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ESSAYS ON UNCONVENTIONAL MONETARY POLICIES

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Gherardo Gennaro Caracciolo

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Department of Economics

Declaration

"I, Gherardo Gennaro Caracciolo confirm that the work presented in my thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis."

Date | Signature

03/08/2022 [redacted]

Abstract

This thesis studies the effects of unconventional monetary policies on social welfare and macroeconomic stability, alongside their interaction with fiscal policies.

Chapter 1 analyses how the effectiveness of central bank communication depends on its precision (the noise in the communication) and its accessibility (the fraction of agents it reaches). Most of the existing theoretical work on central bank communication focuses on one or the other dimension, neglecting their interdependence. In this Chapter I show that accounting for their interaction is essential for optimal communication design. Within two different information structures, I show that disclosing too precise information is detrimental if it reaches a small audience, even if the alternative is no disclosure to anyone. The optimal degree of precision is increasing in the share of people who can understand it. My analysis suggests it is better to provide simple and clear statements rather than very detailed information that only few can understand.

Chapter 2 (joint work with Marco Bassetto) studies how the well known connection between monetary and fiscal policy manifests itself in the context of the Eurozone, where that connection links the European Central Bank, the 19 national central banks, the Treasuries of 19 countries, and the European Union. The goal is twofold. First, we wish to clarify how seigniorage flows from the monetary authority to the budget of each country. Second, we seek to answer the question of how the taxpayers of each country are affected by a default of one of the participants to the union. In answering this question, we analyze the mechanisms that ensure (or do not ensure) that net liabilities across countries stay bounded, and I establish how the answer depends on the liquidity premium that each category of assets commands (cash, excess reserves within the Eurosystem, and government bonds). We find that the official risk-sharing provisions of the policy of quantitative easing (QE), whereby national central banks retain 90% of the risk intrinsic in bonds of their own country, only holds under restric-

tive assumptions; under plausible scenarios, a significantly larger fraction of the risk is mutualized.

Chapter 3 revisits the question of how a central bank should communicate. In this Chapter, alongside precision, I take into account another fundamental feature of communication: credibility. Standard economic practice suggests that central banks should uncontrovertibly maximise their credibility. However, through a new theoretical framework, I show that under realistic circumstances, this might not be consistent with welfare maximisation.

Impact Statement

In this thesis I study the welfare effects of central banks' communication, and the interaction between monetary and fiscal policies, with a particular focus on the complex environment of the Euro Area. It fits within the field that answers macroeconomic questions through theoretical models. Because of its focus, it is also closely related to economics of information and monetary economics.

This work contributes to the existing literature in different ways. Chapter 1 and Chapter 3 provide new theoretical frameworks that help studying central banks' communication problems. In these chapters I show how the effects of forward guidance on social welfare change according to different combinations of various important features of communication: precision (the noise in the communication), accessibility (fraction of agents reached by the communication), and credibility (fraction of agents who believe the communication is informative). In Chapter 2 (joint with Marco Bassetto) we extend the literature that studies fiscal consequences of Quantitative Easing in order to analyse the complex environment of the Eurozone, where the ECB interacts with: 19 independent (?) fiscal authorities, and 19 national central banks.

The theoretical findings of this thesis carry important policy implications. Chapter 1 highlights a new interesting complementarity between precision and accessibility of communication: the more precise (i.e. technical) a central bank wants to be, the bigger its audience (i.e. accessibility) must be in order for the communication to trigger a welfare gain. Chapter 3 shows the non-trivial role of credibility: full credibility, that in practice seems extremely desirable, is not always consistent with welfare maximisation. Both these results can help shaping the communication reforms that many central banks have undertaken in the past few years. The findings of Chapter 2 call for a revision of the TARGET2 system (the tool that settles payments related to the Eurosystem's monetary policy operations) highlighting how this represents an important point of connection between national central banks' budget constraints that could potentially lead to unintended fiscal redistribution.

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Introduction

The effectiveness of the new unconventional tools of monetary policy, namely forward guidance and quantitative easing, came to the forefront of academic and policy research debate during the European debt crisis, and subsequently during the recent pandemic. This thesis aims to contribute to this debate shedding new light on how unconventional monetary policies impact on social welfare and, in the case of quantitative easing, affect central banks' balance sheets and interact with fiscal policies. Understanding the effects that these policies produce requires accurately modelling people's expectation formation process alongside with the fiscal environment in which they fit. Thus, part of this thesis, is devoted to understanding how the information coming from the central banks affects the general public's expectations, therefore changing their behaviour. A second part takes a structural approach in order to understand the functioning of quantitative easing programs in the complex environment of the Euro Area.

In Chapter 1,"Parole, Parole, Parole: The importance of Central Bank Communication)", I study how forward guidance's impact on social welfare, and therefore optimal communication policy prescriptions, depends on the relation between two fundamental features of communication: precision (the noise in the communication), and accessibility (the fraction of agents reached). I start by documenting the fact that the forward guidance implemented by the Fed in the aftermath of the Great Financial Crisis has not been homogeneously accessible to the general public. More precisely, using the Michigan Survey of Consumers, I present new facts on how, following the introduction of calendar-based forward guidance, a significant and systematic difference between the levels of disagreement about the 1-year ahead short-term interest rate of different types of consumers arose. I then develop a Lucas-Phelps island model extending Myatt and Wallace [2014] in which a welfare-maximizing central bank releases a signal regarding the unknown fundamental of the economy. This signal features a certain precision (i.e. noise of the signal) and accessibility levels (i.e. fraction of agents that receives the signal).I show the existence of three key accessibility regions (low, middle, high) that determine the welfare impact of the communication. If the audience reached is in the low-accessibility region, then a central bank's best strategy is to remain silent, as communicating always leads to a welfare loss. This is independent of the precision achievable. On the contrary, if the audience of the central bank falls in the high-accessibility region, then a central bank should always communicate, as by doing so it unequivocally increases welfare. This is also independent of the precision achievable. When the central banks' audience is in the middle-accessibility region, however, the precision level it wants to achieve is crucial in determining whether communicating is welfare enhancing. As for any given precision level, there exists a unique precision-dependent accessibility threshold such that, if the central bank's audience is below this threshold, communicating triggers a welfare loss. On the contrary, if the audience is above the threshold, communicating improves welfare. I also show that this precision-dependent accessibility threshold increases with the precision level the central bank wants to achieve. This last conclusion poses important new policy challenges, as it implies that the more precise a central bank wants to be, the bigger its audience must be in order for this communication to be welfare enhancing. Precision and accessibility are therefore complements, while the natural trade-off highlighted by the empirical literature goes in the exact opposite direction: more precision implies less accessibility Haldane and McMahon [2018].

In Chapter 2,"Monetary/Fiscal Interactions with Forty Budget Constraints" (joint with Marco Bassetto), we study how the well known single budget constraint connection between fiscal and monetary policy manifests itself in the context of the Eurozone. While existing works have focused on the interaction between a single fiscal and a single monetary authority, within the Eurozone that connection is much more complex as it links the European Central Bank, the 19 national central banks, the Treasuries of 19 countries, and the European Union. The central question we ask is the following: if indeed monetary and fiscal policy are inevitably intertwined by their common budget constraint, under what assumptions is there a wall between the budgets of each nation within the Eurozone? Is there still the potential for losses and gains to spill over from one country to another in potentially unintended ways? Our findings suggest that the conditions under which the separation of the budgets of each country holds are quite restrictive. In practice taxpayer risks are pooled to a greater extent than it would be the case de jure. Our chapter emphasizes the role of the Target 2 system in representing the link in the budget constraints across countries.

In Chapter 3, 'Optimal Communication Strategy for Central Banks', I revisit the question of how forward guidance affects social welfare. In this chapter, however, alongside precision, I take into account a different dimension of forward guidance: credibility. I develop a theoretical framework in which a sender controls the two dimensions of its communication jointly. I then apply it to a Central Bank communication problem and study the precision and credibility levels that are consistent with welfare maximization. The result is that while it is true that Central Banks should always be as precise as possible, it is not true that they should maximize credibility of their communication 'a priori'. In fact, credibility should be carefully tailored to the maximum precision achievable. This result sheds new light on the 'forward guidance puzzle' introducing a trade-off between maximizing forward guidance's effectiveness and maximizing social welfare.

Chapter 1

"Parole, Parole, Parole": The Importance of Central Bank Communication

1.1 Introduction

Communication is a fundamental tool for central banks' monetary policy. In particular, an important aspect of monetary policy is sharing superior information[1] with the goal of reducing agents' uncertainty, guiding their expectations, and easing their decision making process (Blinder et al. [2008]). The effectiveness of communication depends on two fundamental features: precision (the noise in the communication) and accessibility (the fraction of agents reached by the communication). Accessibility has increasingly become a first order concern for many central banks, as they have embarked in extensive (and expensive) communication reforms aiming to reach a larger number of agents in the economy. For instance, the Bank of England, the Fed, and the ECB have all started releasing simpler and more concise statements alongside the 'traditional' technical reports, and they significantly increased their presence on social media.

These initiatives are guided by the empirical literature's findings that show how pre-

[1] Campbell et al. [2012] calls "Delphic forward guidance" the case in which a central bank's aim is to transmit superior information regarding the economy to the agents.

cision and accessibility of central banks' communication are deeply linked. The more precise a signal is, the more technical it will be and therefore less accessible to the general public (Binder [2017], Coenen et al. [2017], Jost [2017], Haldane and McMahon [2018]). Haldane and McMahon [2018] provide experimental evidence showing that, while the Bank of England's "traditional" communication reaches a small fraction of the population, the new shorter and simpler reports are accessible to a much broader audience. The key trade-off highlighted in their experiment is straightforward: a more technical (precise) signal affects agents' expectations to a greater extent, but decreases the number of agents' whose expectations are influenced. This is owed to the fact that not everyone possesses the skill set to understand and interpret the more technical and nuanced form of communication. However, on the theoretical side, most of the existing work on central banks' communication focuses solely on precision (Morris and Shin [2002b], Angeletos and Pavan [2004], Svensson [2005], Angeletos and Lian [2016]). When accessibility is also considered, these two features are treated as disjointed and independent dimensions (Cornand and Heinemann [2008]).

