, have a, have their own separate identity and associated resources that could be genotyping, it could be phenotyping.' (I1, genebank staff, UK, 60-65)*

So, the prevailing perspective, in both the interviews and the documents, is that it is not feasible nor desirable to keep *everything*, and that indiscriminate collecting may be detrimental to its use. Indeed, in some cases, there is no certainty that material will even be kept in the collection should it not be considered to be useful enough (I1; 16). In one case, the curator developed a set of metrics used to make decisions about whether material should be removed from the collection (I1).

These findings indicate that there is an apparent ‘carrying capacity’ for genebanks: an optimal amount of material that can be supported under the circumstances. Collections, then, must be managed – and this evidence suggests that the role of genebanks is to ensure that their collection is as valuable as possible: rather than being unselective, or taking for granted the idea that all genetic resources are equally valuable. This makes for an interesting contrast with biomedical collections, where this issue has not been reported previously by analysts. One might speculate that the much higher amount of material available plays a role here: even though seeds might be relatively speaking easier to maintain, the number of potential accessions still outstrips the capacity available. The *a priori* conservation of material therefore raises important questions and quandaries regarding how best to allocate space to the ’most valuable’ samples.

4.2 Genebanks as sites for the management of resources, value, and values

If in the last section we saw how genebanks manage the in-flow of germplasm, the focus of this one is the out-flow of germplasm. Following how genebanks disseminate germplasm shows that staff put considerable effort towards encouraging the use of material in the collection and seek to engage with users to demonstrate the value of the banked material. That might be surprising, in that it is closer to the behaviour of an archival collection than, necessarily, that of biomedical tissues where demand outstrips supply; or where the presumption is of non-access unless specific bilateral agreements have been established between potential users and the providers of germplasm. This difference suggests that the role of the genebank in the germplasm economy has parallels to, but also differences from, other biobanks in tissue economies.

We can therefore think of genebanks as being responsible for managing the collections of genetic resources, both in the technical and the political senses of the word. As I demonstrate in this section, they have to balance priorities and different values as they do so – much like the UK Stem Cell Bank described by Waldby and Mitchell (2006). It is because of this brief that they are responsible for carrying out the ‘sharing’ of genetic resources; that is, for the dissemination of genetic resources. I use this socially significant term precisely to emphasise that this flow of germplasm is not a technical, automatic process; but rather one which involves particular ideas about the value and purpose of genetic resources, about the social good, and the ‘best’ way to protect and make use of what is valuable about them. It is politically and socially significant: it is where the principles/ideas of the Seed Treaty are instantiated in/to practice. This argument is substantiated by the way genebank staff act as ‘gatekeepers’ (who manage the supply of germplasm in accordance with the existing governance framework), and also demonstrators of the value of the material in the genebank. Genebank staff seek to develop the value of the collection, and to demonstrate its value to potential users in ways that are analogous to that of other collections (paid for or not) seeking interest from potential users.

Not all material, however, is available for dissemination, for a few different reasons. An important one is plant health and pathogen transmission. For instance, a new tree arrival might have to undergo quarantine (I6, I15, I20). Where there are known pathogen infections, a whole collection might be under quarantine for a length of time, so that it is not possible to provide material to users at all (I3, I15). In other cases, material may not be available if staff consider that there is not enough to ensure its conservation. Here, again, we see the conservation and facilitation of use objectives in slight tension. Although the tangible implications of this might be small/negligible (ie would anything happen if a genebank refuses access on these grounds?), it is interesting on the grounds that it raises the question of how much mutual access there might actually be in the MLS. Here, too, we see how the genebank managers must take into consideration the different priorities and requirements for genetic resources and do so in ways that are meant to preserve their value. Altogether, this means that germplasm collections are envisaged as rather dynamic and requiring of constant work. Genebank curators emphasise the idea that their collections should not be musea. As one participant, a curator with many decades' experience, put it, 'collections cannot be musea, so they are living entities' (I20). In that particular genebank, s/he told me, the most important aspect was the maintenance of the genetic variability of the vine – without necessarily expecting the numbers of trees themselves to be static. This example demonstrates how keeping valuable genetic resources involves far more than ensuring the preservation of germplasm: rather, it involves making decisions about what should be done in order to maintain the genetic *diversity* through manipulating its proxies.

Genebank curators also see it as their role to engage with a diverse group of users and, indeed, seeking out different ones. When asked, all genebank staff mentioned a diversity of users. Mostly, researchers and plant breeders were seen as the classic ('primary' (I1)) users; but other groups exist: 'hobby' users were also present, especially in the case of small vegetable seeds or cereals; and less so for cash crops/forage. Interestingly, one curator (I1) also mentioned education as a rising sector, with teachers receiving genebank materials as part of specific projects.

Genebank staff mentioned engaging with people both in the private and the public sector, noting that they provide genetic material to both groups without distinction; which is significant in the sense that all are covered by the same regulations. With respect to the material covered by the MLS, especially, the requirements of users are the same – that is, that they operate in agreement with the requirements of the SMTA. Geographically speaking, too, users were not exclusively from within the same country, but they were the majority. European usage was also possible, given the 'Plant Passport' scheme that facilitates the transfer of germplasm. In contrast, other areas of the world could have particularly restrictive plant health requirements (for instance, New Zealand); hence discouraging the 'flow' of material from the UK. The overall sense given by the interviewees is that users are equally, one might say, 'welcome', regardless of their situation in terms of location or use for the germplasm – as long as they are operating within the confines of the germplasm economy. Such an attitude does tally with the focus on interdependence and international cooperation that is central to the Seed Treaty.

More broadly speaking, too, the interview and documents both indicate that genebanking staff seek to actively encourage the flow of material from the genebank. This is seen to be an important part of their role: disseminating material and helping users to access it.

Genebank staff make sense of their own work, and of the resources they keep, in more than one way: these are not only research material, or breeding resources; other aspects can also be articulated: for instance, the role of custodians of heritage material, as described below by a genebank curator from a British public collection:

> *'And you have to recognise that certainly within the UK, (…) the public collections represent, we are the custodians, really, of the national agricultural heritage. There is no other place where people can go to access it. And why shouldn't they? These (…) collections are funded through public channels and in my view they should be able to, within reason, be able to request the material, and we should be, you know, able to provide it. We are able to provide it.' (I1, UK genebank staff, 196-201)*

This quote presents germplasm, and the genebank, as a means of maintaining a sort of shared treasure, of common national heritage, under custodianship: and with it comes a duty to make it available (and it should be noted, this is particularly the case given the public funding of the collections themselves). In this way the 'locality' of the collection is reinforced, even though it can also serve a role as a provider of germplasm to users in other places.

Genebank staff characterise their role as a service to various communities; and not as ‘sellers’ of any kind (as noted, for instance, by I10, another genebank staff member in the UK): germplasm is not considered by them to be a commodity; although not all of it is a public good, necessarily. Moreover, I would suggest, presenting the relationship between user and genebank as one of partnership or collaboration presents a different set of expectations and responsibilities to that of a market relationship between seller and buyer. Doing so might mean, for example, that material received from a genebank should not be held to the same standards as bought material from elsewhere (which might be significant given the possibility of receiving inviable or wrongly identified material).

Because genebanks characterise their activities as the provision of non-commercial services, they reserve themselves the right to not disseminate material, as seen above; and this might involve making decisions about who can, and cannot, be issued material. In this way, too, genebanks regulate the ‘flow’ of material. One important example here is the decision of who counts as a ‘bona fide’ user; a term used in the Seed Treaty to refer to the kinds of users who might request material under the terms of the Treaty. Importantly, this term recurred in interviewees’ talk: it is their role to decide whether the material is being requested for the purposes of breeding, research, or training. Here, they are clearly enacting the terms of the Treaty.

Another way in which they undertake this role is by filtering out, or re-defining, requests that might be too onerous on the supply: for instance, the request for a very large amount of material, such as a sample from all varieties of a crop, were thought to be too much (I4). In this case, however, it was pointed out that the next likely step was to liaise with users in order to find out a way to re-define the request, so as to make it more manageable.

An interesting finding is that genebanks' activities to demonstrate the value of genetic resources to users are analogous to a process of publicising them. Genebanking staff are still very much engaged in a process of making their value clear to users – one might say, publicising to convince users (or especially *potential* users, but who have not got an existing relationship with genebanks) of the use value of banked germplasm to them. Hence, even though genetic resources maintained in public genebanks are not thought to be commodities by actors involved in genetic resources policy (for example, Fowler (2002) argues that 'as a commodity, [PGRFA] are a flop'), there are some instances where the description of curators' work draws clearly from commercial ideas. One fascinating insight took place during an interview with a curator at a well-established public genebank in the UK. S/he had a strong personal interest in developing activities to increase the usage of the genebank collections, which were described as 'public engagement'. When asked in greater depth about them, the rationale drew from commercial/business analogies:

> *'…it is a lot to do with communication, and (…)being able to- you can get far more uptake in material if you have a story, if you have a particular… if you have something to say about it. A unique selling point, USP on the material to take a business analogy. That's increasingly- so, it's not one or the, other it's both. [yes] You need both. And in terms of engaging with the external community, unique selling points are extremely important in getting that interest and you can see that it makes a difference. (I1, UK genebank staff, lines 179-184).*

The idea of the business analogy is not only a helpful heuristic but, I argue, suggests a broader attitude regarding the need to 'sell' the collection (even though access is, itself, free). It is suggestive, perhaps, of the desire to combat the perceived *under*use of collections. Yet, significantly, doing so requires that the value of the material is articulated in ways that appeal to the potential users, therefore implying that there is a need to reassert the value of publicly banked germplasm.

Interestingly, although genebanks may be significant providers of germplasm, they are not the only ones. At interviews, other means of acquiring germplasm through websites or contacts in the industry were mentioned. In other words, there is an 'informal' exchange of germplasm that occurs in parallel with this official economy. What does this mean in light of the new governance system of the seed treaty? There is some evidence that the requirements for greater accountability and tracking of the movement of genetic resources, may have an effect here. With the use of the sMTA, genebanks are now keeping track more keenly of what germplasm is distributed to whom. This is a requirement of the Nagoya Protocol. It can be tracked through the number of sMTAs which are distributed. And, as the next excerpt makes clear how, from the perspective of a genebank curator, the international regulation has impacted the exchange of materials between users and genebanks. It bears quoting at length, because it demonstrates how accountability is created and assigned; and how the regulation of this economy might, in turn, have implications for the utility of genebanks themselves.

> *'I think within the first two years of the International Treaty I began to see that (…) it did begin to improve on the utility; I wouldn't say it upped the numbers significantly but the transactions were easier to manage. I think it's (…) hard to put the clock back and (…) isolate what the International Treaty has done [sure, OK] but I have gone on record as saying that I think that both the [CBD], the International Treaty have stabilised the landscape so they brought clarity on a global level to what is, to how material is accessed; and so people are conversant and happy with it= to the extent that even - a number of groups were insistent on having the International Treaties' sMTA used for their transactions. Now, the Nagoya Protocol has made that even more important because the onus on anybody using germplasm is that they can track to, to a source of germplasm that was either properly collected or accessible under the right terms. So this is essential, so and in fact even for basic research it's important to actually have the sMTA in that trail [yeah] for further down the line because you don't know for what's going to be commercialised later on. So plant breeding industry now has particular offices in some big companies whose sole task is to ensure that before any material is used in a cross they have the right paperwork so it's become that*

important [yes], OK? So that has strengthened the role of gene banks; so you can still go to websites that have thousands of different varieties, of different stocks; you've no idea how they were sourced, you can get hold of them but, would you in time ((Unclear word)) because the onus is on the user to- to have asked on what terms is this material available. So it's putting gene banks in much stronger position and that should translate to greater utility for the gene bank, for the- official (…) ex situ collections.' (I1, UK genebank staff, 348-367)

So, as this interviewee notes, there is now a *responsibility* for ensuring the appropriate sourcing of germplasm which lies with the users of germplasm, without which further transformation and commodification of the resulting product is not possible – and this requirement to reach a controlled supplier might increase the utility of genebanks.

The material in genebanks is therefore imbued with the 'ethical biovalue' (Kowal et al., 2013) which sets it apart from that which is exchanged through other means. From the genebank, these materials enter a global trade of material in a flow that is sanctioned and compliant with the regulations of the Seed Treaty, in the hope that a virtuous circle can result. Thus, much like the blood banks of Waldby and Mitchell's tissue economies (2006), genebanks appear as important centres for the *management* of resources. Being able to offer this guarantee of origin and a sanctioned exchange, should therefore be seen as an important part of the role of genebanks in mediating germplasm flows. In the context of the moral economy (Thompson, 1971; Scott, 1977) of germplasm and the politicized nature of debates around access to and control of germplasm, this is seen as a possibly significant development in the construction of a germplasm economy. They enter a global trade of material which is sanctioned and 'good', in the hope that a virtuous circle can result.

In conclusion, then; much like the banks of Waldby and Mitchell's tissue economies (2006), genebanks appear as important centres for the *management* of not only resources, but competing goods and values. They play a role in the dissemination of genetic resources, and do so in ways that ensures the preservation and maximisation of the value of germplasm, but that also requires that they deal with competing priorities (for instance, between present need and conservation for the future). In the next section, I broaden out the analysis to think about the shape of this economy.

4.3 Sharing genetic resources in the germplasm economy

In Chapter 1, I overviewed the different phases in the international governance of genetic resources policy. Here, I begin from the premise that the ITPGRFA represents a different phase in the political economy of genebanking because it ushered in significant changes to the way material should be shared; and because this treaty (and associated documents) set out specific requirements (although they might be quite vaguely worded) that people are held to. I therefore intend to investigate this new phase through an account of the practices of genebanks - so as to derive insights into the way people conceptualise the conservation system and the value of germplasm.

So far, I have argued that genebanks are responsible for maintaining germplasm that is considered valuable, and for doing so in ways that encompass different priorities and values. It is in that sense that they are a fundamental part of making the germplasm economy happen. In this section, I make the case that this represents a shift in priority towards more tangible, visible value. In other words, there is an effort to make *ex situ* conservation more productive. With the coming into force of the Seed Treaty there was a renewed effort by policy makers to encourage the flow of genetic resources through the MLS. I suggest that interpreting this situation with a focus on the seed bank suggests that this new arrangement is founded on arguments about the need to enable the value in genebanks to be made concrete by prioritizing access to/*use* of genetic resources. Moreover, the ITPGRFA approach hinges on the concept that the main benefit of the new system is *mutual access* to germplasm itself. In this way, this economy does not necessarily focus on money as the exclusive or obvious currency, but also on the flow of germplasm, information, funding, and labour: it appears as though success is measured not in the exchange value of the germplasm, but rather how lively the germplasm economy is in the first place. In a sense, however, the financial angle is never far away, in that making that value obvious is the way to justify further investment in the conservation of genetic resources. So, an interesting paradox emerges: on the one hand, it appears that it is not commercial/exchange value which matters, but rather the ability to demonstrate use value. On the other, genebanks are having to operate as commercial entities in identifying new target audiences and developing means of reaching them.

Altogether, there has been a shift towards greater emphasis on use, and less emphasis put on the growth of collections for their own sake. Of course, the value of genetic resources was grounded on the potential for use from the beginning of *ex situ* conservation (Peres, 2016); but this expectation was not, thus far, fulfilled. So, one might argue that the value of genetic resources has always been (at least when it is within the genebank) potential/promissory. Certainly, there is a clearly promissory aspect[33] to the way people talk about the value of genetic resources – the value of genetic resources is notoriously difficult to assess. [34] Such difficulty can be ascribed at least partially to the difficulty in tracing the value of germplasm used as parentage - although economists have tried (Smale, 2006; Smale & Koo, n.d.; Virchow, 1999), along with many others. The material which is kept in genebanks is considered to be valuable as a kind of raw material for further research, plant

[33] Indeed, it is because this is such a promissory economy that images and rhetoric are quite meaningful; gestures are important. Metaphors like ‘insurance’, ‘rich portfolio’ and ‘heritage’ immediately suggest why specific courses of action are valid. Returning to the idea of the Seed Vault that opened up the thesis, we can see how it is telling – especially when there is a perceived need to make people more aware of the ‘disappearing riches’ that are kept in the world’s gene banks.

[34] Although it should be borne in mind that there are live discussions on this point with regards to what constitutes the ‘use’ of a genebank, given that the provision of information, for example, is useful.

breeding or training. In other words, it has generally been seen to be important not for the respective plant per se, but rather because of the possibility of introducing traits from banked materials into new, improved varieties, which were not present in existing contemporary improved varieties. I demonstrate this in the next extract, where a genebank staff member from the UK explains how they make sense of this interest in 'heritage' material for traits:

> *"there's a good (.) scientific reason why a lot of people are interested in this heritage material and that's because they- the material since the Green Revolution has been mined out, really, for a lot of interesting traits. It's quite uniform, because (.) there were a few sources which were then expanded across, the you know, the globe; whereas the stuff that's before that is a lot more variable so if you're looking for hidden traits that might not be manifest in the elite material, the newer material [yeah] like drought tolerance and aluminium tolerance and you know things like that heat stress tolerance [yeah] then the heritage material might offer you stuff that you wouldn't find in more modern material." (I2, UK, genebank staff lines 178-186)*

In this situation, then, it is difficult to predict what might be useful in the future, and to whom. Genebank collections are created *a priori*, which maximises potential usefulness, but also makes it difficult to predict what material will come to be useful. Another way of putting this would be to think that there are two different kinds of value which can be assigned to PGRFA. A distinction is often made by economists between so-called *use value,* which is the immediate use for a particular sample, and *option value*, which is the potential use value of a sample in the future. This is reflected, for instance, in the uncertainty inherent to the very definition of PGRFA as 'genetic material of *actual or potential value'*. This particular arrangement of value is enacted, or expressed, in the suggestion that genebanks act as 'insurance' for the future of agriculture. Moreover, even when genetic material is used, it is difficult to ascertain the 'farm gate' value of germplasm. Uncertainty, then, is central to the difficulty ascertaining the value of germplasm. There are difficulties knowing, for instance, the full panoply of the traits contained in the genebanks, nor what they could potentially be useful for. In the cases where materials do leave the genebank, it was not easy to trace where genetic resources were used after they left the genebank. In contrast, with the establishment of the MLS, there is the scope for eliminating some of these issues through a streamlined MLS, as well as the establishment of the use of SMTAs with germplasm, thus creating a trail.

Whereas genebanks used to be proposed as the way to conserve genetic diversity, since the CBD came into existence they became considered rather as a complementary method to *in situ* and on-farm conservation. Hence, it makes sense to speak of a realignment of the job of genebanks. This shift towards greater focus on the actual over the potential value of the banked material was articulated in a variety of ideas and practices. Hence, in the current system of genetic resources governance, the sanctioned idea is that genetic material be utilized: that is the way to capitalize on the investment made onto the system itself. For instance, it became part of the impact which donors to international organisations were looking for and it became, in this way, very much prioritised. Such was the rationale for that change as explained by a participant working for an organization that seeks to enable international coordination between genebanks,

> *"So now then the next paradigm shift has been that, okay, it's well and good to be conserving those germplasm either in-situ or ex-situ but, you know, okay, why? What is the benefits of that to humankind, to people's livelihood? You know, livelihood of people became much more important. Donors put a lot more emphasis on the importance of, you know, the benefits that people derive from genetic resources. So our research focus then started to shift at that time…" (I16, international ex situ coordinator, 140-144)*

My argument, then, is that genebanks continually work to demonstrate the value of their own collection. Demonstrating actual services to the community is an important way in which people can make the case for their own existence, and ensure the future of their own collections. In so doing, the nature of the genebank as a resource for valuable genetic material is itself emphasised. This does not mean that genebanks were unconcerned about usefulness in the past; only that there appears to be a greater requirement to demonstrate impact of sorts. The value of genebank collections is, arguably, hard to pin down: both in terms of the value of particular material in the collection (which is hard to appreciate first hand, unless a special plot is made so that people can compare them) and of the post-collection work which happens within genebanks with the aim of 'adding value'. This is demonstrated in the excerpt below, where the interviewee comments on the scarcity of money available to demonstrate what work is already happening in seed banks.

> *Because... this is perhaps my opinion, but I think that if we were able to do this, if we could dedicate more to show what is going on, we could, without any particular effort, already show that gene banks are tremendously useful and the material is flowing to... certainly to research, but also to breeding (I14, coordinator, international organisation, lines 1058-1061)*

It is in this context that we might explain the new direction of activities in genebanks: through active efforts to share it, it makes visible the value of germplasm as a resource and in so doing justifies its conservation in the first place. I return to this theme on Chapter 6 in reference to the funding of genebanks and how that relates to the construction of genebanks as resources. Moreover, not only is this project important to conserve the conservation system itself, it also justifies the current framework of the MLS and, more broadly, the need to share resources internationally. This is significant, given the critiques[35] of the system and the limited nature of the shared gene pool (given that if it can be shown to be effective, the CGRFA may agree to expand the list of Annex I materials, see Visser, 2012). The excerpt below provides explicit evidence

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[35] The critiques of the MLS can provide further detail regarding what is considered to be important about the functioning of genetic resources conservation systems. For instance, those who say that it is bad for farmers because they are being expropriated can make the case that the money is not going to go back to them, and that the language of the Treaty is not actually clear with respect to the feasibility of patenting the 'product' onto which genetic resources might be introduced.

for the reasoning, by an interviewee involved in the policy work of genetic resources, of a need to show the effectiveness of the MLS.

> *'Well I suppose at the, at the plant treaty sort of level, an understanding of the use of the SMTA, and trying to, probably, better demonstrate to critics of (…) the Treaty's Multilateral System that it's not actually creating benefits; actually demonstrate that the use of the SMTA and access in and of itself, is a benefit even if it doesn't derive any financial benefits directly to the Treaty's benefit sharing fund. So, the metrics that sort of have been put together certainly at European level (…) in which the European region has managed to sort of compile (…) collective data about, about demonstrating how much material has been used with the SMTA, is a demonstration of the value of the Multilateral System in itself- but I think there needs to be an extension to that. So what is the question? The question is, as this potentially goes into this breeding programme (…) and so on and so forth [hm hm], but there's still more work to be done in terms of trying to balance the, that with the demand for sort of a, other benefit shared.' (I7, UK, policy maker, lines 96-108)*

Altogether, then, the value of the global gene pool is co-produced with the appropriate economic framework for the exploration of genetic resources. The contemporary activities of genebanks operate to construct a shared genepool, in the sense that they are common pool resources to which access should be facilitated. With it comes a germplasm economy that is arranged around the concept of multilateral access and sharing of germplasm, grounded on the understanding that this is the way to make the most of the germplasm in the genebank, with all its promissory value. In this way, the establishment of the Seed Treaty and the MLS gives new expectations to the power – indeed, the value – of genebanking as a means to preserve genetic material whose value is much debated, but where the amount of material kept in storage outstrips the demand for it. However, I am not ascribing this push for greater recognition of the value of germplasm exclusively to the new rules on access; other factors such as warnings regarding the future challenges for agriculture (eg climate change), could have been significant.

Somewhat paradoxically, then, enabling the continuation of conservation into the future requires an increased attention to demonstrating the value of genetic resources in the here and now; and some quasi-reforms of the *ex situ* system, which will be the subject of chapter 6: making *ex situ* conservation efficient, sustainable, and so on could be read as a decision to create a 'new, improved' system that would encourage a greater uptake of genebank material. The fact that there is such interest in demonstrating that it can be done is, in itself, interesting: it shows a moment of transition in this economy towards a novel way of doing things; one where the 'currencies' are somewhat blurry. As we have seen, people talk about mutual access to germplasm as the great outcome of the MLS: the idea is that everyone 'wins' by sharing their own material. And it is this which makes the idea of sharing germplasm so appealing, or politically workable: by pooling resources in this way, countries are actually working in their own self-interest (as well as, potentially, altruistically). By opening their doors to other countries, they are taking out some kind of insurance.

4.4 Conclusions: A germplasm economy of use value

With this initial empirical chapter, then, I have analysed the role of genebanks in the germplasm economy by exploring the role that they play in the conservation and dissemination of germplasm. Starting from the suggestion that genebanks are, indeed, responsible for the maintenance of a part of biodiversity because it is valuable (rather than because it is diverse *per se*), I have sought to understand the processes whereby genebanks manage germplasm in ways that explicitly seek to maintain their value and are consequently political economic in nature. That insight was originally demonstrated in section 4.1, where I made the case that genebank actors are selective regarding the material that they accept, and conversely that their capacity is not unlimited. Hence, genebank staff manage their genetic resources in ways that maximise the value of the collection, and put to best use the resources that are available to them. In that sense, they are constantly engaging in calculations about the most appropriate way to deploy their resources.

Indeed, it is helpful to think of genebanks as banks that conserve the value of genetic resources in both the technical and the political senses of the word. In section 4.2 I have shown how people in genebanks and genetic resources policy describe how genebanks are involved in the sharing of germplasm. The picture that emerges is one where genebank actors working in collections put considerable effort not only into providing germplasm, but actively seeking out new groups of germplasm users. In this way, the genebanks that carry out the principles of the existing governance framework by acting as 'good stewards' for the material that they have in making sure that these all-important flows are not duly unimpeded.

In addition, they have a significant role as 'gatekeepers' of access to the collection. They make decisions about what counts as a 'bona fide' user, and engage with users to redefine requests where necessary. We have also seen how they play a role in translating the value of the collections to potential users. The fact that only a small proportion of the collection is used at any time is seen as an issue, and people seek to develop new ways to engage with users, old and new. Genebank curators can, effectively, spend a lot of time 'making value visible' to users; and defining ways of making the materials more appealing. One might ask why such concern with gaining users: is it because they are not aware of this material, or is it because there may be other sources? That 'other' market should be a focus for further research in order to determine how particular seeds, trees or other genetic material acquire actual or potential value to users. For starters, they have to be able to keep this material and make it available for others when required. In a sense, then, genebanks make 'genetic resources' out of germplasm. It is through their actions that particular seeds, trees or other genetic material acquire actual or potential value to users. This argument is further fleshed out in the next chapter, with respect to information.

Thinking of genebanks in these terms is helpful, in that it permits us to theorise the current arrangement of the germplasm economy: because of their involvement in the dissemination of genetic resources in accordance with appropriate political safeguards (namely, through the use of SMTAs that commits users to benefit sharing), they underpin the current germplasm economy, where a sharing approach is legitimised as the most appropriate way to maximise the value of the material that is already available, and as the best way to ensure that value – use value, but also social value – can be best conserved and deployed. Finally, I have argued that in seeking to increase the use of the collections, genebanks can demonstrate *their own* value to the people that provide funding for this work. They are also attempting to find new user groups to make use of the material, and developing new reasons why genetic resources will be needed in the future. And, at a broader scale (that is, among people who work in the international coordination of genetic resources) the movement of germplasm is seen as an important thing not only because it is seen as a public good, but also because one of the ideas underpinning the MLS is that the greatest benefits are not monetary, but rather the *mutual access* to genetic resources.

In the next chapter I turn to the production and sharing of data, showing how this is superimposed with, and inseparable from, the flow of germplasm. Over this and the following two chapters I explore the various technical and political issues and specific requirements for genebanks that emerge as a result of this function. Yet my findings about the way genebanks are engaged in managing the flow of genetic resources demonstrate that the role of the genebank is dynamic and evolving, and that various actors are now pushing for greater efficiency with a shift towards the function of facilitating use. Although they are still important for conservation, the priority for the genebanks is, increasingly, opening up and maintaining the material for the facilitation of access.

CHAPTER 5 SHARING INFORMATION: MAKING VALUE VISIBLE

Genebanks, as I argued in the last chapter, are engaged in conservation as a form of value management – and a substantial part of their role is facilitating the use of germplasm (whilst also ensuring its conservation for the future). Yet, actors identified the availability of data about germplasm as an important limiting factor shaping the demand for banked germplasm. Moreover, data and its flows is also a concern for policy actors invested in building an international germplasm conservation system, so that Article 17 of the Seed Treaty mandates the creation of a 'Global Information System'. Hence, following the flows of data into and out of genebanks is the next step towards creating an analysis of the germplasm economy that takes biobanking into account.

Actors involved in genebanking (across the board) believe that 'the usefulness of samples held in genebanks is dependent upon the *degree and quality of information* connected to the samples' (Khoury, Laliberté, & Guarino, 2010) (my italics). Or, as an interviewee conveyed it, it operates as a label on a collected sample; if it is not correct then the sample itself is of no use (I11). Hence, in this chapter I draw from the analysis of the interview and documentary data to describe how genebanks create, accumulate or transmit data and information, and what this can tell us about the nature of the germplasm economy.

Waldby and Mitchell (2006) also find that the circulation of '"information" is a mediating term between individuals and tissues' (Waldby & Mitchell, 2006, p. 26). They state that the background change in the economy from industrial to informational has encouraged the spread of intellectual property rights to objects (including tissues and information about those tissues). This meant that legislative bodies (which can structure the social order) 'have become increasingly interested in understanding, and controlling, how informational flows - especially those between universities and corporations - operate in such economies'. The thing to note here is that whatever objects enter this economy are 'understood as components of vast informational systems that connect the public and the corporate spheres both nationally and globally' (idem).

Exploring the relationship between data and genebanks is a way to think about how genebanks manage the value of genetic resources and their own collections. As I show during the rest of this work, these changes in the way genebanks produce and exchange data tell us much about the underlying changes to the germplasm economy that have accompanied the Seed Treaty. By engaging empirically with the way genebanking actors act on, and think about, the relationship between data and the value of their collections, we can explore how they conceptualise the role of the genebank as a manager of value(s) in the germplasm economy.

