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Original Article

Intellectual monopolies as a new pattern of innovation and technological regime

Cecilia Rikap *

[1]Institute for Innovation and Public Purpose, University College London, 11 Montague St, London WC1B 5BP, UK. e-mail: c.rikap@ucl.ac.uk, [2]COSTECH, Université de Technologie de Compiègne, France and [3]CONICET, Argentina

*Main author for correspondence.

Building on Schumpeter Mark I and Mark II, I propose an additional pattern of innovation and technological regime called the intellectual monopoly (IM) to explain the co-habitation of large incumbent firms with high entry and exit rates and provide evidence for pharmaceuticals and information technologies. I associate the IM pattern and technological regime with corporate innovation systems and illustrate that patterns not only evolve after changes in technological regimes but also due to economic, political, and institutional transformations.

JEL classification: O31, O34, O32, L41

1. Introduction

The co-habitation of what seems to be a stable core of big players -the incumbents- with thousands of small firms that typically exhibit high entry and exit rates escapes from the widely used two patterns of innovation introduced by Malerba and Orsenigo (1995, 1997), which they dubbed Schumpeter Mark I and Schumpeter Mark II. This paper integrates insights from the economics of innovation into political economy studies on intangible assets and associated rents to propose and provide evidence of an additional pattern of innovation and technological regime that I call intellectual monopoly (IM). As this paper shows, in this innovation pattern the interplay among heterogeneous firms is essential for innovation. Firms do not simply co-exist; they co-evolve and co-produce innovation.

The proposed IM pattern addresses intra-industry heterogeneities (Dosi, 1988) conceptualizing the interplay among different types of firms and with other non-firm actors. Innovation is here an outcome of heterogeneous actors' mutual activity while the company exercising the IM captures the bulk of associated rents. Anticipating our reasoning, while Schumpeter Mark I was defined by creative destruction and Mark II by creative accumulation, the IM pattern can be characterized by creative appropriation. This innovation pattern renders particularly relevant to distinguish between the (co)producers of the innovation and those that benefit from it, leading to discussions on diffusion and economic growth.

By analysing the co-production of innovations, the second contribution of this paper is to elaborate on (the emergence, disappearance, and evolution of) patterns of innovation as contextually, thus historically, determined. Here, the possibility of an IM pattern of innovation is not only explained by referring to structural features of knowledge production but also building on political, institutional, and economic transformations that fostered and shaped it. On the contrary, Malerba and Orsenigo (1995, 1997) considered that mostly intra-sectoral technological matters explained a sector's pattern of innovation and its associated technological regime, among others because the empirical evidence they gathered showed similar patterns of intersectoral differences across the United States (US), Europe, and Japan. Furthermore, even if they provided examples of the evolution from Mark I to Mark II and vice versa, they did not contemplate additional patterns that could co-exist with or replace them.

The remainder of this paper is organized as follows. The next section summarizes the literature on patterns of innovation and introduces the possibility of a third pattern to complement Mark I and Mark II on the basis of recent work on rents, intangible assets and the persistence of firms exercising intellectual monopolies. Against this backdrop and referring to recent political, economic and institutional transformations, section 3 elaborates on the emergence of intellectual monopolies vis-à-vis the surge in start-up companies, particularly observed for pharmaceuticals and information technologies. Section 4 presents the methodology used to provide evidence of a new pattern of innovation led by those intellectual monopolies in co-habitation with turbulent peripheries, and my empirical findings are introduced in section 5. These findings are mobilized to compare the three patterns in terms of diffusion, effects on economic growth and expected technological regimes in section 6. Final remarks are presented in section 7.

2. Patterns of innovation and the growing concentration of intangible assets

2.1 Schumpeter Mark I and Schumpeter Mark II

In the Theory of Economic Development, Schumpeter (1934) conceived the introduction of new products, techniques and the creation of new markets (later on called innovations) as the driving force of the economic cycle. Economic growth was the net effect of what he defined as creative destruction: the creation of new firms at the expense of the destruction of those lagging. Potentially any existing or new firm could innovate, thus, enjoy an extraordinary profit in the form of a rent until the other (surviving) firms of the industry adopt the innovation or another (new) firm innovates taking the lead. In his late work, on the contrary, Schumpeter (1942) argued that sometimes the creative side of the creative destruction remains in the hands of the same (big) corporations. He associated this with expensive research and development (R&D) endeavours that only firms with large laboratories and sufficient financial resources could undertake.

Based on both approaches, and considering Nelson and Winter's (1982) modelization of these distinct behaviours, Malerba and Orsenigo (1995) proposed two patterns of innovation: Schumpeter Mark I and Mark II. Drawing on the *Theory of Economic Development,* under Mark I entry is easy and small, often new, firms do the bulk of the innovation. Due to systematic entry, the innovative base is continuously expanding. Established firms cannot hold on to their competitive and technological advantages in such a widening pattern of innovation. Mark II relies on Schumpeter's (1942) late work. Here, innovative capabilities were continuously accumulated by a few dominant large firms, resulting in a deepening or "creative accumulation" pattern of innovation.

In a complementary piece, the authors found that industries sharing a technological regime follow the same pattern of innovation (Malerba and Orsenigo, 1997). In a later work, they defined and applied patent indicators to measure each feature of a pattern of innovation, finding more evidence of those two patterns studied in relation to technological regimes reinforcing the conclusion of the latter determining the former (Breschi *et al.*, 2000).

These contributions provided a conceptualization of the whole innovation cycle, from innovation to diffusion and economic growth. Under Mark I and Mark II, innovation is followed by imitation assuring a diffusion mechanism. Differences laid on the size of the innovators (and imitators) and, thus, on the speed of imitation. As Nelson and Winter (1982: 280) models showed, "market structure influences the speed with which transient quasi-rents are eroded away by imitators". Imitation was conceived as typically slower under creative accumulation, extending rents in time which compensated for larger R&D investments. When imitators moved fast, larger firms could rely on their higher production level, productive capacity, marketing arrangements, and financial resources to exploit their innovations in shorter periods of time than smaller firms, harvesting rents that more than compensated initial investment (Nelson and Winter, 1982: 279).

Schumpeter Mark I and Mark II have been widely applied. Some authors studied how innovation patterns and their associated technological regimes react to crises and others focused on the effects of having different innovation patterns on productivity and economic growth (see for instance Breschi *et al.*, 2000; Castellacci, 2007; Archibugi *et al.*, 2013; Fontana *et al.*, 2013). Malerba and Orsenigo (1995, 1997) were criticized for associating patterns of innovation with industries given the latter internal heterogeneity. In fact, Malerba and Orsenigo (1996) identified the co-evolution of heterogeneous firms in biotechnology and ICT but they did not integrate this finding into their work on patterns of innovation.

Among critical papers, Leiponen and Drejer (2007) found that Finnish and Danish service and manufacturing firms grouped even in the most narrowly defined industries do not follow the same pattern of innovation. In a similar vein, it was argued that industries or sectors may not necessarily provide a clearcut division given the application of digital technologies in the most varied sectors and leading to the emergence of cross-sectoral global value chains (GVCs) (Lee and Gereffi, 2021; Li *et al.*, 2021). Li *et al.* (2021) also referred to the ample evidence showing the persistent leadership of incumbents, which for Malerba and Orsenigo (1997) was not a long-term issue because Mark II industries would eventually become more competitive, organizing innovation more closely to Mark I. Yet, following Dosi (1988), persistent leadership was the expected scenario in sectors with steep dynamic economies of scale.

In fact, the models previously assembled by Nelson and Winter (1982) had analytically shown that industries that begin concentrated tend to remain concentrated and initially unconcentrated industries present a concentration tendency. In their models, concentration was the expected outcome when growth in size is necessary for profitability, such as when the R&D costs per innovation are higher. Concentration was also the most probable scenario when, continued the authors, the same firm innovated successfully again and again or when one innovation was sufficiently dominant. The (increasing) gap with low productivity firms would lead the latter to reduce their R&D investment, which in turn would further limit catching up. Still, even as the concentration of innovation prevailed, for Nelson and Winter (1982), imitation and thus some degree of diffusion would eventually take place.

However, imitation and diffusion depend on firms' absorptive capacities, which are heterogeneous and path dependent. The capacity to absorb and produce new knowledge depends on already acquired knowledge. Firms at the knowledge frontier have the greatest absorptive capacity to keep learning and innovating by absorbing new knowledge from their environment (Cohen and Levinthal, 1990). As they keep expanding the frontier, other firms' innovative capabilities are curtailed. This could be reinforced by the fact that only firms above certain management capability thresholds can benefit from R&D by translating creative outputs into performance outcomes (Coad *et al.*, 2020). Therefore, there is no reason to believe that there will be diffusion and imitation. As Dosi (1988: 1159) explained, even if in principle imitation and diffusion would mean industrial convergence, "asymmetries in the capabilities of firms impose limits on this tendency and its strength remains to be determined".