The main contribution of this chapter is to develop a theoretical framework to analyse how welfare effects produced by the release of a communication change according to any potential precision-accessibility interdependence. The key finding is that, unless the signal of the central bank reaches a precision-dependent minimum audience, communicating unequivocally leads to a welfare loss. From a policy perspective, it is therefore essential for central banks to understand the precision-accessibility mapping of their communication, as shortcomings in assessing this link leads to policy mistakes.

I develop a Lucas-Phelps island model extending Myatt and Wallace [2014] in which a welfare-maximizing central bank releases a signal regarding the unknown fundamental of the economy. This signal features a certain precision level. On the receivers part, only a fraction of agents will be able to access the central bank's signal. The fraction of agents to which the central bank's signal is accessible can be interpreted as being determined by its precision. Throughout the chapter, I purposely keep the mapping between precision and accessibility of the signal as general as possible, avoiding committing to any specific functional form. I show that there are three key accessibility regions (low, middle, high) that determine the welfare impact of the communication. If the audience reached is in the low-accessibility region, then a central bank's best strategy is to remain silent, as communicating always leads to a welfare loss. This is independent of the precision achievable. On the contrary, if the audience of the central bank falls in the high-accessibility region, then a central bank should always communicate, as by doing so it unequivocally increases welfare. This is also independent of the precision achievable. When the central banks' audience is in the middle-accessibility region, however, the precision level it wants to achieve is crucial in determining whether communicating is welfare enhancing. As for any given precision level, there exists a unique precision-dependent accessibility threshold such that, if the central bank's audience is below this threshold, communicating triggers a welfare loss. On the contrary, if the audience is above the threshold, communicating improves welfare. I also show that this precision-dependent accessibility threshold increases with the precision level the central bank wants to achieve.

This last conclusion poses important new policy challenges, as it implies that the more precise a central bank wants to be, the bigger its audience must be in order for this communication to be welfare enhancing. Precision and accessibility are therefore complements, while the natural trade-off highlighted by the empirical literature goes in the exact opposite direction: more precision implies less accessibility (Haldane and McMahon [2018]). All these results are driven by the fact that, in an environment in which agents have a strategic motive, having a small audience does not only lead to a failure in managing agents' expectations. It also causes a harmful 'misweighting' of the available information that leads to further welfare losses.

I then move to a more complex and realistic information structure. The aim is to investigate the effects on welfare of the introduction of a simplified signal, alongside the more technical (and precise) one. This extension is warranted for two reasons. First, the aforementioned communication reforms adopted by many central banks, according to which they started to release simplified versions of their technical reports. Second, even when only technical information is released, it is then interpreted by experts and journalists in a way that adds noise but makes it more widely accessible. I show that the introduction of this new simplified signal does not remove the inefficiencies caused by the misweighting behaviour of the agents. Even in this second model, when the audience of the technical signal is too small (below a certain precision dependent threshold), then the release of two signals decreases welfare. I show that when the audience is below this threshold, a central bank could do better by releasing only one signal—the less precise one. Moreover, in this 'low accessibility region' the bigger the difference in precision between the two signals, the higher the implied welfare loss. As in the first model, the accessibility threshold is increasing in the precision of the more technical signal.

I also look at data on expectations regarding future monetary policy with a twofold goal: gathering a further motivating fact for my theoretical analysis, and carrying out a quantitative exercise. Firstly, I document the fact that the forward guidance implemented by the Fed in the aftermath of the Great Financial Crisis has not been homogeneously accessible to the general public. I use the Michigan Survey of Consumers to show that, following the introduction of calendar-based forward guidance, there was there was an unprecedented difference between the levels of disagreement about the 1-year ahead short-term interest rate among households with different degrees of education. Secondly, I combine the Michigan Survey of Consumers dataset with data on the 3 Month T-Bill Rate in order to quantify the analytical thresholds derived in the first model and simulate the welfare impact of different types of communication.

The remainder of the chapter is organized as follows: section 1.2 presents new facts on general public's disagreement regarding future monetary policy. Here I show that the disagreement levels of different type of consumers react differently to the introduction of calendar-based forward guidance. section 1.3 presents the island-economy model and the first information structure I adopt. In Subsections 1.3.1, 1.3.2 and 1.3.3 I solve the model presenting its equilibrium and the implications for output stabilization. In Section 1.4 and its subsections I present the more complex information structure, the new equilibrium, and the results of this second model, highlighting similarities and differences with the first one. In Section 1.5 I summarize my findings drawing some relevant policy conclusions.

1.1.1 Literature Review

This chapter contributes to the large and growing literature on central bank communication. A big branch of this literature focuses on how the welfare effect of disclosing public information varies with the precision level, the number of signals released, and the agents' desire for coordination: Morris and Shin [2002b], Angeletos and Pavan [2004], Morris and Shin [2005], Svensson [2005], Hellwig [2005], Angeletos and Pavan

[2007], Chahrour [2014]. Angeletos and Pavan [2004] and Angeletos and Pavan [2007] discuss equilibrium versus efficient use of information. Within a class of economies that have externalities, strategic complementarity or substitutability, and heterogeneous information, they analyse the impact on welfare of the release of a signal according to its publicity. This chapter is a generalization of their work. Focusing on an island-economy in which inefficiency is driven by non-socially optimal strategic complementarity it shows how results change once the possibility of having heterogeneous access to information is taken into account. All these works assume homogeneity in the accessibility of the information that is released, in contrast to this chapter. Perhaps the closest to this work is Cornand and Heinemann [2008]. Cornand and Heinemann [2008] claim that partial disclosures might tackle the coordination-driven problems highlighted by the aforementioned literature. In their model, welfare losses occur due to the high level of accessibility and the low levels of precision of the signal released. Whereas releasing information with low accessibility always leads to welfare gains. My work complements their findings shedding light on how, once one enriches the information structure and moves to a different (and broader) class of models, these conclusions are reversed. Welfare losses can only occur when a signal features low levels of accessibility, and this happens for any level of precision of the signal. This chapter offers also a useful theoretical framework to further study the implication of the precision-accessibility trade-off shown by empirical literature evaluating accessibility of central banks communication (Binder [2017], Coenen et al. [2017], Jost [2017], Haldane and McMahon [2018]), as it analytically derives precision-dependent accessibility thresholds that allow to unequivocally determine the welfare effects of communicating.

1.2 The Impact of Forward Guidance on the Public's Disagreement

In August 2011, the Federal Open Market Committee (FOMC) released the following statement: *"The Committee currently anticipates that economic conditions [...] are likely to warrant exceptionally low levels for the federal funds rate at least through mid-2013"*. This marked the beginning of the so called 'calendar-based forward guidance'. The FOMC started implementing forward guidance already in December 2008, however it issued very general and 'open ended' statements, without explicit references to any calendar date or precise time horizon: *"Interest rates are expected to remain low for an extended period"*. In this section I present some facts on the impact of this change of communication on future monetary policy expectations.

Previous works, using surveys of professional forecasters, have shown how the introduction of 'calendar-based' forward guidance led to a sharp decrease in the disagreement among experts (Andrade et al. [2019], Ehrmann et al. [2019]). Using the Michigan Survey of Consumers[2], I perform a similar exercise for the general public's expectations. The Michigan Survey of Consumers asks the following question. *"No one can say for sure, but what do you think will happen to interest rates for borrowing during the next 12 months will they go up, stay the same, or go down?'* Creating a categorical variable that takes value 1, if the answer is 'they will go up', 0 if the answer is 'stay the same', -1 for 'they will go down', and taking its variance, allows me to recover a disagreement index. Figure 1.2.1 shows how disagreement evolved during the period 1980-2019. The vertical line in 2011 marks the beginning of the calendar-based forward guidance.

Fact 1. *After the introduction of date-based forward guidance, consumers' disagreement on future interest rates one-year ahead declined and stabilized around low levels.*