Firstly, I show how the value of accessions relates to the availability of information and influences the use of genebank accessions and, therefore, the realization of their potential (as per the last chapter). As I demonstrate in section 5.1, the availability of data about accessions is a fundamental part of the value of germplasm, and staff in genebanks engage in the creation, accumulation and distribution of data along with germplasm, which they do with a view to maximise the value of their own collections, within the possibilities afforded by the funding available. In the following section (5.2) I turn to the macro-scale through an analysis of the emergence of new artefacts in the germplasm economy: the digital, large-scale databases that represent the existing genebank collection holdings. Representations of germplasm holdings at the international scale enable both the visualisation (and search) of a shared genepool, and are lauded as means to facilitate the optimisation of the genebanking system for users and genebank staff. Yet, I argue, the significance of these databases goes beyond the streamlining of searches for the facilitation of searching through many collections at once. They also serve to provide a means for countries to show what they have to offer, and to comply with the mandate to provide access to the genetic resources that are in their territory. Finally, in section 5.3 I derive some conclusions about the germplasm economy by studying international germplasm databases as materialized instantiations, or enactments, of the political economy of germplasm. On the basis of an overview of the data flow into EURISCO, the European regional database, I make the case that such databases are hybrid artefacts that co-produce the shared genepool and the germplasm economy. More specifically, the creation of international databases for genebank accessions can be understood as part of the effort to encourage the sharing of genetic resources (thus concretizing their value) and making visible a germplasm economy where genetic resources are easily accessible from different countries. Altogether, then, by observing how genebanks manage data flows, I make the case that these activities are part of a broader move to create a germplasm economy that operates on Multilateral grounds.

5.1 The challenge of data: availability, accessibility, and the value of genetic resources

In this section, I show how the management of *data* is part of genebank activities and is, in fact, understood to be a significant factor in the goal of enabling the accumulation and dissemination of valuable genetic resources. I build on this observation by examining actors' views on genebanks' duty to curate and gather information as part of the work to successfully conserve genetic resources and overview how genebanks engage with data production and curation. These findings suggest that actors see the problem of shoring up the use value of genetic resources as one that can be addressed through improving the availability and accessibility of data about germplasm. Moreover, how to acquire, manage and disseminate data appropriately is considered a 'challenge' to be addressed; conversely, adding data is the way to 'add value' to genetic materials and genebanks themselves. Hence, we see how genebanks' engagement with the curation of data, too, is part of their role in accumulating and ensuring the value of genetic resources. Therefore, by managing data flows, genebanks are building the value of their resources and resolving potential conflict between different values (for instance, by carefully defining boundaries between public and private data). Thus, genebanks' management of data is a significant part of the way they operate in the germplasm economy, and the current effort to improve the data associated with germplasm accessions is, I argue, another example of how *ex situ* conservation is permeated with concerns about the maintenance and optimization of resources.

A historical overview of the evolution of documentation about genetic resources over time instructively illustrates the problem that documentation, or data, about genetic resources posed to conservationists (analogous to that identified by Radin, 2015): how does one adequately describe the material that is in collections in a way that enables their use in the future? Such a question is particularly important when dealing with proxies, because it is the only way to contextualise or connect the proxies to their (original) context. Documentation has been considered a fundamental part of the process of conservation and dissemination since the very start of international conservation efforts. As far back as 1975, plant conservationists pointed out that '[d]ocumentation may be the thread with which the whole fabric of [genetic resources centres] is woven' since 'we use information about the plant material (…) rather than the material itself when we wish to communicate' (Rogers, Snoad, & Seidewetz, 1975).

A number of publications (Konzak & Dietz, 1969; Tanksley & McCouch, 1997; Upadhyaya et al., 2008) suggest actors thought (and think) information sharing is important both because it was essential to the *use* of genetic resources, and also to enable the particular approach to conservation that actors envisioned, that is, one which was international and cooperative: in other words, information about collections needed to be mobile, available and understandable. Despite this theoretical recognition of the value of data, in practice genebank actors had limited capacity to develop extensive records about genebank accessions. To this day, many actors feel that the description and characterisation of banked material has lagged far behind the speed of collection, starting with Simmonds in 1962 (Simmonds, 1962). This view is made quite explicit in the first State of the World's Genetic Resources Report (FAO, 1997), which 'highlighted the poor documentation available for much of the world's PGR' (FAO, 2010, p. 77). Briefly, collections vary significantly with regards to how complete or systematic their data is. Compounding the issue of lack of information collected with the material, there is also a degree of lack of standardisation and, finally, the risk that original paper records that contain this data degrade over time. Overall, then, the documentation of genetic resources is something of an outstanding problem for actors.

Why, however, is this issue particularly relevant in the context of the germplasm economy? As I will further demonstrate in this chapter, the problem of data is pertinent to our understanding of the germplasm economy because the flow of data is inevitably bound with the genebanks' role as the accumulators and managers of resources in ways that *maximise* the value of their collections, and that manage the potential conflict between different values – such as transparency – that are seen as central to the successful functioning of the genetic resources. More specifically, this means that the value of genetic resources in a particular genebank depends not only on the way it conserves the genetic material, but also how it manages information: a point which will be illustrated in several ways throughout this chapter. For now, however, the interesting point to note is that there is evidence of a new lift in expectations regarding the potential value of genebanked materials that is, I argue, related to the emergence of novel information technologies, precisely because they can facilitate new ways to manipulate information (for example, through databases) - and, consequently, for genebanks to 'add value' to their collections. The first step in making this argument, however, is an overview of the increasingly comprehensive set of classifications for genetic resources.

PGRFA present thorny challenges in terms of description. As cultivated plants, they are described in accordance with botanical and agronomical conventions, such as Linnaean taxonomical nomenclature. Bowker (2005) has discussed how that system is susceptible to issues of temporality, as he discusses the problem of ascertaining the correct name for a plant when its taxonomy changes. Yet they add a particular challenge, given that the description of genetic diversity at the level of a *population* requires a different level of granularity to that provided by, say, a genus or variety name: the descriptors of genetic resources must be able to deal with the identification of a *sub*group which represents neither a whole species nor an individual specimen. In that sense, the naming task appears to be quite formidable; because the slipperiness of botanical names is compounded by the proliferation of homonyms and synonyms that occur in different varieties as they exist in different locations. For example, one interviewee mentioned how a vine variety that was present in a genebank under the name 'Castelao', was also repeated in the collection under 10 other synonyms (I19). Altogether, then, determining how to describe and name genetic resources (proxies in the genebank) is also, inevitably, a matter of establishing a system of descriptors that are relatively stable and understandable at the global level, and in the future. In so doing, it quite closely mirrors the issues around metadata that Bowker speaks of: how do we know how much context should be maintained with a particular set of data, without knowing how such data will be used in the future? I suggest that actors seek the resolution to these problems by defining what constitutes the necessary metadata that should be kept with genetic resources so that they are useful in the future, and in so doing create a shared gene pool.

Unsurprisingly, then, actors have identified a need to create a structured, general approach to describing genetic resources as a challenge as far back as the 1940s. It is possible to observe the evolution of a common set of descriptors: here, I introduce it, and the way they are managed in the genebanking context (and in section 5.3 I turn in greater depth to the idea of standardisation itself, and its implications in terms of the germplasm economy). Following the evolution of descriptors over time demonstrates the rise of particular characteristics or traits of banked material *as* important or valuable: it suggests that information/data have their own dynamics, which can be quite separate from those of germplasm, in that data can be produced about genetic resources at different times to the 'production' of genetic resources; and have an effect on the development of genebanks themselves. Hence, the ways in which data is created, maintained, and checked – in other words, curated - should be understood as a genebank activity; and one which has implications for the germplasm economy, given that it is very much bound with broader concerns about what kind of information is valuable, to whom, and under what circumstances.

Data about PGRFA are categorised into different classes, and have been increasingly standardised over time (a theme I turn to in greater detail in section 5.3), and I now introduce the main classes of data available, demonstrating how actors think they add to the value of genetic resources. It should be noted, however, that while I suggest that this standardisation is a significant trend, I am not claiming it is totalizing: there is local variation overlaid with this general schema, with different genebanks adapting standard descriptors so as to best suit their own purposes(Bioversity International, 2007, p. 5; I5; 19).

The ways of describing crop genetic diversity/varieties, (specifically in the context of genetic diversity, as other descriptors exist for the purpose of making sense of commercial varieties, for instance) began to be codified in the 1970s through the work of the IBPGR, when it 'became apparent that a universal system was essential for global efforts in PGR conservation and for networks of genebanks to operate effectively' (Gotor et al, 2008). Groups of plant scientists contributed, through the work of the IBPGR, to the creation of so-called Descriptor Lists. Such lists were seen to 'together constitute the basis for a standardised documentation system that provides an internationally agreed format and internationally understood language for PGR data. The adoption of this schema (…) helped create a rapid, reliable, and efficient means for information exchange, storage and retrieval' (idem). Descriptors include 'key attributes, characteristics or traits of a crop, and set out the method used to measure and document them, along with the relevant registration data' (Bioversity International, 2007, p. 5). These lists, then, set out protocols that enable any interested party to determine which traits or attributes of particular accessions should be measured, and how to do so. In that way, they represent a way to set out the ‘metadata’ that enables the same accession to be understandable in different places: thus, it is a significant step in the construction of a shared gene pool – and a shared germplasm economy – through creating a classificatory system that makes material commensurable and comparable.

If one trend has been the increase in the number of crops covered by descriptor lists, another is the evolution in the richness of descriptors themselves. Since their beginning in 1977, descriptors have become increasingly comprehensive, as well as encompassing more different types of information about accessions. The first descriptor lists were ‘minimal’, and therefore focused on basic ‘passport data’ for that crop. From the 1990s onwards, however, crop scientists involved revised the strategy, descriptor lists should include characterisation and evaluation data (1990), information about in vitro and cryopreservation (1995) and ethnobotanical data (1999). Finally, in 2004, descriptors for genetic marker technologies were published. These dynamics show that data about specific traits relating to the qualities of genetic resources have become increasingly prominent in these decades. Hence, I suggest that this change is not 'merely' the inevitable outcome of the development of technologies such as genetic marker detection; rather, it is also the result of efforts to increase the utilization – or the use value – of collections.

Finally, IPGRI developed in 2001 a set of descriptors that was common to different crops: the ‘Multi-Crop Passport Descriptors’ (Hazekamp, Serwinski, & Alercia, 1997; Alercia, Diulgheroff, & Metz, 2001; Gotor, Alercia, Rao, Watts, & Caracciolo, 2008). This set stands out by its *compatibility*: it can be applied to accessions of different crops, and is compatible with existing descriptors in large databases such as WIEWS and GENESYS. Although this might seem like a small change, in reality the availability of MCPDs was an important step towards the creation of *databases* that could themselves contain information about accessions of different crops, together: in turn, that facilitated the ability to create representations of collections arranged geographically – for instance, showing all the collections within a particular institution, or region. I return to this topic in section 5.3 to argue that such databases are important hybrid artefacts that represent and enact the shared gene pool. For now, however, I will focus instead on a description of the different types of data available in contemporary descriptor lists, and ground a discussion regarding the hierarchy of value that is evident.

There are several different classes of data available, covering a variety of descriptors. For the present discussion, I will focus on passport data and characterisation and evaluation (henceforth, 'C&E') data: this is because these different types of data (which I overview below) 'do' quite different work, and as the discussion will show, are seen to affect the perceived use value of banked material differently (and are more prominent in the primary literature than other classes of data). Briefly, passport data provide information about the origin and the identity of the sample. C&E data, on the other hand, provide information about the characteristics and traits of specific genetic resources (generally, when grown into a plant). The other classes of data (which I will not examine further) include environment and site-specific parameters of locations, that are useful in order to help to tease out genotype-environment interactions, as well as management descriptors used for everyday management of the collection which relate to processes such as regeneration and multiplication of accessions, and are essentially for internal use by genebank managers.

Passport data detail the identifying details and the ‘history’ of the accession, and are therefore considered the most essential set of descriptors: the ‘label’ to the accession. They include descriptors such as the genus name, location found, provenance, and others; they provide basic information for the general management of accessions, and describe them along certain parameters/criteria that are defined when they are collected (and when they move). They therefore provide a set of information regarding the provenance of the accession, as well as information about how the sample is handled when in a particular collection. Passport data can also be used to aid actors in finding information about a particular sample in secondary information. In the absence of other specific information about the inheritable traits present in that sample, numerical identifiers that are part of passport data can enable the linkage of particular clones (for instance, of cacao trees) with 'external' sources such as published papers, whose data might aid potential genebank users in the selection of the most appropriate material from genebanks.

Yet if passport data is essential in order to know what, ontologically, is in the genebank, their contribution to the value of the accessions is limited in comparison to the information about the *traits* of the accessions. Hence, potential users, such as breeders, place more importance on information about phenotypic traits that are important for the yield or the market value of the accession. As an interviewee puts it,

> *'(…) the type of information that is mostly available is the passport information. We generally know where it was collected, by whom, etc (…) but much less information is available about the characterisation; that is, what are the traits of that particular accession? Does it have a (…) yellow flesh or a white flesh potato, you know, or does it have yellow flowers or red flowers or white flowers, (…) these characteristics that define the variety (…). And even more importantly, the evaluation one which is more disease traits or adaptation to particular, how they do in particular environments, these are traits that are very important for breeders. So this characterisation and evaluation information is generally very poorly represented in gene bank accessions, okay, in [the] documentation system and that's a challenge. That's a challenge because that really reduces the value of gene bank accessions.' (I16, coordinator in international organisation, lines 223-234)*

Thus, the existence of C&E data significantly determines the value of genebank accessions, and genebanks are increasingly focused on accruing and curating these kinds of data: they represent a 'challenge' for genebank staff. The characterisation of this effort as a 'challenge' is telling because it conveys the idea that, with effort, the contemporary demand for genebank materials can be resolved by tackling that particular aspect of genebank activities. Characterisation and evaluation data are related to the specific behaviour of the material in given environments, and also about the traits that occur within each sample. Characterisation data refers to 'observations used to describe accessions and differentiate them from those belonging to others' (Gotor et al., 2008). They provide useful information for crop development and plant variety claims. On the other hand, evaluation data describe characteristics such as yield, agronomic traits, resistance to pests and diseases, which therefore makes them ‘of great interest to plant breeders for crop improvement and domestication’ (idem).

Yet C&E data are far harder to standardise across collections. They are ‘described in a variety of ways, ranging from an atomic model with one record per observation, to fixed tables with one character per trait and one record per accessions (…) the solutions for other data types are far from standard for genebanks’ (van Hintum, Begemann, & Maggioni, 2010). Moreover, not only are they often recorded in different formats, they are also locally specific in ways that contribute to the ‘challenge’ mentioned above. So, the most valuable material is that which is simultaneously that which is less mobile – precisely because, one might argue, C&E data are a representation of the traits of the variety/plant itself that results from the interaction between the banked genetic resources and their local context in the form of phenotypic traits. The specificity of such traits is difficult to convey, and to agree on a standard way of measuring them. The example below illustrates precisely this problem (see also I18).

> *‘(…) very occasion-specific [hm hm] so in that year, at that site, I grew this accession up and it looked like this. If you do it somewhere else, it may be different and unless the other place records the data in exactly the same format you may miss that, or you know it may not be clear [hm] so (…) it's quite difficult to come up with a standard format for characterisation data. I mean we have standard descriptors [yeah] but anything beyond that it's quite difficult to, yeah, quite difficult to actually come up with a score [and ((unclear word here))] that everyone's happy with, because everyone does it in slightly different ways and they're not always compatible, so.’ (I4, UK genebank coordinator, lines 214-221)*

Altogether, then, these findings indicate that information can be produced about an accession, but not all of it is equally mobile or transmissible. This insight is interesting because it points to a particular imaginary of the germplasm economy where data can make the very diverse materials in collections around the world commensurable through standardised descriptors. After all, as previously stated, it is information, rather than the material, which is used to communicate. Much as plant germplasm is supposed to circulate, the information about plant germplasm should be understandable to different users and in different contexts: ‘[d]ocumentation of the data in any [genebank] will have much wider application than data in the normal setting in which scientists have worked in the past, because the data must serve many different functions beyond that which the individual scientists may have conceived himself’ (Rogers et al., 1975, p. 399). This is another iteration of the problem that Bowker (2005) identifies with calls for data re-use: how much metadata is necessary? How much of ‘the past’ is it necessary to keep, so that the data can be understood elsewhere?

The argument thus far, then, is that the development of means to curate and standardise information mirror concerns about the use of genebank material; in addition, as previously noted, the deficit of information is understood to be a cause for the lack of use. It is for this reason that actors believe that the lack of use can be corrected by addressing that issue and providing better/more comprehensive information. In so doing, providing information becomes a 'challenge' to be addressed by genebanks and scientists involved in the international coordination of genebanking. And indeed, there is evidence that genebanks are shaping their work (further discussed below) accordingly: for instance, through seeking ways to gather more data, or engaging in collaborative work to produce it. Novel technologies that produce bioinformation (that is, genetic analysis) and re-contextualise accessions through ‘big data’ are driving expectations about the potential use of genetic resources – and, I argue, raising the promissory value of genetic resources.

Actors see much potential to improve the efficiency and effectiveness of genebanking and the use of genetic resources by employing new artefacts and classificatory systems to describe genetic resources (CGRFA, 2011, para. 12(c)). For instance, the Second Global Plan of Action (idem) identifies the development of information and communication technologies, along with that of molecular analysis, as ‘most important’ to PGRFA conservation and use since these technologies means conservationists could access data more easily, as well as use different data types. For instance, in the 10 years since the previous GPA, there was ‘significantly greater access to information as well as enhanced analytical capacity available to genetic resource workers’ in the form of geographical information systems (GIS), global positioning systems (GPS), and remote sensing, ‘which allow PGRFA data to be combined with a wide range of other data in order to locate specific areas of diversity or to identify material from particular habitats’ (CGRFA, 2011, para. 12(a)). The use of GPS and GIS is promising, according to actors writing these documents, because it permits users to locate the accession back into its origin with considerable specificity: in other words, it provides a way to *recontextualise* the genetic material by making its original environment visible: it is seen to ‘allow the generation of more detailed information on the extent and distribution of genetic diversity, and can be used in the development of strategies for PGRFA conservation and use.’ (idem, para. 12[b]). On a similar vein, molecular analysis, too, is considered to be a very valuable addition to the characterisation toolset, for two reasons: as one curator suggested, they promise to eventually replace more cumbersome morphological characterisation of accessions (I1); and they also provide a means of analysing stored material that can be used to determine what material is most likely to be valuable for plant breeders (Tanksley & McCouch, 1997). Like GIS, it provides a way to create connections between the material in banks and outside them.

Advances in information technologies have been considered very important for these activities of curating information in genebanking. What kinds of possibilities are afforded by the use of new technologies? Actors seek to maintain correct and complete information about the origin of accessions via its passport data. This is essential because it details the very identity of the samples and their place of geographical origin. For instance, passport data is that which retains the context/past of the sample itself. So, interviewees mentioned that passport information might be checked against existing information about the relevant variety or clone. Starting with the collection of the sample it should, in principle, be collected and stored with the accession, and transferred with it as it is disseminated to other repositories or users. Yet, with the movement of germplasm between repositories (which, as previously mentioned in chapter 4, is quite common) such information is dynamic and subject to change: accessions can acquire new names, or errors can be introduced when classifying accessions or copying information.

If data is incorrect, the implications can be considerable; especially given the relatively long time-scales involved in the plant sciences - so, the receipt of incorrect germplasm is considered to be problematic (I4; I15). Genebank staff work to maintain and ensure the quality of information, which can be less secure than might be expected. This task involves an iterative process of maintaining records associated with banked accessions, that is; it is a matter of curating information. For this reason, any errors found in the existing data should be noted and/or corrected where possible. The most direct approach to ensure that the sample is accurately reflected in the passport data consists of genetic analysis of sample, but there are other means of establishing (non)identity - especially when germplasm was grown into plants, thus enabling visual checks on morphological traits. Concerning cloned trees, for instance:

> *‘So to look for mislabelling you could use phenotypic data, so people would characterise the clones by looking at the [morphological characteristics], that sort of thing (…). [I]n some cases you might have (…) obvious examples of mislabelling [hm hm] so we used to hold a clone (…) and it was pointed out to us that this clone should be a dwarf mutant which our plant definitely wasn't. So we could say with some certainty, without having to do any molecular analysis or anything that that was an off-type. We used to have a consultant and he was able to identify a lot of clones - he'd be able to look at clones and say, this- plant is wrong [yeah] because it should have pigmented flowers or- or whatever so he was a real mine of information. (I6, UK genebank staff, lines 262-273).*

Altogether, this concern about sound identification exemplifies the ways in which genebanks are responsible for the management of data if they are to preserve the value of genetic resources: it suggests that accessions can only be as valuable as their data, which therefore require careful curation. Genebanking staff put effort into ensuring that the ‘past history’ of the accession, too, is preserved, along with the accession itself. It is for that reason, the new possibilities afforded by genetic analysis are significant: they provide a new method for confirming the identity or the traits of a particular accession. Similarly, the ability to keep records electronically (rather than on paper records) is advantageous to actors because staff can correct them or add new information more easily (as well as enabling higher-level databases/representations of diversity, as I describe in section 5.2). Ultimately, it facilitates the management of the genebank collections themselves, and the use of accessions. Keeping the value of genetic resources, then, is also a matter of ensuring that its contextualising information is kept ‘in the present’. I now explore how genebanking actors conceptualise this focus on information as a matter of ‘adding value’, that is, in terms of their role of managing the value of genetic resources.

Genebank staff (particularly those in the UK), speak of accumulating data about their collections as one of the most important ways to ‘add value’. “Adding value” is described as a function of the ability to know the collection in such a way as to enable users to select, from the large numbers available, the samples which would correspond to their needs:

> *how useful [are] genetic resources; how much characterisation data you’ve got on it, how much diversity have you actually captured; trying to get the, the breadth of that diversity; trying to get the full sort of breadth of the characterisation data, no matter what that may be [hm hm]; that makes it arguably more useful to anybody else. Publishing that data, making it available and I think that’s- that’s where you get (…) the added value.’ (I7, UK policy maker, lines 77-81)*

A similar point is made by another interviewee, who emphasises its cumulative nature, developing contextual information that allows better targeting to users' requirements.

> *It, it allows better decisions to be made in the future [hm hm]. If a person comes to me and just says, I want material from country A, well if I can turn around and say, ah well yes, I've got material which is early growing, I've got material which is late growing and I've got material which is material which (.) is intermediate growing, then it's much more value to them and gives them (.) better choices on what sort of material to use, than if I just simply say, well, it comes from France [OK]. And, the bigger picture we can build up like that, then the more value there is to the gene bank. (I9, UK database coordinator and genebank staff, lines 285-291)*

In this section, then, I've suggested that genebanking staff work to conserve both germplasm and information, and that the availability of information is seen to "add value" to the material in the genebank. The availability of new information technologies and means of characterising accessions are therefore welcomed by actors because they are seen to enable a better recontextualisation of genetic resources, and thus increased user interest. I suggest that 'adding value' is one of the ways in which genebanks carry out their role of managing resources within the germplasm economy. In the previous chapter, I've argued that they preserve the value of genetic resources in both a technical and a social sense; in this one, I maintain that the value of genetic resources is further managed by curating information about germplasm. In the remainder of the chapter, I will present more specific examples of this process at work.

5.2 Sharing data: genebanks and the construction of the germplasm economy

The narrative thus far has shown how genebanking actors characterise the relationship between value and data. I now overview the ways in which repositories are involved in the production, accumulation and dissemination of data, and how actors make sense of these activities as contributing to the ultimate aims of conserving and disseminating germplasm. On the basis of the evidence presented here, I argue that genebanks modulate the flow of information in ways that manage the different values at stake, much as they manage the flow of material. Analysing how they do so leads to some insights regarding what – and who - is prioritised in the contemporary arrangements of the germplasm economy. I argue that in following how genebanks encourage the flow of C&E data between users and producers, we see typical political economic questions come into play: regarding how to organise the distribution of costs and benefits of data, what relationships exist between genebanks and users, and what organisation of the germplasm economy will lead to the production of social goods, within the constraints of data ownership. Exploring these questions demonstrates how genebanks are part of, and construct, the germplasm economy by managing the sharing of data in a way that takes into account different priorities and values. Namely, genebanking staff have to be mindful of intellectual property issues around data, while seeking to make as much data available as possible. To do so, they appeal to users to donate data, thus continuing the sense of cooperation as the best approach to ensure that the value of genetic resources is maximised for all.

Data, like accessions, can 'flow' into and out of the genebank. Information about germplasm can be produced in the genebank, or outside it when accessions from the genebank are used in research that produces data which is then published. Hence, information can also 'flow' between its places of production and other places, including the genebank, through publication in journals or databases; a process that is increasingly easy to carry out and manage with digital technologies. Therefore, it is helpful to consider in greater detail the ways in which such data is *shared*. Here, I use that term in order to emphasise that such movement of information, too, has to take into account the property relationships between users and producers of data. Information can be in the public domain or not: after all, plant breeders may develop knowledge from genetic resources and keep it private while they are developing new plant varieties, only making them public after Plant Variety Protection has been granted (if at all). Simultaneously, information is seen as a ‘benefit’ that different countries are encouraged to share through the Multilateral System. Therefore, we can draw a parallel between the way genebanks manage the distribution of data and of germplasm: in both cases, they must take into account different interests and property relations, while seeking to maximise the value associated with their own genetic resources. The ‘flow’ of information presents additional issues to genebanks, as they seek to accrue, curate, and disseminate information which adds value to their materials without affecting private property rights, where they exist: hence, as I will show in the paragraphs that follow, the role of the genebanks also involves negotiating and maintaining these boundaries between the public and the private.

In order to develop that analysis, I explore actors’ perspectives regarding the creation and distribution of C&E data, specifically, into and out of the genebank. This class of data is particularly instructive, given that it is seen to ‘add value’ yet is expensive to produce. It can also be produced at different stages of the ‘lifecycle’ of accessions by anyone with access to the samples and the will and capacity to carry out the work. The characterisation and/or evaluation of genetic resources are activities that ‘add value’ to accessions, but that also require a degree of investment. For that reason, they provide an important case study for interpreting the activities of genebanks as political economic ones, where the outcome (the accumulation of data) reflects the multi-faceted management of value that genebanks must carry out in order to conserve genetic resources.

The trade-off between cost and benefit means that genebanks must make decisions about how best to produce and/or gather C&E data. Although genebanking staff might seek to derive their own C&E data about their material, the expense of the endeavour means that there are limits to what can be achieved. Therefore, I suggest that actors working in genebanks are effectively making decisions about competing priorities, and this situation brings to the fore the different values at play.

Resource issues (human, technical, financial) are thus presented as a factor that shapes how much characterisation work gets done, and what traits can be studied. In some cases, what individual genebanks can provide in terms of characterisation and evaluation may be limited, either to a few 'obvious' (I2) morphological characterisation traits, or limited in scope. So, the effort to add value to genebank accessions through more characterisation is shaped by the availability of funding. As one senior scientist involved in international genebank coordination put it,

> *It's the cost. It takes money. It takes a lot of resources to do characterisation and to do evaluation which should be done in multi-location trials, so these really are costly operations that gene banks cannot afford to do that. (I16, coordinator in international organization, lines 241-243)*

Here, then, is described the quandary that genebanks find themselves faced with (unless the funding available is sufficient to cover all requirements easily). Where that is not the case, genebanks have developed approaches to seek to develop the 'best' approach to C&E data, which I now turn to. One approach taken by some genebank staff is to engage more closely with users in order to determine how to allocate scarce funds available for characterisation. Such input can be informal, but it is also finding its way into cooperative projects where users (and particularly, plant breeders) are involved as collaborators so as to devise ways of characterising PGRFA that will meet their needs. In other cases, the collaboration may not be quite so formal, but genebank staff will still direct their efforts to characterising PGRFA in ways which will make them useful to particular potential user groups. This move can be understood as a reaction to the long-standing criticism offered by some plant breeders (see eg Simmonds, 1961 onwards) that the ways in which genetic material is conserved and described is not matched to what they find useful or important: for instance, developing descriptors that focus on the botanical characteristics of accessions but have less information about agronomic – and often, commercial – interest, such as fruit flavour (I15). Thus, I suggest that this situation can be interpreted as an example of the genebank maximising the value of the funds available for

C&E by developing data that will explicitly increase the use value of germplasm to particular groups of users; especially plant breeders. Thus, in contrast to Waldby and Mitchell's suggestion that UK blood banks privileged donors' wellbeing so as to ensure a continued supply of blood, I would suggest that genebanks are clearly concerned with developing genetic resources in ways that appeal to potential users.

Indeed, it is instructive to think about the assignment of responsibilities for the production of C&E data, and the distribution of costs and benefits arising. After all, it might be difficult to know *a priori* what traits should be observed and recorded, without knowing what particular uses genebanks might be put to. Indeed, according to a senior staff member at an international organisation, the issue of whether it should be the responsibility of curators to undertake characterisation work remains up for debate, in the following quote (that warrants its length as it encapsulates this significant argument).

> *'There has been a lot of debate as well, probably that contributed to the state of affairs, because it was never clear who was responsible to do that work, who was responsible to do the evaluation work. Is it the gene bank curator whose job, as we initially envisage it, is to collect and make sure that this seed lot is not being lost, is being regenerated, you know, when the viability is dropping down below a certain threshold level that, you know, that it is properly managed in the gene bank, so that's what the curator does. But is it the role of the curator to go a step further to characterise that, to obtain more added value to that accession, to do the evaluation trait? Now, what trait would they evaluate, okay? So do they have to evaluate all the traits, you know? So there is a little bit of debate on that. So some school of thought thinks that it's mostly the breeders that need to do that. If a breeder is breeding a drought-resistant variety, you know, he will request accession from the gene bank and he will screen those, he will evaluate those accession for drought. He will not be interested in disease resistance, for example, okay? So different breeders may have different needs, okay? So having one gene bank (…) doing this may be asking for too much, and it may be also very expensive to do it for every single trait which could be done for a given accession, right? So that's it. I would say the cost I think are the main obstacles. (I16, coordinator in international organization, lines 243-259)*

This debate is significant because it directly addresses the interrelation between the political economy of data, and that of conservation itself: the issue of who produces C&E data is also a function of the ability to do so with the funding that is available. Moreover, it again underlines the idea that the genebank is conceptualised by some users as responsible for the development of the value of genetic resources. Hence, it underpins the suggestion that genebank activities are (re)focusing on increasing the appeal and use value of their material to potential users, and becoming ‘complementary’ to *in situ* approaches as means of conservation.