This could lead to sustained leadership of a few with limited and unequal diffusion and imitation. Overall, it is possible to conceive a scenario where firms that have already innovated keep innovating anew before imitation by relying on their previous successes. As I explain in section 3, such serial innovators could leverage on their sustained entry barriers to outsource R&D modules to turbulent peripheries without risking their lead and disproportionately garnering associated rents. Such a possibility would be aligned to previous empirical findings such as Cooke (2006) who concluded that Mark I and Mark II were not valid for explaining innovation networks between large pharmaceuticals and biotechnology start-ups. A similar conclusion was observed for the dynamics of start-ups and big tech companies (Rikap and Lundvall, 2021). Furthermore, such a scenario would be compatible with Marsili's (2002) observation that entry and the cumulative causation of innovation by established firms should not be seen as mutually exclusive mechanisms Precisely, their co-occurrence is at the basis of the IM pattern. Yet, before referring to this additional pattern, the next section explores the rise of an emerging subfield within political economy that, drawing on Marxist analyses of capitalism in the second half of the 20th century, focuses on the recent concentration of intangible assets and associated rents. Together with the literature on economics of innovation overviewed here, these two frameworks provide the conceptual basis of the IM pattern proposed in this paper.

2.2 Monopoly capital and the concentration of intangible assets

Inspired by Schumpeter's (1942) late work, for Baran and Sweezy (1966) giant corporations—conceptualized as monopoly capital—were better equipped and had greater means to systematically introduce new science and technology than competitive firms However, they concluded that these corporations may not have the incentives to use that capacity, particularly if it risked eroding their existing market power. Distancing himself from this thesis, for Mandel (1978), big monopolies or oligopolies needed to keep on innovating because they were never fully shielded from competition. In fact, he associated late capitalism with an impressive growth in "scientific intellectual labour" driven by the "massive reunification of intellectual and productive activity, and the entry of intellectual labour into the sphere of production" (Mandel, 1978: 252–253). Cowling and Sugden (1987: 106) integrated some of these ideas into the overall monopoly capital framework, also distinguishing between the co-production and appropriation of knowledge by giant firms from smaller organizations or individuals, sometimes delaying innovation.

The examination of big businesses' concentration of innovation, and more generally all forms of intangibles, and its effect on economic accumulation recently regained popularity among political economists. In the US, it was suggested that an uneven distribution of intellectual property rights (IPRs) explained profit differentials (Schwartz, 2016) and Orhangazi (2018) revealed that intangible-intensive industries' rate of profit grew faster than their total assets. Also, R&D efforts were shown to be positively and significantly correlated with corporate net profits and with performance in the Standard and Poor's Stock Market Index (Lambert, 2020). Moreover, by means of quantile regressions, Rabinovich (2023) found that R&D had a positive and rising contribution only for high-growth firms. He also showed that the penalty for firms that fail in their innovative efforts has grown over time, pointing to a cumulative concentration of R&D's positive (negative) effects for high-growth (slow-growth) firms. Beyond the US, an OECD report analysed 26 countries between 2001 and 2014 and found that the mark-ups of firms at the top of the distribution had grown and were higher in digital-intensive sectors (Calligaris *et al.*, 2018).

These contributions can be inscribed in a broader political economy tradition that addresses the growing relevance of assets defined as privately appropriated goods used to capture value from society in the form of long-lasting economic rents. For some authors, their growing economic importance and the transformation of all sorts of things into assets -assetization- is characteristic of contemporary capitalism (see for instance Birch and Muniesa, 2020; Christophers, 2020).

This reference to assets as rent-bearing reopened a long-lasting discussion on the concept of economic rents in connection to the economic implications of assets' concentration (see for instance Harvey, 2007; Foley, 2013; Piketty, 2014; Mazzucato, 2018; Christophers, 2020; Baglioni *et al.*, 2021; Stratford, 2022; Birch and Ward, 2023; Mazzucato *et al.*, 2023). Broadly speaking, rents were defined by these authors as a redistribution of value that results from the ownership or control of (artificially made) scarce or monopolized economic resources. These contemporary contributions also emphasized that the size of the rent depended on the power relation exercised by the owner or controller of the asset and those who needed access to it or to products that result from using it. Hence, rent-bearing assets are commercialized in the market with at least a certain degree of monopoly power (Christophers, 2020).

Within this literature, for Foley (2013), the specificity of the so-called information economy is the introduction of new modes of surplus value appropriation, mainly information rents defined as rents derived from information services such as the internet. Foley (2013: 265) continues explaining that, unlike land, knowledge and information "can be rented or sold over and over again in very cheaply produced copies." Pagano (2014) expanded this view by arguing that the exclusion from publicly using an element of knowledge or information is global. The restriction on the use of existing knowledge reduces the potential of learning (thus the production of new knowledge) from its use. It is precisely this characteristic that underlies Baglioni *et al.* (2021) emphasis on intangible assets as expanding through use.

Rents derived from intangible assets have also been dubbed intellectual, knowledge, or techno-scientific rents (Teixeira and Rotta, 2012; Pagano, 2014; Rikap, 2018; Birch, 2019; Durand and Milberg, 2020). Durand and Milberg (2020) proposed a taxonomy of intellectual monopoly rents garnered by leading corporations through GVCs, including data-driven rents. The interest in distinguishing a specific rent derived from the extraction, control, and centralization of data has grown with capitalism's platformization (Birch *et al.*, 2020; Sadowski, 2020; Srnicek, 2021).

2.3 Intellectual Monopoly Capitalism: at the intersection of economics of innovation and political economy

Regardless of their differences, all the authors studying intangible assets and associated rents owe much to the Schumpeterian concept of innovation rent even if not every intangible is an innovation. Combining both traditions, an emerging stream of literature speaks of an era of intellectual monopoly capitalism to describe the sustained concentration of intangible assets in a handful of corporations and their use of monopolized knowledge and information to extract value from other organizations -such as subordinate firms in GVCs, platforms, and franchisees (Pagano, 2014; Rikap, 2021; Rikap and Lundvall, 2021, Chapter 2).[1]

The intellectual monopoly definition is still on the making. Boldrin and Levine (2004: 328) had defined it as "the power of producers of ideas to control how their products are used". However, Rikap (2021) showed that global corporations capture knowledge developed together with other organizations and shape the trajectories of scientific exploration and technological change. Hence, intellectual monopolies are not necessarily the producers of the ideas, but those that systematically capture and turn into assets knowledge and information that is often co-produced with (and sometimes simply produced by) others.

Such behaviours were specially documented for pharmaceutical and information technologies. It was shown that the predominant research agenda in healthcare and biomedical sciences is set by a small group of large pharmaceutical companies and leading universities from developed countries (Testoni *et al.*, 2021). It was also found that Roche, Novartis, and Pfizer systematically turned into their exclusively owned patents discoveries whose related publications were co-authored with hundreds of other organizations, providing evidence of knowledge appropriation (Rikap, 2019). Likewise, despite establishing hundreds of research collaborations, Google, Amazon, Microsoft, Alibaba, and Tencent only shared ownership of up to 0.3% of their patents with other organisations (Rikap, 2020; Rikap and Lundvall, 2020).

The intellectual monopoly framework was mobilized to understand firm-level power dynamics in GVCs (Rikap, 2018; Durand and Milberg, 2020) and to empirically show that countries that specialize in more knowledge-intensive links capture more value than those concentrated in GVCs' production functions (Coveri and Zanfei, 2023). Going beyond specific sectors or architectures like GVCs, Baines and Hager (2023) used data from US-listed firms to identify degrees of intellectual monopolization. Along the lines of Rabinovich (2023), they observed that intellectual monopolization, proxied as intangible accumulation and rentierization—defined as highly financialized companies with high profit margins—is more pronounced for the top 10% firms in revenues from pharmaceuticals, apparel and footwear, defence and aerospace, food and beverage, heavy industry, hotels and restaurants, and ICT. Interestingly, they found that the bottom 50% of firms in apparel and footwear, automotives, pharmaceuticals, ICT, and retail behave like subordinated innovating firms, as described by Rikap (2021). These firms are intensive in

[1] Observing the same trends, Schwartz (2022: 75) suggests that intellectual monopoly capitalism should be renamed as franchise economy given the original meaning of franchise as "a royal grant of monopoly rights over trade, land, or some other activity." The problem with the latter definition is that it ultimately sees the emergence of intellectual monopolies or franchisors as a state's decision, disregarding the contributions of the economics of innovation field concerning the innovation process and associated technological regimes.

intangible assets but enjoy relatively low profit margins compared to firms in the top of the distribution.

Summing up, this literature suggests an expanding intellectual monopolization, but evidence remains scattered and there is an insufficient understanding of the ways in which innovation takes place in such a context. Reconstructing how intellectual monopolies emerged, predominantly in certain sectors, and to what extent they differ from the dynamics of Schumpeter Mark II is the focus of the next section.

3. The intellectual monopoly pattern of innovation

3.1 A conceptual and historical approach to explain the persistence of intellectual monopolies

This paper proposes the IM pattern of innovation to describe innovations produced in systems organized by long-lasting and self-reinforcing intellectual monopolies acting as leading cores that turn temporary windfalls—the privilege of the innovator—into a permanent flow of rents. While innovation is co-produced in innovation systems with many other organizations that integrate turbulent peripheries, associated rents are mostly captured by intellectual monopolies.