[2] Appendix A describes the Michigan Survey of Consumers in detail

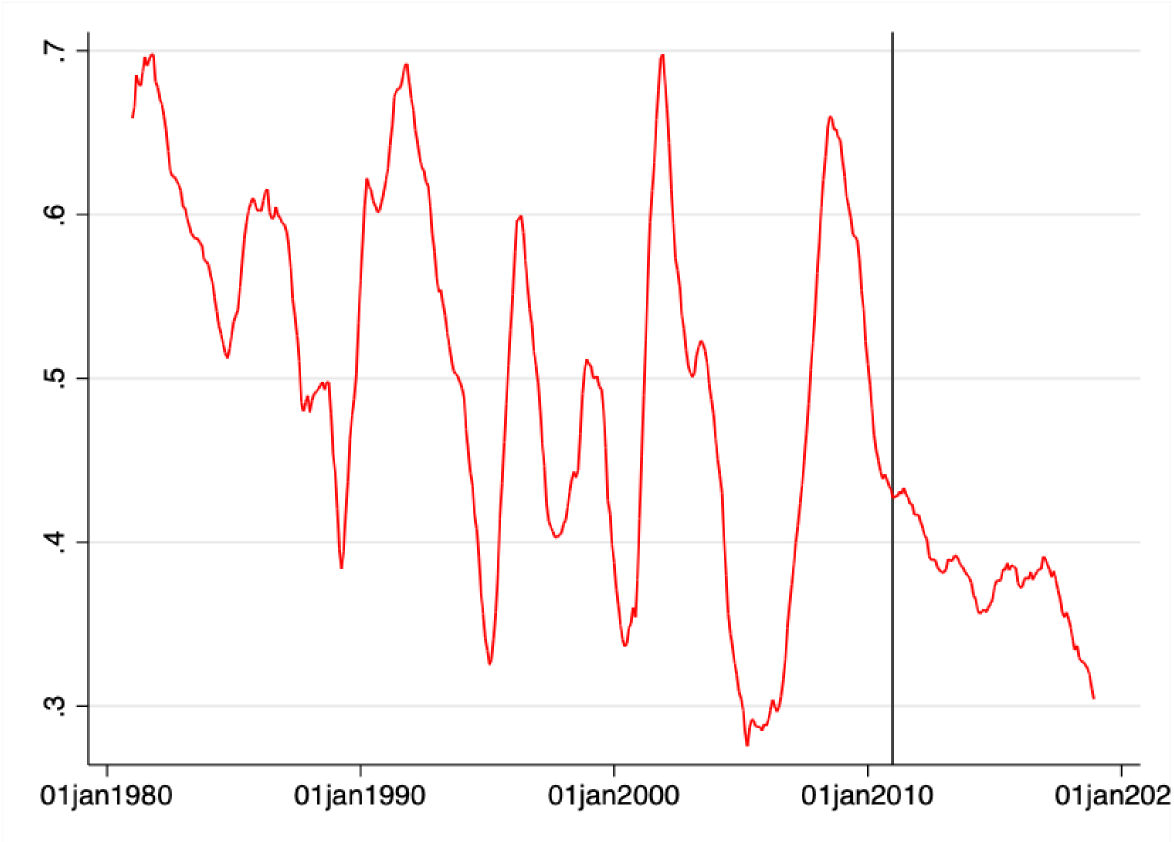

Figure 1.2.1: Disagreement 1980–2020

However, while professional forecasters' ability to understand central banks' communication can be thought as homogeneous, this is far from a realistic assumption when we talk about the general public. It is natural to ask, therefore, whether everyone in the economy processes the information coming from the central bank in the same way? Haldane and McMahon [2018], through a field experiment, suggest that only highly educated people might have the necessary skills to understand central banks' communication. The Michigan Survey of Consumers allows us to divide the respondents according to their education level. I compute the disagreement indices about future monetary policy for two different types of agents: those who went to college ('College-Educated'), and those who have a high-school diploma or less ('High School-Educated'). Figure 1.2.2 reports these two disagreement indices.

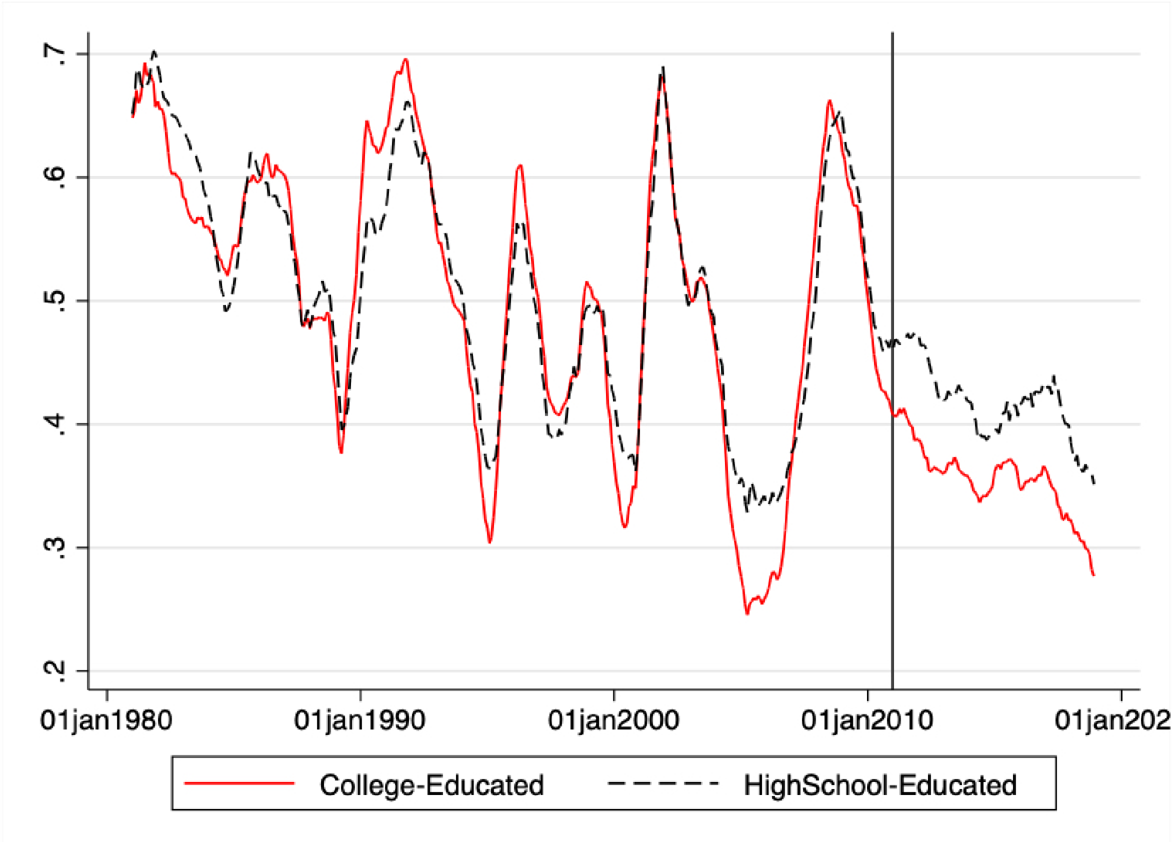

Figure 1.2.2: Disagreement Indices by Educational Attainment

Fact 2. *Before the introduction of date-based forward guidance, there are no clear systematic differences between the two disagreement indices. After the introduction of calendar-based forward guidance the disagreement level of the 'College-Educated' agents falls more, and a systematic gap between the two indices arises.*

Figure 1.2.2 strongly suggests that Fed's forward guidance is much more effective in influencing and coordinating educated agents' expectations, that is, it is perceived as more precise and hence understood better.

1.3 The Model: A Lucas-Phelps Island Economy

In this Section I present the general set up of the model, the first information structure, the welfare criterion I adopt, and the results.

This model closely follows that in Myatt and Wallace [2014], which is a Lucas-Phelps economy (Phelps [1970], Lucas [1972]) with a unit mass of 'islands' indexed by $i \in [0, 1]$. Each island i can be thought of as a sector of an economy. The natural logarithm of the nominal price on each island i is p_i. Log production in island i is given by y_i and the natural level of output is normalized so that its natural logarithm is equal to 0. Aggregate demand, on every island i is driven by the (unique) economy-wide fundamental $\theta \in \mathbb{R}$. If the fundamental θ were common knowledge, then $p_i = \theta$ in each island i and output gap would be eliminated. There is however island-specific uncertainty regarding θ. Aggregate demand, $y_{i,D}$, on each island is defined as follows

$$y_{i,D} = \alpha_d(\mathbb{E}_i[\theta] - p_i), \tag{1.3.1}$$

where p_i is the natural logarithm of the nominal price in island i and α_d is the slope of aggregate demand. In this specification aggregate demand depends on the expectation of θ, which can be considered as an idealized nominal anchor in the economy.

There will also be supply-side uncertainty, because on each island i only p_i is known. All the other prices are not observed. Aggregate supply, $y_{i,S}$, on island i is defined to be

$$y_{i,S} = \alpha_s(p_i - \mathbb{E}_i[\bar{p}]), \tag{1.3.2}$$

where $\bar{p} = \int_0^1 p_i di$ is the average price in the economy and α_s is the slope of aggregate supply. Equating the supply and demand yields the market-clearing price in island i

$$p_i = (1 - \pi)\mathbb{E}_i[\theta] + \pi\mathbb{E}_i[\bar{p}], \tag{1.3.3}$$

where $\pi = \frac{\alpha_s}{\alpha_s + \alpha_d}$. The market-clearing prices in this economy are, therefore, a linear combination of two island-specific expectations. One is an expectation over the hidden state of the world θ. The other is an expectation of the average price across all other islands $\bar{p}$. The weight assigned to each expectation depends on the slopes of aggregate supply and demand. The pricing rule (1.3.3) can be easily microfounded. Myatt and Wallace [2012] show that this is the equilibrium price when differentiated firms compete in Bertrand/price competition. Foundations can also be derived from DSGE models (Angeletos and La'O [2009], Angeletos and Lian [2018]), where the optimal pricing rule of the firms can be represented as a dynamic beauty-contest.

In the Lucas-Phelps island model, the economy's efficiency is generally measured using the output gap for each island. Recall that, given the normalization of the natural-level of output, y_i also represents the output gap of each island in the economy. If the state of the world θ was common knowledge, then there would be a unique price equal to θ and y_i would be always equal to 0. Thus, no output gap in any island would arise. However, uncertainty over θ and over the average price $\bar{p}$ leads to inefficiencies. We can measure the overall efficiency of this economy by aggregating all islands' output gaps (and treating them symmetrically). I therefore use $\int_0^1 y_i^2 di$ as an ex-post measure of output stability. This has an ex-ante value equal to $\mathbb{E}[y_i^2]$.

1.3.1 The Information Structure

The information structure is designed to captures the fact that every agent in the economy is likely to have her own private source of information, alongside a public one.

All islanders share an improper common prior[3] on $\mathbb{R}$ over the economy-wide fundamental θ. On each island i the agents receive a private signal z_i and a public signal Z of θ. This economy also features a third informative signal Y, which is the Central Bank's forward guidance. Based on the empirical evidence presented in Section 1.2, I model forward guidance as a public signal that reduces disagreement among agents. However, this signal is not processed homogeneously by everyone in the economy. In order to capture this heterogeneity, I assume that the signal Y reaches only a fraction of islands $\psi \in [0, 1]$. This happens as Y might be too technical and not accessible to everyone (Haldane and McMahon [2018]). All of these signals are conditionally independent, normally distributed, and centered around the true state of the world θ:

$$z_i \sim \mathcal{N}\left(\theta,\, \frac{1}{\gamma}\right), \qquad Z \sim \mathcal{N}\left(\theta,\, \frac{1}{\alpha}\right), \qquad Y \sim \mathcal{N}\left(\theta,\, \frac{1}{\delta}\right). \tag{1.3.4}$$

(Note: For the rest of the chapter I normalize $\gamma = 1$.) The informativeness of each signal is given by its precision level (γ, α, δ). Given the normality and the conditional independence of the signals, the agents living on each island i will form their expectation (1.3.1) of θ as a precision-weighted average of the signals they have received.