Another approach to gathering C&E data in genebanks is not production, but sharing: in some instances, genebank staff ask recipients of germplasm to return some data about the samples that they had received from particular places in order to seek this ‘added value’ to the sample, as the following genebank staff member puts it:

> *‘they’ll do the experimentation and (…) one of the things we’d like to do is to add more value to the collection by embedding the information that they get in our database, but that’s not always easy [OK] because they may want to protect that information. Because it’s hard won and it may give them an advantage in their research [OK]. So yeah, they tend to do the work- we don’t really have the budget to do too much characterisation of things other than the obvious, [yeah] the morphological, we couldn’t run drought trials or nitrogen use efficiency trials ourselves on a- from the unit on our budget [yeah] so we rely on (.) we try and get information back from people who have used our material(…)’ (I2, UK genebank staff, lines 192-203)*

This approach clearly suggests that a *quid pro quo* could be justified: the access to germplasm counterpointed with the sharing back of data, thus ultimately increasing the use value of the accessions utilised. Yet, at the same time, such data appears to be clearly defined as the property of the user and thus shared back with the genebanks only if they choose to do so. Hence, it is conceptualised as a donation, and therefore not a mandatory action for the users, in a legal sense or a moral sense, in order to receive germplasm. It is seen as a matter of ‘good will’, both in terms of providing free access to data which might conceivably be kept private, and because doing so requires the users to give up some of their time to retrieve and return such data:

> *‘we should always aspire to, to attach as much information as we can to, to our accessions. We require a lot of good will from, from the researchers to do that they’re busy people; as I said sometimes they have they might want to protect their data; in other cases they’re just too busy to actually get their people to collate it and send it to us because it can be a long job [yeah] (I2, UK genebank staff, lines 224-227)*

In the view of both these interviewees, the creation of data is an ‘investment’ and, as such, it is fair that the resulting *exchange* value that might accrue from. Interestingly, it also indicates a potential discrepancy between the relative importance of the act of data sharing between the user and the genebank: if data sharing is time-consuming and an act that does not necessarily derive value to the user, it could be construed as less of a priority for the user/potential data donor.

In addition to these different priorities, C&E data can also yield economic value, but only to users. The user-derived data is, therefore, understood as a source of commercial value and very much a property of the users. All the participants were uniformly respectful of the boundary between private knowledge and the public domain, and appeared to accept that the former had precedence in this situation. This situation is a clear example of the work that genebanks do in seeking to develop the value of the material in the genebank while giving primacy to the private value accruing to users. In these cases, intellectual property is explicitly identified as a reason against the sharing of information about genetic resources, creating the boundary between what can and cannot be accumulated and shared into the genebank.

> *‘If a breeder has evaluated accessions and found a gene of great importance for disease resistance (…) he may not wish to share that information with the rest of the world because they would like (…) to reap their, the benefits of their*

> *investment in developing varieties that would be resistant to those diseases and sell it on the market, so that's understandable, you know. So there may be copyright issues, intellectual property right issues around that. So all of those make it difficult for having a fully comprehensive information about gene bank accession. (I16, coordinator in international organization, lines 262-268)*

In summary, not all data is created equal: characterisation and evaluation data can be private or public, and as the evidence in this section suggests, that property relation is still predominant in determining the flow of information, including by the genebank. That insight is not surprising *per se*, yet it is very interesting for what it tells us regarding the role of the genebank in managing that flow: staff take on the responsibility for reworking the boundary between what counts as public and private. They do so by seeking to engage users in releasing data back to the genebank, thus increasing the amount of data that is in the public domain. In addition, they must also carefully check what data can be released as 'public domain' data, as I demonstrate in the next section. Altogether, these findings demonstrate clearly that the genebank is responsible for the management of information, and that doing so requires taking into account different priorities.

Here, genebanks emerge as places where socially valuable data can be accumulated and distributed. Central to this discussion, then, are political-economic issues regarding the distribution of costs and benefits arising from the characterisation of PGRFA. I have demonstrated in this section how genebanks operate as nodes through which *data*, as well as germplasm, is created, processed, and passed on. These findings demonstrate that what data is produced and by whom are questions with a clear economic slant: on the one hand, interviewees are asking themselves questions about cost and benefit; on the other, what is considered 'doable' – or fair – is dependent on overarching ideas about social and economic value. Hence, actors appear to differentiate between access to germplasm, which should be widely disseminated, and access to data, which can be shared or not depending on who produced it, and where. So, the germplasm economy is shaped by the flow of not only germplasm, but also information about it; and they can operate in accordance to different, if overlapping, ‘flows’ – even though, as the Seed Treaty seems to put it, all are ‘benefits’ that countries should endeavour to share among themselves for the common good. As in the previous chapter, this analysis makes clear how framing this economy in terms of sharing enables the coexistence of humanitarian/social value principles with the autonomy of repositories/countries to protect private property concerns. Yet that is not to say that these values are equal in relevance: the return flow of information is limited with respect to the germplasm first sent out. That is important, as it points to a hierarchy of resources (between germplasm and information) and also of value/s (between private value to the investor users and the future use value to be dispensed from the genebank). Again, this situation illustrates how genebanks play a pivotal role in managing the germplasm economy, and also how their doing so reflects certain broader social trends – namely, the significance of property rights over and above the social value of making information public.

5.3 Shared values: representing the common gene pool

Thus far, I explored the creation and dissemination of information at the level of the genebank. Yet, genebanks are not the only places where one might find information about accessions, nor does information transfer happen solely between genebanks and users. It can circulate at much larger scales, both spatially and in terms of quantity. It is, in fact, possible to represent entire collections – or, even more abstractly, ‘gene pools’ at the regional or global scale through digital databases. Although catalogues have existed for as long as genebanks have, I argue that with the new governance framework set out in the Seed Treaty, along with the development of novel information and communication technologies, there have been renewed efforts to create databases which permit the surveying of large datasets and searching through multiple genebanks’ holdings simultaneously, through a single interface. Such databases can be dedicated to a particular genus, such as the International Cocoa Germplasm Database[36] and the varied Central Crop Databases originally developed within the context of the ECPGR[37]. Other databases can assemble data about various crops simultaneously (sometimes known as 'multicrop databases'), but have an international geographical range, such as GENESYS[38] (Nawar & Mackay, 2010), FAO's WIEWS[39], and EURISCO[40] (in Europe) (Dias, Dulloo, & Arnaud, 2012). These databases, I argue, are a significant development in the contemporary phase in the germplasm economy. Through them, actors seek to facilitate the flow of information – a step towards addressing the 'challenge' of information as identified in 5.1. Yet these databases can also be said to do work at a representational level, creating an image of the spread and availability of genetic resources around the world that is, I suggest, significant at a time when the germplasm economy is in flux. For instance, the homepage to the GENESYS database (see Figure below), described as a 'global gateway to genetic resources', provides a way to search for information about genetic resources accessions around the world. It also offers the potential database user other information about the database and how to utilise it, an 'atom feed' for news, and information about ongoing projects and institutions involved in the conservation of genetic resources. This new database (established in 2011) is, I suggest, a neat example of the ways in which communication technologies and the germplasm economy can be imbricated. GENESYS not only permits a global overview of the holdings maintained across the world, it also conveys a sense of immediacy and ease of access, along with the capacity to bring genebanks and users together with minimal effort and

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[36] 'International Cocoa Germplasm Database' http://www.icgd.reading.ac.uk/index.php
[37] Listed at http://www.ecpgr.cgiar.org/resources/germplasm-databases/ecpgr-central-crop-databases/
[38] 'Genesys: Gateway to Genetic Resources' https://www.genesys-pgr.org/welcome. Accessed 25.08.16
[39] 'WIEWS' http://www.fao.org/wiews/en/ Accessed 25.08.16
[40] 'Welcome to EURISCO' http://eurisco.ipk-gatersleben.de/apex/f?p=103:1:::::: Accessed 25.08.16

maximum coverage (estimated to have opened with passport data and C&E data for 11 million accessions[41]). In addition to the ease of use and global coverage, GENESYS conveys *immediacy*, suggesting a responsive economy of germplasm.

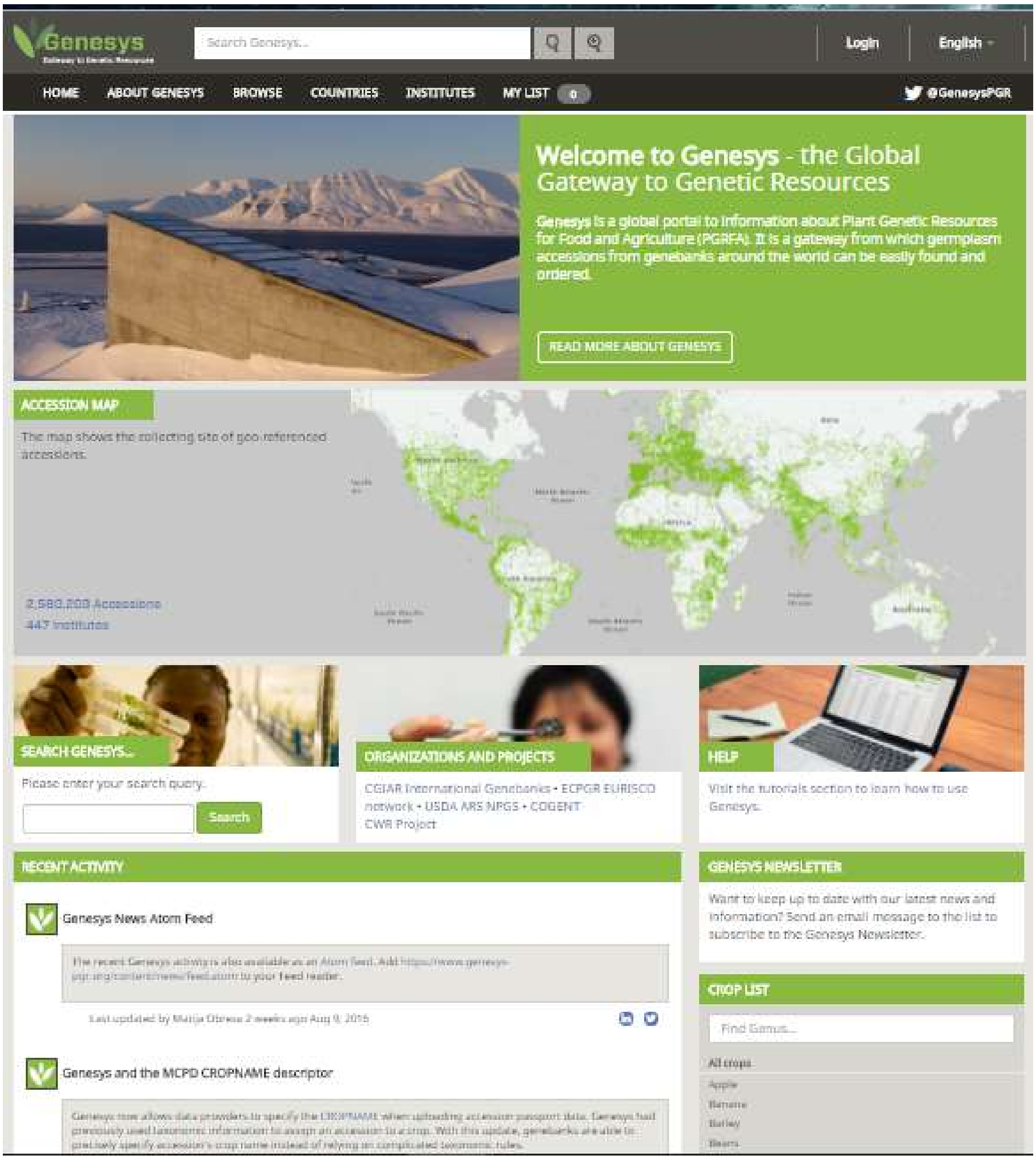

Figure 7. GENESYS[27] interface: this 'global gateway' to genetic resources provides a means to search for genebank material while also

[41] https://www.genesys-pgr.org/content/about/about Accessed 25.08.16

providing a representation of the shared genepool and genebank activities worldwide.

Altogether, then, there is a trend to produce databases dedicated to banked germplasm which can make information about genetic resources more accessible, making use of the internet and the development of germplasm-specific descriptors and metadata dedicated to the description of genebank material, such as the Darwin Core extension for genebanks (Endresen & Knüpffer, 2012). Yet this development should be contextualised and understood as part of the germplasm economy. Specifically, they illustrate the importance placed on shared repositories of information for the facilitation of information flow and, through it, germplasm flow. As I demonstrate below in reference to EURISCO, databases are part of the germplasm economy, enabling countries and genebanks to share information and 'make visible' both their compliance with the governance system *and* the value of their genetic material, according to the prevailing belief that information 'adds value' to a collection.

The remainder of this chapter is dedicated to exploring these databases as artefacts that produce *representations* of the shared genepool and the germplasm economy which have political implications, as well as technical ones. Taking as my starting point the idea that 'information infrastructures such as databases should be read both discursively and materially [because] they are a site of political and ethical as well as technical work' (Bowker, 2005, p. 123), I explore the emergence (post-2000) of germplasm databases that bring together information about the genetic resources collections of different countries. Such representations, I argue, have power: databases are important technologies of 'control of the world and each other': they are 'contemporary key to both state and scientific power' because of their ability to order information about entities in specific ways (Bowker, 2005, p. 108). Moreover, as Bowker notes, 'our databases provide a very good representation of our political economy, broadly conceived: that which we can use through our current modes of interaction with nature and other cultures is well mirrored in our data structures (…) This is one of the ways in which the world converges (messily, partially) with its representation – that which can be represented is that which is measured, protected, saved. As the representation becomes internally more manipulable, it becomes externally more apparently real' (Bowker, 2005, pp. 153–154). From that perspective, then, these databases can be seen as a sign of, and an 'aid' to, the sort of germplasm economy that is envisaged by policy actors, emphasising transparency and the flow of germplasm and data.

Specifically, I argue that the databases produce the contents of genebanks *as* a shared gene pool both in a technical/ontological sense and in a political one, in the sense that it is (a) uniformly described due to the use of standard descriptors and (b) shareable, by flagging up what material is available to users through the MLS. Thus, databases permit the creation of specific permutations of the germplasm economy, while enacting it through the construction of particular representations of genebanking contents. They make visible the value of genebank collections, while upscaling the genepool from the level of individual *collections* to that of the *region*. To make this case, I first overview the ways in which information has been increasingly marshalled towards a shared representation by describing the development of EURISCO, which is the regional database for the European continent, and describing how the datasets in EURISCO are constructed; or, in other words, by tracing the flows of information to EURISCO in order to show that countries have the autonomy to decide what is to be shared.

These databases can only exist now because of previous decisions to facilitate data flows and make information shareable. Hence, it is worth overviewing how these concerns about how best to ensure data flow have evolved over time, leading up to the contemporary interest in databases. Firstly, I turn to the matter of the standardisation of crop descriptors. The creation of a standardised set of crop descriptors can be thought of as a way to create an international economy of genetic resources by enabling actors to know what material is available elsewhere and to have a basis for comparison with one's own material. The work on descriptors was enabled through funding from Bioversity International, which took on the role of capacity-building, which included funding for carrying out the work and IT training. This is not surprising, given this organisation's outlook[42] and remit to encourage international cooperation on genetic resources. Descriptor lists were intended to provide a common language with which to understand and describe genebank materials precisely because the vision for *ex situ* conservation put forward by Bioversity was, *a priori,* international. Standardisation was considered to be an important 'lingua franca' that can increase both the use of collections and the efficiency with which genebanking is undertaken, because it facilitates the exchange of information between national programmes.

Of course, standards can become established only where others are willing to incorporate them into practice. Hence, descriptor lists had to be acceptable to different groups. One approach to ensuring this was to involve different groups of people in their production: in each case, the descriptor lists were the result of a collaboration between IPGRI/Bioversity, ad-hoc 'Crop Advisory Groups', and external experts. The success of these standards (like others) is dependent on the ability to enrol (Latour, 1987) different repositories around the world in their use. Thus, it is not surprising that Bioversity celebrates the uptake of these descriptors by a majority of genebanks surveyed (Bioversity, 2007). Indeed, all genebank staff surveyed in my research used such descriptors in their own collections – including one collection that operates on a more 'peer to peer' basis (and hence is likely to have a different pool of users, consisting of a greater proportion of non-researchers) (I7). This is indicative of a broad acceptance of Bioversity descriptors (including against other 'standards' such as those of COMECON and UPOV).

Standards were important, therefore, as the means to create a shared 'language' – and this step was seen to have economic implications, in the

[42] To this day, the creation of descriptor lists is managed through the 'Managing and Understanding Biodiversity' Programme.

sense that it permitted the sharing of information and thus, the closer cooperation of genebanking actors in different countries – which, in turn, was thought to permit gains in efficiency and was therefore welcomed. Bioversity's guidelines for developers of descriptor lists suggest that the '[e]xchange of data and information between national programmes for plant genetic resources can help to increase these programmes' efficiency by minimizing unnecessary duplication of activities and facilitating priority setting for germplasm collecting, regeneration of accessions and other activities.' (Bioversity International, 2007, p. vii). The standardisation of sample description methods was considered to be an essential step for 'ensuring that the vast amount of data on crop species and varieties is available to countries to improve their capacity to store, manage and share information about biodiversity'.

> *The development of descriptor lists will assist in the systematic and objective recording and exchange of information such as passport, characterization and evaluation data, which in turn will increase utilization of germplasm so that people can make better use of biodiversity.' (Bioversity International, 2007: vii).*

So, germplasm is to be made understandable; but moreover, the promise of the system lies in the ability to 'minimise unnecessary duplication of activities' – which, necessarily, requires that different organisations are willing to work together. This case demonstrates how issues about how best to share data should be understood as motivated by concerns related to the shape of the germplasm economy. This suggestion is also borne out by the way the exchange of information is mandated in the Seed Treaty, so when countries contribute data to large databases they are also carrying out their commitments under the Seed Treaty, which are as follows:

> *'The Contracting Parties agree to make available information which shall, inter alia, encompass catalogues and inventories, information on technologies, results of technical, scientific and socio-economic research, including characterization, evaluation and utilization, regarding those plant genetic resources for food and agriculture under the*

Multilateral System. Such information shall be made available, where non-confidential, subject to applicable law and in accordance with national capabilities. Such information shall be made available to all Contracting Parties to this Treaty through the information system, provided for in Article 17.' (ITPGRFA, art. 13.2a)

A considerable amount of expectations surrounds these developments, which I now overview. According to the interviewees, EURISCO and other such databases appear as a clearly advantageous tool, and an obvious way of making use of new technological developments (I1). They are not only expected to be helpful to putative users, but also as tools to aid in making collection management decisions, thus making the system more efficient. As explained further in the following excerpt, the creation of a common database tool has the potential of enabling the location of needed material from various genebanks at once. In so doing, they both facilitate and represent the idea of an international germplasm economy, by making the “supply” more easily accessible and searchable by users - as exemplified by the quote below.

'The intention is to have a common entry point to a distributed structure in order to enable users to identify and locate from world-wide available sources the germplasm most suitable for their needs. Existing regional catalogues, such as EURISCO and SINGER, as well as other regional systems are expected to play their role in providing germplasm data to the global level. This can also be an opportunity for a concerted exercise to develop new standards and to increase their use at the global level.' (van Hintum et al., 2010)

Broadly speaking, the use of such a database can be explained as an aid to *increasing the use of collections* and *help genebank staff in the management of their own collections*. It is important, firstly, because it permits the identification of duplicates *across* collections, which itself has implications for the way material is actually managed and used. In changing the scale of representation to the regional scale (as is the case with EURISCO), it makes it possible to identify duplicates across collections. This means that a potential user could find the material in different genebanks, thus increasing options for acquiring germplasm. For genebank staff it can serve as an aid to making decisions regarding what parts of one's own collection to prioritise. By this I mean that material which is also kept elsewhere can be de-prioritised, and material which is unique can be kept in particular regard (I4).

These, then, are the reasons actors think databases like EURISCO are important in making the germplasm economy better: it is a matter of enabling potential users to see the whole, and easily access further information about whatever material they might be interested in, because the databases are interconnected. As such, it is not solely the capacity to search through the 'European' gene pool which is of value, but also the ability to access (and download) further information about certain germplasm of interest with great ease. It is possible to define a search through different variables, including genus and species, but also country of origin, habitat, and other characteristics. For this reason, it is seen as a boon in terms of the possibilities of increasing the usability of material.

When asked to explain how, an interviewee suggested that it was a 'common sense assumption', albeit a likely evidenced one (I13). Another interviewee explained that the reason why it was helpful to publish trait data on the databases. Note the resurgence of the idea of the 'USP'.

> *'arguably if, if there's trait information and people are looking to breed for a certain trait then there's a, there's your sort of USP for genetic resources, someone could go sort of shopping for it and if you can publish that data, then (…) the genetic resource becomes more valuable and interesting to people because of the different traits that are demonstrated.' (I7, UK policy maker, line 214-218)*

With the emergence of the Multilateral System it became necessary to develop a means of *reporting* the transactions that occurred under the Seed Treaty (van Hintum et al, 2008), and databases became a fitting tool to do so. Such a mandate was translated into practice through the creation of larger databases that centralised the information about collections available in different repositories and countries around the globe; these became a tool for complying with international legislation. Databases like GRIN-Global, FAO's WIEWS, EURISCO (in Europe), and SINGER (the CGIAR databases) are all examples of this trend.

These databases are therefore politically important artefacts which are required as part of the commitments made as part of the Seed Treaty. They both enable the sharing of information and demonstrate that countries are engaged with sharing, and do so in a way which is standardised and acts through a central database, 'at a distrance' – which manages to be both transparent and visible. as genebank information available through a technological artefact rather than through direct contact with individual repositories. Hence, databases are significant because they enable the representation of different collections as part of the same, shared genepool; and in so doing also contribute to the 'challenge' of making information available – which is politically significant because, as one interviewee put it, it 'makes visible' the value of the material which is held in genebanks (I14) by demonstrating what, exactly, is available for use in genebanks around the world.

Finally, I now turn to the case of EURISCO to expand on this argument in greater detail. As the previous quotes by Bowker remind us, it should not be taken for granted that the database is a straightforward representation of the material kept in genebanks. Instead, EURISCO is a means to share information about the gene pool which *privileges material and information that is available to be shared* - which I demonstrate by describing how EURISCO works. It is shaped not only by technical but legal factors. Hence, and drawing from Geoff Bowker's ideas about databases, I go on to argue that these databases, in their practices and representations, include social as well as technical concerns. EURISCO and the European gene pool are therefore co-produced with specific ways of working and representing the national gene pools.

EURISCO is a database that became operational in 2003, shortly after the ITPGRFA came into existence. It was intended to represent the material available at a variety of genebanks around Europe[43].It is but one of several databases that have emerged since 2000, as plant conservationists seized upon the possibilities afforded by new digital technologies (Faberová, 2010; van Hintum, 2010). These regional and global databases are, I suggest, the newest iteration of catalogues for genetic resources collections; yet they are also thought of as different, as I argue in this section. So they are continuous in some ways with previous catalogues, and are simply the most recent way of listing what material exists in genetic resources collections. Since the beginning of genetic resources conservation, actors have sought to publish catalogues for that purpose, but the availability of online databases and easy exchange of information has made it possible to create representations of the genebanked material that are far more helpful to potential users in terms of enabling their search.

EURISCO is a significant part of the development of genetic resources conservation at the regional level in Europe. It is meant to be a source of information about the collections which are available around the continent and suggested to be useful to breeders, researchers, policymakers, students, and other citizens. It was the outcome of a project, EPGRIS, designed in the context of the ECPGR and funded through the European Commission. According to its own website, EURISCO is presented as 'a window into Europe's genetic diversity'; and this metaphor is telling. Through such a 'window', all the different accessions in the continent are available for perusal in a way that is both easy and transparent.

The data from EURISCO is compiled and provided to its secretariat by each country through a designated custodian, known as the National Focal Point. It is their responsibility to ensure that the information 'can be publicly available and used without limitation or restraint': it is at the level of the National Inventory that 'should not replicate confidential or otherwise

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[43] Available at www.eurisco.org. Originally, it was managed by a team sited with ECPGR at the headquarters of Bioversity International in Rome. It has sinceSince it moved to Germany in 2014/5.

restricted data'   In this document is set out the primacy of the impartiality of EURISCO, with the onus being at country level. Decisions about the data which is shared in this way has to be sanctioned by the country. As a result, this model of data flow places the responsibility, and the power, to sanction what data should be shared on to individual *countries*, via the role of the National Focal Point. In contrast to the data flow to other databases, like the Central Crop Databases of the ECPGR, the data flow towards EURISCO has a 'checkpoint' in the form of the National Focal Point. The two different approaches can be compared in Figure 8, below. The presence of the National Inventory step thus enacts, in data structure form, the sovereignty of the countries to decide what counts as public or private information. The relationship between the National Inventory and EURISCO is characterised as being a 'structural collaboration with mutual benefits' (Memorandum of Understanding between EURISCO and participating countries, 2003).

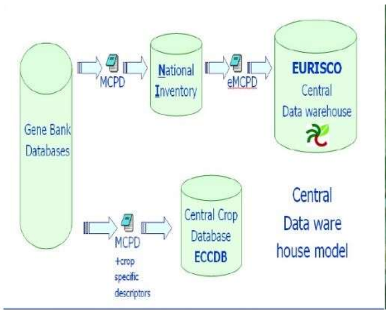

Figure 8. The data flows to EURISCO versus the Central Crop Databases, by Dag Endresen, licensed under CC BY 4.0[44]. Note how the existence of the National Inventory means that the sharing of data to EURISCO undergoes an extra step where countries effectively sanction the sharing of data.

So, in this way we see how the process of data flow between the national and the European level requires careful operation and calibration if it is to achieve the goals of the Seed Treaty in terms of making information available

[44] Endresen, D. (2008). Global Information Systems for Plant Genetic Resources. (ctrl+click for link). License: https://creativecommons.org/licenses/by/4.0/

and value visible while avoiding any expropriation of material that is privately owned. Moreover, we can see this represented also in the way EURISCO is not the first of its kind. Indeed, there were already other databases that were created in the same mold: the European Central Crop Databases. By comparing the two we see that the material in the latter is sanctioned at country level by the National Focal Point who is responsible for managing the flow of data between the country and EURISCO, whereas the former are much less formalised, and more piecemeal. Hence, the new means of transmitting information from each European country and to EURISCO via the National Inventories are important because they serve at once as a means of constructing a picture of the genepool, and a means for countries to be held responsible (through the National Focal Point) for making decisions about what data is shared; and which part of their genepool is visible to everyone. Hence, the final picture as it emerges in EURISCO is the result of the material which different countries are happy to pool together. In this way, it makes visible the material which is shared – and, one might argue, legitimises the Multilateral system (and the principle of interdependence) by making it visible.

In having a single place to search, the idea is to increase use by facilitating the searchability of all collections. This database can be seen as an effort to standardise and centralise the means of accessing information about genetic resources in Europe: not only because the information is available in one database, but also because it makes it possible to view and search the holdings of collections across countries and around the entire continent. As a result, all genebanks and germplasm are now represented together, becoming effectively part of the same 'puzzle'. Yet the standardisation process also means that only that information which 'fits' can be entered: in this case, only information which is standardised, but also in the public domain, and which countries have agreed to share. Hence, this representation at a greater scale is also, necessarily, partial - and 'evacuated', to use Bowker's (2005) term, of local specificity. Such an effect relates back to the idea of standardisation of descriptors and centralisation of databases in order to facilitate the sharing of information. Simultaneously, the construction of these representations could possibly encourage visitors to the database to presume that copies of the same sample kept in different genebanks are 'the same' because the information which is standardised is that which is related to the less localised/more abstract data; whereas it might not have anything to say about, for instance, the conditions in which different samples were kept. Therefore, these more global representations have the effect of enacting the ‘shared’ nature of the genepool while hiding the local specificity. In this sense, they mirror quite closely the situation with biodiversity data, as described by Bowker (2010). That is not surprising as they are, effectively, part of the same project. Indeed, data about germplasm collections is beginning to feature in large virtual representations of the entirety of biodiversity on earth such as the Global Biodiversity Information Facility, GBIF (I11). To achieve this, plant scientists and conservationists are currently developing extensions of standardised languages (namely, Darwin Core for genebanks) (Endresen & Knüpffer, 2012) that enable the integration of genebank data into existing, global databases of biodiversity data. In this way, ‘banked’ material is beginning to figure in these representations. This activity is another way of transforming banked germplasm into a resource which is visible.

This has some interesting implications with respect to the representation of collections: at its most obvious, it means that the first point of contact with the contents of the collection might be through a search through the database, rather than contact with a member of staff. There are, however, concerns about the life-cycle of the data: there is a need to update the material in EURISCO, and not all countries have had the capacity to do so on a regular basis.

5.4 Conclusions

In this chapter I’ve developed the analysis of the germplasm economy further by analysing how genebanks manage data, as well as germplasm. I’ve argued that actors portray data curation and improvement as the ‘challenge’ to be addressed so as to make genetic resources more appealing to users. Hence, genebanks make germplasm *visible* and *retrievable* through the practices of creating and managing information. The results suggest, therefore, that genebanking is seen as a process where actors can ‘add value’ to their collections through practices of data curation and dissemination, aided by the judicious use of new technologies (like information technologies) that enable users to have a more comprehensive idea of the material available.

Consequently, analysing *how* genebank staff and other actors in the germplasm economy produce, disseminate and share data about germplasm is a significant step in understanding how the germplasm economy is organised and the role that genebanks play in it. Throughout the chapter, we see how concerns about how information should flow are tied into decisions about how to separate private from public information; how best to make information shareable (through a ‘common language’); and how to make information about germplasm accessible and transparent.

Observing the role of genebanks in shaping flows of information indicates that data is a significant ingredient in the creation of a shared gene pool, a process that happens through the description of germplasm that genebanks carry out. Yet it is also instructive because it brings to the fore the ways genebanks have to manage the different priorities between the value of their own collection and the protection of the interests of private owners of information. Hence, again, *sharing* becomes a prominent feature of the organisation of the data flow, as different institutions find ways to encourage the accumulation of information as part of the project to maximise the value of genebank collections, through strategies that encompass also the donation of data from elsewhere. The genebank appears from this analysis to be a site where the continual work of managing genetic resources is not isolated from users of genetic resources – instead, they figure as potential contributors in this germplasm economy, so that ‘giving back’ data contributes to the overall germplasm economy.‘

Finally, I made the case that the construction of the shared genepool – and of the germplasm economy – also happens through the creation of novel databases that represent the new organisation of material across collections, which privileges the public value and the common ground between different genebank accessions. The analysis here leads me to suggest that these new representations matter: for one, actors believe they enable closer coordination between genebanks. Moreover, they are seen as a way of increasing the 'transparency' of the genepool, making information about the genepool more easily accessible to everyone and, simultaneously, making visible the new multilateral system in action: both through numbers of germplasm samples available, and by enabling the following of 'flows' of germplasm through international borders. And so in the creation of such databases/artefacts is also a statement of intent, to enact the kind of open system that is envisaged.