From an evolutionary perspective, intellectual monopolies could have sprung from successful innovators that reinvested at least part of their intellectual rents in R&D, attempting to systematically innovate anew before imitation. Considering knowledge as a path-dependent process with economies of scale (Dosi, 1988; Johnson and Lundvall, 1994; Antonelli, 1999), it demands minimum knowledge thresholds to allow copies, leaving companies at the knowledge frontier in a better position to appropriate their own and others' intangibles, thus garnering intellectual rents. Furthermore, as explained above, absorptive and management capacities expand as more knowledge is accumulated, which favours knowledge production and adoption (Cohen and Levinthal, 1990; Coad *et al.*, 2020). These characteristics of knowledge expand innovation probabilities for those at the frontier, which could prompt a sustained flow of new innovations before imitation and diffusion, thus a self-reinforcing entry barrier.

Like in the model proposed by Shaked and Sutton (1987: 141–142), "the possibility exists, primarily through incurring additional fixed costs, of shifting the technological frontier constantly forward towards more sophisticated products". This path dependence also presents a financial side. The returns of previous innovations expand available resources for more R&D, which increases the probability to innovate (Nelson and Winter, 1982). Indeed, global top non-financial corporations in market capitalization are also those leading the business expenditure on R&D (BERD) rankings (European Commission, 2022).

In such a scenario, the more a firm learns and innovates, the more it will know how to do it. As identified by Orsenigo (2006) when analysing the biotechnology field, previous innovators retain higher innovating opportunities; "success breeds success" (Dosi, 1988: 1161). Knowledge may remain cumulative even between paradigms in the sense that learning by doing, in this case by the act of doing R&D, creates competencies that facilitate absorbing and producing new knowledge even from a new technological paradigm. Hence, a lead innovator may even be better prepared—have more financial and intellectual resources—to lead the transition to a new paradigm.

The gap between the intellectual monopoly and the rest of the firms producing the same or similar products widens. The latter remain structurally behind and their chances to imitate further shrink as time passes by. The less a firm learns and innovates, the less it will know how to do it. Learning can be hampered to the point where awareness of the existence of a new technique would not be enough for adoption even without IPRs because adoption depends on having the necessary capabilities and resources for developing or using techniques. As Dosi (2023: 219) explains, "precisely because technological knowledge is partly tacit, also embodied in complex organizational practices, etc., technological lags and lead may well be persistent even without legal appropriation."

Such cumulative dynamics have been seen both for healthcare and information technologies, the two sectors with the largest share of firms among BERD top investors (European Commission, 2022). In the case of information technologies, these advantages were further fostered by platform network effects. To some extent, a similar phenomenon could have taken place with so-called blockbuster drugs. As more practitioners started prescribing them, network effects could have contributed to making other physicians keener to do so too. These dynamics expand intellectual rents, thus providing more financial leeway to the leader to keep innovating.

The contemporary form and relevance of the IM pattern relies on specific political, economic, institutional, and technological changes. Stable cores were favoured by the weaking of antitrust regulations in the US and then in other Western economies, narrowly redefined by looking at consumer welfare measured through market prices (Glick, 2019). This particularly benefited large pharmaceutical companies selling to governments, thus not directly to final consumers. It also favoured Big Tech companies, which offer products for free (or more accurately for a price measured in data and attention) or at lower prices than non-platform incumbents.

The persistence of intellectual monopolies also relies on the establishment of a more stringent and extensive IPRs regime in the US since the 1980s, later exported globally with TRIPS and follow-up agreements (Drahos, 1995; Coriat and Orsi, 2002; Dreyfuss and Frankel, 2014). The authorisation to patent living organisms since the landmark case Diamond v. Chakrabarty and more stringent IPRs particularly favoured large pharmaceutical companies, whose innovations are easier to reverse engineer. Precisely since the 1980s, profitability and innovation in the sector delinked; patents became largely (ab)used to sustain higher drug prices and do not positively correlate with newly approved drugs (Işık and Orhangazi, 2022; Dosi *et al.*, 2023).

Patents are at the basis and origin of large pharmaceutical companies' intellectual monopolies (Dutfield, 2020) but these corporations have also captured other less studied intangibles, such as brands, that the literature has conceptualized as tools of ghost management (Sismondo, 2007, 2020; Gagnon and Lexchin, 2008; Gagnon, 2021). Trademarks decreased generic drugs' entry and trademarked-drugs are more expensive yet not of higher quality, as shown in Castaldi's (2023) review of the trademarks' literature.

Large pharmaceuticals have also concentrated the exclusive knowledge on how to turn a promising result into a widely prescribed drug. Going from *bench to bed* requires knowing how to conduct all the clinical trials, legal paperwork, and procedures for approval. These firms also keep privileged contacts with the US Food and Drug Administration and other similar agencies around the world. They also influence networks of physicians and other specialists that, convinced or not of their effectiveness, end up prescribing large pharmaceuticals' drugs (Gagnon and Lexchin, 2008; Gagnon, 2021).

The new IPRs regime also included software, no longer sold integrated into hardware since IBM unbundled them by January 1970 in an attempt to pre-empt a US Department of Justice antitrust suit and limit damage claims from existing suits from competitors (Grad, 2002). Patents in the tech sector have been widely (ab)used too (see for instance WIPO, 2014). Nonetheless, in this industry, IPRs are not the main knowledge appropriation mechanism (Jacobides *et al.*, 2006; Sampat, 2018; Comino *et al.*, 2019). Secrecy plays a fundamental role in deterring digital technologies' diffusion. Big Tech companies' search engine algorithms and harvested big data are kept secret and only 15% of the scientific articles on artificial intelligence, where Microsoft and Google loom large (Ahmed and Wahed, 2020), disclose code (Benaich and Hogarth, 2020). In this field, greater absorptive capacities leading to learning advantages are also particularly relevant for explaining the persistence of intellectual monopolies. As stated by Lemley and Feldman (2016: 188), "in fast-moving industries, such as information technology, the technology described in the patent may be obsolete by the time anyone could read it."

Contemporary intellectual monopolies also benefited from technological advances that facilitated access to knowledge from around the world. Since the Cold War, several industries became more science and technology driven among which pharmaceuticals looms large (Dutfield, 2020), making R&D more expensive. Information technologies also became more science-based over time as artificial intelligence, which is an interdisciplinary science-based field, grew in importance (Crawford, 2021).

Furthermore, the ICT revolution has accelerated the circulation of public knowledge, which can be more easily appropriated by companies with the highest absorptive capacities. All these transformations relied on the US hidden industrial policy. Highly connected to its military complex, it was essential in developing fundamental technologies for both ICT and pharmaceutical industries (Block, 2008; Mazzucato, 2013; Weiss, 2014). States were also central in the emergence of Samsung, TSMC, and Chinese Big Tech (Lundvall and Rikap, 2022; Miller, 2022).

More recently, deep learning algorithms that improve by themselves as they crunch data represents a new method of invention that accelerates innovation (Cockburn *et al.*, 2018). It is a primary source of self-reinforcing intellectual monopolization for Big Tech companies that have monopolized not only diverse and vast big datasets but also the most advanced machine learning (Rikap and Lundvall, 2021). Similarly, for Bessen (2022, Chapter 3), product differentiation—which makes lead firms less subjected to disruption—has been favoured by big data analysis enabling customization at large scale. Of course, product differentiation must be validated in the market, and the greater granularity of data makes this easier. Moreover, according to the author, increased differentiation requires larger intangible investments (in advertising and R&D) than rivals.

The monopolization of digital technologies was also enabled by a vacuum of regulations, ranging from missing definitions on who could harvest and what type of data could be harvested, to absent trade policies for digital services' exports and imports. Proper measures to account for intangibles' world trade are still missing (Fu and Ghauri, 2021) as well as standardized global indicators for data concentration at the firm level (UNCTAD, 2019).[2] Without adequate measurement, regulation is constraint, further shielding knowledge monopolization.

3.2 Why are intellectual monopolies different from Schumpeter Mark II?

The spread and persistence of intellectual monopolies could have resulted in the evolution towards Mark II patterns of innovation in all the affected industries. Yet, particularly in information technologies and pharmaceuticals, something different occurred.

Since the 1980s, R&D in the pharmaceutical industry became more complex and fragmented (Lane, 2007; Dutfield, 2020). While the core of big pharmaceuticals remains mostly untouched, Dutfield (2020: 291) describes in detail the emergence of a new actor, "highly specialised small firms, often spun out of universities who have useful services and possibly quite unique skills to offer, and perhaps a few highly valuable patents, but who have no products at all to sell". As I explained above, large pharmaceutical companies retained the know how to go from bench to bed, the development side of the R&D. At the other end, start-ups, among which biotechnology firms lstand out, focus on specialized discoveries. This model can be exemplified with the Pfizer–BionTech Covid-19 vaccine. Precision drugs and more broadly personalized medicine give further testament to extreme specialization.