[3]Uninformative prior is without loss of generality, as any information from the prior can be subsumed into the public signal Z

1.3.2 Equilibrium

In this section I define and characterize the equilibrium of the model. Let S_i be the vector of signals received by island i. A fraction ψ of the islands are *Receivers* and $S_i = (z_i, Z, Y)$. The remaining fraction, $1 - \psi$, of the islands are *Non-Receivers* and $S_i = (z_i, Z)$. Note that every agent on an island has the same information, that's why we can label some islands as Receivers, and some others as Non-Receivers

An equilibrium consists of two pricing functions (one for Receivers and one for Non-Receivers) that maps the signals received on that island into market clearing prices. We will denote these functions $p^R(S_i)$ and $p^{NR}(S_i)$. (Islands of each type are symmetric, we can therefore assume they use symmetric pricing strategies.) The expectations that determine the market-clearing prices in island i (1.3.3) can in general be written

$$p(S_i) = (1 - \pi)\mathbb{E}_i[\theta \mid S_i] + \pi\mathbb{E}_i[p(S_j) \mid S_i]. \tag{1.3.5}$$

(Here the second expectation is over j as well S_j.) Since all the signals are normally distributed, it is well known that these expectations are linear and that the model has a unique linear equilibrium. Therefore, the equilibrium pricing functions are described by sets of weights $w_R := (w_R^{pvt}, w_R^{pub}, w_R^Y)$, $w_{NR} := (w_{NR}^{pvt}, w_{NR}^{pub})$, where: $w_R^{pvt} + w_R^{pub} + w_R^Y = 1$, $w_{NR}^{pvt} + w_{NR}^{pub} = 1$, and

$$\begin{aligned} p^R(S_i) &= w_R^{pvt} z_i + w_R^{pub} Z + w_R^Y Y, \\ p^{NR}(S_i) &= w_{NR}^{pvt} z_i + w_{NR}^{pub} Z. \end{aligned} \tag{1.3.6}$$

Since the two groups of islanders (Receivers and Non-Receivers) have a different information sets, they will weight each signal they have received differently. Appendix B provides derivation and explicit formulas for these equilibrium weights.

In the absence of the strategic motive ($\pi = 0$), prices would only be driven by the expectation over the state of the world ($p_i = \mathbb{E}_i[\theta]$). In this case only the precision level of the signals would matter for the equilibrium weights. However, when prices also depend upon the expectation over the average price in the economy, $\mathbb{E}[\bar{p}]$, the difference in publicity of the signals is also important. The higher the desire for coordination, measured by the slope of aggregate supply function α_s, the more the degree of publicity of each signal matters.

1.3.3 Accessibility, Precision, and Output Stability

Up to this point we have described the model and its equilibrium. We now move on to analyzing how different levels of precision (δ) and accessibility (ψ) of the signal Y change the Central Bank's optimal communication strategy.

In this model, the Central Bank acts as a benevolent social planner whose goal is maximizing the efficiency of the economy. The Central Bank's objective is to keep output stable by minimizing the output gap. The Central Bank pursues output stabilization by carrying out 'Delphic' forward guidance over the state of the world θ. This takes the form of the signal Y (1.3.4) with precision δ. Recall from Section 1.3 that output stability is given by $E[y_i^2]$. Furthermore, note that aggregate demand is $y_{i,D} = \alpha_D(\mathbb{E}_i[\theta] - p_i)$, hence in equilibrium $y_i \propto (E[\theta|I_i] - p(I_i))$. Therefore Myatt and Wallace [2014] define the loss function for the Central Bank as follows

$$L(z_i, Z, Y, \psi) = E\left[\left(E[\theta|I_i] - p(I_i)\right)^2 \middle| \ \theta, \psi \ \right]. \tag{1.3.7}$$

Some algebraic manipulation can be used to show that this function is independent of the hidden state of the world.[4] Below the loss is expressed as a function of the two sets of equilibrium weights and the precision levels of the signals.

$$\begin{aligned} L(z_i, Z, Y, \psi) = \psi &\left(\frac{(w_R^{pvt} - \frac{\gamma}{\gamma+\alpha+\delta})^2}{\gamma} + \frac{(w_R^{pub} - \frac{\alpha}{\gamma+\alpha+\delta})^2}{\alpha} + \frac{(w_R^{Y} - \frac{\delta}{\gamma+\alpha+\delta})^2}{\delta} \right) \\ &+ (1-\psi)\left(\frac{(w_{NR}^{pvt} - \frac{\gamma}{\gamma+\alpha})^2}{\gamma} + \frac{(w_{NR}^{pub} - \frac{\alpha}{\gamma+\alpha})^2}{\alpha} \right) \end{aligned} \tag{1.3.8}$$

From (1.3.8) it is clear that in this economy the welfare loss is driven by the difference between the price-setting and the expectation-formation process. Output gaps arise when prices (linear functions of the signals) differ from the agents' expectations of the state of the world (also linear functions of the signals). The more weights the agents place on the signals in their expectations ($w_R^{pvt}, w_{NR}^{pvt}, \dots$) differ from the weights used when setting the prices ($\frac{\gamma}{\gamma+\alpha+\delta}, \frac{\gamma}{\alpha+\gamma}, \dots$), the bigger is the welfare loss. Note that this is a different scenario from the ones analysed in Angeletos and Pavan [2007], where it is the public or private nature of the signal released that causes a loss, depending on the relation between social optimum and equilibrium degree of coordination. In the

[4] Appendix C gives the derivation of the loss function.

environment I analyse publicity or privateness of a signal do not cause a loss per se: inefficiency is driven by the difference in publicity of signals.

Consider the case where the central bank is silent (the economy only has the private signal z_i and the public signal Z). In this case the prices and expectations differ, because the private signal upsets the coordination role of the public signal Z. When firms set their prices, they are not only interested in the state of the world θ, but also in the average price $\bar{p}$ (1.3.3). The public signal Z is much more relevant than the private signal z_i in terms of forecasting the prices set by other firms. This opens a gap between the weights firms assign to Z during the price-setting and the expectation-formation process. The difference between these two weights is a measure of the overweighting of the public signal Z. It is this that generates a welfare loss (Morris and Shin [2002b])

When the Central Bank's signal is fully accessible ($\psi = 1$), then the following holds:

Proposition 1. *For all δ, the introduction of the Central Bank's signal Y reduces welfare loss whenever $\frac{\alpha}{\gamma} > \underline{\alpha}$.*

This Proposition states that when the precision level (α) of the public source of information Z is higher than a certain threshold $\underline{\alpha}$, a central bank whose signal is fully accessible should always communicate. By doing this it reduces the welfare loss. This reduction in loss holds for all precision levels δ that the central bank can achieve[5]. The intuition for this result is that introducing a fully-accessible Central Bank signal, Y, produces two welfare-enhancing effects. The first one is the 'Informative' effect in which the presence of Y makes agents better informed. This reduces the loss (the denominator of the loss function increases). The second one is the 'Rebalancing' effect in which the second public signal Y, increases the overall precision of the public sources of information. When $\frac{\alpha}{\gamma} > \underline{\alpha}$ this leads to a greater increase in the weight of public information in the price-setting decision compared to the expectation formation, reducing the inefficiency generated by the discrepancy between the two.

Even when information is unambiguously good, once we allow the Central Bank's signal Y to feature different accessibility levels, things become more complex and these conclusions change. When the accessibility of Y is imperfect, the 'informative' effect is weaker. This is because the number of 'Receivers' is lower and so the overall ben-

[5] Jehiel [2014] and Fujiwara and Waki [2020] analyse environments in which this may fail.

eficial impact of providing more information is lower. In short there are fewer agents that are better informed. Secondly, there is a higher order beliefs problem, so the introduction of Y produces a harmful 'misweighting' effect that can harm the stability of the economy. This happens because Receivers will tend to downplay this signal when setting their prices, as they know that only few other islands have access it. So in spite of its informativeness, the coordination role of Y is limited. This manifests itself as a gap between the weights the Receivers assign to Y during the price-setting and the expectation-formation processes. The difference between these two weights is a measure of the 'underweighting' of the central bank's signal Y. The introduction of an imperfectly accessible signal Y also widens the already existing gap between the weights the firms assign to the public signal Z during the price-setting and the expectation-formation process. This happens because after the release of Y the relative informativeness of Z in predicting θ falls. The precision-driven weight the receivers place on Z during the expectation-formation process falls. When Y's receivers are few in number, Z's coordination role remains fundamental. The weight the receivers place on Z during the price-setting process does not fall at the same rate. As a consequence, the overweighting of the signal Z increases.

The release of an imperfectly accessible signal Y produces therefore a positive 'informative' effect and a negative 'misweighting' effect. The relative strength of the two effects, and consequently the overall impact on welfare of forward guidance, depends on the number of receivers, that is, accessibility. If Y is well-accessible we have the following result.

Proposition 2. *When $\frac{\alpha}{\gamma} > \underline{\alpha}$ there exists an accessibility level $\bar{\psi}$, such that for all δ and all $\psi > \bar{\psi}$, $L(z_i, Z) > L(z_i, Z, Y, \psi)$.*

This proposition states that if the precision level of the public source of information Z (α) is higher than a certain threshold $\underline{\alpha}$, then a Central Bank whose signal reaches an audience larger than $\bar{\psi}$ should always communicate.In this case the informative effect dominates the misweighting effect and by communicating a Central Bank unequivocally reduces the welfare loss. This is independent of the precision level δ that the Central Bank can achieve. This proposition generalizes the result of Proposition 1 for cases in which the Central Bank's signal Y is *almost* fully accessible. However, when Y's accessibility is low, the exact opposite holds...

Proposition 3. *When $\frac{\alpha}{\gamma} > \underline{\alpha}$, there exists a minimum accessibility level $\underline{\psi}$ such that, for all $\psi < \underline{\psi}$, $L(z_i, Z) < L(z_i, Z, Y, \psi)$, independently of δ.*[6]

Proposition 3 states that, when the precision level of the public source of information Z (α) is higher than a certain threshold $\underline{\alpha}$, a Central Bank whose signal reaches an audience smaller than $\underline{\psi}$ should never communicate, as by doing so it increases the welfare loss. This is independent of the precision level δ that the Central Bank can achieve. This happens as in this low-accessibility region of Y the 'misweighting' effect dominates the 'informative' effect. Notice, in such a scenario, that the policy implication for a central bank is the exact opposite of the one derived in the case of high accessibility (Proposition 2): the best strategy is to remain silent, independently of the precision achievable.