CHAPTER 6 CONSERVING THE CONSERVATION SYSTEM: FUNDING AND THE DYNAMICS OF GENEPOOL MANAGEMENT

The narrative thus far suggests that the present day is a point of relative flux for genebanks, with actors interested in developing and maximising the potential value of their collections through the management of germplasm and of data. I have argued that these changes are part of a renewed effort to facilitate the flow of genetic resources from the genebank and, consequently, enable its potential value to be realised. In this chapter, I turn instead to the flow of funding. By following the ways in which genebanks manage the necessary financial resources to maintain their activities, I show that funding is an important factor shaping these changes to genebanking practices. The resulting findings indicate that the germplasm economy is a dynamic system which is inseparable from the broader political economy of genebanks themselves. For this reason, it is important that analysts take it into consideration when developing accounts of the way biobanks operate.

In previous chapters, I have argued that genebanks are fundamental to the construction and organisation of the germplasm economy in ways that are analogous to biobanks which, according to Waldby and Mitchell (2006) are part of emergent tissue economies. In the case of banks for cord blood or stem cells, these repositories enable the accumulation and distribution of fragments of tissues that are understood to be valuable, and in ways that call into question the idea that biomaterials can be either gifts or commodities. Exploring conservation in this way makes it possible to observe the processes of conservation *as* political economic processes, that revolve around considerations of value (what counts as the most appropriate use of resources) and values (what kind of relationships should there be between actors in the germplasm economy, and what principles and priorities should be upheld?). Consequently, I've argued that the role of genebanks is to maintain germplasm so that its value is maintained and maximised. The banking of germplasm means preserving seeds and other plant materials as temporal proxies (as noted in chapter 4), that is, genebanks are responsible for maintaining the genetic integrity of accessions and for making them available for future users through their practices of conservation and characterisation of material (that was collected at a particular time, from a specific location) so as to make it available/understandable in the present, to a variety of users. In that sense, they create that material as a ‘genetic *resource*’ with potential, promissory *value*. In turn, that value (use value, and potentially commercial value) can be extracted by users. Hence, genebanks are responsible for managing different priorities and values, in accordance with the underlying rationale of ‘sharing’ and multilateral access.

Genebanks are also central to the creation of the shared genepool and the germplasm economy itself because it is in such sites that actors manage different and potentially conflicting expectations and values, for instance, between the common interest in maintaining genetic resources for the future and the use of genetic resources in the present; or by collating and making available data while respecting the intellectual property of data producers. In this way, they continually manage the production of social value and promissory value as they go about enacting the conservation of genetic resources. Therefore, genebanking creates the shared genepool through practices that are at once ontological and political; that is, through the classification of genetic resources in standardised ways and through the carrying out the dissemination of germplasm in accordance with the stipulations of the Seed Treaty. As these repositories accumulate and disseminate germplasm, genebank staff make decisions about what germplasm should be shared, or not. Moreover, by describing germplasm in accordance with standardised descriptors, genebanks make banked accessions ‘visible’, commensurable, and comparable to other accessions in different genebanks. They also contribute information to databases that produce regional or global representations of genebank collections – which I have suggested are representations of the shared genepool. Altogether, then, genebanks do serve as sites where the ‘flow’ of germplasm and information is managed and regulated. Hence, genebanks are active nodes in the germplasm economy, engaging in the sharing of these ‘resources’ with a view to implementing particular ideas, conceptualised around the view of ‘interdependence’. Germplasm that is banked becomes understandable as part of a genepool that is accessible to potential future users: genebanks are actively involved in the boundary work between what constitutes private and public knowledge, and private and public material.

However, the narrative thus far does indicate that the availability of funding is a central factor that modulates the activities of the genebank: the capacity to ‘insure’ material for the future is finite. Therefore, it is important that the *funding* of genebanks is part of any analysis of the germplasm economy. That is the theme of this chapter. I focus on the flow of financial resources, and suggest that there is indeed an ongoing struggle – reflected in the governance framework set up by the Seed Treaty – to justify the value of *ex situ* conservation itself. As I argue throughout, the work of genebanks is particularly defined by their need to maintain the conservation system itself. After all, if genebanks actively construct genetic resources and the shared gene pool, these activities require work and, consequently, other inputs, both material and social – namely, funding and expertise. Hence, in order to understand the organisation of the germplasm economy we must also trace and analyse the ‘flow’ of funding and expertise between genebanks, as well as the flow of data and germplasm, because labour (which requires funding and expert knowledge) is important for the conservation of the conservation system itself.

In summary, then, examining how the work of genebanks is conditioned by the availability of funding allows us to explore the organisation of the germplasm economy from a materialist/economic standpoint, and look for the common ground between the germplasm economy and the political economy of genebanks. Understanding the role that economic concerns play in the development of the germplasm economy adds depth to our accounts of germplasm economies because it means taking into account the material limitations that apply to genebanking, and provides a way into thinking about the way other actors evaluate the material in genebanks.

6.1 Flows of material resources: funding, expertise, and the germplasm economy

Genebanks require financial resources in order to carry out their activities, yet one of the primary outputs of that work is the preservation of genetic resources, whose value is promissory and can only ever be concretized ‘in the future’. Costs, on the other hand, are rather more tangible, immediate, and continuous. Salaries must be paid, and there are costs associated with the running and the maintenance of equipment, including freezers, drying rooms, microscopes, and other material that is used in the manipulation and preservation of genetic resources. **Error! Reference source not found.**Table 3, below, is an example of the cost elements that economists working on genebanks identify as being significant in the carrying out of conservation activities. In addition to capital (equipment) costs, specialized labour is required in order to carry out these actions, and yet it is not unusual for genebanks to have issues retaining trained staff members (I15, line 519). In addition, we have already seen in Chapter 5 how the description and, particularly, the characterisation and evaluation of accessions are quite costly. Finally, regeneration activities are particularly expensive, as they require the germination of germplasm into new accessions, often under very stringent conditions. In summary, then, genebanks require funds - precisely because they are not passive repositories for the storage of germplasm, but instead are sites where the value in biological material can be ‘captured’, made commensurable and visible (if not extracted); and this process requires considerable input.

On one level, the observation that genebanks have costs is unremarkable, since all collections require funds to carry out their work. Yet, as I’ve shown with respect to the production of characterisation and evaluation data, the availability of funding is a factor in curators’ decision-making with respect to collection management. Hence, the self-evident observation that genebanks have costs is analytically interesting because it foregrounds questions about the relationship between funding and the activities that take place in genebanks. As genebanking actors seek to work within the limits of what is financially feasible, how does funding come into decisions regarding what data can be produced, or what material included in genebanks? And, most significantly, how do genebanks keep up the conservation of germplasm *over time* when the political economic situation can, and does, change?

Table 3. Costs associated with genebanks. Adapted from Engels and Visser, 2003, p. 98.

Operation	Non-capital			Capital
	Quasi-fixed	Labour	Non-labour	
Information management	Information manager Data analyst	For data entry and equipment maintenance	Computer supplies Publication expenses Software licenses	Servers Computer equipment
General management	Genebank head/manager	Secretaries Other labour	Office expenses Electricity Other expenses	Buildings Equipment
Storage (medium and long-term) Viability testing, acquisition, safety duplication, dissemination	Genebank curator Scientist for seed health testing	For maintaining and operating refrigeration equipment and facility Lab technician Field worker for agronomic characterization Lab technician for molecular characterization	Electricity for storage rooms Chemicals and supplies Seed envelopes Packing supplies Shipping cost	Cold storage room Refrigeration equipment Storage shelves and seed containers Lab equipment and supplies Lab facility
Regeneration	Genebank curator Field manager	Field worker Equipment technician Temporary worker	Chemicals and supplies for field Fuel for vehicle Electricity for drying machine	Farming land Screenhouse Seed dryer Seed cleaning equipment
Characterisation, evaluation, pre-breeding	Field manager Lab scientist	Lab technician Field worker	Lab chemicals and supplies	Lab equipment and facility

Other research	Genebank curator Lab scientist	Lab technician	Lab chemicals and supplies	Lab equipment and facility

Given this situation, it is important to explore the ways genebanks are maintained and funded in order to explore the interpenetration between the economy of genetic resources themselves and that of genebanks. Doing otherwise means that we might unwittingly obscure from our analyses the work that goes into conserving the conservation system itself – and therefore not attend to the active work that occurs in genebanks. And yet, as the findings of this chapter demonstrate, the contemporary organisation of the germplasm economy (with its focus on the maximisation of efficiency and value) is related to the ways in which genebanks are funded. Moreover, tracing the relationship between funding and the conservation practices of genebanks shows that there is a temporal dynamic in place, with changes in collection management and funding over time. As I show throughout the next two chapters, then, following the political economy of genebanking adds another layer of analysis to the tissue economy framework suggested by Waldby and Mitchell (2006), and therefore helps to draw out some interpretations about contemporary arrangements of genetic conservation.

Consequently, it is important that we explore the ‘flow’ of funding itself; its sources and general trends as the role of genebanks evolved over time. Particularly, the findings in this chapter show that despite the constant characterization of genetic resources as valuable, ensuring the flow of funding to genebanks is not always easy, particularly in poorer regions. The flow of funding into genebanks for the maintenance and the development of genebank collections should not be taken for granted: rather, it operates at quite different timeframes from the long-term commitment implicit in the idea of conservation - and it is often contingent on genebanking practices, including their ability to demonstrate their usefulness. Thus, I suggest that the pronounced interest, on the part of genebank actors, in ensuring the use value of collections and in maximising the value added to collections (for example, by working towards facilitating use, or making collections attractive to a greater and more diverse group of people) is explained, at least in part, by concurrent changes in the funding context. Concurrently, the guiding principles for the management of *ex situ* conservation activities appears to be shifting toward a greater emphasis on the maximisation of value from the funding that is available: it is this underlying dynamic that explains why genebanking actors are concerned with demonstrating the value, or the impact, of their own activities (e.g. by demonstrating that users can access their collection). Through such demonstrations of impact, genebanks can prove their own use value and therefore engage funders to continue providing financial resources to carry out work; a concern that is increasingly important as the inconsistency of funding is explicitly identified as a potential barrier to the success of ex situ conservation.

These changes do not affect only individual collections, but appear to be the result of a far more coordinated policy. A look at the funding available for large, international genebanking projects, and what actors think of it, demonstrates that funding is considered to be relatively low, and genebanks have to adapt accordingly. There are signs of a real-term decrease in the funding available for genebanks. For example, Imperial College released in 2002 a report highlighting budget cutbacks to 25% of collections, while 35% remained static and improved in 33% of countries, while collection size increased in 66% of countries (while remaining static in 13%); with these cutbacks affecting especially, although not exclusively, lower income countries (Department of Agricultural Science, Imperial College Wye, 2002). Similarly, funding for the CGIAR was said to have 'stalled' during the 1990s, before returning to increases of 5.5% annually (Pardey, Alston, & Piggott, 2006). Indeed, by 2005, Esquinas-Alcazar was writing in Nature Reviews Genetics that '[t]he cost of conserving plant genetic diversity is high, but the cost of not taking action is much higher. Economic resources for the conservation and sustainable use of agricultural genetic resources are well below adequate levels.' There is, therefore, a sense that the flow of funding to genebanks is a significant concern for actors working on *ex situ* conservation; and this concern requires political action and a commitment on the part of countries to enable the continuation of the work of genebanks. For instance, the Second Global Plan of Action states that

> *Difficult as the world economic situation currently is, we cannot afford not to continue and increase national and international investments in the priorities and programmes that Governments have agreed on through the Second Global Plan of Action. This means a substantial increase in current activities in countries, and the active involvement of international and regional organizations, donors, scientists, farmers, indigenous and local communities, the public and private sectors, civil society, and research and educational institutes. (CGRFA, 2011, para. 5)*

This exhortation encapsulates how policy actors at the international level present the contemporary state of genebanking: it requires investment and collaboration between different groups if it is to deliver on its promise to bank potential value and make it available for future withdrawal. Institutions like FAO, then, develop a discourse that emphasises the need to create a working germplasm economy which can engage different actors – which, arguably, will be cognizant of the 'true' value of genetic resources and consequently act to enable its conservation and make the most of the material available.

So, taking these changes in funding into consideration provides a different perspective on the implications of the governance framework set by the Seed Treaty and associated documents. Article 17 of the Seed Treaty sets out a fund, to be managed by the Crop Trust (previously Global Crop Diversity Trust), in order to ensure that 'globally important' genebanks like those of the CGIAR can be guaranteed funding 'in perpetuity'. The Seed Treaty and other global policy instruments represent a commitment by governments to the funding of some collections – or, put in a different way, they are seen as a recognition of the value of genetic resources (I7, I18). A very powerful discourse is evident in these documents that mixes the need for wise investment in genetic resources as the 'future' of agriculture with suggestions on what the genetic resources system should look like in order to permit the best 'return'. International policy documents thus set out the case for national government support for continued funding genetic resources conservation: doing otherwise would be tantamount to ‘mortgaging our children’s future’ (CGRFA, 2011). By ratifying the ITPGRFA, Parties (that is, national governments) take on the responsibility to ensure the funding of national collections. On that basis, too, the Treaty (and its implementation at the national level) is perceived as beneficial to the work of *ex situ* collections. However, the ways in which it provides a benefit may be somewhat circuitous. Falcon and Fowler’s prediction in 2002 regarding the eventual output of the MLS was that

> *‘If our interpretation is correct, the multilateral provision is unlikely to generate substantial funding. Royalties will be assessed as a percentage of profits from seed sales of particular new varieties, which is not a particularly large base. Moreover, the two countries where such patenting is available and most widely used—the US and Japan—are unlikely to ratify the treaty. Generation of funding was the prize sought by many countries. Time will undoubtedly reveal, however, that access itself is by far the most important benefit, not funding. (Falcon & Fowler, 2002, p. 23)*

The state, then, has an important role in funding and overseeing national collections. There is a recognition, at the national level, that certain designated, national *ex situ* collections of germplasm should receive state support. Hence, decisions about funding allocation are undertaken at the national level, as per the policy set out in the Seed Treaty. National action plans detailing policy, like Portugal’s National Plan for PGRFA (Plano Nacional para os Recursos Geneticos Vegetais) (published in 2015) note that ‘the matter of financial support is vital for the maintenance and regeneration of [PGRFA collections]’. In the UK, the Department for Food, Agriculture and Rural Affairs allocates is responsible for the basic funding of three public collections: the National Fruit Collection at Brogdale, the Pea collection at the John Innes Centre and the Vegetable Collection at Warwick University. In Portugal, the Ministerio da Agricultura also provides funds to the Banco Portugues de Germoplasma Vegetal, along with other, smaller collections. Yet the Seed Treaty does not (and arguably, could not) set out precisely how much funding is required.

What constitutes the right level of support, on the other hand, is in all likelihood the more difficult question, given the possibility of competing priorities for funding, along with budget cuts. So, for instance, government officials involved in the coordination of *ex situ* collections mention exactly the sort of questions that emerge around how much funding is enough. In that sense, genetic resources conservation is yet another project in the line of sight of state actors, along with other potential projects that require attention. Consequently, there are pressures on genebanks to demonstrate that they can make the most of the funding that is allocated to them, and to show that their work has impact. This situation, then, has parallels with those cases where biobanks are engaged in constructing the promissory value of their materials – except that, in this case, the audience for that discourse are not individual depositers/owners, but rather states. The implication of this argument, therefore, is that the continued existence of genebanks depends on states' calculations of the value of genetic resources.

That is not to say that direct state funding, however, is the only source of funding for genebanks. On top of basic state funding, national collections might rely on applying for extra funds, either from the government or other sources, for example research funding bodies, from the European Union, or possibly other organizations.[45] Below, one curator describes how their collection was successful in applying for a different stream of government funding because staff could demonstrate the impact of the collection, both in terms of the contents of the collection (conservation) and of the service it was providing to users (facilitating use):

> *'…clearly we address some of the key strategic goals of the government. We were a unique facility, we had the expertise,*

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[45] For instance, the Millennium Seed Bank (admittedly, a repository which is not directly part of my research) received funding from a variety of funders (including 23 different organisations, running the gamut from Defra to Sainsbury's, GlaxoSmithKline, several charitable foundations – see http://www.kew.org/science-conservation/collections/millennium-seed-bank/about-millennium-seed-bank)

we were outward-facing, so we were accessible to the wider community, so we were well placed to bid for that. The resources we had were unique and already engaged with sufficiently broad representation of the community to tick the criteria (…) So we bid and we were successful. Not only successful, they gave us additional resources because they- which was unexpected, I can say on the record - that they saw that, actually, in order to keep us relevant and to move us forward so we kept that relevance they had to give us extra resources (…) to keep us fit for purpose [I understand]. So that's set for a five year period.' (I1, UK genebank staff, 257-268)

This quote is suggestive of the ways in which genebanks have to demonstrate their own value – their contribution to the production of value. It therefore illustrates how genebanks that can prove their impact, demonstrating their value to funders, can be awarded financial resources for future. However, for this extra funding they must cultivate the recognition that the collection is valued or valuable to others – for example, by demonstrating that it is useful to a particular group of users, or by acquiring a particular status, like being part of the European collection. However, it is interesting that as part of the job of genebanks, they must not only maintain the value of their collection and grow it, but also ensure that the value of *genebanks* is itself recognised.

Moreover, we can see how genebanks have sought to develop new avenues for funding, much like governments have found ways to make collaborative arrangements with the private sector to carry out conservation. National collections, then, can (at least in some cases) bring in extra funding in order to develop their collections. Similarly, not all genebanks that contain publicly available genetic resources are funded solely by the state. Another way of distributing the cost of genetic resources conservation is to engage non-state actors in in the carrying out and, eventually, the funding of conservation. In some European countries, conservation policy can include efforts to involve independent organizations. In Germany, for instance, organizations such as universities (or, in the case of living collections, heritage organizations) can house, and be responsible for, subsets of the German national collection.

Consequently, these changes emerge at the same time as the previous phase of expansion in genebank collections has now been replaced with a new phase of focusing on utility. From this perspective, the substantial growth of collections from its start in the 1970s, to circa 7m accessions by 2010 is 'excessive' – because individual repositories have to process material for conservation at a rate that is not sustainable. Some actors now believe that there is too much material in genebanks: as one interviewee (involved in genetic resources policy as a national coordinator) put it, 'there is a question over whether countries might have been 'genebanking to excess'' (I7). As mentioned in Chapter 4, there is greater emphasis on the *use* of material, and some curators are focusing on encouraging the use value of banked material, rather than introducing accessions into the genebank without assessing their potential use value, in order to ensure that existing funds are used in a way that creates maximum benefit. Again, we are reminded of curators' criteria for adding material to collections: utility, uniqueness and/or a specific genus. These different criteria are a means to make decisions about what material fits the criteria that justifies its inclusion in the shared genepool. This example illustrates how genebank staff take the logic of impact into consideration when making decisions about genebank management. In that sense, genebanking shares some characteristics with Mode 2 science (Gibbons et al., 1994; Nowotny, Scott, & Gibbons, 2001), in that its purpose is outcome-oriented and it depends on transdisciplinarity. The success of genebanking is a function of how well it can fulfil the requirements of different stakeholders who make use of the material in the collections, but also the state, which has a political commitment to maintain them and which provides financial support to these repositories so that they may adequately preserve the value of genetic resources, as insurance, so that it might be drawn from when required. However, genebanks also differ from more obvious examples of Mode 2 science simultaneously it differs in that what is being produced is not primarily knowledge, but semi-informational 'resources' – and therefore the priority is not necessarily 'applied' science, but rather the focusing of efforts on material that is possibly most valuable.

Genebank curators, then, are acutely aware of the need to manage the collection in a way that is financially viable and attracts users (through the mechanisms of data and resource production and dissemination that I've overviewed in different chapters thus far). They are therefore making decisions about how to use the resources available. For some collections, this meant stopping specific activities and focusing on others: for instance, one genebank stopped undertaking collection trips to gather new material, unless it was *commissioned* to do so specifically (I9). In another, specific accessions were *prioritised* for management (for instance, regeneration) in order to allocate the funds available in the 'best' way. Yet whichever approach they take, it seems that genebanks (re)focus or prioritise specific activities that are the most pressing for their mission at the time.

Nonetheless, the case of genebanks and their funding is interesting because it makes visible the problems that are specific to these projects of conservation; where their work *is* the maintenance of *potentially valuable* material. The value of 'conservation and facilitation of use' is not easy to express straightforwardly or quantitatively - even though there are economists that seek to develop just those kinds of numbers for funders (Smale and Koo, 1997). The existence of a relationship between the availability of funding and genebanking practices is significant because it means that there is a potential for the 'winnowing down' of genebanking (and genetic resources) to those activities and materials that are evaluated as useful, to the detriment of others whose use value might not be so clear. However, this potential risk is mitigated by the idea that any genetic resource can be *potentially* valuable, given that it is collected a priori. In summary, then, genebanks are responsive to what funding is available (and to the requirements of funders) when carrying out their activities. They are not unique in that sense: indeed, such a situation is common to other public bodies or publicly funded activities – and increasingly so in times of austerity: genebanks are being required to demonstrate the impact, or value, of their work. So, there is a case to be made that the germplasm economy is indirectly affected by changes in the large-scale changes to the economy, such as the increasing privatization of plant breeding research, and the limits to the funding available for public sector research. In that sense, it does speak to the concerns and trends identified by the literature on the political economy of science, in that I identify a pressure on a public service (in this case, on the provision of the genetic resources) to ensure that value is maximised and that it is catering to the requirements of users. Yet the case of genebanks is also interesting because it provides a different narrative to that of relentless commodification of (genetic) resources. Whereas other work in the Political Economy of Science literature is focused on the creation of exchange value, there is a role for the understanding how the funding of conservation works in this situation, where the value of the conserved material is *not* obviously or easily set out in terms of money.

The discussion thus far suggests that genebanks seek to carry out their remit for long-term conservation of genetic resources, but do so under conditions of relative uncertainty with respect to funding. Although governments are committed to funding basic conservation (as per the Seed Treaty), such commitment does not necessarily mean that genebanks can count on a specified level of funding. Instead, it can be assigned over limited periods and is subject to review. Hence, I would argue that it is also part of the activities that genebanks carry out. The management of the flow of funding that they can manage to pull into the genebank is a fundamental aspect of their work. I provide a specific example of that in the next section, with the example of rationalization.

So, the ongoing, long-term conservation of genetic resources can be reliant on funding that is renewable over specific cycles, and subject to review. To what extent genebanks might be able to count on stable levels of funding will, of course, vary depending on criteria such as the amount of financial resources available to the state and the importance awarded to the conservation of genetic resources by policymakers. Yet, it is possible to identify situations where collections – and particularly, field collections – were identified as being ‘at risk’ because of lack of support or sell-off of the land on which they are located (such as the Pavlovsk station in Russia[46,47]). One might then argue that there is a tension between the timescales of conservation and those of funding, which could be problematic for precisely the kind of 'forward planning' that one might associate with assuring the continued existence of genebank accessions into the future.

Curators, then, take the availability of funding into consideration quite seriously, and take action to ensure that the collections under their care are recognisably valuable. For example, the curator of one field collection (I20) sought to future-proof their collection by organizing the planting of new clones and, in particular, ensuring that the organization of the new trees in the field was as useful and accurate as possible, given the present taxonomical organization of that crop. This particular instance demonstrates, once again, how genebanks are not static, but actively maintain their collections – and, in addition, how such work is done with a view towards maintaining their perceived value.

If funding indicates the need to prioritise, and if that could potentially mean the restriction of activities because they are less viable (with the funding available), genebanks' organisation (as well as practices) also respond to the need to make the most of funding. Hence, the subject of the next section is the way these concerns with economic efficiency are translated into the everyday practices of genebanks, particularly in the form of rationalization. By analysing different actors' perspectives on rationalization, it becomes clear that there are different perspectives on what counts as the most appropriate organization for the germplasm economy.

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46 'Scientific community calls to halt destruction of Pavlovsk station' https://www.croptrust.org/press-release/scientific-community-calls-halt-destruction-pavlovsk-station/ Accessed on 24.08.16

47 'Russia backs away from plans to break up the unique Pavlovsk seed bank' The Guardian, 12.10.2010 https://www.theguardian.com/environment/2010/oct/12/russia-seed-bank-vavilov-pavlovsk Accessed on 24.08.16

6.2 Organising hierarchies of value in the germplasm economy: the case of rationalization

In this section, I explore one of the actions proposed to make genebanks more efficient: the rationalization of genebank collections. This aspect of the work of genebanks is interesting because it illustrates that there is a link between the genebanks' work to manage *germplasm* and to manage their own *funding* resources. Rationalization involves the removal of accessions considered to be duplicates of each other, or their 'lumping' together (Engels & Visser, 2003). This process can be implemented *within* collections or, more significantly to the case at hand, *between* them – and both are significant in different ways. Hence, in addition to showing how genebanks maximise value, it begins to hint at the broader discourse that posits cooperation and interdependence as arrangements that are both socially helpful and economically efficient (a theme that I discuss in greater length in Chapter 7).

Here, I examine in closer detail what such economic concepts like 'rationalization' mean for the germplasm economy. As noted in 6.1, some actors believe that genebanks should be operating in such a way as to maximise the utility of their collections and, consequently, the use of the resources that are available. Rationalizing a collection is proposed as a means of making a collection more efficient. The interest in reducing the amount of duplication in collections is evident in the publication of research into how to identify them (see for example van Treuren, de Groot, Boukema, van de Wiel, & van Hintum, 2010) and how best to manage collections where there is substantial duplication of material.

The documents analysed show that there is a perception of considerable *duplication* of genetic resources in genebanks around the world: although the numbers aren't definitive, 'only' 1.5 - 2m PGRFA are thought to be unique, while the others are 'copies' of these; meaning that a significant proportion of the germplasm that is stored in genebanks around the world is found in one or more repositories. Although rationalization can be done at the level of individual collections, there is considerable enthusiasm for inter-collection rationalization too. Rationalization within collections is a process that can be undertaken individually, in the sense that it does not rely on particular sorts of relationships with other genebanks.

On the other hand, where genebank managers are choosing to take into account the material in other collections, it necessarily means making calculations regarding the future accessibility of that variety from somewhere else. Rationalization is therefore a means to create a shared genepool among different genebanks, and if implemented it can have implications for the 'landscape' of genebanking because it increases the 'scale' of the collection is increased from national to regional/global.

So, the suggestion that genebanks might become more efficient, means that rather than all genebanks attempting to keep everything, instead, different genebanks specialise in different materials, thus focusing their resources on a subset of accessions – and, presumably, maximising their value. Of course, for this approach to work would require that users can approach genebanks in different countries for access to certain samples – and the international databases explored in chapter 5 would therefore be required to facilitate that access. Altogether, then, suggesting that the rationalization of collections is important for the success of conservation is also making a statement about the 'proper scale' for the germplasm economy; that is, that genebanking should be an international endeavour where actors share genetic resources.

> *'Once the principle of free availability of PGRFA is accepted, or at least the free availability of the most important PGRFA for food security and on which countries are most interdependent, then the field is open for the rationalization of ex situ conservation at the global level and the consequent improvement in the quality and availability of conserved PGRFA as well as the releasing of funds and effort that can be fruitfully redirected towards other activities. (Moore, 2013, p. 330)*

Hence, the suggestion that genebanks should rationalize – especially between collections - is also interesting from an academic perspective because it exemplifies the choices facing genebanks in order to square the competing values and priorities. As noted in the following quote, some actors have identified potential 'efficiencies' to be gained if countries cooperate more because it would enable different collections to focus their resources in unique – and therefore valuable – resources. Consequently, not only would the genebanking system as a whole become more efficient, but each individual collection would be able to dedicate more resources to the curation of rationalized collections. Cooperation, as we have seen, plays a significant role here.

> *'Perhaps the most obvious target area for cooperation has been ex situ conservation, where significant efficiencies are to be gained through international cooperation. (...) Developments at the regional level demonstrate an understanding of the need to share responsibilities and resources and to take advantage of the opportunities for rationalization of the system of ex situ conservation provided by the Treaty's multilateral system.' (Moore, 2013, p. 330)*

Although rationalization has supporters, and it is advocated in policy documents, as well as books about genetic resources management (Engels and Engelmann, 2002), not everyone agrees that rationalization is advantageous or, alternatively, that it is *worth* the cost required to identify duplicates. Some actors think of rationalization as a way to minimise 'waste' of funds. By doing so, genebank funds can be spent on the most worthwhile material: that which is genetically unique. However, others think that the cost of rationalizing the collection is prohibitive, and certainly does not warrant the 'benefit' as it is in reality more expensive than the cost of keeping an accession in the genebank:

> *'(…) some people say you don't bother. [oh? OK] So (…) don't ask that question, because in a sense it's non-productive. What i- what if you find out, what are you going to do? If you find out something's the same, then what difference does it make? The cost of keeping something in a gene bank is five dollars a year, that's nothing. So it would*

> *be much more expensive to sort out duplicates than just leave them there. (…) But it does mean that you will get an (…) over-sampling in the gene bank. So many- many gene banks will have a high percentage- maybe as high as 25% of the accessions will be duplicates.' (I5, UK researcher, ex situ conservation coordinator, lines 128-137)*

When asked whether duplicates had an impact on genebank management, the participant replied

> *Well it does in the sense that they're wasting money in conserving that stuff. But as I said, the cost of getting rid of them might be more than the cost of just keeping them (I5, UK researcher, ex situ conservation coordinator lines 128-137)*

These positions highlight the different priorities for actors with respect to what constitutes the most appropriate use of funds, and again suggest that although policy documents might present a specific vision of collective action towards the development of a cohesive and economically more efficient system, that does not mean that such a particular imaginary of the genepool is shared/accepted equally in different places – evoking, perhaps, the same tension (noted with respect to the Genebank Standards) between the idea of what is rational or effective at the global scale or the local one. In that sense, too,

Rationalization is an interesting case study, as it shows how genebanks' practices are shaped by issues relating to funding, because genebank managers have to take into consideration criteria like utility when making decisions about how to deal with germplasm. Unsurprisingly, actors differ in their perceptions of what makes an investment, or a particular cost, 'worthwhile'. It is interesting because it means that people have different views about what 'makes sense' and make different decisions on criteria of usefulness and economic sense, and according to the local context. Yet interestingly, it might also depend on differing views on what constitutes a duplicate, a matter on which there are different perspective. In addition, if an actor states that material in different collections is a duplicate, *despite* its maintenance in separate genebanks and, consequently, potentially very different conditions, they would be privileging genetic identity/similarity and presuming that the genetic integrity of the samples remained unchanged since their collection – effectively, erasing the possibility of genetic drift or material changes since then. So, suggesting rationalization of duplicates across collections in different places suggests a vision of the germplasm economy that privileges both the genetic scale and the global economy simultaneously.