The US state not only favored intellectual monopolization as described in the previous section but also, as Popp Berman (2011, Chapter 4) explains, fostered academics to spin off companies to exploit biotechnology applications. The US Congress decided not to regulate rDNA research in 1977. In 1978, large capital gains' tax cuts were granted and in 1979 pension funds were authorized to invest in venture capital, precisely at a time of venture capital scarcity. These regulatory changes unleashed venture capital flows, funding biotechnology spin-offs as well as start-ups from the other emerging technology of the time, ICT. Entrants did not displace already existent pharmaceutical leaders and, in the ICT sector, a relatively stable core of leading corporations differentiated from myriads of start-ups. As an outcome, small innovating companies depend on intellectual monopolies to offer their (new) products. Examples include developers depending on Big Tech platforms to sell their apps (Bergvall-Kareborn and Howcroft, 2011; Norfield, 2017; Rikap, 2020) and so-called partners offering software as a service in Big Tech cloud marketplaces (see section 5.2.2).

To some extent, this stratification can be explained by advancements in scientific disciplines—both of biotechnology and ICT—together with specific innovations in computational capabilities and the instruments used to perform experiments, analyse, and record. Altogether, these changes

[2] A recent paper introduced a way to measure data concentration, but it relies on access to data that is only available in the US (Abis and Veldkamp, 2020).

enabled the modularization of knowledge, so that different steps of the same R&D project could be performed by different organizations in different parts of the world (Arora and Gambardella, 1994).

In sectors where knowledge or more generally intangibles can remain detached from tangible assets, transportation costs became equal to communication costs (Arora *et al.*, 1997) and ICT technologies made intangibles' modularization cheaper. This particularly applies to science-based innovation, such as in healthcare and software as noted by Arora *et al.*, (1997), today including artificial intelligence (AI) algorithms. In comparison, in sectors whose intangibles are not easily detached from tangibles, such as heavy manufacturing, knowledge modularization is harder. Arora *et al.* (1997) further distinguished between the production of modules and their combination. The evolution of both healthcare and information technologies points to leading corporations monopolizing the combination of modules that are co-produced by several organizations.

Google and Meta are indispensable to the source code of the vast majority of apps (Blanke and Pybus, 2020). Moreover, Jacobides *et al.*, 2021 identified the infrastructural power of Big Tech companies in AI, largely due to their role as cloud computing providers. In both examples, Big Tech companies' intellectual monopoly is concentrated on the combination of modules as well as on the more abstract or general modules, while leaving the specific ones—thus those with less economies of scales and scope—to start-ups or small firms In the case of large pharmaceuticals, by monopolizing general knowledge modules required for the approval of every drug—from how to conduct a clinical trial to brand building—biotechnology start-ups did not displace them (Dutfield, 2020).

Hence, from a scenario in which large firms would conduct the bulk of R&D in-house, as in the case of large pharmaceuticals before biotechnology or IBM before unbundling hardware and software, we observe a prevalence of intellectual monopolies outsourcing R&D modules or steps, among others, to emerging start-up firms that often do not aim to sell a product but innovation. This is the main difference with Schumpeter Mark II, intellectual monopolies perpetuate, among others, by outsourcing R&D modules, thus enabling entry.

Outsourced R&D offsets related risks without losing the chance to predominantly profit from successful results (Dolgin, 2010; Collier, 2011; Baranes, 2016; Lazonick *et al.*, 2017; Rikap, 2019). Innovation is produced systemically but stratified and reducing the risks for the incumbent of losing its intellectual monopoly. This co-production dynamic in which an intellectual monopoly organizes outsourced R&D was defined as corporate innovation systems.[3] Besides the intellectual monopoly, they are integrated, among others, by universities, public (research) organization, and start-up firms (Rikap and Lundvall, 2020; Lundvall and Rikap, 2022). All these organizations co-produce innovation for the main benefit of firms with intellectual monopolies. The latter combines the modules produced by different sets of actors. The intellectual monopoly has the main say in the general R&D orientations and desired results within this system yet leaving degrees of autonomy to the other participants. It is expected that the latter will be experts in specific domains producing modules of larger innovation processes, thus probably unaware of how other modules are produced, by whom or even what is been produced in the rest of the system and how they are recombined.

This does not mean that every single start-up will be subjected to one or many leading firms exercising intellectual monopolies. Nonetheless, there are hundreds of firms following this trajectory both in pharmaceuticals and information technologies (see Section 5 for empirical evidence). For these companies, conducting independent research becomes more expensive, among others due to royalty payments to access knowledge and because R&D requires more expensive machinery. Leading corporations overcome the former with cross-licensing agreements[4] and have more financial leeway. Furthermore, large-scale patenting demands skills to face claims in courts and

[3] The frontiers of a corporate innovation system may not coincide with an industrial sector. Furthermore, firms in a sectoral innovation system were supposed to share or exchange relevant knowledge (Malerba, 2005). This is significantly curtailed within corporate systems where subordinated actors only get access to and co-produce parts of the knowledge being produced.

[4] For instance, Microsoft discloses a list of its IP agreements, including cross-licensing agreements with Apple and Amazon (see https://news.microsoft.com/ip-agreements/).

a deterrence capacity (Pagano, 2014). All these conditions raise high entry barriers for newcomers that attempt to go beyond their modular role and benefit firms already holding intellectual monopolies. As explained before, secrecy also limits learning opportunities.

All in all, in these sectors, the relation between leading corporations and start-ups results in an innovation pattern with stable cores and turbulent peripheries (see section 5). The crucial difference with Mark II, as this section highlighted, is that the innovator of a Mark II pattern is a big firm; the innovation process takes place mostly in-house. Meanwhile, knowledge is co-produced at the corporate innovation system level in the IM pattern, thus in the interaction among its actors, even if then it is disproportionately turned into assets by the intellectual monopoly. This is why under this pattern of innovation entry is expected to be higher in comparison to Mark II.

4. Methodology

To provide evidence of the existence of an IM pattern of innovation along the lines described above, I followed two strategies. First, I calculated patent indicators on the basis of those proposed by Breschi *et al.* (2000) for mapping Mark I and Mark II patterns. I compared four sectors, including pharmaceuticals and a sub-sector within information technologies. Then, given that the IM pattern predicts unequal relations between companies from the core and some of those in the periphery, I developed two complementary empirical studies of core-periphery dynamics between firms inside corporate innovation systems.

4.1 Adjusted patent indicators for identifying patterns of innovation

In total, I analyzed 498 929 patents. I selected and compared the two sectors that I have identified as potentially following the IM pattern—pharmaceuticals and a proxy for information technology—with one potential Mark I and one potential Mark II sectors. Based on Breschi *et al.* (2000), I chose "Engines, pumps, and turbines" as a Mark II candidate and fertilizers as a possible Mark I. I followed the tabulation provided by WIPO (Schmoch, 2008) to identify the IPC classes that proxy these sectors. Because of limits in the number of patents that I could simultaneously retrieve from Derwent Innovation, I only retrieved "Electric digital data processing" (G06F) patents from the larger set corresponding to information technologies.

I retrieved patents for 2013 and 2022. Baines and Hager (2023) have recently shown that while intellectual monopolization in pharmaceuticals started several decades ago, in ICT, it took off in the last decade. Furthermore, 2012 is an inflection point in the second phase of the ICT revolution. That year a computer vision breakthrough was achieved, the AlexNet convolutional neural network architecture (Ahmed and Wahed, 2020; Jurowetzki *et al.*, 2021).

Breschi *et al.* (2000) analyzed patents from three European countries. I instead retrieved patents for the chosen classes from all the patent offices in the world as provided by Derwent Innovation. Unlike the period they studied—late 1980s and early 1990s—the 21st century is associated with the globalization of innovation, both driven by the consolidation of GVCs as well as by specific features of the production of innovation such as the above mentioned modularization and the establishment of an international IPRs regime (Arora *et al.*, 1997; Liu *et al.*, 2013; Parrilli *et al.*, 2013; Baldwin, 2014; Chaminade *et al.*, 2016). Even if such globalization is not evenly distributed (Paunov *et al.*, 2019; Balland *et al.*, 2020), patterns of innovation and particularly the operation of intellectual monopolies take place at an international level.

I also made some adjustments to Breschi *et al.* (2000)'s indicators. The authors proposed one indicator for each dimension of the pattern of innovation: entry, stability of the ranking of patent assignees, and concentration of patents by those at the top. I defined entry as in Breschi *et al.* (2000), thus measured as the share of patents of new patent assignees when comparing two periods. In my case, 2013 and 2022.

To measure stability of the whole list of patent assignees, Breschi *et al.* (2000) used the Spearman rank correlation coefficient. The IM pattern, as described above, does not prescribe stability of the full ranking of innovators but a split between a stable core and a periphery characterized by comparatively high levels of entry and exit. We could expect that Mark II should also present stability of those in the top while the opposite should be the case of Mark I. Thus, as an indicator of stability of the core, I calculated the number of organizations that belonged to the top 10, top 20, and top 30 patent assignees both in 2013 and 2022.