When the accessibility of Y lies between the two thresholds $\underline{\psi}$ and $\bar{\psi}$ it impossible to state, a priori, whether the 'information' or the 'misweighting' effect prevails. In this middle-accessibility region, Y's precision plays a fundamental role. In fact, it is possible to establish the following result:

Proposition 4. *When $\frac{\alpha}{\gamma} > \underline{\alpha}$, and $\psi \in (\underline{\psi}, \bar{\psi})$, there exists a unique $\psi^*(\delta)$ such that if $\psi < \psi^*(\delta)$, then $L(z_i, Z) < L(z_i, Z, Y, \psi)$, else $L(z_i, Z) > L(z_i, Z, Y, \psi)$.*[7]

This Proposition highlights the crucial need for a central bank to delve as deep as possible into the precision-accessibility mapping. In fact, when Y's accessibility lies in the middle region $(\underline{\psi}, \bar{\psi})$, this mapping becomes fundamental to understand the welfare effect of Y's release. As for any possible precision level δ a central bank might want to achieve, there exists a unique accessibility threshold $\psi^*(\delta)$ such that: if Y's accessibility is below this threshold, then the 'misweighting' effect is stronger than the 'informative' effect. In this case, communicating leads to a welfare loss. On the contrary, when Y's accessibility is above the threshold, the opposite happens: the 'informative' effect prevails on the 'misweighting' effect and communicating is welfare enhancing.

Proposition 5. *The accessibility threshold $\psi^*(\delta)$, which marks the beginning of the accessibility region in which $L(z_i, Z, Y, \psi) < L(z_i, Z)$, increases as δ increases.*

[6]Mathematical argument in Appendix F

[7]Mathematical argument in Appendix F

Moreover, $\forall\psi \in (0, \psi^*(\delta))$, $\forall\delta$, $\frac{\delta L}{\delta\delta} > 0$*; on the contrary,* $\forall\psi \in (\psi^*(\delta), 1)$*, and* $\forall\delta$, $\frac{\delta L}{\delta\delta} < 0$.[8]

The first part of this Proposition claims that, the higher is the precision a central bank wants to achieve, the higher its accessibility must be in order to trigger an efficiency gain. This result comes from the fact that, the more precise Y is, the more weight the receivers place on it when setting their expected value over θ. Now, recall that, in this model, the loss is driven by the difference between the weights used in the price-setting and the expectation-formation process. Therefore, ideally, the higher the precision driven weight the receivers attach on Y when setting their expectations over θ, the higher must be the weight they assign to it during the price-setting process. However, this will happen only if Y has a coordination role: Y must be accessible to large number of agents. This result poses also an interesting policy dilemma as it shows that precision and accessibility are indeed complements, while the natural trade-off highlighted by the empirical literature goes in the exact opposite direction: more precision implies less accessibility (Haldane and McMahon [2018]). The second part of Proposition 5 highlights how, in the region below the threshold $\psi^*(\delta)$ ($\psi \in (0, \psi^*(\delta))$), increasing the precision of Y decreases welfare even keeping the accessibility level constant. This sheds once more light on how, from a policy perspective, it is extremely important for a central bank to fully learn the accessibility level implied by its communication's precision. As a mistake in assessing the size of the audience reached, might lead to consequences that are the exact opposite of the ones desired. It also suggests that there will often be an interior solution: since optimal precision is increasing with accessibility, if the technological trade-off goes in the other direction the central bank will find it optimal to release a signal that is neither universally understandable nor as informative as the CB could make it.

1.3.4 A Numerical Exercise

In this subsection I perform a numerical exercise: I quantify the ratio of the precision level of the signals z_i and Z, determining therefore the thresholds $\underline{\psi}$, and $\bar{\psi}$. I then simulate the impact on welfare of the release of signal Y for different precision-accessibility

[8] Mathematical argument in Appendix F

combinations. To calibrate $\frac{\alpha}{\gamma}$, I combine the data from the Michigan Survey of Consumers presented in Section 2, with data on the 3 Month T-Bill Rate. Recall that, from the Michigan Survey of Consumers I recover a disagreement index for the general public. Following the information structure described in Section 3.1, before the introduction of calendar-based forward guidance (third quarter of 2011), disagreement can be expressed as a function of the precision levels of the private and public sources of information:

$$D = (\int_0^1 (\mathbb{E}_i[\theta] - \bar{\mathbb{E}}[\theta])^2 \, di) = \mathbb{E}\left[\left(\frac{\gamma}{(\alpha+\gamma)}(z_i - \theta)\right)^2\right] = \frac{\gamma}{(\alpha+\gamma)^2}. \tag{1.3.9}$$

Using data on the 3-Month T-Bill Rate and converting 12 months-changes in the rates in a categorical variable (-1 when interest rates decrease, 0 when they stay constant, 1 when they increase), I compute the Mean Square Forecast error:

$$MSFE = \mathbb{E}[(\mathbb{E}_i[\theta] - \theta)^2] = \frac{1}{(\alpha+\gamma)}. \tag{1.3.10}$$

Taking the ratio of Disagreement and Mean Square Forecast Error allows us to recover the ratio between the two precision levels:

$$\frac{D}{MSFE} = \frac{\gamma}{\alpha} + 1. \tag{1.3.11}$$

Figure 1.3.1 shows the values of the thresholds and the evolution of the Output gap according to the accessibility of Y for different values of its precision level δ and 3 different possible values of the strategic motive π. Note that the threshold $\underline{\psi}$, that marks the minimum size of the audience a Central Bank should talk to in order not to increase the welfare loss, consists of a significantly high fraction of the population in all the three cases reported. According to the findings of Haldane et al. [2020] the main Central Bank communication in the US have a reading grade level roughly equivalent to a college-level, reaching therefore a mere 10% of the population. This exercise suggests that, given such a low accessibility level, the FED would, in most of the cases (i.e. for most values of π), trigger a welfare loss by carrying out forward guidance.

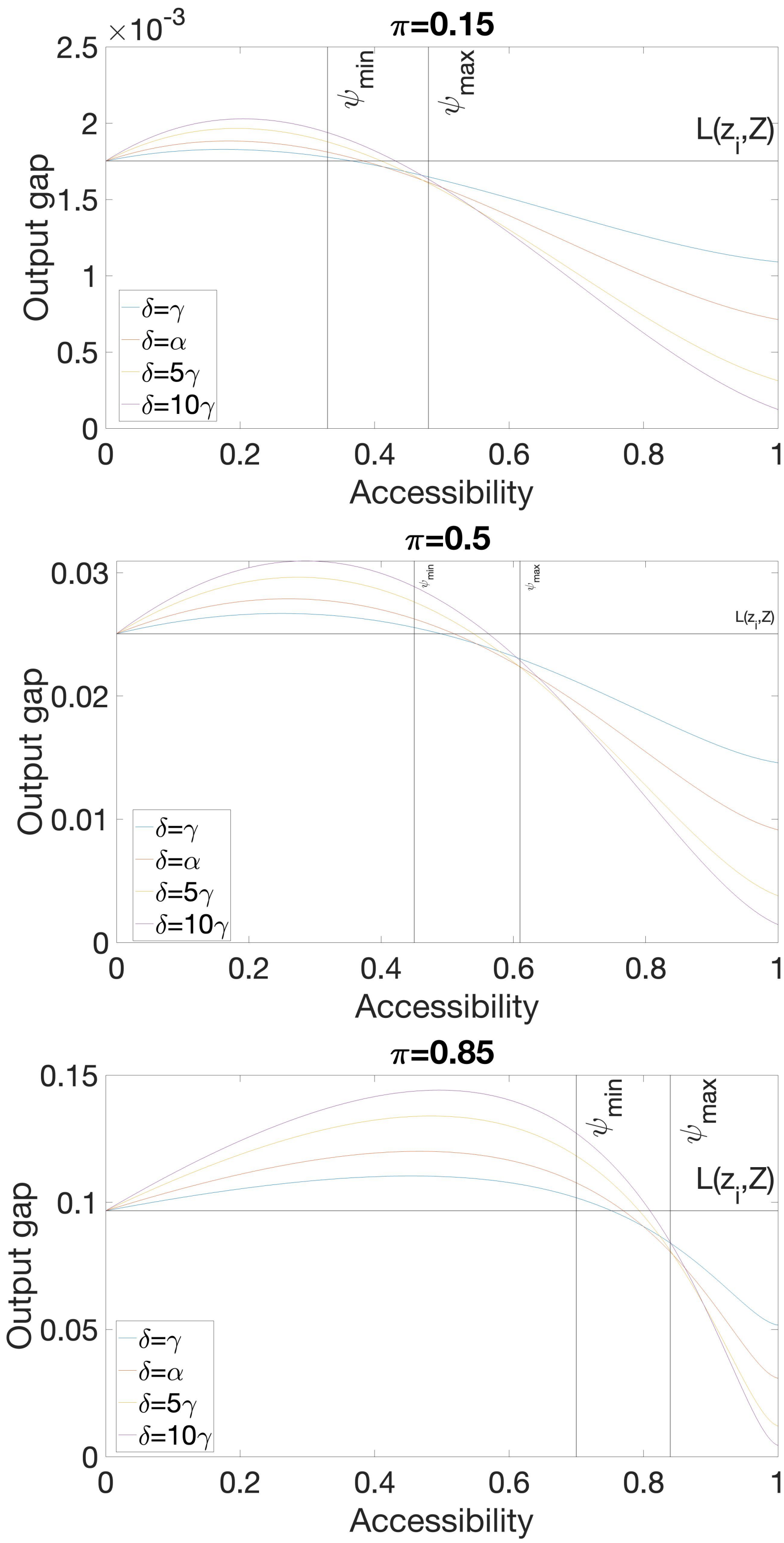

Figure 1.3.1: Output gap with $\frac{\alpha}{\gamma} = 2.1$

1.4 Introducing a Simplified Version of Central Bank's Signal

Worried by the small size of their audience, many central banks started releasing simplified communication, alongside the more technical one. The aim is increasing accessibility without sacrificing precision e.g. Bank of England's new inflation reports includes a considerably simpler version in which the most important information is summarized. Bholat et al. [2019] and Lamla and Vinogradov [2019] praise this initiative showing how the release of simplified communication can significantly improve welfare.