Moreover, making claims about genetic identity on the basis of factors such as accession numbers requires the existence of artefacts (such as SINGER, GRIN or EURISCO), which permit the finding of samples that might potentially be the same across a broad scale. Simply put, a sample would not be considered a duplicate of another if there wasn't the ability to account for them in the same 'picture' - or database, in this case. So, the creation of common means of representation of the collections (like databases) of different genebanks might be a means to re-evaluate the samples at a different level. In that sense, then, such a database becomes a tool through which to organise the germplasm economy because it is a management tool for coordination at the international level.

6.3 Conclusions

Recently, there have been calls for STS scholars to research the political economy of science in ways that can take into account how contemporary economic and financial arrangements shape technoscience (Birch, 2013; Birch & Tyfield, 2013). In the present chapter, I sought to implement that suggestion to the study of genebanks by bringing into my analysis of the germplasm economy not only the study of the management of genetic resources and data, but also that of the flow of funding, so as to better understand how genebanks' work involves not only conserving germplasm, but also 'conserving' the genebanking system itself. The findings show how genebanks are active constructors of the germplasm economy. They also show that the continued existence of these collections should not be taken for granted; instead, genebanks must develop strategies to manage their own activities in light of the funding available. Genebanking practices of value management *are* shaped by the availability of funding and the need to maintain the flows of funding into the genebank: thus, genebanks might only carry out certain activities and not others due to limited funding; or curators might manage the germplasm collection in ways that they feel make the most of the funding available, namely by rationalizing collections.

These findings also make visible the relationship between genebank funding and the contemporary policy on PGRFA conservation and use: the Seed Treaty, Global Plan of Action and the establishment of the Global Crop Diversity Trust all point to a move by international institutions to develop a longer-term plan for the continual support of important germplasm collections. I argue that these developments are the context within which to make sense of the other changes in the practices of genebanks that seek to encourage the concretization of the value in genebanks. Moreover, these actions for the maximisation of value are connected to the changes in the funding patterns of genebanks. Altogether, these findings support the argument that one must take into consideration the political economy of genebanks in order to develop a more detailed account of the germplasm economy itself.

Interestingly, by bringing funding into the analysis of the germplasm economy, I found a means to understand the temporal dynamics inherent to this biobanking project, and to make visible the challenges that arise with the development over time of a collection of genebanked material whose value is necessarily potential and consequently under-determined. In this situation, I argue, the way to get commitment from state actors (and others, namely the private and public organisations that fund the CGIAR) to ensure the flow of funding into genebanks is to emphasise the need to maintain this ‘insurance’ against possible, even likely, changes in the future (namely, climate change and attendant shifts in agricultural production and a growing world population). In summary, then, one might say that the developments I've identified in genebanking practice – the emphasis on maximising value through facilitating use and contributing to the creation of an easily accessible shared genepool) can be interpreted as an adaptation to the changing political economic context of genebank funding and policy itself. In a sense, it shows genebanking actors seeking to create a system that can be understood as both capable of maintain the value of genetic resources and as a worthwhile investment.

The findings in this chapter suggest that genebanks are far from passive in the discussions around how best to organise the germplasm economy: so, understanding why the contemporary system emphasises a multilateral approach to sharing resources should take into account the trends identified so far in this thesis. Doing so, I argue, provides a different perspective on the sharing rationale: one which focuses on the implications that the discourse of PGRFA interdependence has for the conservation of genetic resources, rather than their use. In order to do so, I next examine how actors conceptualise *collaborations* between different genebanks and different countries. In so doing, I develop an account of the multiple, sometimes overlapping relationships that are established between people and which have implications that are at once economic, political and social. As I go on to argue, making sense of the germplasm economy requires that we understand how genebanks engage in exchanges that are best described as neither commercial nor gift, but rather a complex example of the types of emergent economies that become possible under the current bioeconomy.

CHAPTER 7 UNDERSTANDING THE GERMPLASM ECONOMY

During the previous three chapters, I have built the argument that genebanks are essential parts of the 'flow' of genetic resources in the germplasm economy. Genebanks enable the existence of the germplasm economy because they are the centres from whence the different flows of funding, germplasm, and information can be *managed* (for instance, accumulated or distributed) in accordance with both economic and legal requirements and different values accumulated and directed towards particular goals. Much as in the case of biobanks described by Waldby and Mitchell (2006), these institutions ensure that genetic resources are conserved in ways that maintain their value, and turn germplasm and information into a *shared* genepool both ontologically and politically. This is because genebanks carry out their activities in accordance with international and national laws that amount to what I have called a regime of sharing, in that multilateral access is encouraged over bilateral, *ad hoc* agreements before access. Some actors, especially professionals working in or for international organizations like Bioversity International or the Crop Trust, construct the idea of the shared gene pool as a global crop commons (Dedeurwaerdere, 2010; Halewood, Noriega, & Louafi, 2012b).

That regime, and how it is translated into the germplasm economy in practice, are the main topic of this chapter, where I return to the question first posed in the introduction: how might we make sense of a germplasm economy that is organised around a multilateral system, and that is organised around both *interdependence* and *national sovereignty*? Is it a matter of facilitating the commodification of genetic resources by facilitating international access to genetic resources? The period post-Seed Treaty is, I suggest, a new phase in the political economy of genebanking, where the national sovereignty mandated in the Convention on Biological Diversity is reaffirmed and recognised as central to the governance of agricultural genetic resources, but at the same time Parties (that is, individual states) agree to share resources, having accepted that there is interdependence between countries with respect to agricultural genetic resources specifically. To answer these questions, I consider firstly the discourse of cooperation in policy documents, and then how actors see cooperation and its role in practice.

My argument in this chapter is that the current sharing regime is precisely a means to overcome the tension between these potentially antithetical priorities between the common good and national interest by creating a discourse that frames cooperation and mutual access as better for everyone in the long term, while simultaneously leaving considerable leeway for autonomous decision making by different countries and/or individual collections. I conclude that the idea of the shared genepool therefore transcends concerns about access and also encompasses the division of responsibilities for conservation. Thus, it manages to bind economic efficiency with desirable social outcomes; namely, contributing to food security. In that way, the most fruitful arrangement of the germplasm economy is productive of both economic and social value.

In the introduction, I suggested that the Seed Treaty and associated documents sought to harmonise the concept of genetic resources as objects under national sovereignty with the perceived interdependence of countries with respect to PGRFA by appealing to *greater international cooperation* with respect to PGRFA conservation and use. One might therefore say that this arrangement bridges the two potentially opposing concepts of genetic resources as a common goods versus private goods by developing a system where countries agree to pool their resources by facilitating access without requiring bilateral agreements. In this section, I discuss how *cooperation* is reified as an organising principle for the arrangement of genebanking, and suggest that it (and the multilateral system of access and benefit sharing more broadly) is presented as a way to make the genebanking system more efficient, and consequently to maximise the value of genetic resources – therefore, it has an effect on the germplasm economy.

The contemporary germplasm economy is organised around the idea of interdependence. What, however, does this mean in terms of the funding policy for genebanks? The existence of the Seed Treaty enables the 'globalization' of conservation by resolving outstanding uncertainties around the property status of genetic resources. It does so by recognising the national sovereignty of countries and, consequently, their autonomy over genetic resources (and particularly those not in the MLS). In this way, in the policy documents we can see how countries are assigned the power to make decisions about how to organize their own conservation system – therefore, there is a nationalization of the cost of genetic resources. On the other hand, there are many discussions at the international level about how to share internationally the responsibility for conservation. Yet to do so requires that there is trust in the ability to access genetic resources in other places, and some sort of assurances for the future that these other sources are dependable. This, in turn, connects to the mandate that each country has to fund their own genebanks, as they should, in theory, be able to offer access to their collections.

Consequently, it is worth analysing in greater depth how political economic concerns about funding, effectiveness and the preservation of value(s) are incorporated into, and reflected in, the central tenets of the Seed Treaty and associated policy documents – chief among which is cooperation. According to these documents, then, collaboration is helpful as it enables the reduction of duplicated effort, as I discussed with respect to rationalization in the previous chapter. By envisioning genetic conservation at a global scale, where users and providers of germplasm (including genebanks) do not place barriers on the exchange of genetic resources, these documents refer to a common heritage and a common future for people, and effectively portray genetic resources as material that should be shared. There is power in this depiction of a shared approach, in that it can create the image of a broader network/constellation of *ex situ* conservation where different collections, institutions and individuals operate as a 'global system', even if the ownership status of the genetic resources themselves has changed in international law from 'common heritage' to national resources.

7.1 The policy perspective: cooperation and the germplasm economy

I start with an analysis of the cooperation discourse in policy documents, and especially in relation to the practices of genebanks. Cooperation, in this context, means greater involvement in joint projects and activities relating to the conservation of genetic resources – along with the sharing of germplasm and data. Cooperation is the means through which expertise, labour and genebank capacity can be shared between countries, and is therefore significant in that it can potentially increase the existing capacity for conserving genetic resources, not least through rationalization as previously discussed. In other words, cooperation can be portrayed as beneficial to the parties in the joint activity (benefits arising from the mutual access or benefits emerging from the result of the cooperation). In that sense, it can seem rather appealing in light of the funding pressures that are associated with genebanking.

Cooperation, I argue, is the way through which people seek to create a germplasm economy that is 'efficient' while taking into consideration the requirements of the CBD. Consequently, it is set up as the way to bridge national and international concerns. By having individual genebanks and policy makers act in an independent, but coordinated way, it would be possible to create a 'Global System' that is envisaged in policy documents like the Global Plan of Action. Increased international collaboration is presented as the way to make the genebanking system more 'efficient, self-sustaining, rational' (CGRFA, 2011). Thus, a more globalized, international germplasm economy, where countries agree to cooperate in conservation and use activities, is presented as a means to ensure that conservation will be carried out, enabling the most benefit in the long term. According to the Seed Treaty, such cooperation spans the total gamut of conservation and use activities – as well as contributing to the funding of globally important collections, such as those of the CGIAR:

International collaboration shall, in particular, be directed to: (b) enhancing international activities to promote conservation, evaluation, documentation, genetic enhancement, plant breeding, seed multiplication; and sharing, providing access to, and exchanging, in conformity with Part IV, [PGRFA] and appropriate information and technology; (c) maintaining and strengthening the institutional arrangements provided for in Part V and (d) implementing the funding strategy of Article 18. (ITPGRFA, para 7.2)

As Article 5.1 of the Seed Treaty (below) sets out, countries are mandated to cooperate on matters of genebanking, so that they might 'promote the development of an efficient and sustainable system of *ex situ* conservation':

'Each contracting party shall, subject to national legislation, and in cooperation with other contracting parties where appropriate, promote an integrated approach to the exploration, conservation and sustainable use of [PGRFA] and shall, in particular (…)

(e) Cooperate to promote the development of an efficient and sustainable system of ex situ conservation, giving due attention to the need for adequate documentation, characterization, regeneration and evaluation, and promote the development and transfer of technologies for this purpose with a view to improving the sustainable use of plant genetic resources for food and agriculture' (ITPGRFA, para 5.1)

What these policies set out, then, is that genebanking must be efficient and economically sustainable in order to be successful - and international cooperation and the mutual access to genetic resources, information and capacity are precisely the way to reach this ideal of genebanking: it means that different countries engage in the sharing of responsibilities for conservation, and can therefore overcome the issues that arise the availability of funding, as identified in Chapter 6. This attitude is illustrated quite clearly by actors who argue for interdependence as requiring a global system, as Cary Fowler does below:

'The reality is that all countries are interdependent, and therefore all are dependent on a global system, on

> *cooperation. This reality is not currently reflected in institutional cultures or indeed even in the global politics surrounding plant genetic resources. Countries persist in keeping hundreds of sub-standard genebanks operating on life support systems despite the fact that they cannot actually provide the services for which they were created (long-term conservation and distribution), rather than joining together to endow a limited number of genebanks with this responsibility and the requisite resources to do the job properly. The benefits accruing to countries from this situation are very questionable.' (Fowler, 2010)*

This quote points to the direct relationship envisaged between cooperation and the success of the genebanking project. International cooperation is presented as one of the most important ways - if not *the* way - to ensure that genebanking is effective, self-sustaining, and making the most of the resources that are available. Seeking efficiency through increasing the scale of an economy recalls the appeals to the division of labour across countries that engendered the globalization of industry and economies in the 20th century. Yet it is interesting to see such a discourse present in this particular context, since it applies to PGRFA, but not other (wild) biodiversity, where bilateral arrangements are the norm.

The 'vision' for the genebanking system suggests that its organisation is perceived as an economic problem (as well as a political and technical one), where the accumulation, conservation and distribution of genetic resources are themselves subject to calculations of cost and benefit that require careful consideration - hence, such concerns should feature more prominently in analyses of the bioeconomy. Genebanking is relevant to contemporary discourses about the ways in which nature is transformed into resources because, I argue, the genebank economy is defined by the attempts (by genebank actors and others) to maintain the 'flow' and the use value of genetic resources over and above their monetization. Therefore, the outcome of these calculations is to favour *interdependence* over market exchanges. This case therefore differs from the narrative of the ongoing marketization of biological resources – at least, between genebanks and users. Instead, they resemble other resources considered to be 'raw materials', that is, where access to these resources underpins the production of biovalue (Waldby & Mitchell, 2006). In comparison, scholarship that focuses on the valorisation of genetic resources often considers the accessibility of the material, but not the conservation processes and how they might be dependent on economic processes.

The idea of cooperation and sharing resources in the germplasm economy, then, is grounded in the need to maintain the genebanking system, as much as it is about accessing the germplasm. The discourse here is that cooperation will enable the conservation of germplasm most appropriately because it is a globally distributed resource, 'our' common heritage, and the only way that is capable of ensuring its safe conservation into the future against an increasingly uncertain landscape in terms of the security of genetic resources (both metaphorically and, in some cases, physically). Here, we return to the idea of the Svalbard Global Seed Vault: it exists to ensure that material is not lost forever if the samples in the original collection are lost; however, the depositing of material in the Seed Vault requires a degree of willingness to engage in the Multi-lateral System, as this is a pre-condition for accession to this secure 'back-up' (or, alternatively, the sample must originate in the depositor's country) (Westengen et al., 2013) although exceptions are possible). This is important because it points to where the 'power' of a shared approach comes from: actors in these papers conceptualise a broader network/constellation of *ex situ* conservation to which different collections, institutions and individuals contribute.

The germplasm economy is depicted as a collaborative, international one, wherein circulate not only germplasm and data, but also technologies and expertise – and where, therefore, acting collaboratively is in the best interest of everyone. Consequently, the shared gene pool goes beyond the idea of mutual access: it is also about the sharing of conservation responsibilities. Policy documents encourage the mutual sharing of germplasm and information; *along with* genebanking capacity. Countries should coordinate their activities – this is seen as maximising the efficiency of genebanks – and consequently, the value of the collections. In so doing, new ways of linking collections in different countries are emerging, and there is a globalization of the material that is taking place here.

Cooperation is presented as a means of enabling the maximisation of the value of the collections through collaborations between countries that may have the genetic resources, but others have the technology to make them more valuable. Here, reciprocal facilitated access to germplasm should itself be considered a benefit (Falcon & Fowler, 2002), along with the exchange of information, ‘capacity building’ and monetary benefits – to a general MLS fund that can be dispensed to fund ‘globally important’ collections, such as those of the CGIAR (ITPGRFA, 2001).

Under this arrangement, with facilitated movement of germplasm, information, and capacity/expertise between countries, mutual access and cooperation is presented as the most efficient way to use funding and, consequently, ensure the financial sustainability of genebanks into the future. Of course, countries are not required to share more resources than those mandated by the Seed Treaty (in the MLS), which is why the narrative of openness being economically worthwhile could be a significant part of the argument for greater sharing. Being overly protective of one’s genetic resources can therefore be presented as being inefficient and potentially damaging on the grounds that different collections might be deploying their relatively scarce resources in keeping germplasm that is also available elsewhere. In turn, that suggestion is built on the idea that all countries are interdependent with respect to genetic diversity, so that every country will need access to materials in other countries, so that one shared gene pool would be far more sensible than having ‘silos’ of genetic resources only available to each country.

This situation suggests that the organization of the germplasm economy is not geared towards facilitated access solely as a way to facilitate the access to germplasm (that is, about the flow of germplasm) but also, I would suggest, takes into consideration the distribution of the costs of conservation; that is, a multilateral system is framed as the most efficient way of making the most of the material which is available. Hence, the Second Global Plan of Action explicitly states that in order to achieve objective 6, 'Sustaining and expanding *ex situ* conservation of germplasm', the conservation infrastructure requires investment that can ensure its continuation over time (thus underscoring the analysis from 0 regarding the availability of funding), while making a link between the long-term sustainability of genebanking and the ways in which different institutions and countries manage their own gene pools. That perspective is exemplified in the following paragraph:

> *'Globally, governments and donor agencies need to invest more in conservation infrastructure, in particular for species that cannot be conserved in seed banks, taking particular account of maintenance costs over the long term. This will stem the steady deterioration of many facilities and enhance their ability to perform basic conservation functions. The severity of the threat to ex situ collections is reflected in the high percentage of accessions identified as needing regeneration in country reports3 105. Regional collaboration on ex situ conservation must be strengthened. as well as in the lists of technical and administrative problems associated with maintaining gene bank activities. The Trust aims to support better planning and more coordination and cooperation in order to limit redundancy and promote rationalization at the global level. The goal is to reduce the overall costs of conservation and place gene bank operations on a scientifically sound and financially sustainable basis. Options need to be further explored for more cost-effective and rational conservation' (CGRFA, 2011, para. 103)*

Other work on the creation of global commons indicates that there is often an argument for the need to encourage innovation by maintaining freedom to operate, but in the case of genebanking those arguments are supplemented by concerns about the total cost of conservation. As noted in the previous chapter, for some actors at least there are changes that can be made in order to make genebanking 'more rational' by changing the way the genepool is arranged.

Interestingly, then, the monetary benefit of conserved material is *under*played in this perspective. Instead, actors writing about the need to cooperate emphasise that the most important benefits should be understood to be the *reciprocity* of facilitated access to germplasm, along with the exchange of information, as well as 'capacity building' and monetary benefits – to a general MLS fund that can be dispensed to fund 'globally important' collections, such as those of the CGIAR. (ITPGRFA, 2001). In fact, this is considered to be one of the most important benefits. So, it would appear that the organisation of genetic conservation might be arranged in such a way as to privilege the more immediate use value.

One could argue that there is little evidence that the emphasis on cooperation as the means to ensure conservation is presented as a genuine policy alternative, rather than a convincing argument for lifting restrictions on access to facilitate the appropriation of genetic resources. Although there is no possible way to determine those deeper motives either way, I would argue that it would be wrong to *dis*count the material concerns around conservation from our explanation of the organisation of the germplasm economy. By this I mean that the continuation of the genebanking system is likely to be a factor that does transcend more immediate/local concerns and that different groups could engage with under a common purpose, and out of a shared interest in maintaining resources which, as detailed in Chapter 4, have a complex status but a clear multiplicity of values (social and use, as well as/more than economic) for people across the world.

In the following section, I develop an account of actors' views of cooperation in practice. Doing so provides a way into querying actors' views on the organization of genebanking and the kinds of relationships that are involved in maintaining genetic resources.

7.2 The germplasm economy in practice

In Chapters 4 and 5, I have shown that genebanks develop certain relationships to users in order to target their activities (such as characterisation) in such ways that maximise the value of the material to. In this section, I turn to a different kind of relationship/cooperation: that which occurs between actors involved in genebanking as they carry out genebanking activities or coordinate international activities. That is because cooperation is presented in policy documents as a fundamental part of the germplasm economy since, as I have shown in this chapter, it is the bridge between the primacy of national sovereignty and the establishment of mutual access to germplasm, information, and labour/genebanking capacity. In this section, I explore the ways in which genebanking staff (and other actors involved in professional networks) cooperate in more and less formal ways. As I show in the paragraphs that follow, cooperation takes different forms, and the sharing of knowledge and expertise is recognised as an important factor in the continuing operation of genebanks. Hence, by analysing how genebanking actors think about collaborative/cooperative efforts, with whom, and in under what circumstances, I develop conclusions about how individuals manage different priorities and activities within the constraints of their particular situation, while enacting the principles – indeed, the values – that actors say characterise the genebanking culture. More specifically, descriptions of cooperation emphasise ‘in kind’ contributions and reciprocity between genebank collections; mirroring the view that genetic resources should themselves ‘flow’. Therefore, the rhetoric of sharing encompasses not only the use of genetic resources but also the undertaking of conservation itself; embedded in an understanding of genebanking as an effort that can be more successfully undertaken at a global scale.

Cooperative activities can be parsed into occasions where actors contribute *expertise* and *capacity.* In both cases, one might say that the purpose was to contribute to the overall functioning of the genebanking system (in that there was a decision on the part of genebanking actors to provide that help), but in one case the input is less material than in the other. In the former actors can utilise their professional expertise in ways that benefit the community. Two possible forms of contribution are apparent here. The first is the contribution of expertise. Some of the participants recalled, for instance, taking an active role in contributing to, or providing feedback for, the creation of documents like the Genebank Standards (I1, I14, I16). In addition, novel projects like the Crop Genebank Knowledge Base[48] invite actors to contribute in order to share information and best practice. This project, which originated as an output of the World Bank-funded project *Collective Action for the Rehabilitation of Global Public Goods in the CGIAR Genetic Resources System, Phase 2 (GPG2)* explicitly sought to contribute to 'more efficient and effective *ex situ* conservation and use of crop genetic resources through facilitating access [to information]',[49] thus drawing a link between sharing/cooperative behaviour and the goals of the Global Plan of Action. The database was designed with a view to encourage participation, where conservation professionals were (and are) encouraged to contribute to the knowledge bank by providing materials or engaging with the content, and made use of open-source software (Jorge et al., 2010). This database provides extensive documentation about various aspects of germplasm conservation, along with training materials and information on 'management strategies' to aid genebank staff. In that sense, like the genebank databases discussed in 5.3, it is an artefact that encourages the sharing of resources so as to facilitate the conservation of value – and demonstrates again how cooperation is seen as central to that work.

Another possible form of contribution I have called the contribution of '*capacity'*: in this form, genebanks/actors can work with, or provide assistance to, other genebanks in order to enable them to carry out specific conservation activities: therefore, they contribute to the conservation of value in genebanks, or to the conservation of the conservation system itself, as illustrated by the explanation provided by a participant who contributed extensively to genebanking policy. That perspective is particularly telling, as it ties cooperation back to the idea of sustainability and future challenges such

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[48] 'Crop Genebank Knowledge Base' http://cropgenebank.sgrp.cgiar.org/. Accessed 20.08.16
[49] 'Crop Genebank Knowledge Base: about this site' http://cropgenebank.sgrp.cgiar.org/index.php/home-mainmenu-71/about-this-site Accessed 20.08.16

as climate change. In that way, organizational change is directly related to the broader context within which genebanking is developing as a cooperative endeavour:

> *'Yes, I think that there is a growing realisation that, you know, organisations or countries even, they cannot work independently from each other, okay? […] for example, characterisation evaluation calls for collaboration between different stakeholders, all right, so it is… people are recognising that they cannot work alone. They have to work in collaboration with each other in order to be able to get the most of the gene bank accessions that exist [in] gene banks. Now, another really important driving force towards these international collaborations is the fact that a lot of countries, one of the biggest challenges the world is facing not only in terms of food security and nutrition, but climate change I think is driving a lot of the way that organisations are working.' (I16, international organization coordinator, 323-331)*

At the genebank level, cooperative activities are, indeed, presented as an important part of the day-to-day management of genetic resource value. Interviewees do engage in cooperation with other genebanks and consider it to be an important part of maintaining the conservation system working. The interview data indicates that actors put great stock on the idea of a *community* of genebank members as a source of help; be it in terms of knowledge transmission or emergency help (for instance, if material requires urgent regeneration). There is much volunteer work and cooperative activity between people that work in different repositories/organisations: this includes the ability to provide help doing emergency regeneration, or hosting 'safety duplicates' for a different collection. In addition, actors involved in genebanking and use of collections (for instance, as plant breeders) contribute in an expert capacity to the organization of genetic resources.

These acts of cooperation are often informal, or *ad hoc*; and they can inform or otherwise shape the ways in which individual curators manage their own local collections. For example, one curator stated that they might contact other genebanks for information that would help them to make decisions regarding their own collection and what material should be prioritized (I4). In that case, communication is important in deciding how best to maximise the value of the collection under the curator's care. In other cases, scientists or curators from different collections might collaborate in work that has the effect of 'adding value' to genetic material – for instance, by developing projects that support the characterization of certain genebank accessions. In these cases, actors might be said to be making use of their social network; drawing on personal relationships that are struck at international meetings such as those of the European Co-operative Programme on Genetic Resources.

Actors describe their own involvement in cooperative activities as a 'contribution' to the efforts to maintain and develop *ex situ* conservation. Specifically, they take part in cooperative initiatives like the ECPGR, generally paid for by their employer, and take on professional roles without remuneration. In fact, ECPGR is financed through member-country contributions; hence, one might argue that their maintenance of the genebanking system does rely on the flow of 'in kind' contributions of actors' work in order to create the activities explored in section 6.2. Certainly, actors noted during interviews the importance of the collaborative approach of workers in different genebanks, and the participation in particular professional networks and fora (such as, for example, the ECPGR) in order to coordinate activities and create cooperative projects.

> *IE: [Yes] Well the thing about community is an interesting one in that it's (.) to a great extent a lot of it is a service provision; and so it takes us out- we're not part of a- we're not at the cutting – got to be careful here, some are cutting edge elements of the work but generally we're not (.) we're not having to compete (.) for funds the way the scientific community is. It's not the same. There is competition, but it's not the same. There is a recognition of the importance of conservation which sees to basic funding there. You may have to find additional funds to, to do to bring to bring further funds in to get to where you want to be; but it's not as competitive as mainstream research. So that way it's more of a collegiate community; we can help each other. And that's quite important for how the community operates. I think the gene bank community is very generous in in sharing*

information and sharing expertise given that it's a technical operation. I'm (.) I and others are quite, quite generous in sharing our views== I've come from a different perspective and I'm quite open in sharing that. So I think it operates on that level, very well== there are joint initiatives that are quite important to engage with (I1, UK genebank staff, lines 444-456)

Actors therefore often describe their contribution in terms that refer to the local culture; so that in a collegiate community, cooperation is a norm and a social value; and one that is 'quite important' for the operations of the community. This activity is also a way to improve the value of the collections within genebanks (and therefore, of the genebanks themselves). Cooperation, then, is a means of attempting to improve the value of genebanks that is based on individual activities, rather than a change in the structural funding approach to genebanks. Yet that is not to say that it is cost-less: instead, it is directed, and funded, by individual genebanks.

The interview data indicates that the sort of engagement that happens with other genebank professions, including within international networks like the ECPGR, is carried out in addition to the 'everyday' activities of genebanking staff or experts, and is not often, or necessarily, funded separately. Therefore, if the collegiate attitude is an important part of the collective identity, involvement with these networks often has to be self-directed, as exemplified by the quote below:

'… I do some capacity building [yeah] we have people over for short training projects, and I do I do advise and help out where I can. Within Europe, the European cooperative programme, ECPGR, I've put in a lot of personal time in chairing groups and attending Working Groups of different crop networks in order to meet other people [yes] but also to help other people; and certainly the role of chairing and facilitating is to facilitate progress and to help everyone move forward; and I - I'm very passionate about that so I have- I hope that I've played my part within that. (I1, UK genebank staff, 433-438)

Depending on the circumstance, then, participation in these projects can be considered as ‘altruistic’ and done out of ‘personal time’. For instance, one plant breeder described their input into ECPGR as ‘Friday afternoon work’, which was made possible as part of their day job but was not necessarily part of their main work outputs. Instead, it appears as a less tangible contribution to the ‘community’ more broadly defined. These participants are therefore providing expert ‘input’ cooperatively. Interestingly, although actors are aware of the need to contribute to the system through ‘in kind’ contributions like these, there is also the impression that this contribution is to the collective as a whole, in that it ‘helps everyone move forward’. Again, then, we see the how the boundaries between a collective endeavour that benefits everyone is superimposed onto the more local contexts, where individuals might feel that they are contributing something. An important implication that arises from this finding is that the availability of funding does shape the engagement of genebank staff in cooperative activities, especially of the more formal kind. Indeed, several interviewees noted that funding was a significant factor in enabling collaboration, not only between genebank staff but also between them and users (see also I16, I13, I14). Consequently, this insight raises the question: how do people deal with the different capacities for funding in the context of cooperative activities?