Then, Breschi *et al.* (2000) proxied the concentration of patents at the top with the share of patents of the top 4 patent assignees. However, there are significant sectoral discrepancies in terms both of the use of patents as an appropriation mechanism and the degree and speed of innovation at any point in time. Therefore, I looked at the concentration of patents for the top 1% and top 0.1% of total patent assignees (see Section 5.1).

Finally, Breschi *et al.* (2000) combined their results for patterns of innovation with data from a survey that included specific questions to proxy key variables for identifying technological regimes. It could have been interesting to also study these variables with updated data for the chosen sectors. For the sake of space and given the lack of such a survey, I only focused on patterns of innovation indicators. This limitation can also be seen as an open research question for future investigations, as introduced in section 6.

4.2 Studying core-periphery dynamics in the IM pattern

The patent indicators built on the basis of Breschi *et al.* (2000) do not enable to map relations between those at the core and the rest. Hence, I followed two complementary strategies to provide evidence of the unequal links between intellectual monopolies and innovating firms that are not part of the core.

First, I collected evidence of intellectual monopolies directly funding—without acquiring—start-ups or other innovating firms. I obtained from Crunchbase the list of companies in which 15 selected intellectual monopolies appeared among the top five investors by June 10th, 2023. Crunchbase is a database aimed at providing venture capital business information about private and listed innovating companies, particularly start-ups. I looked at the total number of companies that had an intellectual monopoly among its top five investors and then filtered this list to identify the number of funded firms with a maximum of five investors. These can be seen as cases in which the intellectual monopoly has a potentially larger capacity to influence the funded firm's innovation strategy (see Section 5.2.1). I then focused on the link between OpenAI and Microsoft to exemplify the type of conditioning accompanying large funding by intellectual monopolies.

Next, I delved into a case in which intellectual monopolies to some extent steer innovation in other organizations without any ownership tie. I explored the case of Amazon Web Services (AWS) and the firms that offer software as a service in this cloud (see Section 5.2.2). AWS is the absolute world market leader with a stable share of 32 to 34%.[5]

The top investors' analysis can be seen as an original indicator for mapping innovating firms that, albeit being formally independent entities, depend financially and thus could be subjected to the influence of an intellectual monopoly. This type of study complements the evidence of corporate innovation systems already available in the literature, which maps and compares co-authorships and co-ownerships (Rikap, 2019, 2020, 2021; Rikap and Lundvall, 2020). Furthermore, the specific case study of AWS shows concrete ways in which an intellectual monopoly affects how other firms innovate and provides evidence of intellectual rent capture.

5. Empirical findings

5.1 Patent indicators

Table 1 presents the indicators of patterns of innovation for the four chosen sectors. Results are in line with the intellectual monopoly literature for pharmaceuticals and electric digital data processing. Also as expected, fertilizers follow a Mark I and engines, pumps, and turbines (hereon engines) a Mark II pattern.

While the indicators mapping the stability of the top patent assignees show that top patent assignees for fertilizers are highly unstable, with less than a third of organizations remaining in

[5] https://www.srgresearch.com/articles/cloud-spending-growth-rate-slows-but-q4-still-up-by-10-billion-from-2021-microsoft-gains-market-share.

Table 1. Indicators of patterns of innovation

Patent code	Sector	Pattern of Innovation	Stability of the top patent assignees: Stability of the top 10	Stability of the top 20	Stability of the top 30	Share of patents of top assignees, 2013: Top 1% of patent assignees	2013: Top 0.1% of patent assignees	2022: Top 1% of patent assignees	2022: Top 0.1% of patent assignees	Entry: Number of new patent assignees in 2022	Entry: Share of patents of new assignees in 2022
C05	Fertilizers	Mark I	3	4	9	12%	3%	14%	3%	1876	72%
G06F	Electric digital data processing	Intellectual monopoly	4	10	13	61%	27%	60%	28%	26 268	42%
A61K (chosen)	Pharmaceuticals	Intellectual monopoly	7	15	21	44%	18%	38%	15%	13 115	41%
F01B, F01C, F01D, F01K, F01L, F01M, F01P; F02; F03; F04; F23R	Engines, pumps and turbines	Mark II	8	14	21	56%	26%	55%	22%	8349	30%

Author's analysis, data extracted from Derwent Innovation.

either the top 10, top 20, or top 30 between 2013 and 2022, the other three sectors show a significantly more stable core of top patenting organizations. The case of "Electric digital data processing" is particularly interesting because the lower stability of the top in comparison with pharmaceuticals and engines is explained by the entry of Chinese organizations (Table A.1 in appendix). Entry to pharmaceuticals' core also includes two Chinese organization, the Chinese Academy of Sciences and the People's Liberation Army (Table A.2 in appendix). While the former also enters the core of "Electric digital data processing" in the 20th position, the main core disrupters of this sector are Chinese Big Tech and State Grid Corporation of China, all of them conceived as intellectual monopolies that emerged in the last 10 to 15 years (Lundvall and Rikap, 2022; Rikap, 2022a). These firms jumped from marginal positions to integrate the top 10 in 2022, displacing Apple, LG, Intel and Cannon to the 12ve to 15th positions respectively. Interestingly, apart from BASF, the few organizations that remained in the fertilizers' core between periods are also Chinese, signaling that China's entry to this sector predates their disruption of pharmaceuticals and ICT (Table A.3 in appendix). This Chinese effect is only marginal for engines where the few core disruptors are western multinationals (Table A.4 in appendix).

The shares of patents concentrated by the top assignees, either by the top 1% or by the top 0.1% of total patent assignees, exhibit an extremely high concentration for "Electric digital data processing", even larger than for engines. Pharmaceuticals are also highly concentrated, which is clear when compared to fertilizers, but concentration diminishes over time. It remains to be seen to what extent this is the effect of innovations associated with the pandemic, reflects internal dynamics of the sector or the entry of Chinese organizations.

Finally, the intellectual monopoly sectors show relatively high entry compared to Mark II considering both to engines (Table 1) and the results of Breschi *et al.* (2000). Although in terms of the shares of patents of new assignees they are still lower than Fertilizers, the number of new patent assignees is impressive in both pharmaceuticals and "Electric digital data processing", pointing to sectors where the stability of the top is not at the expense of entry while it does prevent entrants from concentrating larger shares of patents and reaching the core. In this respect, it is noteworthy that most of the entrants in these sectors are Chinese organizations, where the state played a crucial role in developing the country's national innovation system, including multiple protectionist measures (Lundvall and Rikap, 2022). In relation to degrees of entry for different patterns of innovation, Marsili (2002) proposed three (high, medium, and low) instead of two entry degrees. From her perspective, it could be argued that the two IM sectors exhibit medium entry levels. Yet, given patent concentration and the relative stability of the top patent assignees for these two sectors (Table 1), it would have been mathematically extremely hard to get entry shares as high as those in Mark I. Either way, it is clear that the behaviour of these two industries neither reflects Mark I nor Mark II, with empirical results supporting this paper's suggestion of an IM pattern of innovation.

5.2 Core and periphery dynamics within corporate innovation systems

5.2.1 Control with partial ownership

Intellectual monopolies, particularly from information technologies, heavily invest in start-up firms (see Table A.5 in Appendix). As explained in section 4.2, I selected 15 intellectual monopolies and retrieved the information of all the firms for which any of those 15 appeared among their top five investors yielding a total of 2856 firms by June 2023. It may be the case that financial dependence is addressed by some of this almost 3000 companies by relying on many investors resulting in low chances of influence by any of them. To control for this option, Crunchbase does not provide data on the amounts received from each funder. Yet, it provides the total number of investors per company. For each of the 15 intellectual monopolies, Table 2 presents the number of firms that have at most five investors in total and that, among these five, one is that intellectual monopoly. Table 2 also shows that over 80% of the funded firms in that table have less than 100 employees, which is another sign of their relatively lower chances to bargain with an intellectual monopoly when the latter is a major funder. The overall results from Table 1 hold; Big Tech companies both from the US and China lead in this corporate venture capital strategy. From all the firms depending on any of these intellectual monopolies, almost a quarter have Microsoft among its top five investors (392 out of 1267 firms).

Table 2. Intellectual monopolies among top five investors for companies with a maximum of five investors

Investor	Number of firms
Microsoft	392
Google	179
Tencent	175
Alibaba (including Ant Group)	154
Samsung	116
Amazon	81
Johnson & Johnson	45
Meta	27
Nvidia	20
Merck	19
Pfizer	19
Abbvie	14
Apple	9
Roche	9
Eli Lilly	8
Total	1267
Companies with employee data	1203
Total with up to 100 employees	985

Author's analysis, data extracted from Crunchbase.

Among its funded firms, Microsoft first investment in OpenAI (USD 1 billion) dates from 2019. Microsoft negotiated in exchange an exclusive license to GPT-3, which was the frontier large language model (LLM) and afterwards powered the first version of ChatGPT. A group of AI researchers left OpenAI due to internal tensions over its research direction and priorities since Microsoft stepped in.[6] OpenAI's dependence on Microsoft also extends to the latter's computing power, without which training the former's LLMs would have been impossible.[7] After ChatGPT's success and its almost immediate integration to Microsoft Bing,[8] Microsoft committed an additional USD 10 billion investment in OpenAI.[9] Later developments of this saga further confirmed Microsoft's controlling arm in this company.