In the following section I twist the original information structure introducing a simplified version of the original central bank's communication. This simplified signal is accessible to all the agents of the economy i.e. every agent understands it. Every agent is also aware that this simplified signal features a lower precision than the more technical one[9]. The goal is to check whether the introduction of a 'simpler' signal could mitigate the 'misweighting' effect described in the previous sections. This case equivalently captures what happens if the central bank signals are interpreted and mediated by experts, that add noise by providing a simplified and fully accessible commentary.

1.4.1 The Second Information Structure

The pre-central bank's communication information structure is unchanged. All the islanders share an improper common prior on $\mathbb{R}$ over the economy-wide fundamental θ. In each island i, agents receive a private signal z_i, and a public one Z. The central bank releases two signals regarding θ: a technical signal Y, which will be accessible to only a fraction ψ of 'sophisticated' agents, and a simplified signal U (a noisy version of Y), available to everyone. The signals are defined as follows:

$$z_i \sim \mathcal{N}(\theta, \frac{1}{\gamma}) \quad Z \sim \mathcal{N}(\theta, \frac{1}{\alpha}) \quad Y \sim \mathcal{N}(\theta, \frac{1}{\delta}) \quad U \sim \mathcal{N}(Y, \frac{1}{\phi})\,^{10} \tag{1.4.1}$$

[9] Bholat et al. [2019], Lamla and Vinogradov [2019], and Istrefi [2019] discuss potential dangerous implications of having agents that mistake simplicity of the signal for low uncertainty, here I assume that everyone knows U is a noisier signal.

[10] where $U = Y + \nu$, and its precision is ϵ (i.e. $\epsilon = \frac{\phi\delta}{\phi+\delta}$)

The fraction ψ of 'sophisticated' agents receive all four signals. The remaining $1-\psi$ 'unsophisticated' only see z_i, Z and U. The unsophisticated agents are aware that there is a fraction ϕ of sophisticated agents endowed with superior information. The unsophisticated don't see Y, but they know its precision level δ, and that U is its noisy version.
When forming an expectation over the state of the world θ, the sophisticated agents will therefore use z_i, Z, and Y. On the other hand, the 'unsophisticated', in order to predict θ, assign positive weight to all the signals in their information set.

1.4.2 Equilibrium

In this section I define and characterize the equilibrium of the model. Let S_i be the signal-space of island i. A fraction ψ of the islands are *Sophisticated* and $S_i = (z_i, Z, Y, U)$. The remaining fraction, $1-\psi$, of the islands are *Non-Sophisticated* and $S_i = (z_i, Z)$.

An equilibrium consists of two pricing functions (one for the Sophisticated and one for the Non-Sophisticated) that map the signals received on that island into market clearing prices. We will denote these functions $p^S(S_i)$ and $p^{NS}(S_i)$. (Islands are symmetric, we can therefore look at symmetric pricing strategies $p_i = p(S_i)$ for all i.) Market clearing prices (3) can be written as:

$$p(S_i) = (1-\pi)\mathbb{E}_i[\theta|S_i] + \pi\mathbb{E}_i[p(S_j)|S_i] \tag{1.4.2}$$

(Here the second expectation is over j as well S_j.) Since all the signals are normally distributed, as said earlier, these expectations are linear there is a unique linear equilibrium characterized by the following set of weights $w_S := (w_S^{pvt}, w_S^{pub}, w_S^Y, w_S^U)$, $w_{NS} := (w_{NS}^{pvt}, w_{NS}^{pub}, w_{NS}^U)$, where

$$\begin{aligned} p^S(S_i) &= w_S^{pvt} z_i + w_S^{pub} Z + w_S^Y Y + w_S^U U, \\ p^{NS}(S_i) &= w_{NS}^{pvt} z_i + w_{NS}^{pub} Z + w_{NS}^U U. \end{aligned} \tag{1.4.3}$$

where $w_S^{pvt} + w_S^{pub} + w_S^Y + w_S^U = 1$ and $w_{NS}^{pvt} + w_{NS}^{pub} + w_{NS}^U = 1$. Appendix C provides derivation and explicit formulas for the equilibrium weights. Note that, the Sophisticated agents still assign a positive weight to U in the price-setting process, as this signal, although uninformative regarding θ, helps them to coordinate with the unsophisticated.

1.4.3 Accessibility, precision, and output stability

As in the first specification of the model, the Central Bank's goal is maximizing output stability by minimizing output gap. As a result, the Loss function remains the following:

$$L(z_i, Z, Y, U, \psi) = E[(E[\theta|I_i] - p(I_i))^2|\theta, \psi] \tag{1.4.4}$$

Once again, we can manipulate this function in order to show its independence from the hidden state of the world, expressing it as a function of the two sets of equilibrium weights used by the islanders and the precision level of the signals received (Appendix E provides the explicit expression for the Loss function). Let us, at first, establish the following proposition.

Proposition 6. *When* $\frac{\alpha}{\gamma} > \underline{\alpha}$*,* $L(z_i, Z, Y, U, \psi) < L(z_i, Z, Y)$.[11]

This proposition states that, independently of both the number of sophisticated agents and the precision level of the technical signal Y, a central bank should always release its simplified version U, as by doing this it unequivocally reduces the welfare loss. This result should not come as a surprise, as it derives directly from Proposition 1: when $\frac{\alpha}{\gamma} > \underline{\alpha}$ releasing a fully accessible signal has a positive impact on welfare.

On the other hand, the welfare effect of the technical signal Y still depends on the number of sophisticated agents in the economy.

Proposition 7. *When* $\epsilon > \alpha > \underline{\alpha}$*, there exists a unique* $\psi^*(\delta)$ *such that,* $\forall \psi \in (0, \psi^*(\delta))$*,* $L(z_i, Z, U) < L(z_i, Z, U, Y, \psi)$*. On the contrary,* $\forall \psi \in (\psi^*(\delta), 1)$*,* $L(z_i, Z, U) > L(z_i, Z, U, Y, \psi)$[12]

This proposition shows how the introduction of the simplified signal U does not solve the issues highlighted within the first model. In fact, unless the number of sophisticated

[11] Mathematical argument in Appendix F

[12] Mathematical argument in Appendix F

agents is large enough, the central bank increases the welfare loss by releasing the technical signal Y. The central bank could do better by releasing only one signal: the simplified one U. As it happens in the first model, when Y's audience is large enough, Y's informative effect dominates the misweighting effect. However, when Y's accessibility is low (and falls below ψ^*), its misweighting effect prevails. When Y's accessibility ψ is low, once again the sophisticated agents underweight Y due to its lack of coordination power. The release of Y also leads to a massive overweight of the simplified signal U for both: sophisticated, and unsophisticated agents. In fact, the sophisticated agents use U to predict $\bar{p}$, assigning therefore a positive weight to it during the price-setting process. However, once the sophisticated agents have Y, U is completely uninformative regarding θ: they do not use it in the expectation-formation process. Also the unsophsisticated agents overweight U, as this signal is fully public, and also the best source of information they have to predict Y, and therefore the pricing strategy of the sophisticated agents.

Finally, in line with the results derived for the first model we state the following proposition.

Proposition 8. *When $\epsilon > \alpha > \underline{\alpha}$, keeping ϵ fixed, the level of accessibility $\psi^*(\delta)$ which marks the beginning of the accessibility region in which $L(z_i, Z, U) > L(z_i, Z, U, Y, \psi)$ increases as δ increases.*
$\forall \psi \in (0, \psi^*(\delta))$, $\forall \delta$, $\frac{\delta L}{\delta \delta} > 0$; on the contrary, $\forall \psi \in (\psi^*(\delta), 1)$, and $\forall \delta$, $\frac{\delta L}{\delta \delta} < 0$.[13]

This proposition implies that, the bigger is the difference in precision between Y and U the central bank wants to achieve, the bigger needs to be the number of sophisticated agents in order to have a welfare increase. Furthermore, if the difference in precision between Y and U is increased when the number of sophisticated agents is below $\psi^*(\delta)$, this triggers a welfare loss, even keeping constant Y's accessibility level.

I carry out a numerical exercise to show how the release of the technical signal Y affects welfare according to different precision-accessibility combination. I use the same calibration of Section 1.3.4 to set $\frac{\alpha}{\gamma}$, and assume that the simplified signal U has the same precision of the public one Z. Figure 1.4.1 shows the results for four possible precision levels δ and 3 different values of π.