The fact that this collaboration is conceptualised as a contribution is also interesting because it might be seen to put it in competition with other work that is directed to the more immediate activities of the collection. By this I mean that since international activities are collaborative, self-directed, and likely to be self-funded, they require the coordination of many people. Projects can require considerable input, as actors have to find time and funding to carry it out. In that way, as the participant suggests at the end of the quote, the participation in formal international collaborative projects are considered to be effectively an ‘in kind contribution’ that have to be fitted into the other work of the genebank, and without preventing the successful completion of other ‘deliverables’. At the same time, the interviewee notes that this cooperative act of participation in professional networks is mandated precisely as a result of current genebanking policy: it is an example of the ‘flow’ of capacity and expertise which is envisioned to be part of the germplasm economy, along with the flow of germplasm and data. Therefore, this insight suggests to me that genebanking practices construct the ‘shared genepool’ as much through their collaborative practices with other collections as through the distribution of genetic resources or data.

> *So, some of the collation of passport data across gene banks is important to provide either European or a global set of information on either specific crop wild relatives, or material in cultivation. That material, those exercises are actually going on all the time and one thing I would say is that it is sensible to have on the one hand a sort of the large, formal international move to do that but that’s, that needs to sit alongside the individual initiatives that are wanting to do this on the fly [ok] (…) Because they’re immediate, they’re quick, and they get the results that are required to stimulate the science, and the utility. Those will always go on, I don’t think that they’re ever going to stop; and in fact that’s what needs to be the form of the rest of the community. Because the larger initiatives at the international level are quite slow to develop, to get all parties joined up. Because a lot of the work is done on an ‘in kind’ basis. We’re not paid to do it, we do it because there is altruistic and motivation that is a good idea but we’re not funded to do that specifically. Well, in part we are, because we’re mandated to actually engage with European and international initiatives; that’s fine. But it’s not-it’s not specific funding. We have to be careful in terms of vying against, against the other objectives and [yeah] deliverables that we have. (I1, UK genebank staff, lines 456-470)*

So, there are two important aspects to take into consideration: firstly, the characterisation of the engagement with the broader genebank community, and the inputs to it; secondly; the extent to which the cooperative efforts should be formalized (or, put differently, how much autonomy/informality should be retained in these interactions). Here the interviewee differentiates between the formal, slower projects of cooperation between different countries and more *ad hoc* collaborations that are more bilateral and/or driven by interpersonal relationships. For this interviewee, there appears to be something rather more productive and agile about the ‘on the fly’ approach with its self-directedness and speed. They would later make the argument that instead of seeking to create large, all-encompassing projects

> *'that will capture everything (…) we shouldn't get so hooked up on one system; we should keep an open mind and things (…) will be done on the fly more and more, that's absolutely fine. Because you get to it arguably, as long as you can evaluate what it is you've got.'(I1, UK genebank staff, 473-478)*

A certain contrast can therefore be noted here between the more targeted, agile ways of cooperation that emphasise autonomous work at different institutions, and the top-down, slower, more bureaucratic plan for what it means to share/collaborate in the germplasm economy. The distribution of the costs and benefits of cooperation appears as yet another arena where there is potential for tension between the responsibilities of genebanks toward *both* national and international priorities and requirements. I would suggest that actors make decisions about what activities and developments are worth the investment (in terms of funding), and that the contemporary environment with respect to genetic resources is at a turning point: for some people, it is important that cooperation is increasingly formalized, but not for all. The discussion thus far makes visible the economic issues at the centre of the cooperative issue in the germplasm economy; as the distribution of social value and the 'best' allocation of localised funds can, be at odds.

7.3 Cooperation and autonomy in the germplasm economy: the establishment of AEGIS

The final step in this analysis of the sharing regime in the germplasm economy focuses on the recent establishment of AEGIS (an acronym for 'A European Integrated Genebank System') - a project that took shape in the context of the ECPGR. Its objective is the establishment of a 'European collection' of PGRFA, albeit one which is 'virtual': instead of creating a specific repository, the material is maintained in different genebanks across

Europe, with staff in different collections agreeing to share responsibility for PGRFA conservation by committing to conserving and making available these accessions. This project is an interesting corollary to the theme of cooperation in the germplasm economy because, I would argue, it encapsulates the post-ITPGRFA imaginary for genebanking as an example of the implementation of the policy concepts expressed in 7.1, that is, that the strategy to ensure successful genebanking should be increased cooperation and rationalization of genebank collections.

AEGIS, then, is an example of the longer-term, more formalised approach to cooperation, and is introduced here in order to explore actors' perspectives on what some actors see as the strategy to ensure the future of genebanking. I argue that the European collection emphasises long-term commitment to sharing, but also privileges national sovereignty. In that sense, too, I suggest it can be seen as an attempt to bridge the tension between PGRFA as a common concern and a national resource. However, as I go on to show, the aim of creating a regional shared genepool comes up against the existing spatial distribution of genetic and financial resources, therefore bringing to the fore the outstanding questions regarding the sharing of conservation capacity; that is, how to account for the differences in national genebanking systems.

Maggioni and Engels set out the goals of AEGIS as follows:

> *'The goal of AEGIS is to create a European genebank integrated system for PGRFA, aimed at conserving the genetically unique and important accessions in Europe and making them available for breeding and research. Such material will be safely conserved under conditions that ensure genetic integrity and viability in the long term. The perceived benefits of this initiative consist of improved security of germplasm through long term commitment and systematic safety duplication; facilitated access to and availability of high quality germplasm; agreed quality standards for conservation and use; more cost efficient conservation activities; reduced duplication of germplasm material; and improved sharing of knowledge and information.' (Maggioni & Engels, 2014, p. 287)*

As this quote demonstrates, the project is intended to ensure both the value of genetic resources and the long term sustainability of conservation itself. The material which is in the European Collection is genetically unique: therefore, what is in the European Collection would be known to potential users as being particularly valuable or of good quality, both in terms of its conservation and use. Hence, the European collection is an example of the way the scale of conservation – and the germplasm economy – are resolutely international, because the evaluation of material (what is considered unique and/or valuable) is gauged at the regional scale. This internationalisation is not only theoretical, or legal; there are real implications for the way accessions are supposed to be managed in the genebank through the implementation of AQUAS, the quality assurance system – which could therefore be interpreted as a formalization of the gene pool, ensuring standardised treatment across physical collections. These ideas are corroborated/further elaborated by an interviewee working in an international organization, as follows:

> *'Now, the idea of AEGIS is to ensure that they are conserving the unique diversity. I was telling you that there is so much duplication in gene banks, so the idea of AEGIS essentially is to ensure that the most important collections are recognised and put aside, you know, are declared by the countries that they want to put this in AEGIS. And (…) for any accession to enter AEGIS it needs to adhere to a number of important criteria, like their uniqueness and they are being maintained at the international standard, you know, and things like that, and other criteria as well. So that's one aspect of a sort of decentralised way of looking at a gene bank.' (I16, international network coordinator, lines 440-446).*

Effectively, then, AEGIS creates a form of 'rationalization' that operates at the regional level by means of creating a (sub)collection that is physically based within more general collections. It leads to a regional collection, but one which does not all physically reside in the same space: instead, it is decentralised. By comparison, the original idea for the creation of regional collections in the genebank network of the 1970s was focused on establishing fewer regional collections that would serve the whole region –

such as the genebanks in Bari (Italy) or Izmir (Turkey). So, through AEGIS, actors seem to have sought to develop a way to guarantee the flow of genetic resources of certified value between countries, while at the same time operating in accordance with the requirements of the Seed Treaty and the CBD with respect to national autonomy and sovereignty over genetic resources. Geographically speaking, then, the scale of the genepool (that is, what counts as a European collection) has been decoupled from its physical location, in that the collections are maintained in their respective genebanks.

AEGIS is also, I would argue, a project that seeks to provide guarantees with respect to the value of genebanking and genetic resources. Not only does it emphasise particularly valuable material, it also requires that particular criteria are met with respect to the quality of conservation and availability. There is also the expectation that the value of that material can be further maintained, or added to – as is detailed in the quote below, where the same authors set out their vision for the future European collection – which, once more, touch upon the subject of improvement of data (previously discussed in Chapter 5).

> *'…breeders and other users will be able to have easy access to well characterised and well maintained samples from any of the associate member institutions in Europe that collectively hold the dispersed European Collection and under equal terms. The quantity and quality of data contained in the EURISCO catalogue, including characterisation and evaluation data of useful traits is expected to improve.' (Maggioni & Engels, 2014)*

Interestingly, the association between quality and AEGIS applies not only to genetic material, but to collections themselves. An insight from one interviewee leads to the tentative suggestion that participation in international activities might also serve as a means for genebanks to demonstrate impact and thus encourage future funding, as per the interaction below:

> *'SP: OK. And in terms of coopera- or, distribution of responsibilities [hm] within a project such as AEGIS what implications do you think that has for: members of AEGIS?*

So what I'm trying to say is, when people talk about sharing of responsibilities [yeah], when they share out the colle- within parenthesis, share out the collections. What benefits does that bring for participating institutions?

IE: (.) Presumably a little bit of increased visibility, within their own institution that they are the guardian of a particularly valuable (.) genetic resource. And that's as I said earlier a sort of a highlights the importance to the [sponsor] (I7, UK policy maker 251-258)

Thus far, then, I have argued that AEGIS is an example of the contemporary genebanking policy framework in practice, whereby the European Collection is conceptualised as a way to conserve and make available the most valuable of genetic resources through a project of formal, long-term, international collaboration. Therefore, AEGIS appears both a means of identifying the most valuable accessions within the collections of genebanks, and is a method of sharing responsibilities between different countries for the shared genepool. Yet that distribution does not take place in a vacuum, but is instead superimposed onto a continent where countries have quite different capacities, priorities and interests when it comes to genebanking. Consequently, the establishment of AEGIS, with its formal requirements and standards, brings to the fore discussions about the implications of cooperating (or not) for different European countries and makes visible the geographical pattern to the 'flows' of genetic resources and funding.

Exploring this question in greater detail requires firstly that I describe the process of offering material to be part of AEGIS. Its boundaries are, in a sense, quite broad: countries that are members of the European Cooperative Programme for Genetic Resources can decide to offer material to be part of AEGIS. Yet, in order to become Associate Members of AEGIS, countries/institutions must achieve particular criteria, including signing a Memorandum of Understanding that sets out each party's obligations, and making a long-term commitment to the maintenance of this material. In turn, that commitment has financial implications (in order to maintain the quality standards, for instance). Although the commitment is the same – a step that is essential for the creation of a standardised, but decentralised collection –

the genebanks that could participate in the project have rather different levels of access to funding, as well as national conservation priorities. Yet, again, this globalizing impetus is in tension with the local differences between genebanks; and particularly with respect to differences in funding – as the amount of funding that genebanks have access to can vary considerably.

For some actors, the requirement for a formal commitment might exclude smaller genebanks or countries from contributing because they can't meet, or might not consider it a priority to meet, the standard requirements for their material to be part of the European Collection. Below, an interviewee (who has *ex situ* expertise and experience in international projects) expresses his concerns on the matter, illustrating how a project such as this could effectively benefit some countries with well-developed collections over others:

> *SP: Ok. [is there] a sense of creating synergies by distributing responsibilities or distributing work by arranging projects and arranging operations at the supranational level, for instance the European level [yes]: is there something to be gained by working togeth[er]…?*
>
> *IE: It is an interesting question [hm] so if- if you're [country A] or [country B], then, then I would guess they would say yes to that [hm]. But they have- they have the most money for doing that kind of work, and they're doing it anyway. If you talk to [country C], or last week I was in [country D]. You talk to the [genebank staff in country D] they would say no, we don't want that approach because that means that we have no- we have very little genetic resources here, we have one gene bank, gene bank's very small; we have a small number of accessions in it and we will never figure in a European level, we don't have the skills to do it [ah, OK]. We have one person [ok, yes] working in genetic resources in our country. So we won't be- we'll end up being excluded. So my fear is that that might end up excluding some minor countries (…).*
>
> *SP: OK. And what would be the(.) what would lead to some people, or some countries being more included than other- is it economic? Is [it]*
>
> *IE: Yes. It's economic, it's in terms of the number of people working on genetic resources in the country, the number of plant breeding companies based in that country. So the smaller the country, the less, if you'd like, less affluent the*

country the less likely they are to have benefit from that. (I5, UK researcher and conservation coordinator lines 265-287)

The perspective put forward by this participant, then, suggests that there are political-economic implications arising from international collaboration through projects such as AEGIS that are tied into the geography of genebanking in the region. Therefore, this example demonstrates once more how the political economy of germplasm and that of genebanks themselves are intricately connected, and how the appeal to collaboration can raise questions about participation and inclusivity, even as it seeks to resolve the issue of autonomy. Indeed, interestingly, another actor raises the parallels between this case and that of the European single currency, thus highlighting the different spatial patterning of valuable resources:

'…we have at the moment in Europe (…) a situation that those countries that have the funds and the means to use the germplasm, they don't have the diversity. The diversity is there where the means and the funds are least, so we have almost a north/south conflict like in the Euro with the currency, and we don't know what... so that's possibly the easiest explanation why things don't move, but I think it is a very fundamental issue and that's where we somehow seem to have gotten a little bit stuck.' (I14, international ex situ coordinator, lines 359-365)

Altogether, then, the European collection project which seeks to develop a shared genepool with specific quality criteria and a secure future brings up certain issues about what it means to share responsibilities and valuable resources in the context of a whole region. As the case of AEGIS shows, the *envisioned* system requires that countries or genebanks take on particular responsibilities on behalf of the collective, at their own expense. However, simultaneously, for some countries, at least, participation might not be possible because it would require specific skills or economic input that is not desirable or attainable. The implication, then, is that the sharing of conservation duties through these formal cooperative projects is *geographically heterogeneous*: what is (and isn't) part of AEGIS is the result of specific, contingent decisions that take into account not only the evaluation of genetic resources, but also the capacity of different genebanks. Hence, the bureaucratic structure of a formal European collection is geared toward a particular purpose – that of unlocking value for users – but that such a purpose might (in some cases, at least) be in tension with other interests, namely those about conservation.

To conclude, then, the case of AEGIS demonstrates a possible logical next step towards enacting the sharing regime in the germplasm economy; where a shared genepool is created between genebanks, with requirements to standardise certain spaces and practices, which is also a formalised system for the sharing of germplasm, data, and conservation responsibilities. In it, we see a coming together of values and value, in that ideas about cooperation and sharing, of the common good, of successful conservation, can be important – but on the other side, there are concerns regarding the availability of funds to maintain the commitments and the responsibilities involved. In this way, what is interesting about the emergence of a European collection is precisely the playing out of these very important decisions about how to engage in 'common' projects between countries.

7.4 Conclusions

Cooperation, I have shown in this Chapter, is a defining principle in the organisation of the germplasm economy, and exploring its significance is worthwhile: it provides a lens with which to make sense of the germplasm economy because it is applicable to the organisation of the shared genepool and of the germplasm economy. I have argued that the sharing rationale that defines the germplasm economy at the moment maintains a degree of flexibility between the priorities of different actors, and might therefore be acceptable to them. I've shown that actors can hold quite different views on matters such as how to organise cooperation without necessarily threatening the arrangement itself. In other words, the sharing approach appeals to the idea of both value and values: interdependence is, at once, an economic and social relation that is used to justify the current organisation of genebanking as beneficial to all. The evidence in this chapter indicates that cooperation and interdependence are presented as the way to ensure the long-term continuation of the conservation project. That, it seems, is the most significant factor; a working germplasm economy therefore is organized in those terms. It is for that reason that the cooperation argument is so powerful, I suggest: it can be expressed in terms that operate at different levels, or discourses: it is presented as the strategy to achieve value, both social and economic.

Moreover, the idea of cooperation again brings to the fore the importance of stability and continuity as drivers for cooperation. The discourse of a common past and future are essential as the basis for the germplasm conservation system, and its implications can be found in the 'flow' of germplasm, information, and funding. As the conceptualisation of genetic resources changes from 'common heritage' to 'resource under national sovereignty', the genebanking (sociotechnical) infrastructure is still present, if responsive. Hence, it makes sense to talk of a new phase in the political economy of genebanks, but at the same time, the idea of a shared conservation system is developing, albeit in a contingent and fragmented way (that is, I am not claiming it is a homogeneous process). Still, the analysis presented here suggests that this is a genebanking system in flux – and one in which temporality plays a significant part in shaping.

If genetic resources are germplasm of 'actual or potential value', it is through the germplasm economy that its value can be 'banked' over time (e.g. a sample gets old and loses its vitality; or, conversely, if a sample is characterised, it becomes more valuable). The analysis in this chapter reminds us that this economy is international, and that genebanks engage in organisation and collaborative activities that are an essential part of the idea of the shared gene pool, in that actors in different genebanks cooperate in order to try to maintain the value of these genetic resources and ensure that it is not lost – for instance, through programmes of emergency regeneration. Understanding the Multilateral System, then, should include not only the study of the political implications in terms of use, but also take into account how the management of conservation is a factor in determining how the costs and benefits of conservation should be distributed. Genebanks, then, appear to influence, or manage, the value of the genetic resources that they maintain in large and small ways; from the creation of data about them to the ways in which they choose to communicate to users, as well as determining the conditions at which to maintain genetic resources. Effectively, I'd suggest one could go as far as to say that the value of genetic resources is a function of the financial resources available to maintain them.

My findings lead me to argue that there is another sense in which we can think of the 'shared gene pool': not only about genetic resources, but rather also taking into consideration the network of collections in which they are kept. By this I mean that we can interpret the current interest in closer cooperation as a way to work on the 'integration' of genebanks' practices into a coordinated system. This suggestion implies that the shared gene pool is also constructed through the choices actors make regarding the way they conserve germplasm: it is not just about mutual access. By this I mean that if we look at ideas like rationalization, regional collections, and standards (for example), the idea underpinning it is that genebanks in different countries work together in the conservation of material, rather than operating independently and therefore 'duplicating' effort.

However, the data also shows that this vision of a global system where people operate as coordinated parts of the whole is resisted by different actors, and presumably for various reasons. Yet the most pressing/obvious challenge from a material perspective is that certain countries do not have the ability to maintain their collections to the same standard as others. The subject of how genebanks should work together and what it means to share responsibility for the genepool indicates that genebanks operate at the junction of two different geographies of value; one, how 'valuable' the germplasm is that they contain, and two, how much money they have to maintain the value of that germplasm.

The germplasm economy, then, appears to be organised around the concept of sharing and cooperation. That is to say, the flow of germplasm should be encouraged, if the value of the germplasm is ever to be realised; but there is scope for countries to have the ‘final say’ over what germplasm they are willing to donate, and which they wish to keep private. We see a similar issue at play with the sharing of data: some, but not all, is in the public domain; and commercial values vie with openness. So the shared gene pool is a subset of all genetic resources, and it is organised at a supranational level. This case has, therefore, a few parallels with the tissue economies described for the biomedical sciences by Waldby and Mitchell (2006). However, there is an interesting difference, in that the idea of interdependence is a way of distributing not only the value, but also the cost of the conservation of genetic resources. As we saw throughout the empirical chapters, genebanking requires constant effort to maintain the value of genetic resources. Not only must they keep the genetic integrity of the material (thus keeping value in the technical sense), they also have to ensure its ethical value (in that they have to ensure that they are disseminated according to the stipulations of the CBD and the Seed Treaty) and, as we’ve seen, they must work to make others, especially users, aware of the value of genetic resources so as to encourage their use. Here, I would suggest, the situation is indeed different from that seen with respect to ESC cells, whose value appears to be widely accepted. It is somewhat closer to the cases of fat cells or cord blood, in that their value remain potential until a use is necessary.

The germplasm economy is at a transitional period: the role of genebanks is increasingly defined as the sharing of germplasm, and the usefulness of banked materials is increasingly important to the funders and other genebanking actors. Genebanking staff and users are acting on the availability and accessibility of data about accessions as a means of making visible the value of genebank collections. They also construct the representation of the genepool at larger scales, thus providing the impression that all these different institutions are part of the same, shared genepool.

A sharing regime, then, is the concept that structures the organisation of genebanking as an economy: the expression of the common goal that permits the successful conservation of genetic resources. Analysing the practices of genebanks and the way they are involved in the sharing of these various resources suggests that we should think of the ‘germplasm economy’ as a technical concept, just as much as it is a material and social one. In the next, final chapter, I seek to bring together the conclusions of these four empirical chapters in order to develop an account of the role of genebanks in the germplasm economy, and to think about what this means in light of contemporary thought in STS/Geography.

CHAPTER 8 CONCLUSIONS

At the end of this exploration of the role of genebanks in the germplasm economy, I bring together the conclusions from the different strands of analysis, to discuss what it reveals about the co-construction of the shared genepool and a conservation system that is grounded on common action and multilateral access. As the empirical analyses in this thesis show, these two questions are bound together; in that the conservation of genetic resources is part of a germplasm economy defined by the idea of interdependence. Sharing of genetic resources and genebanking capacity alike is presented in policy as the way to maximise the value of both in a germplasm economy that can encompass both the production of social values and economic value. In this concluding chapter, then, I reflect on my findings and arguments, and discuss what the study of economies through biobanks could contribute to STS work on how to conceptualise the value of biological material, its accumulation, and its exchange.

The genebank is a significant site for analysis because it is there that genebank staff accumulate resources (donated/collected from farmers and plant breeders) and 'bank' them. The value of genetic resources must be continually worked on: it requires maintenance – hence, genebanking activities have the effect of *managing value*, by shaping the flow of germplasm, information, and funding. Moreover, they do so in accordance with different, sometimes competing, priorities and requirements: that is, with the aim of ensuring that social values and economic values are maintained. It is for this reason, then, that we should study genebanks: It can change our perspective on the broader economic context – because it enables us to think about the construction of value and of the economy in the same breath.

In the present account, genebanks emerge as fundamental actors in creating the germplasm economy: I've argued that they create the shared genepool in that they enable the flow of resources (germplasm, information, and funding/labour) in both a technical and a political sense. It is because policy actors entrust them with the capacity to *manage value,* that is, to ensure that genetic resources are accumulated without loss of genetic integrity and disseminated in accordance with the appropriate governance framework that it is possible to talk about a genetic conservation system that has parallels with the tissue economies that Waldby and Mitchell (2006) explored. Hence, my research demonstrates the applicability of their framework beyond tissue economies, although with a different emphasis (further discussed in section 8.2.3).

Scholars in STS and cognate areas have examined the novel ways in which biological material, money, and other resources circulate through new kinds of economies (Parry, 2004; Waldby and Mitchell, 2006). They have shown how banks that house collections of tissues, organs, specimens, and data have a role in managing those materials because they can enable the relative articulation of different values and stabilise them, enabling the continued exchange of these materials (Waldby and Mitchell; 2006; Ehlers, 2015). For example, Waldby and Mitchell (2006) showed how the UK eSC Bank plays a role in 'disentangling' (after Callon, 1998) embryonic material and facilitating its move through different locations and commodity status, thus contributing to the emergence of new kinds of tissue economies where biological material can be transformed from gift to commodity, precisely because these repositories can accumulate and disseminate that material in acceptable terms (economically and socially) and manage potential conflicts between values. In this thesis, I demonstrated that genebanks fulfil a similar role, constructing and accumulating genetic resources whose potential value can not only be preserved, but made accessible, in accordance with international law.

Yet, my findings also suggest that theorising the political economies of biological materials such as germplasm (that is, how genetic resources are accumulated and traded) should involve greater attention to the political economy of biobanks themselves. Genebanks are not passive germplasm repositories; and their role encompasses both the process of continually assuring the value of genetic resources, and that of assuring the continued existence of the conservation system itself. This thesis shows that the multilateral system mandated by the Seed Treaty is grounded on ideas of interdependence and cooperation that are presented as the only way to ensure that the value of genetic and financial resources can be maximised, and its future can be assured. Taking into account the political economy of genebanks as well as genetic resources provides a way to extend the analysis *temporally*, hence recognising the weight that concerns about sustainability and permanence have in organising the germplasm economy. That insight provides a different perspective on the current efforts to create a Global System, by foregrounding the processes of conservation, over and above the speculative calculations on the value of germplasm alone.

To illustrate that point, I return to the Svalbard Global Seed Vault, introduced at the start of this thesis as the exemplar of the germplasm economy post-Seed Treaty, whose rationale is the sharing of resources and conservation responsibilities. It is only once different countries sign up to a governance system that reifies cooperation that the Seed Vault can exist. The Vault thus illustrates the link between the values of the germplasm economy – interdependence, cooperation – and the political-economic concerns regarding the value of the genetic resources themselves. The presence of a global 'insurance system' for genebanks is the sign that this organisation of the germplasm economy is centred on matters of value. Genebanking is an ongoing process that cannot be taken for granted (collections can be susceptible to small and large catastrophes) and that political actors have bet on international cooperation as a way to 'insure' genetic resources via a common 'safety net' against the risk of loss. Ongoing interdependence between countries is therefore seen as a strategy to maintain genetic resources.

My fundamental argument, then, is that in order to understand why the germplasm economy is organised around a rationale of sharing resources and mutual access we should consider that genebanks, too, can be conceptualised as a resource; much like germplasm. One could focus on describing a germplasm economy post-ITPGRFA in terms of access policy; that is, that it mandates multilateral access in order to make valuable genetic resources more available to users (to the possible detriment of donors in that it limits their ability to negotiate bilateral agreements). However, the research findings presented here indicate that (a) genebanks matter significantly in the construction of the germplasm economy and (b) that ensuring the ‘flow’ of genetic resources is cast as important because of conservation, as well as use. There is another set of themes that are deployed to explain multilateral cooperation: the need to *ensure* the value of genetic resources against loss in the genebanks, first and foremost; and also to maximise their value. The germplasm economy is organised around Multilateral access and benefit sharing because, in the case of the conservation of genetic resources, the sharing of genetic resources, data, and responsibilities are presented as the way to ensure that conservation is efficient, yet also economically sustainable.

In the sections that follow I will provide a synthesis of the research findings in this thesis (8.1), followed by a discussion of these results in light of the four empirical Chapters (in 8.2). In 8.3 I consider the future avenues for research that emerge from these findings, before concluding with a reflection on genebanking as a topic that invites reflection on what it means to share resources.

8.1 Summary of the findings and synthesis

In this section I provide a complete synthesis of the research project by reviewing the aims and objectives of this research and providing a summary of the research findings from the four empirical chapters. My findings coalesce into a narrative of genebanking as a process of conserving value, where actors seek to ensure that they maximise the impact, and thus the value, of conserved collections. I argued that genebanks are involved in the construction of genetic resources, and of the germplasm economy, by making germplasm into proxies whose value can be effectively deposited in a genebank and then ‘withdrawn’ later on. Salient themes in this story include the continual construction of the promissory value of genetic resources; the primacy of data as a marker of use value; faith in the transformative potential of new technologies, and ideas of trust and community. The current germplasm economy (comprising the Seed Treaty, the emergence of international databases, and the centrality of cooperation) is grounded on the discourse of sharing: it is only through mutual access and collaboration on conservation projects that the genebanking project can deliver on the objective of preserving valuable genetic resources. Therefore, observing the germplasm economy suggests that the value of biobanks, as well as their biological materials, are significant factors in determining how particular materials are valued and exchanged.

In my Introduction, I argued that genebanks, *qua* banks, enable us to explore from a new angle the 'Multilateral System' of reciprocal access and benefit sharing; by training the analysis on the process of conservation, rather than use, of germplasm. In that sense, it is significantly different from that pertaining to wild biodiversity (set out in the CBD), where bilateral agreements are the norm. Given that social scientists working on biobanks have demonstrated the role that biobanks play in the establishment of political economies of biomaterials (Waldby, 2002; Malinowski, 2005; Waldby & Mitchell, 2006; Waldby, 2008; Hurlbut, 2015; Fannin, 2013; Ehlers, 2015), I started from the hypothesis that genebanks were a significant factor in determining the shape of the germplasm economy. Consequently, I developed three research questions that relate the organisation of the germplasm economy to the work of genebanks, so as to develop an account that can take into consideration how the germplasm economy operates in practice.

1. **How do gene banks transform germplasm into 'genetic resources'?**
2. **How is the shared gene pool constructed in/through the practices and organisation of gene banks through which they accumulate, disseminate and exchange genetic resources?**
3. **What can we learn about the organisation of the germplasm economy (that is, the strategies in place to organise the accumulation and dissemination of genetic resources) by**

studying the practices of genebanks? What role do they play in constructing the germplasm economy?

I then proceeded to review the STS literature about the commodification of science and of biological material, suggesting that although there are compelling accounts of the way new economies arose from the possibilities engendered by biotechnology (inclusively, the ability to store and disseminate biological material and information in new ways) and 20th century socioeconomic regimes (Waldby, 2002; Parry, 2004; Waldby and Mitchell, 2006; Cooper, 2008), such work could be further extended. In particular, I argued that there was scope for closer integration between the work on tissue economies (Waldby and Mitchell, 2006) and that on political economy of biobanks themselves. I've suggested that such a work could be grounded on focusing more explicitly on biobanks as institutions with their own material and economic needs, which had to deal with ongoing broader contexts (in the case of genebanks, the progressive privatization of plant breeding and the decrease in funding for agricultural research) as well as developing ideas about the valorization of biological materials. In other words, this research was grounded on the perspective that genebanks 'matter'. With this I meant that (a) genebanks are part of the germplasm economy and should figure in our explanations of why the governance framework favours multilateral access, and that (b) the continued existence of genebank collections requires constant investment to exist, that is, they are not immaterial. I argued therefore that examining the germplasm economy by focusing on genebanking - instead of focusing exclusively on the exchange of genetic resources 'downstream', as they are used for particular purposes - could be constructive from an STS and Geography perspectives. On a more concrete level, I also wanted to contribute to a discussion on why PGRFA governance was different from the governance of other biodiversity. So, given that the Seed Treaty mandates that Parties should facilitate access to their resources (including germplasm, information, and expertise) as well as share benefits, I set about investigating the role of genebanks in the 'flow' of these resources (Chapters 4, 5 and 6), before discussing the germplasm economy more broadly in Chapter 7.