There is also space to think that the effects of Big Tech and large pharmaceutical companies funding a selected group of start-ups includes favouring the development of certain technologies—those receiving the funding—over the rest. In the tech sector, due to large investments by intellectual monopolies we may even see an expansion of the kill zone, in which once Google or Facebook acquires a start-up, venture capitals reduce their investments in competing companies or companies in close markets (Kamepalli *et al.*, 2020). Their centrality as funders, particularly of some Big Tech, could also have an effect at the level of the overall orientation of related science and technology along the lines observed by Rikap (2023) for AI.

5.2.2 Control without ownership

Finally, this section analyses Amazon's cloud (AWS), an example of an innovation platform (Cusumano *et al.*, 2019). Unlike e-commerce marketplaces where sold products are consumed outside of the market, computing services are never sold as independent products, they are all linked to other services and ultimately to the larger cloud infrastructure. Services can only be

[6] https://www.geekwire.com/2020/openai-renamed-closedai-reaction-microsofts-exclusive-license-openais-gpt-3/ and https://www.ft.com/content/8de92f3a-228e-4bb8-961f-96f2dce70ebb.

[7] https://news.microsoft.com/source/features/ai/how-microsofts-bet-on-azure-unlocked-an-ai-revolution/?ocid=eml_pg394041_gdc_comm_mw&mkt_tok=MTU3LUdRRS0zODIAAAGKwmbrwlHO5mYvwKCSRwk2rcEO-79_q_J-nzO8jDiYkLCqxQDI3WXezvp1v-R1XS1chmfOLULFh7NnuL1mIejIT2WWNnZHWf1mc2zzg39WJ2aT7z8ppJQFXEi5.

[8] In interviews that I did for another investigation it was confirmed to me that Microsoft was aware of the launch time in advance and was already working to integrate ChatGPT to its search engine and other products (Rikap, 2023).

[9] https://blogs.microsoft.com/blog/2023/01/23/microsoftandopenaiextendpartnership/.

used inside the Big Tech cloud for which they were created, and development must follow specific requirements defined by the major cloud providers.

In AWS marketplace other companies, so-called partners by Amazon, offer hardware, software, and even business consultancies as online services.[10] By January 2023, AWS marketplace had 6783 registered partners associated with 178 qualifications, which can be defined as classes of cloud services. Among them, 2374 companies offered only one service on AWS, while Barracuda Networks offered the largest number of services (49). This cybersecurity software firm only operates as a cloud services' provider: it was the first to offer software as a service on AWS.

Regardless of the number of offered services, AWS imposes a detailed set of frequently changing rules and protocols to its partners. The requirements are so thorough and complex that the so-called partners are mandated to have certifications for every type of service they expect to develop or integrate into larger solutions. Since 2012, major changes that include new guidelines on how to create specific cloud services are informed to partners at a paid conference called re:Invent (fees were USD 1799 in 2022).

Nubiral is an example of a small to medium size company whose business is fully dependent on AWS cloud. It defines itself on AWS website as providing "personalized solutions and professional services focused on IT Consultancy, DevOps, Cloud, and Data & Innovation." Nubiral specializes in data infrastructure projects that require to install and connect IoT to the cloud enabling customers' migration to the cloud. Amazon recommendations to partners precisely include focusing on migration as stated by Jarrod Buckley, AWS Director of Global Partner Programs, at the 2018 re:Invent Conference. While increasing partners' revenues, this recommendation simultaneously means focusing on expanding AWS clients without endangering the latter's lead.

Another recommendation provided by Buckley at the same event was to specialize, defined as concentrating on an area like migration, "data and analytics or a vertical like healthcare and life sciences".[11] Specialization can be interpreted as narrowing down development to specific modules along the lines discussed in section 3.2. If partners specialize in developing solutions for concrete modules within the cloud, they will mostly learn and innovate in a tiny part of the cloud, a specific module within a much larger solution in which pieces of software provided by AWS are connected to those of partners as black boxes, further limiting learning opportunities (Fernández Franco *et al.*, 2023). Moreover, specialized partners may never consider developing capabilities to integrate or combine modules, which would be required to become a standalone cloud provider. Therefore, the specialization strategy, even when it is profitable for partners, at the same time cements a division of intellectual labour in the cloud.

By setting the protocols and guidelines to develop cloud services while recommending others to specialize, Amazon reinforces its intellectual monopoly by virtually eliminating the potential emergence of challengers among those that participate in its corporate innovation system while expanding its intellectual rents. Listing a service on AWS is free but there is a 30% transaction fee for each sale.[12] Price changes must be reviewed and approved by Amazon, a process that takes between one and three months.[13] Since services are ultimately private lines of code—including private software with hardware—their price is mainly defined as a rent garnered after making an intangible artificially scarce (Rikap, 2022b).

6. Discussion: effects on diffusion, economic growth, and technological regimes

The previous section provided evidence of a distinct pattern of innovation based on sustained intellectual monopolies with a turbulent periphery, part of which is subordinated by the former, which organize innovation at the level of corporate innovation systems. This section compares

[10] https://aws.amazon.com/partners/paths/?nc = sn&loc = 2.
[11] See the whole talk here: https://www.youtube.com/watch?v=LDRzckjVABM.
[12] https://smallbusinessbonfire.com/what-partner-programs-are-available-with-aws-marketplaces/.
[13] On AWS pricing see: https://docs.aws.amazon.com/marketplace/latest/userguide/pricing.html and https://docs.aws.amazon.com/marketplace/latest/userguide/saas-contracts.html.

Table 3. Patterns of innovation dynamics

	Schumpeter Mark I: creative destruction	Schumpeter Mark II: creative accumulation	Intellectual monopoly (IM): creative appropriation
Who innovates/ captures associated returns	Any firm, usually small entrants	Large incumbent firms with large R&D laboratories	The same (big) firm captures most of rents from innovations conducted at its Corporate Innovation System
Length of the innovation privilege	Temporary, eroded by imitation and new innovations	Temporary, eroded by slower imitation than in Mark I and by other large firms' innovation	Persistent for the IM. Laggard imitation. Temporary for innovating firms that are not IMs because the latter captures most of that rent and because the innovation pace is set at the level of the whole corporate innovation system for the benefit of the IM.
Innovation cycle	Innovation → Imitation and diffusion → Growth	Innovation → Imitation and diffusion → Growth	Innovation → Limited, subordinated and stratified diffusion → perpetuation of the rentiers with impacts on growth

Author's analysis based on Mark I, Mark II, and intellectual monopoly literature.

this pattern with Mark I and Mark II. Table 3 provides a summary of the dynamics of each pattern of innovation in relation to diffusion and growth.

The curtailment of diffusion–which entails adaptation and imitation processes–distinguishes the IM pattern. Since the intellectual monopoly captures and combines diverse knowledge modules and thus garners the bulk of rents corresponding to its corporate innovation system, this pattern can be characterized as creative appropriation or creative assetization. Adoption yields more rents and the different types of imitators associated with this innovation pattern do not trigger wide diffusion. Catching-up is limited. Hence, we may expect reduced economic growth.

Firms without an intellectual monopoly may imitate old technologies, partially catching up, such as generic drug makers, arriving once the patent expired yet not being able to compete with the trademarked-drugs or with new patented-drugs prescribed in larger numbers by using the above-mentioned network of physicians. In the case of monopolized digital systems for businesses such as Big Tech clouds, as Bessen (2022: 57) explains, "the ever-greater complexity of the technology makes independent creation difficult". Intellectual monopolies' modular corporate innovation system of complementary and self-reinforcing intangibles prevents these attempts from jeopardizing their lead.

Alternatively, the intellectual monopoly may decide to arrive late and copy successful innovations. Nelson and Winter (1982) anticipated that sometimes innovation is so expensive and imitation fast enough that the latter results more beneficial. Intellectual monopolies foster start-ups to take the riskiest endeavours, occasionally funding them, while still profiting from successful results (see section 5.2.1.). In this context, following Nelson and Winter (1982), the chances of subordinated innovating firms to innovate anew before imitation by the intellectual monopoly shrink due to lower available funds and because the time-lapse between innovation and imitation is too short.

This is often the case of biotechnology and information technology start-ups (Cooke, 2006; Fernald *et al.*, 2017; Glick and Ruetschlin, 2019; Bourreau and de Streel, 2020; Kamepalli *et al.*, 2020). Among AWS partners, Elastic offered its products Elasticsearch and Kibana. As their popularity grew, Amazon started offering its own versions of these services, displacing Elastic from the market.[14] AWS offered them under the name Amazon Elasticsearch Service, misleading devel-

[14] https://www.theregister.com/2021/01/22/aws_elastic_fork/.

opers by potentially making them think that this was the same product they were using before. This is an example of how Amazon, which has one of world's most valued brands[15] and over 800 trademarks,[16] infringes other companies' trademark as part of its strategy to capture innovation. Acquisition of the successful innovator is another means to curtail the more distributed development of a technology. Also, subordinating potential disruptors or leaders of specific modules, not only due to financial needs but also because of the effects of intangibles' monopolization, is another effective way to reinforce this pattern of innovation. This was the case of Microsoft and OpenAI, with the latter depending on Microsoft's technologies to make its specific modules -LLMs- work.