[13] Mathematical argument in Appendix F

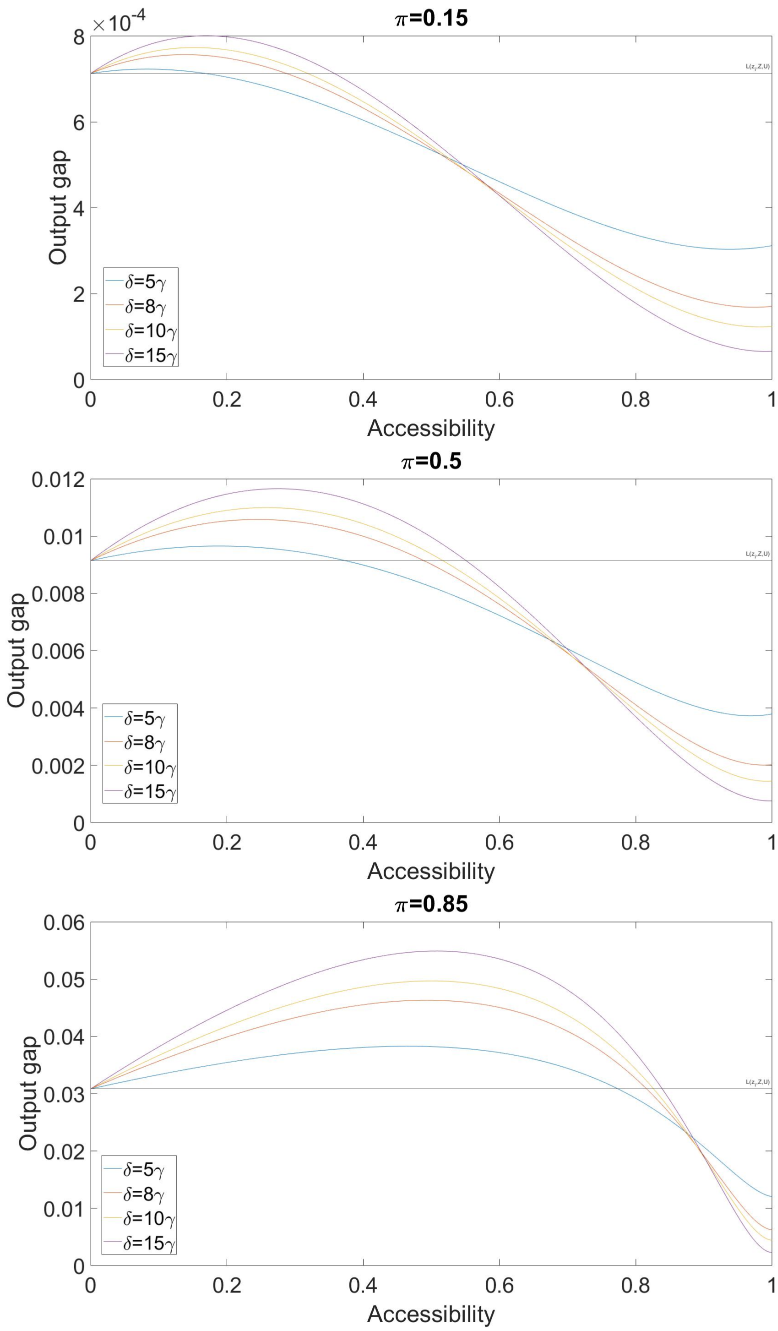

Figure 1.4.1: Output gap with $\frac{\alpha}{\gamma} = \epsilon = 2.1$

1.5 Conclusions

This chapter shows how the accessibility level of a communication crucially determines its impact on welfare. Using two different information structures I show that lack of accessibility of a signal does not only lead to a failure in managing agents' expectations but it implies much higher welfare costs. I prove that, given any possible precision level of a signal, there always exists a unique precision determined accessibility threshold (i.e. a minimum audience size) such that, if the audience reached by the signal is below this threshold, then its release triggers a welfare loss. I also show that this threshold increases with the precision level, i.e. the more precise a central bank wants to be, the more accessible its communication must be. The introduction of a 'fully accessible' simplified version of the central bank's signal, does not change these conclusions.

Appendix A: Michigan Survey of Consumers and expected future monetary policy

Michigan Survey of consumers summarizes U.S. consumers' attitudes and expectations with respect to employment, income, wealth, prices, and interest rates. Every month, about 500 households are surveyed. The sample is designed to be representative of the entire US population. 60% of individuals are first time respondents to the survey. The remaining 40% of the households are second time respondents, but with a 6 months period between the two interviews. Due to this repeated cross-section structure it is unfortunately not possible to compute revisions of forecasts between 2 subsequent survey rounds for the whole sample of household surveyed. Many of the questions asked, call for qualitative (and not quantitative) answers. The monthly survey data begin in January 1978. Besides the inclusion of new questions, no substantial changes have been made to the pre-existing questionnaire since that time.

The expected future monetary policy variable corresponds to the answer to the following survey question: *"No one can say for sure, but what do you think will happen to interest rates for borrowing during the next 12 months will they go up, stay the same, or go down?'* One potential issue arises from the fact that this question refers to 'interest rates for borrowing', and does not specify the measure it refers to. As in Nechio and Carvalho [2012] I assume that the answers to an analogous question about the policy interest rate would be the same. This assumption works as long as the spread between the household's perceived borrowing rates and the policy rate does not vary too much.

Appendix B: Equilibrium Weights

Here I solve for the unique linear equilibrium. Suppose that in each island i the pricing strategy is linear and has the following form:

$$p(z_i, Z, Y) = \sum_{i=1}^{n} = w_i I_i(n), \tag{1.5.1}$$

where $\sum_{i=1}^{n} w_i = 1$. Then the optimal price for the 'Receivers' is

$$\begin{aligned} p_i = (1-\pi)\mathbb{E}[\theta] + \pi\mathbb{E}[\bar{p}] = (1-\pi)\left(\frac{\gamma z_i + \alpha Z + \delta Y}{\gamma + \alpha + \delta}\right) + \\ \pi\left(\psi\left(w_R^{pvt}\left(\frac{\gamma z_i + \alpha Z + \delta Y}{\gamma + \alpha + \delta}\right) + w_R^{pub} Z + w_R^{Y} Y\right) + \right. \\ \left.(1-\psi)\left(w_{NR}^{pvt}\left(\frac{\gamma z_i + \alpha Z + \delta Y}{\gamma + \alpha + \delta}\right) + w_{NR}^{pub} Z\right)\right) \end{aligned} \tag{1.5.2}$$

Rewriting everything in terms of γ delivers:

$$\begin{aligned} p_i = (1-\pi)\mathbb{E}[\theta] + \pi\mathbb{E}[\bar{p}] = (1-\pi)\left(\frac{z_i + \frac{\alpha}{\gamma} Z + \frac{\delta}{\gamma} Y}{1 + \frac{\alpha}{\gamma} + \frac{\delta}{\gamma}}\right) + \\ \pi\left(\psi\left(w_R^{pvt}\left(\frac{z_i + \frac{\alpha}{\gamma} Z + \frac{\delta}{\gamma} Y}{1 + \frac{\alpha}{\gamma} + \frac{\delta}{\gamma}}\right) + w_R^{pub} Z + w_R^{Y} Y\right) + \right. \\ \left.(1-\psi)\left(w_{NR}^{pvt}\left(\frac{z_i + \frac{\alpha}{\gamma} Z + \frac{\delta}{\gamma} Y}{1 + \frac{\alpha}{\gamma} + \frac{\delta}{\gamma}}\right) + w_{NR}^{pub} Z\right)\right) \end{aligned} \tag{1.5.3}$$

Comparing the coefficients of (1.3.6) and (1.5.3) we can solve for the equilibrium weights for the 'Receivers':

$$w_R^{pvt} = \frac{(1-\pi)(1 + \frac{\alpha}{\gamma} - \pi\psi)}{(1 + \frac{\alpha}{\gamma} - \pi)(1 + \frac{\alpha}{\gamma} + \frac{\delta}{\gamma} - \pi\psi)} \tag{1.5.4}$$

$$w_R^{pub} = \frac{\frac{\alpha}{\gamma}\left(\frac{\delta}{\gamma}\pi(-1+\psi) + \frac{\alpha}{\gamma}(-1+\pi\psi) - (-1+\pi\psi)^2\right)}{(1 + \frac{\alpha}{\gamma} - \pi)(1 + \frac{\alpha}{\gamma} + \frac{\delta}{\gamma} - \pi\psi)(-1+\pi\psi)} \tag{1.5.5}$$

$$w_R^{Y} = \frac{\frac{\delta}{\gamma}(-1+\pi)(1 + \frac{\alpha}{\gamma} - \pi\psi)}{(1 + \frac{\alpha}{\gamma} - \pi)(1 + \frac{\alpha}{\gamma} + \frac{\delta}{\gamma} - \pi\psi)(-1+\pi\psi)} \tag{1.5.6}$$

Similarly, the optimal price for the 'Non Receivers' is:

$$\begin{aligned} p_i = (1-\pi)\mathbb{E}[\theta] + \pi\mathbb{E}[\bar{p}] = (1-\pi)\left(\frac{\gamma z_i + \alpha Z}{\gamma + \alpha}\right) + \\ \pi\left(w_{NR}^{pvt}\left(\frac{\gamma z_i + \alpha Z}{\gamma + \alpha}\right) + w_{NR}^{pub} Z\right) \end{aligned} \tag{1.5.7}$$

Rewriting everything in terms of γ delivers:

$$\begin{aligned} p_i = (1-\pi)\mathbb{E}[\theta] + \pi\mathbb{E}[\bar{p}] = (1-\pi)\left(\frac{z_i + \frac{\alpha}{\gamma} Z}{1 + \frac{\alpha}{\gamma}}\right) + \\ \pi\left(w_{NR}^{pvt}\left(\frac{z_i + \frac{\alpha}{\gamma} Z}{1 + \frac{\alpha}{\gamma}}\right) + w_{NR}^{pub} Z\right) \end{aligned} \tag{1.5.8}$$

Comparing the coefficients of (1.3.6) and (1.5.8) we solve for the equilibrium weights for the 'Non Receivers':

$$w_{NR}^{pvt} = \frac{(1-\pi)}{1+\frac{\alpha}{\gamma}-\pi} \tag{1.5.9}$$

$$w_{NR}^{pub} = \frac{\frac{\alpha}{\gamma}}{1+\frac{\alpha}{\gamma}-\pi} \tag{1.5.10}$$