8.1.1 Genebanks as managers of value

In the first empirical chapter (chapter 4), I explored the role of genebanks in relation to the conservation, accumulation and distribution of germplasm. I used these findings to argue that we can conceptualise genebanking as a means of preserving and disseminating germplasm so as to preserve the value of germplasm (in a technical and a social sense), and whose activities are essential to the germplasm economy. I showed that genebank staff make decisions about what germplasm is valuable enough for conservation; that is, they are selective and must make decisions about how to maximise the value of genetic resources in their collection. In 4.2 I showed how genebanks are involved in the sharing of germplasm by overviewing how genetic resources are incorporated into collections, and how they are retrieved from these to be disseminated to users. This work suggests that genebank staff are ‘gatekeepers’ that manage the supply of germplasm, and demonstrate the value of the material in the genebanks. Simultaneously, genebank managers work to develop the value of the collections, and demonstrate it to potential users in ways that are analogous to that of other collections (paid or not). On this basis, I drew parallels between the work of genebanks and that of the UK Stem Cell Bank: like the latter, genebanks ensure that genetic resources are accumulated in ways that preserve their value in both a technical and an ethical sense and that disseminate these accessions in accordance with the requirements of users and the stipulations of the governance framework. I also explored in greater detail what we can learn about the germplasm economy from the working of genebanks. From this evidence it is clear that the new governance framework places great importance in facilitating the flow of germplasm. Genebanks are the means through which germplasm is distributed and best placed to encourage it to flow. I suggested that in the current phase of the genebank economy, there was a sort of realignment of the job of genebanks: increasingly, they must engage in facilitating use. I’ve argued that such a shift can be explained as reflecting the idea that the value of genetic resources can only be extracted through use. The facilitation of use of germplasm therefore validates the conservation of the material in the first place. Through active efforts to share germplasm, then, genebanks are also making obvious their own value.

8.1.2 Representing value: data curation and the challenge of making value visible

The second empirical chapter (chapter 5) dealt with genebanks' activities and their implications for the flow of data/information about banked genetic resources. Here, I argued that genebanks also manage the accumulation and dissemination of data in ways that emphasise the value of their collection and maximise the potential value of genetic resources to users. Especially, we have seen that there is greater care to maintain that information correct and up to date (because it is such a fundamental part of the value of genetic resources) and to share that information along specific politically sanctioned lines. I began by introducing the different forms of data that can be produced about germplasm, and discussed the hierarchy of value that exists between the different sorts of data. In 5.1 I noted that actors see the availability of data as a challenge to be overcome in order to 'add value' to their own collections by curating and assembling information. Dealing with data, genebanks continuously mind the boundary between public value and private property; therefore managing different, sometimes conflicting priorities. Finally, I argued that the establishment of databases represented a means of constructing both the shared genepool and the germplasm economy as a viable approach. The significance of these databases goes beyond the streamlining of searches for the facilitation of searching through many collections at once. They also serve to provide a means for countries to show selectively what they have to offer, and to comply with the mandate to provide access to the genetic resources that are in their territory, hence providing a representation of the material that was to be shared, and made the value of genetic resources - and therefore, genebanks – increasingly visible.

8.1.3 Funding genebanks, insuring conservation

In addition to examining the role of genebanks in shaping the flow of biological or informational materials, I analysed financial resources and how they structure the activities of genebanks, since the evidence from the previous two chapters showed that funding was a significant factor determining the extent to which genebanks can carry out their practices, both now and in the future, and be part of the broader, international germplasm economy. Yet, and importantly, the availability of funding for genebanks is itself a recognised challenge, and there is a clear relationship between it and the kinds of activities that can be carried out in genebanks, now and in the future. Thus, *ex situ* conservation involves making decisions about how to ensure the continuation of genetic material, but also that of genebanks themselves: conserving the genetic resources inevitably involves making decisions about how best to conserve the genebank (that is, ensuring its financial future) as well. From this perspective, the need to allocate funds in order to achieve the most efficient use of resources and provides a different way to make sense of the sharing rationale. As policy documents frame investment in genebanking as the only way to avoid “mortgaging the future”, it is clear that the current germplasm economy encourages the funding of genebanks by mandating state responsibility for them. Hence, there is a clear relationship between the value of genetic resources and that of genebanks, and this link should be attended to in order to explore why multilateralism is favoured over competition and market approaches.

8.1.4 Conserving the conservation system: sharing in the germplasm economy

The final empirical chapter delved in greater depth into the rationale of sharing and its implications for the organisation of genebanking by focusing on actors’ views on cooperation. It provided a way to understand how interdependence and cooperation were presented as vital for the success of the conservation of genetic resources successfully. I suggested that sharing both germplasm and genebanking capacity was presented as the strategy to make it as productive as possible, and discussed interviewees' views on their own involvement in cooperative activities: what they are for, and what barriers and drivers exist to participation in these projects. I further developed these questions by considering an example of the formal cooperation in practice by looking at the case of AEGIS. Here, the potential tension between common and local goals, and between costs and benefits, come to the fore. It is particularly interesting as a demonstration of the questions facing genebanking staff as they seek to allocate resources. I note, too, the implications of the availability of funding for the geographies of the germplasm economy. I argued that the governance laid out in the Seed Treaty is a means of bridging the requirements of the CBD for national sovereignty with the existing practices of exchange of genetic resources. Instead of creating exchange value for their resources by negotiating bilateral agreements, parties were encouraged to share resources and collaborate – in turn, acting cooperatively is presented as helpful both on economic ground, and as the obvious course of action given the 'interdependence' between countries that exists in the germplasm economy. By bringing into the analysis the factor of genebanks as active repositories, the sharing rationale becomes part of the strategy to ensure the conservation of genetic resources, as well as determining how they will be used.

In summary, then, the findings of these four empirical chapters illustrate how genebanks are actively involved in the creation of both the shared genepool and the germplasm economy in the ways they accumulate and disseminate genetic resources and find ways to carry out long-term conservation. In the next section, I turn to a discussion of these results, bringing together the strands of the different resources in order to discuss each of the research questions in turn.

8.2 Discussion of the results and theoretical contribution

Next, I discuss these findings in light of the theoretical framework for the understanding of tissue economies, drawing out some inferences for the study of genebanks and bioeconomies. The essential message is that these approaches could benefit from including into the analysis the study of biobanks themselves as material entities whose continued existence should figure in the factors that shape the bioeconomy: in other words, as resources whose status as goods is significant too. In other words, a comprehensive answer to the question 'why does the policy with respect to PGRFA conservation and use emphasise interdependence and cooperation?' should include the co-production of the shared genepool and of this specific approach to conservation as a factor, as well as tracing the ways in which materials are transformed into (economically and socially) productive goods once they are in use.

This research shows that the germplasm economy is as much about how to structure conservation – banking – as it is about the status of genetic resources as common goods, public goods, or commodities. Throughout the thesis, there are indications that actors perceive genebanks as institutions whose role it is to preserve valuable resources (and do so on behalf of a variety of user groups), and carry out the work of accumulating and disseminating them in ways that maximise their value; for instance, through characterisation work, or engagement with users. Moreover, policy documents and interviews alike demonstrate a general concern with forward planning and how to ensure the sustainability of genebanks: talking about the conservation of genetic resources is inevitably also a conversation about how to conserve the genebanking system. For that reason, then, I argue that Waldby and Mitchell's (2006) framework is an important starting point for an exploration of biological resource economies, but that it can be extended to incorporate the biobank itself as a part of that economy more fully, by considering genebanks themselves as resources that have their own materiality, costs, and status (for instance, as public goods). I develop this suggestion further with the discussion of each research question, below (section 8.2.1-8.2.3). Considering genebanks as nodes in the germplasm economy, but also as resources, means that their continued existence is not taken for granted. In so doing, it brings genebanks into the account as active constructors of both the genepool and the germplasm economy, but also as dependent on other debates about the role, and support, for genebanks themselves. Genebanking's own economies influence the ways in which genetic resources are valued, maintained, and exchanged. Therefore, writing STS analyses of these tissue economies or germplasm economies should also explicitly take into consideration the relationship between the political economy of biological resources and that of biobanks themselves.

This thesis also provides some insights into genebanks as sites of activity and production of genetic resources. These can contribute to the nascent body of academic thought on genebanks (Kloppenburg, 2004; Bowker, 2005; van Dooren, 2009, Waterton, Ellis and Wynne, 2013). Van Dooren (2009), as previously stated (see section 1.2.1), argued that genebanks, if they were to 'bank well', needed to ensure the continual flow of seeds, not (necessarily) as genetic resources for use by breeders, but also to other user groups so that a diversity of crops may continue to exist. My findings concur with his insights regarding the emphasis on use value. Yet there are also indications that genebanking actors, too, advocate the distribution of seed to a greater variety of users, including farmers, hobbyists, or education groups as well as the traditional user groups of plant breeders and researchers. I interpreted this effort to engage as part of the drive to maximise the value of the existing collections. In that I include the multiplicity of values that seeds can have (as Haraway, 1997 noted), and which genebank staff were aware of.

In detailing genebanking as an ongoing process, my account also speaks to the suggestion that genebanking can be construed as an archive of nature (Bowker, 2005; Waterton, Ellis and Wynne, 2013), that promise the possibility of creating totalizing representations of nature at a time of biodiversity loss. Building on this work, I have previously suggested that genebanks can also be construed as archives because they emerged in the 1960s-70s as sites for the conservation of mainly old, localised landraces. Hence, describing them as archives brings to the fore how genebanks were seen as a way to disrupt the ongoing 'erosion' of landraces by newly bred, scientific varieties (Peres, 2016). Indeed, one might say that the establishment of genebanks and associated institutions made possible new geographies of genetic resources, as they accumulated and disseminated germplasm through networks of germplasm users at breeding institutes or companies, agricultural research stations, and other places of use.

Kloppenburg's work remains very significant on the implications of the privatization of plant biotechnology and the geopolitical implications of genebanking. My thesis has sought to extended his interest on the implications of the 'germplasm flow'. It has shown that the questions he raised about the governance of access to genetic resources remain live ones, and suggests that the coming into force of the Seed Treaty does appear to have spurred on new efforts to assert interdependence and the need to consider PGRFA as part of a shared genepool. The full implications of these shifts towards greater collaboration and rationalization, with a view to maximising the value/s of genetic resources and genebanks alike, remains to be seen. Yet it is interesting to note that, despite the shift in the status of PGRFA away from 'common heritage' to 'resources under national sovereignty', the idea of the PGRFA as a commons, that Saraiva (2014) identified in his work, has hardly disappeared as an concept in discourse (although especially in policy documents - see for example Falcon & Fowler, 2002; Dedeurwaerdere, 2010; Halewood et al., 2012a). I have shown that the characterisation of genetic resources as part of a commons, or a shared pool, is an important factor in determining how actors strategize their banking. This particular strand of work deserves further empirical development.

Having situated my research findings in relation to the literature about genebanking specifically, I will now turn to the two theoretical implications that follow from incorporating the analysis of genebanks more fully into the study of biomaterial economies: one about variation in genebanking over space and time, and the other regarding the political economy of technoscience itself. The first point is related to the opening up of the genebank to analysis. By following the ways in which these sites evolve and adapt to over time, their historical contingency becomes part of the analysis. This approach makes it possible to add to the analysis a certain sensitivity to the spatial and temporal dynamics of biobanking. This is particularly helpful in the case of the germplasm economy, where the objective of long-term conservation figures as an important priority in defining its organisation. Being attentive to the work that goes into maintaining germplasm, and genebanks, over time demonstrates that there are significant dynamics to it. As Bowker (2005) has argued, the creation of large biodiversity archives of data and material is tied into a specific temporality and approach to collecting, where the present can be ‘frozen’, hence ensuring the preservation of future options; but which in fact requires constant work to maintain. The case of genebanking presents certain examples of that work taking effect, and provides some clues regarding its influence in the organisation of the germplasm economy.

The second point, in turn, focuses on the implications of my conclusion for the relationship between the political economy of genetic resources and that of genebanks. If, as I have found in this thesis, genebanking is at a phase of potential transformation (with attempts to create a more ‘rational’ and integrated genebanking system), it is also clear that this change is understood by participants as part of the need to respond to developments in the broader political economy of agricultural research and conservation funding. In addition, it is notable that the language of economics is incorporated into the strategizing of conservation: terms like efficiency and rationalization therefore become applicable to the management of the genepool. This systematic correlation between the project of managing the valuable genepool and creating the effective and efficient conservation system show why it is important, as Birch (2013) argues, that STS trains its analyses on the relationship between economic rationalities and technoscience. Arguably, such work is far better developed in relation to commercial activities. We know from the work of Martin et al (2008) that commercial biobanks create narratives of hope in order to encourage people to buy into their services. Yet the case of genebanks presents a different, but complementary, situation as it refers to the development of biobanking as a common project.

Pursuing this analysis in depth has the potential to provide different perspectives on matters such as value, too, by developing an analysis of the role of genebanks in its creation. In response to Waldby and Mitchell (2006), I argue with Birch and Tyfield (2013) that value is not inherent to biomaterials, but is rather dependent on the work that genebanks put into maintaining and building it. Yet, what is interesting about the situation of the germplasm economy is that value here is not necessarily exchange value, but rather *use* value. Therefore, the case of genebanking is different from the study of other tissue economies where the material can be sold as is. In order to do so, I bring together the different strands of the argument from each chapter in order to address each research question in turn, as well as discussing their theoretical implications.

8.2.1 How do genebanks transform germplasm into genetic resources?

The first research question aimed to explore how genebanks were involved in the construction of genetic resources in order to demonstrate how germplasm is constituted as a valuable resource through conservation processes. It showed that genebank staff are engaged in particular political economic decisions as they do so. In turn, the empirical findings that provide an answer to this question offer a way into discussing how we think about value, and values, in bioeconomies. More specifically, it suggests that we need to pay more attention to the funding of biobanks themselves, because they underpin the ways in which 'valuable' genetic resources are created. Thus, thinking about bioeconomies requires that we take into account not only the political economy of the biological materials, as Waldby and Mitchell (2006) suggested, but also the political economies of genebanks themselves: after all, the two are related. The answer to this question can be summarised as follows: the process of genebanking can be seen as a means to accumulate germplasm in such a way as to make its ‘integrity’ - in both a physical and ethical sense – and, in so doing, make them valuable to potential users. I am claiming that genebanks construct germplasm as genetic resources, that is, as ‘bankable’ proxies that can contain the valuable genetic diversity in such a way that it can be kept and drawn from in the future.

Creating ‘genetic resources’, then, means maintaining germplasm in such a way that its ‘actual or potential value’ is maintained – so that their use value can eventually be realized. The evidence in Chapter 4 led me to argue that genebanks are responsible for maintaining the value of germplasm, so it can be maintained and is retrievable as required. They are responsible for ensuring that the germplasm they keep maintains its genetic integrity – and, therefore, its value. Genetic resources act as proxies (Parry, 2004; van Dooren, 2009) because they stand in for the particular adaptations that existed between specific plants and their environment. Although what is being kept is genetic material, the aim is to keep the genetic information encoded within – and in such a way that it can be retrieved. So, once a sample enters a genebank, it takes on a particular classification; it is not simply a seed/sample of seeds but simultaneously it is a source of particular genetic materials that exist at a specific place and time: as *records*. However, that task involves its own awkward materiality, as actors seek to maintain the genotypic variation of the sample by manipulating/preserving the genetic material, including by regenerating the sample if needed.

Genetic resources are therefore *disentangled germplasm* (after Callon, 1998; Waldby and Mitchell, 2006) that is available, technically and socially, to others. It is not ‘tied’ to its place of origin. Through the processes of preservation and of classification/description that they undergo as they become part of the catalogues and databases that make them visible to potential users as resources that can be accessed under particular conditions of exchange, and that are more or less part of the common genepool. Nonetheless, in order to assess the use value of proxies, users need information about their traits and context in order to make decisions about what genetic resources have potential use value for them. Genebanks therefore also strive to keep/manipulate the value of genetic resources by creating, accumulating and disseminating *data* about these genetic resources (although this is expensive). Moreover, information about accessions is standardised - such standardisation this is important as it makes 'local' germplasm into a more global resource, because it could (theoretically) be understood as part of a global representation of diversity and understood. Interestingly, the trust in the information keeping at the genebank is one of the ways in which people might measure their trust in the genebank as a whole. The accumulation and maintenance of data is interesting because it requires curation over time, or at least some awareness of the 'history' of the accession/data itself. Bowker (2005) demonstrates the problems with the keeping sufficient context to enable data to be re-used after its original creation; and indeed with making global representations of biodiversity. So, in order to successfully create genetic resources from germplasm, it is important that genebanks have the sort of data which enables potential users to make the link back to the original context of the germplasm. The thesis findings, then, make evident that the value of genetic resources is a function of factors external to the germplasm itself, namely, characterisation and evaluation work. Moreover, it appears that one of the main features of genetic resources are their underdetermination *a priori* – whether or not the potential or actual value of the material will ever become concrete depends on the use it might have at some unspecified point in the future, as well as the way in which it is distributed. By pointing to the constructed nature of genetic resources, another significant factor becomes evident: if (genebanking) labour goes into maintaining the value of genetic resources, there is a limit to the 'carrying capacity' to the genebank, which is a function of the financial input that it has available.

Ex situ conservation – or rather, the transformation of germplasm into a 'genetic resource' is actually a process, not a one-off. It requires constant, ongoing work and money (or, if you will, material and human 'input' - e.g. energy for freezers, expertise and people-power to do the regeneration and so on). In Chapter 6 we see that the organisation and activities of genebanks is shaped by the need to guarantee funding - a great concern of genebanking actors; and how they think about the best way to do/organise genebanking (needs to make the best possible use of money). One might go as far as to suggest that the value of genetic resources is a function of the biomaterial, but also of the funds available for conservation. Indeed, we see how actors in different genebanks cooperate in order to try to maintain the value of these genetic resources and ensure that it is not lost – for instance, through programmes of emergency regeneration.

These findings lead me to suggest that genebanks certainly appear to play a role that is quite analogous to that of the UK Stem Cell Bank, as told by Waldby and Mitchell (2006). However, although studies of biobanks like the UK Stem Cell Bank have contributed an important insight in noting how biobanks can be sites for the management of value and values in the bioeconomy, this framework could be extended to include more attention to the political economy of biobanks themselves, as well as that of the materials that they carry. That move would shed some light on the role of genebanks in the creation of (bio)value in the germplasm economy; this would also complement existing work that identifies the labour undertaken by research participants and others as the source of value in biobanks (Waldby and Mitchell, 2010; Tutton, 2010).

In summary, then, the answer to the first research question shows that genebanks create ‘genetic resources’ out of germplasm by generating accessions that are kept in such a way as to be available, searchable, and selectable in accordance with the requirements of users: they must be appropriately stored and, ideally, as characterised as possible. Doing so requires work and management on the part of genebanking staff, it is not passive – without enough input/work to ensure that accessions are well preserved, they might lose its value over time. In that way, this transformation requires its own resources. Therefore, the answer to this research question also illustrates the active role of genebanks within the germplasm economy: it is through the ways in which they keep the material ‘substrate’ of these genetic resources (the seeds) and how (much) context we have about the traits that users consider the value of genebanked activities. When germplasm enters the genebank, it is transformed into a genetic resource in the sense that it becomes retrievable from that collection, in accordance with the needs of the (potential future user). In the next section I turn to the second research question, that deals more directly with the ways in which genebanks' activities shape the shared gene pool.

8.2.2 How do genebanks construct the shared genepool?

The second research question was dedicated to investigating how genebanks construct the *shared genepool* through their quotidian practices and organisation. Genebanks create a shared genepool both in a practical and representational sense: firstly, the genetic resources that they keep can be made available to users at the global level, through the Multilateral System. Secondly, 'the genepool' itself can be represented and understood at the international scale through the use of standardised descriptors.

The starting assumption for this question is the perspective that the germplasm economy – and the shared genepool – are co-productions (Jasanoff, 2004): they should not be understood as social constructions or wholly technical/material networks, but rather as hybrids where both material and political aspects of genebanking shape the constitution of the pool and the economy. Therefore, it is important that we try not to essentialize, nor give primacy to, either the economic nor the scientific realms (Sunder Rajan, 2012) when developing an account of the way genebanking has evolved.

A good example of the 'hybrid' ways in which social and technical factors matter to the germplasm economy is that, as noted in Chapter 4, both are important in determining whether any particular accession is available at a given time. Not all samples are accessible to everyone everywhere or under the same circumstances. This means that genebank staff are also responsible for making decisions about what genetic material is can be shared, to whom, and under what circumstances. In so doing, they are involved in working out the boundaries of what is and what isn't in the shared genepool. The shared genepool is not necessarily all that is available at the genebank at a specific time: factors determining the sharing of germplasm include national and international policy; certainly; but also plant health/quarantine requirements, as well as the availability of seed - conservation vs use, and the validity of requests). In Europe, certainly, genebank curators seek 'openness' and making the collections accessible. The implication of this finding is that explaining what accessions are and are not shared in the germplasm economy should include *material* factors, as well as, say, political or technical reasons.

Another conclusion emerging from the study of data is that the shared genepool can be constructed also through its *representations* as well as through the classificatory practices that occur in each genebank, as noted in the study of the construction of databases (chapter 5). I've shown that there are standard ways of describing these resources - there was, from the beginning, an attempt to create a 'common language' for genetic resources that made them available to everyone and enabled people to understand (and compare) the materials that were kept in the genebanks across the globe. In addition, there are new – and increasingly comprehensive – means to share data about what genetic resources exist and are available through the creation of databases. My suggestion here is that the novel databases that provide information about the collections available in different genebanks, such as EURISCO, produce representations of the shared genepool that emphasise the parts that are commensurable. Hence, the information provided through EURISCO provides a way to visualise, and search, the genepool at a broader scale than that of the individual collection; while also 'hiding' the local context by virtue of only being able to incorporate information about the history of the sample, but not necessarily its 'local' conditions in the genebank. So, it recalls Bowker's (2005) argument that comprehensive biodiversity databases are nonetheless only able to contain and reproduce specific representations of biodiversity and not others: they must fit within the prevailing data structure and political economy. These databases are a hybrid artefact that produces representations of the shared genepool and (re)create the germplasm economy: because they bring together the catalogues of different collections, they both increase the scale at which the genepool can be visualised *and* make the various sources/locations of germplasm visible to different actors scrutinizing the collections through these databases. Through the standardisation of data about the available holdings and through the setting up of data flows that make the shared material more visible, genebanks end up creating a shared genepool that is both visible and (to the eyes of actors) more accessible.

The findings on Chapter 6 show how the genepool (meaning, the accessions in storage in the different genebanks that exist around the world) is becoming 'shared' in the material sense; that is, that there are some actors and organizations involved with the organization of genetic resources conservation who advocate closer coordination between different genebanks. I've argued, with respect to rationalization, and the establishment of the European collection (AEGIS), that the MLS was a step towards the sharing of the genebanking effort, with different countries encouraged to share the responsibility for the material that has been kept within their collections. Doing so would also make these geographically distinct collections into parts of the same broader genepool, in terms of access. It is in that sense that, I suggest, we can talk about a shared genepool. It is notable that now the 'shared gene pool' can be constituted even without the physical removal of the individual seeds from different countries, as was seen in the case of AEGIS: it is sufficient to have an agreement in place whereby countries agree to take responsibility for the conservation of different parts of the genepool.

In Chapter 7, then, I explored in greater detail the relationship between the shared genepool and the germplasm economy. Mutual access, and the sharing of responsibilities for conservation, is presented in the policy literature as an obvious step that should be taken: *not* doing so is inefficient, similarly, the concept of *interdependence* is deployed often as a reason for this organisation of the genepool: *not* sharing genetic resources goes somewhat against the main principle of interdependency. AEGIS exemplifies the effort to share conservation responsibilities at the European level. Again, it is notable that it too has to deal with the difference in financial capabilities between different genebanks. Taking into account the constructed nature of genetic resources and the work that goes into maintaining them, it follows that one might argue for the inclusion of genebanks themselves in what we consider to be ‘the genepool’ in its material form. This shift in perspective follows from my suggestion that we need to consider the genebanks as active sites for the construction of genetic resources and the germplasm economy. Altogether, the findings on Chapter 6 and 7 lead me to suggest that the concept of the shared genepool is actually as much about conservation as it is use. In other words, we see how cooperation/global system is grounded not only on the idea that people need access to the genetic resources in other countries too, but also that if people share the responsibility for the conservation of the genepool then it is more likely that the material can be conserved appropriately. We can think of this new phase as providing an interesting workaround whereby it is up to the countries that constitute it what, precisely, gets to be part of the ‘global gene pool’. This point is made most clearly when thinking about the National Inventory and the simultaneous traceability of the material through the Reporting Mechanism of the Seed Treaty.

The new tools that have emerged after the Treaty mean that there is a renewed expectation for the ability to create a ‘global gene pool’ which works because it is now possible to share resources (money, information, germplasm, labour) in a much faster way, meaning that genebanking could work as an international effort without side-lining the concept of national control over genetic resources. Yet simultaneously, these changes (e.g. databases, creating standards, sharing responsibilities) could potentially end up leaving behind those countries/genebanks that do not have the resources (either genetic or financial) to ensure their ‘presence’ in the global gene pool. Moreover, even though the idea is that this is a ‘global’ system, there are re-territorializations taking place that mean that not everywhere is ‘the same’. Hence, the global genebanking system works due to voluntary actions on the part of countries; they are modulated very much. The potential value of the germplasm could be applicable to any country, regardless of where the seeds came from.

Effectively, the shared genepool is also constructed through the activities of genebanks at the level of conservation, rather than 'only' mutual access through the sharing of capacity. We see for instance that there are opportunities for genebanks to collaborate: they keep each other's material for safety duplication; they might take into account what is happening in different collections when making decisions about how to manage one's own. The Genebank Standards and ideas like rationalization, therefore, indicate that the conservation of genetic resources is envisioned as operating at an international level.

8.2.3 What, then, do we learn about the germplasm economy?

Where the previous two research questions dealt with the role of genebanks in the creation of genetic resources and the idea of a shared genepool, the last one deals more directly with the concept of the germplasm economy, that is, the *strategies* that are in place to [manage/organise] the accumulation and the distribution of genetic resources. With this question I aimed to characterise both how genebanks were involved in organising the sharing of germplasm and data *and* how their practices were important to de/legitimise particular economies; namely, a germplasm economy that is organised around the concept of interdependence and sharing.

Waldby and Mitchell made the case that there is no obvious distinction between a gift economy with social values and a market economy, here we see a similar problem. Taking into consideration the use side alone, one might develop two quite different interpretations of the Seed Treaty. One might be that it represents a move *against* the progressive commodification of genetic resources, because it clarifies that the material in the shared genepool cannot itself be enclosed. In that sense, it encourages access over protectionism. Yet, another perspective is also possible: that the MLS in fact facilitates the appropriation of germplasm by actors that can extract from it economic value, while not enabling the countries of origin to benefit monetarily, and directly, from that resource. However, incorporating the genebanks more thoroughly into the analysis proposes a different possibility; that the idea of interdependence in the germplasm economy is articulated as the way to ensure the continued existence of the genebanking system and its resources.

The germplasm economy is undergoing a period of transition after the ITPGRFA. As described in the empirical Chapters, genebanks are re-focusing on the sharing of germplasm, and the usefulness of banked materials is increasingly important to the funders and other genebanking actors. Moreover, genebanking staff and users work to make data available and accessible so as to make visible the value of genebank collections. They also construct the representation of the genepool at larger scales, thus providing the impression that all these different institutions are part of the same, shared genepool. Based on the empirical findings of my research I have argued that this is an economy where decisions and activities generally tend to be geared towards the maximisation of use value. Yet what is particularly significant here is that this particular regime is not geared towards the accumulation of profit from genetic resources; under the MLS, there is no *direct* financial incentive for genebanking. Instead, in this case, the arguments made for the continued support of conservation activities are based on the value of genetic resources, but similarly, the very investment in conservation is a form of investment in a project that is designed to provide a service. It is, in that sense, a ‘resource’ or public good in and of itself – and it is in that sense that the maintenance of genebanks becomes part of broader trends in the funding for science and institutional arrangements. These have been explored in STS with respect to the political economy of knowledge production (Etzkowitz & Leydesdorff, 2000; Gibbons et al., 1994; Nowotny et al., 2013)

Yet this framing also enables countries to have the ‘final say’ over what germplasm they are willing to donate, and which they wish to keep private. We see a similar thing at play with the sharing of data: some, but not all, is in the public domain; and commercial values vie with openness. So the shared gene pool is a subset of all genetic resources, and it is organised at a supranational level. Curators and other staff were rather keen to encourage users, rather than *dis*courage them. We saw, in the evolution of the role of genebanks in the germplasm economy, how their role was thought to evolve away from being ‘a museum’ to having to be more focused on the user and the requirement for the facilitation of use. So, the successful genebank is one that can demonstrate that it is engaged in sharing its collection.

Genebanks carry out the germplasm economy in the sense that they enable the release of material under the terms of the MLS and therefore bridge the boundaries between national sovereignty and the need to contribute to the global conservation effort. It is in these places that the everyday practices of providing resources (chapter 4 and 5) and also expertise/spare capacity (chapter 6) happen together. Genebanks are the official sources for acquiring genetic resources that have attached particular (potential) value – in terms of their genotype/phenotype but also, as I argued in chapter 4, ‘ethical’ value. In other words, the genebank is a site for the accumulation of use value and social values, if not necessarily the extraction of commercial value.

The germplasm economy itself is arranged around the idea of interdependence in the sense that the successful development of conservation is tied into the maintenance of ‘germplasm flow’. This ‘sharing economy’ is the correct approach to ensure that the project of conservation is successful – it cannot be developed as a market, but has to be carried out through cooperative work and facilitated access. It is only through this approach that the potential value of the material kept in genebanks can be realised. Indeed, it is for this reason that we see the emphasis placed on new initiatives to increase access to information, such as the new databases explored in chapter 5. If the political economy is constituted around the idea that the germplasm economy is international, transparent, and cooperative, the new databases (such as EURISCO) are the tools through which it is enacted. These permit the visualization of the material in different collections/countries through the same platform. For this reason, they are seen to increase accessibility to the *information* about what is kept in the collections too. So, as argued, the germplasm economy appears to be arranged around the idea of interdependence. The case of international cooperation and the different perspectives regarding the 'best' way to organise the germplasm economy lead me to identify certain questions that are, I think, quite fundamentally about political economy. Chiefly, how best to distribute resources and who should be responsible for specific conservation duties. Once and again, there are questions about the relative priorities of countries and how the idea of international cooperation is expected to play out in practice. Yet the solution that was arranged is necessarily one which relies almost on the 'good will' of countries. Importantly, the funding of genebanks itself becomes a core part of this argument, because the correct 'reward' is not necessarily financial. the circumstances where the funding for genebanking itself is getting to be problematic and funders are looking for signs of impact.