A third alternative is for an intellectual monopoly to successfully imitate another intellectual monopoly. This dynamic, far from eliminating intellectual monopolies, accelerates innovation at the core, as in the case of the smartphone industry (Dedrick and Kraemer, 2017). Another option could be for a wannabe intellectual monopoly to succeed and become an intellectual monopoly, as in the case of State Grid Corporation of China (SGCC) (Rikap, 2022a). Yet, this (uncommon but still feasible) process would entail more than imitation for the reasons explained before and does not trigger wide diffusion. Both in the case of SGCC and other Chinese intellectual monopolies, as I pointed out above, their emergence cannot be reduced to internal dynamics of their technological regime but requires considering political and institutional transformations (Lundvall and Rikap, 2022).

Precisely in relation to technological regimes, Malerba and Orsenigo (1997) proposed two, one for Mark I and another one for Mark II, according to degrees of knowledge cumulativeness, opportunity, and appropriability, and considering knowledge base characteristics. Based on the analysis presented in this paper, it is expected that the IM associated technological regime would present high knowledge cumulativeness at the level of the corporate innovation system and high levels of opportunity and appropriability but mostly for the intellectual monopoly. The picture is less clear when it comes to its turbulent peripheries.

Opportunity is expected to be high for peripheral organizations integrating intellectual monopolies' corporate innovation systems producing concrete modules, such as successful start-ups and leading universities. However, unlike the intellectual monopoly, their innovative opportunity may be limited to those specific modules, with a low opportunity also for recombining modules, among others, due to prohibitive costs and the effect of knowledge monopolization limiting learning opportunities beyond specific modules for those without intellectual monopolies.

Also, start-ups' overall high rates of failure point to low opportunities, among others for many of those that do not integrate such corporate innovation systems and also for many that do so but fail. As innovation risks are outsourced to start-ups and other organizations, most of these organizations fail, even most Silicon Valley start-ups.[17] Start-ups' failure rates are a sign of how turbulent the peripheries are. Those successful will enjoy intellectual rents but, if they integrate an intellectual monopoly's corporate innovation system, the latter will capture part of that rent. In other cases, being a successful start-up means been acquired, prominently by leading companies (Montalban and Sakinç, 2013; Lazonick *et al.*, 2017; Lopez Giron and Vialle, 2017; Rikap, 2019; World Intellectual Property Organization, 2019; Bourreau and de Streel, 2020; Dutfield, 2020).

The fact that concrete modules often only make sense once they are integrated or combined with others is a reason to think that appropriability may be lower for start-ups and academic or public organizations in comparison to intellectual monopolies. Finally, in relation to the knowledge base of both sectors identified as following the IM pattern, I have already explained in section 3.2 that they became more science-based over time, integrating diverse disciplines. Dutfield (2020) speaks of a convergence of biotechnology with digital technologies included in pharmaceuticals' contemporary knowledge base. Likewise, digital technologies, in particular AI, point to information technology as also becoming more science-based and

[15] See for instance https://brandirectory.com/rankings/global/.
[16] https://www.amazon.com/gp/help/customer/display.html?nodeId=GCX77V9988LUPMB2.
[17] Retrieved from https://www.startups.com/community/questions/396/for-every-success-story-in-silicon-valley-how-many-are-there-that-fail last accessed on December 22, 2022.

more interdisciplinary, thus more complex in the terms considered by Malerba and Orsenigo (1997). Overall, in both cases the interplay between science and technology is strong and the frontiers between basic and applied science are blurred, with large pharmaceuticals gaining more centrality over time in the highest impact factor health and biomedical sciences journals (Testoni *et al.*, 2021) and the extreme case of Microsoft and Google as the organizations presenting more scientific papers in the leading AI scientific conferences (Jurowetzki *et al.*, 2021).

7. Final remarks

All in all, by introducing the IM pattern of innovation and technological regime, in which benefits accrued from innovation developed by corporate innovation systems are disproportionately harvested by intellectual monopolies, this paper has contributed to our understanding of patterns of innovation and innovation systems. The focus on systems was crucial for identifying and studying the interplay between different heterogeneous firms co-producing innovation. As evidenced empirically, this pattern of innovation is characterized by a stable core and turbulent and dynamic peripheries among which many innovating companies subordinate to intellectual monopolies, as in the cases of AWS partners and innovating firms that are heavily reliant on funding -and technology- provided by an intellectual monopoly.

The second general contribution of this paper was its historical approach to explain the IM pattern of innovation. The confluence of political, institutional, technological, and economic transformations fostered the perpetuation of intellectual monopolies but also encouraged knowledge modularization and the spread of start-ups in certain sectors—pharmaceuticals and information technologies—leading to the emergence of a distinct pattern. Among others, the role of the US hidden industrial policy as well as China's protectionism, the weakening of antitrust, a more stringent and extensive IPRs regime, new technologies—that accelerate but also make R&D more expensive—and globalization have contributed to perpetuating intellectual monopolies.

These contributions leave room for continuous work on the evolution of taxonomies and patterns of innovation both given the dynamics of technological change, as pointed out by Archibugi (2001), but also considering social, political, and economic changes as well as the performative effect of science to making things happen. Additionally, more systematic empirical research is needed to map the IM regime, for instance, using the entire patent database to complement the preliminary analyses on a subset of the database presented here.

Finally, the portrayal presented here could be contested in the future and efforts shall be put in that direction. One could hope for civil society reactions to knowledge monopolization, which could tilt the scale against intellectual monopolies and create new collaborative patterns of innovation. Yet other future scenarios are also feasible. Potential decoupling of global innovation due to the US–China conflict, the evolution of the international IPRs regime and antitrust laws may also shape existing and create new patterns. Therefore, there is room for expanding the study of patterns of innovation, their evolution and how they are shaped not only by technological regimes but also political, economic, and social factors, including the prefiguration of new ways of conceiving innovation.

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Appendix

Table A.1. Electric digital data processing (stability of the core)

		Stability		
Top 30 in 2013	**Top 30 in 2022**	**Top 30**	**Top 20**	**Top 10**
INTERNATIONAL BUSINESS MACHINES CORP	SAMSUNG	3	3	3
MICROSOFT	INTERNATIONAL BUSINESS MACHINES CORP	1	1	1
SAMSUNG	TENCENT	New	New	New
SONY CORP	MICROSOFT	2	2	2
FUJITSU LIMITED	HUAWEI	New	New	New
GOOGLE INC.	STATE GRID CORP OF CHINA	New	New	New
APPLE INC	INSPUR GROUP CO. LTD	New	New	New
CANON INC	ALIBABA	New	New	New
INTEL CORPORATION	GOOGLE INC.	6	6	6
HITACHI LTD	BAIDU INC	New	New	New
LG	DELL	20	20	
HON HAI PRECISION INDUSTRY CO. LTD	APPLE INC	7	7	
QUALCOMM INC	LG	11	11	
BROADCOM LTD	INTEL CORPORATION	9	9	
NEC CORP	CANON INC	8	8	
TOSHIBA CORP	MICRON TECHNOLOGY INC.	New	New	
BLACKBERRY LTD.	ADVANCED NEW TECHNOLOGIES CO. LTD	New	New	
HEWLETT PACKARD ENTERPRISES	AMAZON.COM INC.	New	New	
ORACLE CORPORATION	SONY CORP	4	4	
DELL	CHINESE ACADEMY OF SCIENCE	New	New	
PANASONIC HOLDING CORPORATION	HEWLETT PACKARD ENTERPRISES	18		
HONG FUJIN PRECISION INDUSTRY	BOE TECHNOLOGY GROUP LTD	New		
RICOH CO. LTD.	SK HYNIX INC	New		
SAP SE	OPPO ELECTRONICS CORP	New		
SHARP CORP	HANGZHOU HIKVISION DIGITAL TECHNOLOGY CO LT	New		
ELECTRONICS AND TELECOMMUNICATIONS RE	PING AN INSURANCE (GROUP) COMPANY OF CHINA	New		
GLOBAL FOUNDRIES INC	FUJIFILM	28		
FUJIFILM	PEOPLE'S LIBERATION ARMY	New		
VANTIVA SA (FORMER TECHNICOLOR SA)	TIANMA MICROELECTRONICS CO LTD	New		
KYOCERA CORP.	FUJITSU LIMITED	5		

Author's analysis, data extracted from Derwent Innovation.