A sharing regime, then, is presented as important for the success of conservation in the germplasm economy. That is to say, the flow of germplasm should be encouraged, if the value of the germplasm is ever to be realised; but there is scope for countries to have the 'final say' over what germplasm they are willing to donate, and which they wish to keep private. We see a similar thing at play with the sharing of data: some, but not all, is in the public domain; and commercial values vie with openness. The argument seems to be that cooperation is more efficient because it means a 'better' allocation of money to genetic resources. As Waldby and Mitchell put it, it is indeed a way to adjudicate between different claims on resources and work out which values are the most important. So, for example, the idea of having a 'global' system involves the idea that control over genetic resources is not as important as access to those resources. However, there might be a tension here between the scales: what might be a priority at the global level might not be so at the local level, and vice-versa. I believe that the current attempts at organising collaborative projects like AEGIS show how actors have sought to resolve the tension between national autonomy and global economies.

8.2.4 General summing up

We should study genebanks (and other biobanks) if we want to understand the economies that they inhabit – because, as the findings of this thesis suggest, genebanks are completely essential to the *construction* of these economies. Consequently, when we want to understand why tissue or biomaterial economies are organised in a particular way (for instance, asking why is there a Multilateral System for PGRFA) we should not disregard the sociotechnical and material factors that shape the ways genebanks work. That is why undertaking this empirical research into the practices of genebanks is helpful: it shows that the value of specific genetic resources is constructed and continuously managed, crafted through technoscientific practices of collecting and describing that have effects on the materiality of genes and ontology of germplasm – in ways that make that value conservable into the future and across space. It is not, therefore, an exclusively political economy; but rather one where materiality and political concerns both create the eventual shape of the germplasm economy at the international scale.

In turn, that means that genebanks have to maintain their own funding in order to ensure the value of genetic resources is kept. Hence, the work on the tissue economies and the role of biobanks by Fannin (2013), Waldby and Mitchell (2006, 2010), Ehlers (2015) provides a way to begin to approach the ways in which genebanks construct the value of genetic resources over time. However, as the present research shows, it would be helpful to continue to develop the concept of biobanks themselves as resources: to understand why the germplasm economy is arranged as a multilateral system, we should look beyond the implications for access to genetic resources and to genebanks. My research suggests that the germplasm economy is arranged as it is, multilaterally, because it is underpinned by a logic of ‘flow’ where the way to maximise the security of the collections and the value of the material is by making it accessible. These collections ‘matter’ in the sense that their circumstances influence how the germplasm is managed. Genebanks are far from passive repositories for germplasm, not only in the sense that they maintain, manipulate, classify, the germplasm – but also because they create both the shared genepool and the germplasm economy.

The present case study suggests that STS analyses of tissue economies and of collections should take into account how the continued existence of these collections is itself a factor shaping the organisation of the germplasm economy. We should think about the external factors to the collections, as suggested by Birch and others: not think that they are insulated from the changes to the broader political economy. Doing so demonstrates that the current shape of the germplasm economy, with its attempts at decentralization, coordination across borders, and so on is a response to the increased concerns about efficiency and demonstration of use value. In the contemporary phase of the germplasm economy, curators are engaging in activities that can make the value of genetic resources visible; either by engaging users, or facilitating access to collections. A conceptual framework that includes both STS and political economy makes it possible to follow the relationship between genebanking practices and broader changes to the political economy of genetic resources. The germplasm economy is based around sharing not (only) because of the concerns with accessing the value in genebanks, but also because sharing is a way of justifying the existence of the conservation system itself – because it increases the possibilities of making that use value visible. I have found that both genebanking and the germplasm economy are constructed as endeavours that should be international and based on mutualism/cooperation if they are to be successful; and it seems very clear that success is defined as the availability of genetic resources for use.

8.3 Further work

The conservation of plant genetic diversity, *ex situ* or not, is a very rich topic, ripe for further exploration: the present thesis is not intended as a final or totalizing account of genebanks and their role in the broader germplasm economy. In this section, then, I propose further directions that such research could take in order to contribute more empirical data and extend our theoretical understandings of genebanking. They can be parsed into investigations of individual genebanks, on the one hand, and further work on cooperation and the broader germplasm economy on the other.

My decision to focus on the activities of genebanks in order to make sense of the germplasm economy means that there is less detail on the practices and history of *individual* genebanks. Studies of individual genebanks would therefore be a very worthwhile next step. This is because studying genebanks requires attention to the local and historical specificity of germplasm economies, which is best understood through more long-term study of different sites. Single or multi-sited ethnographic research would be very welcome, as it would complement the data available on actors' conceptions of genebanks with greater detail about their *practices* and meaning-making (Geertz, 1976; Spradley, 1979; Wolcott, 1990). This approach would be particularly suited to understanding the day-to-day work of conserving valuable resources, and provide far more detailed insight into the valuation and management practices that go on in genebanks. Moreover, anthropological approaches to understanding value (see for example Graeber, 2001, 2005) might provide a methodological and theoretical stepping stone with which to explore the construction of potential and use value further. Moreover, an ethnographic study would be an excellent way of developing accounts of the material and classificatory practices of genebanking. Such knowledge about the fundamental bases of genebanking feed, in turn, into further research into the construction of genetic resources and their constitution. The differences between the various types of genetic resources, for example, are ripe for further exploration, both in terms of their origin and the interaction between germplasm and biotechnology; after all, there are significant differences between, for example, germplasm as seed versus in vitro cell culture or a field collection. Studying the material practices and infrastructures of genebanking at this level, then, will contribute to a broader understanding of the themes raised in the present thesis.

There is also scope for considerable more work describing and analysing the broader constellation of genebanking, with or without the concept of the germplasm economy. One clear avenue to explore is the geographical one. As so often happens with case study research, representativeness is a significant issue (Yin, 2013, pp. 42–43): the choice of empirical case studies shapes what the observations of this particular region, but we should not expect that it applies equally to all. One must, therefore, be careful to delineate the geographical region to which this work applies. My focus on Europe was grounded in a methodological decision to observe the germplasm economy within a context where there is significant political unity and long-standing collaboration. In European countries, *ex situ* crop conservation has some technical, governance and political aspects in common (such as EURISCO, the ECPGR, and the E.U. signature and ratification of the ITPGRFA as a bloc). Among these countries, actors tend to subscribe to the suggestion that germplasm flows are important, along with a cooperative ethos. However, and as the findings corroborate, there are still important geographical differences even within the region - and these are empirically productive. To continue the study of this particular case, then, a more detailed analysis of genetic resources cooperation over time would be a way to historicize the findings from this research and develop a sense of how policy, institutions, and technoscientific aspects of genebanking developed over time. Particularly, a study of the common tools developed in the context of regional cooperation, such as EURISCO, could provide a means to interrogate the role of shared tools and representations in these projects of international collaboration.

I opted for a broader geographical coverage over more in-depth study of individual collections. This choice is justified for what I have learned regarding different local/national attitudes to specific issues, like cooperation.

By analysing the discourse and themes emerging from the research, my aim was to draw out the common ground between different genebanks, and develop an account that can speak to the broader political economic issues. However, the situation can be different in other countries (for instance, in South American countries with high levels of crop diversity), whose national policies advocate tighter controls over access to their genetic resources (I6). Thus, we should expect that there are other aspects that would become visible if the research was expanded to include other regions. It is highly likely that the relationship between the practices of genebanks, their political economy, and the values accorded to genetic resources have their own geographies. Nonetheless, there is no reason to suggest that the *association* between the three (which is the focus of my thesis) would not be found, but they might be contingent on different geographical contexts. Chief among these outstanding questions is the ongoing question of what relationships are constituted between the global North and the global South in these germplasm economies, and are they fair, sustainable, or productive? I would argue that the incipient understanding the MLS as an economy that I provide in this thesis is a step in that direction, but it is clear that it can only work with further dedicated empirical attention to other regions and a future comparative approach.

In addition to extending these analyses geographically, it would be helpful to map further the interactions between genebank actors and users of various kinds. This approach would be a step towards exploring further how these relationships relate to the ways genetic resources are kept, described, and disseminated. Indeed, this enquiry could constitute part of a broader comparative analysis of formal and community genebanks – an approach used successfully by van Dooren (2009), albeit at a small scale.

Finally, historical studies of genebanking would be very welcome. As this thesis demonstrates, there is a definite temporal dynamic to ex situ conservation, visible in the ways in which the role of genebanks and their organisation have changed over time. It is important, then, that historical perspectives are brought to bear in the study of genebanking more broadly.

Such work could involve both archival research, especially as more archival material might become available, and oral histories, thus providing a very different, and complementary, set of sources to complement the more official, published sources that were analysed here. Such work would, however, do far more than historicise contemporary genebanks: it is a fundamental step in exploring fully repositories whose entire purpose is bound into notions of avoiding loss and creating spaces where germplasm can be maintained into the future. As I now conclude with, that effort involves constant work in the present, and fundamentally shapes genebanking and its organisation.

8.4 Back to the Seed Vault

Having explored the relationship between the organisation of the genebanking system and shared genepool, I conclude with one last look at the Svalbard Global Seed Vault. My conclusions suggest this unique structure is not as much an example of the way technoscience enables the ‘freezing away’ of genetic resources, but instead a sign of the ways in which genebanking is a contingent and continual process, rather than an act of depositing. Indeed, the process of preserving germplasm ‘for the future’ requires constant work in the present, and is the result of the emergence of networks of plant scientists, conservationists, and users, with quite different experiences, perspectives, and interests. Unsurprisingly, then, the Vault (and conservation more broadly) is enrolled in narratives where genetic resources exchange figure as part of a hopeful future. The Svalbard Global Seed Vault emerges as the latest development on a longer history that is powerful precisely because it brings to the fore the issue of sharing and how it relates to the architecture of conservation. Genebanking systems are being constructed and (re)defined as actors go about reflecting on what it means to be interdependent, and what constitutes a fair and efficient system when there are such great differences between countries and their resources, both genetic and material.

It is significant, then, that the Vault is described as a global ‘insurance system’. The idea of crop genetic resources as a global concern are fundamentally linked with the way in which we choose to distribute value – the ultimate economic matter. But it also springs from actors’ concerns about what is valuable about biodiversity (what is a resource?), and about the kind of sociotechnical system (read: society) that can maintain and manage the ‘actual or potential value’ of genetic resources (what does it mean to be ‘interdependent’?). Therefore, I hope that this work might contribute to our understanding of what it means to maintain genetic resources for the future, while not neglecting the very real, contemporary issues that come with our newly-found capacities to keep, order, and share plant material in novel ways that are mediated by technoscientific apparatus such as genebanks. They are interesting because they have created a situation where the future of collections becomes an issue of technical but also political import, and where the future – both that of the collections and that of the germplasm contained within – will be important in shaping the decisions that are made in the present.

Yet the story of the contemporary political economy of genebanks also invites a more general reflection on the ways in which different actors conceptualise and negotiate ways of working together for the sake of a common good, and bring the possibility of sharing not just material (or genetic) resources, but also genebanking itself as a good. The work and capacity required to maintain crops that are, in a very real sense, part of the (bio)cultural heritage of humanity, as well as essential for our collective future. It is this tight weave of values, histories and potential that make the germplasm economy so intriguing. Studying genebanks is always, in some ways, an exploration of people’s ideas for the future and how to achieve it; therefore, to find a sense of collective purpose: a story about how to maintain future possibilities alive, even against certain obstacles. As such, it invites reflection on our own work, and how we might seek a social studies of science that is open to possibilities – that is, be optimistic about human nature – without losing its critical edge. While that objective, too, remains largely a possibility (at least as far as the present work is concerned), it is a reason to be hopeful.

CHAPTER 9 APPENDIX 1: 'ANNEX 1' CROPS

This list[50] sets out the genetic resources that are to be made available through the Multilateral System set out by the Seed Treaty.

Food crops

Crop	Genus	Observations
Breadfruit	Artocarpus	Breadfruit only.
Asparagus	Asparagus	
Oat	Avena	
Beet	Beta	
Brassica complex	Brassica et al.	Genera included are: Brassica, Armoracia, Barbarea, Camelina, Crambe, Diplotaxis, Eruca, Isatis, Lepidium, Raphanobrassica, Raphanus, Rorippa, and Sinapis. This comprises oilseed and vegetable crops such as cabbage, rapeseed, mustard, cress, rocket, radish, and turnip. The species Lepidium meyenii (maca) is excluded.

[50] Available online at http://www.planttreaty.org/content/crops-and-forages-annex-1. Accessed 28.08.16

Pigeon Pea	Cajanus	
Chickpea	Cicer	
Citrus	Citrus	Genera *Poncirus* and *Fortunella* are included as root stock.
Coconut	Cocos	
Major aroids	Colocasia, Xanthosoma	Major aroids include taro, cocoyam, dasheen and tannia.
Carrot	Daucus	
Yams	Dioscorea	
Finger Millet	Eleusine	
Strawberry	Fragaria	
Sunflower	Helianthus	
Barley	Hordeum	
Sweet Potato	Ipomoea	

Grass pea	Lathyrus	
Lentil	Lens	
Apple	Malus	
Cassava	Manihot	Manihot esculenta only.
Banana / Plantain	Musa	Except Musa textilis.
Rice	Oryza	
Pearl Millet	Pennisetum	
Beans	Phaseolus	Except Phaseolus polyanthus.
Pea	Pisum	
Rye	Secale	
Potato	Solanum	Section tuberosa included, except *Solanum phureja*.
Eggplant	Solanum	Section melongena included.
Sorghum	Sorghum	

Triticale	Triticosecale	
Wheat	Triticum et al.	Including Agropyron, Elymus, and Secale.
Faba Bean / Vetch	Vicia	
Cowpea et al.	Vigna	
Maize	Zea	Excluding Zea perennis, Zea diploperennis, and Zea luxurians.

Forages

Genera	Species
LEGUME FORAGES	
Astragalus	chinensis, cicer, arenarius
Canavalia	ensiformis
Coronilla	varia

Hedysarum	coronarium
Lathyrus	cicera, ciliolatus, hirsutus, ochrus, odoratus, sativus
Lespedeza	cuneata, striata, stipulacea
Lotus	corniculatus, subbiflorus, uliginosus
Lupinus	albus, angustifolius, luteus
Medicago	arborea, falcata, sativa, scutellata, rigidula, truncatula
Melilotus	albus, officinalis
Onobrychis	viciifolia
Ornithopus	sativus
Prosopis	affinis, alba, chilensis, nigra, pallida
Pueraria	phaseoloides
Trifolium	alexandrinum, alpestre, ambiguum, angustifolium, arvense, agrocicerum, hybridum, incarnatum, pratense, repens, resupinatum, rueppellianum, semipilosum, subterraneum, vesiculosum

GRASS FORAGES	
Andropogon	gayanus
Agropyron	cristatum, desertorum
Agrostis	stolonifera, tenuis
Alopecurus	pratensis
Arrhenatherum	elatius
Dactylis	glomerata
Festuca	arundinacea, gigantea, heterophylla, ovina, pratensis, rubra
Lolium	hybridum, multiflorum, perenne, rigidum, temulentum
Phalaris	aquatica, arundinacea
Phleum	pratense
Poa	alpina, annua, pratensis
Tripsacum	laxum

OTHER FORAGES	
Atriplex	halimus, nummularia
Salsola	vermiculata

APPENDIX 2: INVITATION TO PARTICIPATE

Dear [insert name],

My name is Sara Peres and I am a PhD student at the Departments of Science and Technology Studies and Geography at UCL. My research is focused on the organisation and practices of ex situ conservation of crop diversity, and I am seeking to interview various people about their experiences of, and perspectives on, gene banking.

Given your work on **[insert project]** I think it would be very interesting to talk to you and would like to invite you to be interviewed for the project.

I have attached to this email an information sheet which introduces the project. Further information about me can be found in my departmental web page (details below).

Should you agree I expect that our conversation would take approximately one hour, to be arranged at a time and place convenient for you. I would like to seek your consent to audio record it.

Please contact me should you have any questions - I would be very happy to discuss any of this further. Alternatively, I will follow up this email within 5 to 7 working days to find out whether or not you are willing to be interviewed. I look forwards to speaking to you then.

Many thanks in advance for your time.

Kind regards,

APPENDIX 3: PARTICIPANT INFORMATION SHEET

Department of

Science and Technology Studies

UCL

INFORMATION SHEET

PhD Project: Cooperation and Commons in *Ex Situ* Conservation of Crop Genetic Diversity

Introduction

Many thanks for taking the time to read about my PhD research project, which is dedicated to exploring policies and practices of *ex situ* conservation of plant genetic resources for food and agriculture (PGRFA).

My aim is to understand how gene bank collections are safeguarded for the future; and how the emphasis on a global system for PGRFA conservation and use (leading to the Global Plans of Action, the Global Crop Diversity Trust and the State of the World Reports) governed by the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) may shape the ways in which we create, maintain and use these collections.

I am looking into this equally as an interesting situation and as a case study to think about how and why collaboration and sharing happen between these institutions – a subject of interest to both sociologists and geographers of science more generally.

As part of this research I am seeking to interview people who have experience of, and/or a specific interest in, gene banking of PGRFA. I would therefore like to invite you to be interviewed for this research project – your contribution would be very valuable.

Should you agree, our conversation will be broadly focused on your experiences and perspectives on the topics introduced above. This is an exploratory social science project and is designed to be responsive to the themes and issues raised by participants rather than a more structured investigation into pre-defined themes. I am keen on listening to a variety of views and discovering what you and others with a personal or professional involvement think are the important issues around *ex situ* conservation of PGRFA.

The next sections provide further details about the research project, relevant ethical considerations and processes, and about myself. I would be very happy to discuss these further and answer any questions you may have. Thank you again for your time.

The Research Project

This doctoral research project is funded by the UK Economic and Social Research Council (ESRC) through the Doctoral Training Centre at UCL and supervised by Prof Brian Balmer (STS, UCL) and Dr Samuel Randalls (Geography, UCL).

This is a timely project, given the continuing interest in ensuring PGRFA conservation and use and the existence of an international governance framework that marks it out as an important global concern and sets out how PGRFA collections are to be monitored, managed, shared and utilised.

This research will provide empirical data about how such a framework translates into gene banking practices and which factors influence them; I will then explore these findings through an approach that brings together perspectives from the Sociology of Science and Technology and from Human Geography.

The data gathered during these interviews will supplement written documentary evidence such as journal articles, policy papers and media reports to provide a more complete overview of perspectives on gene banks and their role in plant conservation and use. Together they will form the data set for my PhD thesis in Science and Technology Studies which is due for completion after April 2015.

Project participants

I am seeking interviewees who have experience and/or an interest in the way gene banks operate and in the organisation of PGRFA conservation and use at the international level. Participants may include gene bank managers and scientists, users of accessions (for research, breeding or other ends), and those with an interest in PGRFA-related policy, from diplomats to campaigners.

I would like to emphasise that I am interested in a broad range of experiences and perspectives on how we safeguard plant genetic diversity and would find it useful to speak to those who may not have had direct involvement with the governance documents mentioned above.

Uses of Interview Data and Project Outputs

Quotations from our conversation will always be anonymised and no information will be included in the quotes which may compromise this (see also the section on Confidentiality and Anonymity, below). This applies equally to the thesis itself and to any papers produced for peer-reviewed journals or conference presentations. Its conclusions will be further disseminated at conferences and through articles in peer-reviewed journals.

This work is intended to be useful to researchers interested in plant genetic diversity conservation as well as those who work in social studies of science more generally.

Ethical Considerations and Processes

This project was designed with reference to the ESRC Framework for Research Ethics and has received ethics approval from UCL (reference number STSEth013). This ensures that the safety and choices of participants are paramount and processes are in place to protect these (e.g., through the requirements for informed consent and confidentiality).

Informed Consent and Withdrawal

Participation in this project is completely voluntary. I will seek written informed consent before any data collection; ensuring that we have the opportunity to discuss the project and the parameters of your participation in advance of this.

You can withdraw from the project at any time and without giving a reason by contacting me. Withdrawal means that all data collected with that participant will be securely destroyed. **Please note that to ensure that no data is included in the thesis the participant must withdraw by the 1st of April 2015**. For withdrawals after this date I can only guarantee that no data will be used in any subsequent research outputs.

Confidentiality and Anonymity

I am committed to protecting participant confidentiality and anonymity. I will not disclose to others who I have spoken to without explicit permission, and undertake to make anonymous any quotations or information used in the thesis. Participants will be referred to solely by their professional role and quotations which include identifying information will be avoided.

Confidentiality and anonymity will be discussed before informed consent is requested.

No one except me (and, potentially, a professional transcriber) will have access to the transcripts while this research is ongoing – please refer to the Data section below for information on data archiving.

Data

All research materials will be securely held in accordance with the Data Protection Act (1998). Data storage processes are reviewed annually as part of the STS Department's data holdings.

Any data which contain participants' details (i.e., consent forms) will be stored securely and separate from the interview transcripts.

I will seek your permission to make an audio record of the interview. The corresponding transcript can be made available to you on request.

The ESRC encourages the deposition of research data in the UK Data Archive (http://dataarchive.ac.uk/), a secure data repository. Therefore, at interview I will ask whether you would be happy for a transcript of your interview to be deposited there. These transcripts will be anonymised..

Before informed consent is taken a discussion will be had about your choices regarding what to do with your interview data (e.g. whether it is archived, under what formats), and the result will be recorded in the Consent Form.

As interview tapes are covered by copyright laws, to comply with copyright guidance it is important to have your explicit agreement to cede the copyright over these to me for research purposes only. This will be recorded in the Consent Form by ticking the appropriate box.

About Me

My name is Sara Peres and I am a PhD student at the departments of Science and Technology Studies (STS, www.ucl.ac.uk/sts) and Geography (www.ucl.ac.uk/geography) at UCL.

Originally trained as a human geneticist, I was led to social studies of science by curiosity about the human questions raised by advances genetics and genomics. Before starting this PhD I have gained experience of genetics lab work (as a student, assistant and technician), clinical research data management and public engagement with museum visitors and other groups.

Further biographical information is available on my personal page in the STS website. I can be contacted at sara.peres.11@ucl.ac.uk

Further Information

Personal page in the UCL STS website:
http://www.ucl.ac.uk/sts/students/peres UK Data Service:

http://ukdataservice.ac.uk/

ESRC Framework for Research Ethics:

http://www.esrc.ac.uk/about-esrc/information/research- ethics.aspx UCL Research Ethics Framework: http://www.ucl.ac.uk/research/images/research-ethics-framework

□□3

APPENDIX 4: CONSENT FORM

UCL

Department of Science and Technology Studies

CONSENT FORM

PhD Project: Cooperation and Commons in *Ex Situ* Conservation of Crop Genetic Diversity

Please tick the appropriate boxes	Yes	No
Taking Part		
I have read and understood the Project Information Sheet dated 03.03.14.	☐	☐
I have been given the opportunity to ask questions about the project.	☐	☐
I agree to take part in the project. Taking part in the project will include being interviewed and audio/video recorded *[to be deleted as appropriate]*	☐	☐
I understand that the content of the interview will remain confidential and will be anonymised for use in the thesis and other outputs.	☐	☐
I understand that my taking part is voluntary; I can withdraw from the study at any time and I do not have to	☐	☐
give any reasons for why I no longer want to take part.	☐	☐

I understand that for my words to be removed from the PhD thesis I will need to withdraw before the 1st of April 2015

Use of the information I provide for this project only

I understand my personal details such as phone number and address will not be revealed to people outside the project. ☐ ☐

I understand that my anonymised words may be quoted in publications, reports, web pages, and other research outputs. ☐ ☐

Please choose **one** of the following two options:

I **do** wish for the fact that I have participated to remain confidential ☐

☐

I **donot** wish for the fact that I have participated to remain confidential

This refers to your wishes regarding whether or not to disclose that you have been interviewed – the content remains confidential.

Use of the information I provide beyond this project

I agree for the data I provide to be archived at the UK Data Archive in the form of a transcript. This document will preserve the confidentiality of the information as requested in this form. ☐ ☐

I understand that other genuine researchers will have access to this data only if they agree to preserve the ☐ ☐

confidentiality of the information as requested in this form.

I understand that other genuine researchers may use my words in publications, reports, web pages, and other research outputs, only if they agree to preserve the confidentiality of the information as requested in this form. ☐ ☐

So that the information you provide can be legally used:

I agree to assign the copyright I hold in any materials related to this project to Sara Peres. ☐ ☐

________________________________ ____________________ ________________

Name of participant [printed] Signature Date

________________________________ ____________________ ________________

Name of researcher [printed] Signature Date

Researcher Contact Details:

Sara Peres, UCL Department of Science and Technology Studies, Gower St, WC1E 6BT. E: sara.peres.11@ucl.ac.uk

APPENDIX 5: INTERVIEW INFORMATION

Interview number	Country	Date(s) of interview	Professional role	Interview method	Language	Interview length	Notes
I1	UK	10/09/2013	Genebank staff	Face-to-face	English	00:59:27	
I2	UK	10/09/2013	Genebank staff	Face-to-face	English	00:46:50	There was also a visit to the bank
I3	UK	19/09/2013	Genebank staff	Face-to-face	English	01:04:07	
I4	UK	24/09/2013	Genebank staff	Face-to-face	English	00:49:19	There was also a visit to the bank
I5	UK	03/10/2013	Academic; ex situ conservation coordinator	Face-to-face	English	00:24:22	
I6	UK	07/11/2013	Genebank staff	Face-to-face	English	01:01:52	
I7	UK	03/12/2013	Policy	Face-to-face	English	01:00:39	
I8	UK	05/12/2013	Genebank staff	Skype	English	00:57:59	
I9	UK	06/01/2014	Plant breeder Genebank staff	Skype	English	01:09:42	
I10	UK	21/01/2014	Database coordinator	Face-to-face	English	01:31:00	
I11	UK	30/01/2014	Academic - Database coordinator	Face-to-face	English	00:48:28	
I12	UK	21/03/2014 and 28/03/2014	Genebank staff Database coordinator	Face-to-face	English	02:11:57	
I13	International	10/04/2014	Ex situ conservation coordinator	Face-to-face	English	01:22:07	
I14	International	08/04/2014	Ex situ conservation coordinator	Face-to-face	English	01:34:00	
I15	UK	15/05/2014	Plant breeder	Skype	English	01:02:07	

			Genebank staff				
I16	International	23/05/2014	Ex situ conservation coordinator	Skype	English	00:47:57	
I17	Portugal	24/06/2014	Genebank staff	Face-to-face	Portuguese	01:04:00	
I18	Portugal	25/06/2014	Genebank staff	Face-to-face	Portuguese	01:21:17	
I19	Portugal	26/06/2014	Genebank staff	Face-to-face	Portuguese	02:02:37	There was also a visit to the bank
I20	Portugal	27/06/2014	Academic	Face-to-face	Portuguese	00:59:00	
I21	Portugal	30/06/2014	Genebank staff	Face-to-face	Portuguese	01:19:00	Interview with I22
I22	Portugal	01/07/2014	Genebank staff	Face-to-face	Portuguese	01:19:00	Interview with I21
I23	Germany	09/09/2014	Policy	Face-to-face	English	01:14:31	
Total	13 UK 6 Portugal 3 International 1 Germany		14 Genebank staff 3 Researchers 4 Ex situ coordination 3 Database coordination 2 Policy 2 Plant breeders (N=27 because 5 people had double roles)	4 Skype 18 Face to face	16 in English, 6 in Portuguese N=23		

APPENDIX 6: SAMPLE INTERVIEW SCHEDULE

APPENDIX 7: SELECTED CODES

Conservation of germplasm

- Reasons
- Modes of conservation
    - Ex situ
        - Role of genebanks
        - History of collections
        - Size and trends
        - Analogies
        - Problems and challenges
    - In situ

Economic concepts and language

- In vivo concepts
- Commercial interests and routes
- Commons
- Enclosure
- Freedom to operate
- Funding
- Intellectual property protection
- Markets, private and public sector
- Privatisation and concentration
- Public domain
- Public versus private

Organisation of genebanking

- Different national styles of conservation
- Global system
    - GPA
    - GPA 2
    - SoW
    - WIEWS
- National policy
- Organisation within a country
- Centralisation and decentralisation
- Country of origin
- European context
- 'landscape'
- Scale
- Global and local contexts

Genebanking practices

- Collecting
- Collection management
- Communication
- Dissemination and access
    - Data
    - Germplasm
- Evaluation
- Gathering information about accessions
    - Characterising
    - Making decisions about data
- Growing material
- Maintaining records
- Monitoring
- Publishing information
- Regenerating accessions
- Safety duplication
- Searching for and selecting material
- Survey and inventory
- Technical assistance
- Updating information

Relationship nodes

- Country-country
- Country-international organisation
- Country-network
- Country-user
- Genebank-network
- Genebank-country
- Genebank-genebank
- Genebank-international organisation
- Genebank-user
- International organisation-network
- International organisation-user
- Participant-network
- User-network
- User-user

Resources

- Genetic resources/PGRFA
  - As genetic diversity
  - As trait donors
  - As research tools
  - Longevity
  - Definitions
  - Origins
  - Value
- Information
  - Assembling information
    - As technical challenge
    - As social challenge
  - Molecular data
  - Morphological data
  - Passport data
  - Links to other information
  - Reasons for lack of information
- Financial information
  - Funding sources
  - Implications
  - Finiteness

Use of germplasm

- Breeding
- Participatory plant breeding
- Pre-breeding
- Research into traditional varieties
- Usefulness
- Who are the users

Access

- To PGRFA
  - Germplasm flow
  - Barriers
- To information
  - Barriers
- To technologies

Benefit sharing

- Benefits – capacity building
- Benefits – information
- Benefits – money
- Benefits – technology

Types of practice or relationships

- Collaborative
- Formal
- Informal
- Non-collaborative
- Paid
- Volunteered/'in kind'

Concepts

- Value
- Accessibility
- Autonomy
- Collaboration
- Cooperation

- Duplication
- Effectiveness
- Interdependence
- National sovereignty
- Prioritising
- 'Rational, efficient, sustainable'
- Rational(isation)
- Responsibility
- Sharing
- Standardisation
- Relationship between conservation and use
- Museum

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