Table A.2. Pharmaceuticals core

Top 30 in 2013	Top 30 in 2022	Stability top 30	Stability top 20	Stability top 10
NOVARTIS	ROCHE HOLDING LTD.	2	2	2
ROCHE HOLDING LTD.	JOHNSON & JOHNSON	3	3	3
JOHNSON & JOHNSON	BRISTOL-MYERS SQUIBB CO.	12	12	New
SANOFI	NOVARTIS	1	1	1
BOEHRINGER INGELHEIM GMBH	SANOFI	4	4	4
GSK (FORMER GLAXOSMITHKLINE PLC)	PFIZER INC	9	9	9
MERCK & CO. INC.	MERCK & CO. INC.	7	7	7
ASTRAZENECA PLC	CHINESE ACADEMY OF SCIENCE	New	New	New
PFIZER INC	ASTRAZENECA PLC	8	8	8
BAYER AG	AMGEN INC	17	17	New
TAKEDA PHARMACEUTICAL CO LTD	BOEHRINGER INGELHEIM GMBH	5	5	
BRISTOL-MYERS SQUIBB CO.	GILEAD SCIENCES INC.	25	New	
MERCK KGAA (GERMANY)	BAYER AG	10	10	
UNITED STATES HEALTH & HUMAN SERVICES	TAKEDA PHARMACEUTICAL CO LTD	11	11	
ELI LILLY AND COMPANY	UNIVERSITY OF CALIFORNIA	27	New	
ALLERGAN PLC (now ABBVIE)	REGENERON PHARMACEUTICALS INC.	New	New	
AMGEN INC	INSTITUT NATIONAL DE LA SANTE ET DE LA RECHERCHE MEDICALE	New	New	
ABBOTT LABORATORIES	GSK (FORMER GLAXOSMITHKLINE PLC)	6	6	
NESTLE S.A.	UNITED STATES HEALTH & HUMAN SERVICES	14	14	
ABBVIE	ELI LILLY AND COMPANY	15	15	
OTSUKA PHARMACEUTICAL CO LTD	OTSUKA PHARMACEUTICAL CO LTD	21		
VERTEX PHARMACEUTICALS INC.	CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIC	28		
CELGENE CORP. (now Bristol Myers Squibb)	INCYTE CORPORATION	New		
DAIICHI SANKYO CO LTD	HARVARD UNIVERSITY	New		
GILEAD SCIENCES INC.	PEOPLE'S LIBERATION ARMY	New		
TEVA PHARMACEUTICAL INDUSTRIES LTD.	MERCK KGAA (GERMANY)	13		
UNIVERSITY OF CALIFORNIA	ABBVIE	20		
CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIC	SUN YAT-SEN UNIVERSITY (CHINA)	New		
NOVO-NORDISK A/S	UNIVERSITY OF PENNSYLVANIA	New		
SERVIER SA	IMMATICS NV (FORMER IMMATICS BIOTECHNOLOGIES GMBH)	New		

Author's analysis, data extracted from Derwent Innovation.

Table A.3. Fertilizers (stability of the core)

Top 30 in 2013	Top 30 in 2022	Top 30	Top 20	Top 10
CHINESE ACADEMY OF SCIENCE	CHINESE ACADEMY OF SCIENCE	1	1	1
INST AGRO FOOD SCI & TECHNOLOGY CHINESE	INST AGRO FOOD SCI & TECHNOLOGY CHINESE	2	2	2
SYNGENTA AG	YARA INTERNATIONAL ASA	22	New	New
SHANDONG GUANGDA FERTILIZER IND TECHNOLO	GUANGXI ZHUANG NATIONALITY AUTONOMOUS RE	New	New	New
BASF SE	BASF SE	5	5	5
STANLEY FERTILIZER CO LTD	CHINESE ACAD TROPICAL AGRIC SCI	New	New	New
ISRAEL CHEMICALS LTD	EUROCHEM	New	New	New
HUNAN ZHONGKE AGRIC CO LTD	SAUDI BASIC INDUSTRIES CORP.	New	New	New
ZAKHAROV JURIJ VASIL'EVICH	CHINA TOBACCO HENAN IND CO LTD	17	17	New
BAYER	SAWANT ARUN VITTHAL	New	New	New
PLA ACADEMY OF MILITARY MEDICAL SCIENCES	RHODIA S.A.	New	New	
KINGENTA ECOLOGICAL ENG GROUP CO LTD	SHANDONG ACAD AGRIC MACHINERY SCI	24	New	
SHENZHEN BATIAN ECOTYPIC ENG CO LTD	GUANGXI ZHUANG AUTONOMOUS REGION INST	New	New	
UNIV CHINA AGRICULTURAL	UNIV SHANDONG AGRIC	21	New	
WENGFU GROUP CO LTD	SINOCHEM HOLDING (FORMERLY SINOCHEM CORP)	New	New	
SUMITOMO	VERDESIAN LIFE SCI US LLC	New	New	
CHINA TOBACCO HENAN IND CO LTD	UNIV NANJING AGRIC	28	New	
ZHEJIANG UNIVERSITY	ROYAL DSM NV	New	New	
SHANGHAI LVLE BIOTECHNOLOGY CO LTD	ANGLO AMERICAN	New	New	
BIJAM BIOSCIENCES PRIVATE LTD	UNIV GUIZHOU	New	New	
UNIV SHANDONG AGRIC	LG CHEM LTD.	New		
YARA INTERNATIONAL ASA	SHELL OIL COMPANY	New		
KOCH AG & ENERGY SOLUTIONS (FORMERLY KOCH FERITILIZER LLC)	UNIV QILU TECHNOLOGY	New		
SHANDONG ACAD AGRIC MACHINERY SCI	AZOTIC TECH LIMITED	New		
UNIV TIANJIN NORMAL	UNIV NORTHWEST A & F	New		
HUBEI FORBON TECHNOLOGY CO LTD	FINANCE DEV ENVIRONEMENT CHARREYRE-FIDEC	New		
UHDE GMBH	KOCH AG & ENERGY SOLUTIONS (FORMERLY KOCH FERITILIZER LLC)	23		
UNIV NANJING AGRIC	JIANGSU AGRIC SCI INST	New		
SPECIALTY FERTILIZER PRO LLC	UNIV SOUTH CHINA AGRIC	New		
INST SOIL&FERTILIZER GUANGDONG PROV AC	EASYMINING SWEDEN AB	New		

Author's analysis, data extracted from Derwent Innovation.

Table A.4. Engines, pumps, and turbines (stability of the core)

Top 30 in 2013	Top 30 in 2022	Top 30	Top 20	Top 10
TOYOTA	GENERAL ELECTRIC COMPANY	2	2	2
GENERAL ELECTRIC COMPANY	SAFRAN S.A.	8	8	8
MITSUBISHI	MITSUBISHI	3	3	3
HONDA MOTOR CO. LTD.(HONDA GIKEN KOGYO KK)	TOYOTA	1	1	1
SIEMENS	RAYTHEON CO.	26	New	New
DENSO CORP	SIEMENS	5	5	5
BOSCH (ROBERT) GMBH	HYUNDAI MOTOR CO.	9	9	9
SAFRAN S.A.	DENSO CORP	6	6	6
HYUNDAI MOTOR CO.	BOSCH (ROBERT) GMBH	7	7	7
HITACHI LTD	VOLKSWAGEN A.G.	13	13	New
GENERAL MOTORS CORP	ROLLS ROYCE HOLDINGS PLC	16	16	
NISSAN MOTOR CO. LTD.	HITACHI LTD	10	10	
VOLKSWAGEN A.G.	FORD MOTOR CO.	14	14	
FORD MOTOR CO.	HONDA MOTOR CO. LTD.(HONDA GIKEN KOGYO KK)	4	4	
PANASONIC	LG CORP	18	18	
ROLLS ROYCE HOLDINGS PLC	UNITED TECHNOLOGIES CORP	New	New	
SAMSUNG	WEICHAI POWER CO LTD	New	New	
LG CORP	PRATT & WHITNEY CORPORATION	29	New	
BORGWARNER INC.	VESTAS WIND SYSTEMS A/S	23	New	
AISIN	MAZDA MOTOR CORP.	21	New	
MAZDA MOTOR CORP.	TIANMA MICROELECTRONICS CO LTD	New		
IHI CORP	GREE ELECTRIC APPLIANCES INC OF ZHUHAI	New		
VESTAS WIND SYSTEMS A/S	CUMMINS INC.	New		
YAMAHA MOTOR CO. LTD.	GENERAL MOTORS CORP	11		
INA-HOLDING SCHAEFFLER KG	BEIJING GOLDWIND SCI & CREATION WINDPOWE	New		
RAYTHEON CO.	NISSAN MOTOR CO. LTD.	12		
MAHLE GMBH	BORGWARNER INC.	19		
DAIKIN INDUSTRIES LTD	VITESCO TECHNOLOGIES GMBH DE	New		
PRATT & WHITNEY CORPORATION	CATERPILLAR INC.	New		
TOSHIBA CORP	STATE GRID CORP OF CHINA	New		

Author's analysis, data extracted from Derwent Innovation.

Table A.5. Selected intellectual monopolies among top five investors of other firms

Investor	Number of firms
Google	793
Microsoft	496
Tencent	427
Samsung	368
Alibaba incl Ant	273
Amazon	140
Johnson & Johnson	88
Meta	51
Pfizer	46
Nvidia	43
Eli Lilly	39
Merck	35
Abbvie	23
Roche	20
Apple	14
Total	**2856**

Author's analysis, data extracted from Crunchbase.