Appendix C: Derivation of the Loss Function

The (normalized) central bank's loss function reads:

$$L(z_i, Z, Y, \psi) = [(E[\theta|I_i] - p(I_i))^2|\theta, \psi] =$$

$$\begin{aligned}
\gamma\Bigg\{\psi \Bigg[&\left(w_R^{pvt} - \frac{1}{1+\frac{\alpha}{\gamma}+\frac{\delta}{\gamma}}\right)^2 \left(\frac{1}{\gamma}+\theta^2\right) + \left(w_R^{pub} - \frac{\frac{\alpha}{\gamma}}{1+\frac{\alpha}{\gamma}+\frac{\delta}{\gamma}}\right)^2 \left(\frac{1}{\alpha}+\theta^2\right) \\
&+ \left(w_R^{Y} - \frac{\frac{\delta}{\gamma}}{1+\frac{\alpha}{\gamma}+\frac{\delta}{\gamma}}\right)^2 \left(\frac{1}{\delta}+\theta^2\right) + 2\left(w_R^{pvt} - \frac{1}{1+\frac{\alpha}{\gamma}+\frac{\delta}{\gamma}}\right)\left(w_R^{pub} - \frac{\frac{\alpha}{\gamma}}{1+\frac{\alpha}{\gamma}+\frac{\delta}{\gamma}}\right)\theta^2 \\
&+ 2\left(w_R^{pvt} - \frac{1}{1+\frac{\alpha}{\gamma}+\frac{\delta}{\gamma}}\right)\left(w_R^{Y} - \frac{\frac{\delta}{\gamma}}{1+\frac{\alpha}{\gamma}+\frac{\delta}{\gamma}}\right)\theta^2 \\
&+2\left(w_R^{pub} - \frac{\frac{\alpha}{\gamma}}{1+\frac{\alpha}{\gamma}+\frac{\delta}{\gamma}}\right)\left(w_R^{Y} - \frac{\frac{\delta}{\gamma}}{1+\frac{\alpha}{\gamma}+\frac{\delta}{\gamma}}\right)\theta^2\Bigg] \\
+ (1-\psi)\Bigg[&\left(w_{NR}^{pvt} - \frac{1}{\frac{\alpha}{\gamma}+1}\right)^2\left(\frac{1}{\gamma}+\theta^2\right) + \left(w_{NR}^{pub} - \frac{\frac{\alpha}{\gamma}}{\frac{\alpha}{\gamma}+1}\right)^2\left(\frac{1}{\alpha}+\theta^2\right) \\
&+2\left(w_{NR}^{pvt} - \frac{1}{\frac{\alpha}{\gamma}+1}\right)\left(w_{NR}^{pub} - \frac{\frac{\alpha}{\gamma}}{\frac{\alpha}{\gamma}+1}\right)\theta^2\Bigg]\Bigg\}
\end{aligned}$$

Using the facts that $w_R^{pvt} + w_R^{pub} + w_R^Y = 1$ and $w_{NR}^{pvt} + w_{NR}^{pub} = 1$, we can rewrite the above equation as follows:

$$L(z_i, Z, Y, \psi) = E[(E[\theta|I_i] - p(I_i))^2|\theta, \psi] =$$
$$\gamma\Bigg\{\psi\Bigg[\left(w_R^{pvt} - \frac{1}{+\frac{\alpha}{\gamma}+\frac{\delta}{\gamma}}\right)^2(\frac{1}{\gamma}) + \left(\frac{\frac{\alpha}{\gamma}}{1+\frac{\alpha}{\gamma}+\frac{\delta}{\gamma}} - w_R^{pub} + \frac{\frac{\delta}{\gamma}}{1+\frac{\alpha}{\gamma}+\frac{\delta}{\gamma}} - w_R^Y\right)^2(\theta^2)+$$
$$\left(w_R^{pub} - \frac{\frac{\alpha}{\gamma}}{1+\frac{\alpha}{\gamma}+\frac{\delta}{\gamma}}\right)^2(\frac{1}{\alpha}+\theta^2) + \left(w_R^Y - \frac{\frac{\delta}{\gamma}}{1+\frac{\alpha}{\gamma}+\frac{\delta}{\gamma}}\right)^2(\frac{1}{\delta}+\theta^2)-$$
$$2\left(w_R^{pvt} - \frac{1}{1+\frac{\alpha}{\gamma}+\frac{\delta}{\gamma}}\right)^2\theta^2 + 2\left(w_R^{pub} - \frac{\frac{\alpha}{\gamma}}{1+\frac{\alpha}{\gamma}+\frac{\delta}{\gamma}}\right)\left(w_R^Y - \frac{\frac{\delta}{\gamma}}{1+\frac{\alpha}{\gamma}+\frac{\delta}{\gamma}}\right)\theta^2\Bigg]+$$
$$(1-\psi)\Bigg[\left(w_{NR}^{pvt} - \frac{1}{\frac{\alpha}{\gamma}+1}\right)^2(\frac{1}{\gamma}) + \left(w_{NR}^{pub} - \frac{\frac{\alpha}{\gamma}}{\frac{\alpha}{\gamma}+1}\right)^2\theta^2 + \left(w_{NR}^{pub} - \frac{\frac{\alpha}{\gamma}}{\frac{\alpha}{\gamma}+1}\right)^2(\frac{1}{\alpha}+\theta^2)-$$
$$2\left(w_{NR}^{pub} - \frac{\frac{\alpha}{\gamma}}{\frac{\alpha}{\gamma}+1}\right)^2\theta^2\Bigg]\Bigg\}$$

Simplifying this equation leads to (1.3.8).

Appendix D: Equilibrium Weights of the Second Model

Here I solve for the unique linear equilibrium of the second model. Suppose that in each island i, the pricing strategy is linear and has the following form:

$$p(z_i, Z, Y) = \sum_{i=1}^{n} = w_i I_i(n), \tag{1.5.11}$$

where $\sum_{i=1}^{n} w_i = 1$. Then the optimal price for the 'Sophisticated' agents is:

$$\begin{aligned} p_i = (1-\pi)\mathbb{E}[\theta] + \pi\mathbb{E}[\bar{p}] = (1-\pi)&\left(\frac{\gamma z_i + \alpha Z + \delta Y}{\gamma+\alpha+\delta}\right)+ \\ \pi\Bigg(\psi\Bigg(w_S^{pvt}&\left(\frac{\gamma z_i + \alpha Z + \delta Y}{\gamma+\alpha+\delta}\right) + w_S^{pub}Z + w_S^Y Y\Bigg)+ \\ (1-\psi)\Bigg(w_{NS}^{pvt}&\left(\frac{\gamma z_i + \alpha Z + \delta Y}{\gamma+\alpha+\delta}\right) + w_{NS}^{pub}Z + w_{NS}^U U\Bigg). \end{aligned} \tag{1.5.12}$$

Rewriting everything in terms of γ delivers:

$$p(z_i, Z, Y) = \sum_{i=1}^{n} = w_i I_i(n), \tag{1.5.13}$$

where $\sum_{i=1}^{n} w_i = 1$. Then the optimal price for the 'Sophisticated' agents is:

$$\begin{aligned} p_i = (1-\pi)\mathbb{E}[\theta] + \pi\mathbb{E}[\bar{p}] = (1-\pi)\left(\frac{z_i + \frac{\alpha}{\gamma}Z + \frac{\delta}{\gamma}Y}{1 + \frac{\alpha}{\gamma} + \frac{\delta}{\gamma}}\right) + \\ \pi\left(\psi\left(w_S^{pvt}\left(\frac{z_i + \frac{\alpha}{\gamma}Z + \frac{\delta}{\gamma}Y}{1 + \frac{\alpha}{\gamma} + \frac{\delta}{\gamma}}\right) + w_S^{pub}Z + w_S^Y Y\right) + \right. \\ \left.(1-\psi)\left(w_{NS}^{pvt}\left(\frac{z_i + \frac{\alpha}{\gamma}Z + \frac{\delta}{\gamma}Y}{1 + \frac{\alpha}{\gamma} + \frac{\delta}{\gamma}}\right) + w_{NS}^{pub}Z + w_{NS}^U U\right)\right). \end{aligned} \tag{1.5.14}$$

Comparing the coefficients of (1.5.14) and (1.4.3) we can again solve for the equilibrium weights of the 'Sophisticated' agents:

$$w_S^{pvt} = \frac{\left((1 + \frac{\alpha}{\gamma})\frac{\phi}{\gamma} + \frac{\delta}{\gamma}(1 + \frac{\alpha}{\gamma} + \frac{\phi}{\gamma})\right)(-1+\pi)(-1+\pi\psi)}{A(\frac{\delta}{\gamma}, \frac{\alpha}{\gamma}, \pi, \frac{\phi}{\gamma}, \psi)} \tag{1.5.15}$$

$$w_S^{pub} = \frac{\frac{\alpha}{\gamma}\left(\frac{\delta}{\gamma}^2\pi(-1+\psi) + (1 + \frac{\alpha}{\gamma}\frac{\phi}{\gamma}(-1+\pi\psi) + \frac{\delta}{\gamma}(1 + \frac{\alpha}{\gamma} + \frac{\phi}{\gamma})(-1 + \frac{\phi}{\gamma}\psi)\right)}{-A(\frac{\delta}{\gamma}, \frac{\alpha}{\gamma}, \pi, \frac{\phi}{\gamma}, \psi)} \tag{1.5.16}$$

$$w_S^Y = \frac{\delta\left((1 + \frac{\alpha}{\gamma})\frac{\phi}{\gamma} + \frac{\delta}{\gamma}(1 + \frac{\alpha}{\gamma} + \frac{\phi}{\gamma})\right)(-1+\pi)}{-A(\frac{\delta}{\gamma}, \frac{\alpha}{\gamma}, \pi, \frac{\phi}{\gamma}, \psi)} \tag{1.5.17}$$

$$w_S^U = \frac{\frac{\delta}{\gamma}(1 + \frac{\alpha}{\gamma} + \frac{\delta}{\gamma})\frac{\phi}{\gamma}\pi(-1+\psi)}{-A(\frac{\delta}{\gamma}, \frac{\alpha}{\gamma}, \pi, \frac{\phi}{\gamma}, \psi)} \tag{1.5.18}$$

Using a similar approach, the optimal price for the 'Non Sophisticated' is:

$$\begin{aligned} p_i = (1-\pi)\mathbb{E}[\theta] + \pi\mathbb{E}[\bar{p}] = (1-\pi)\left(\frac{\gamma z_i + \alpha Z + \epsilon U}{\gamma + \alpha + \epsilon}\right) + \\ \pi\left(\psi\left(w_S^{pvt}\left(\frac{\gamma z_i + \alpha Z + \epsilon U}{\gamma + \alpha + \epsilon}\right) + w_S^{pub}Z + w_S^Y\left(\frac{\frac{\gamma\delta}{\gamma+\delta}z_i + \frac{\alpha\delta}{\alpha+\delta}Z + \frac{\epsilon\delta}{\delta-\epsilon}U}{\frac{\gamma\delta}{\gamma+\delta} + \frac{\alpha\delta}{\alpha+\delta} + \frac{\epsilon\delta}{\delta-\epsilon}}\right)\right)\right) + \\ (1-\psi)\left(w_{NS}^{pvt}\left(\frac{\gamma z_i + \alpha Z + \epsilon U}{\gamma + \alpha + \epsilon}\right) + w_{NS}^{pub}Z + w_{NS}^U U\right) \end{aligned} \tag{1.5.19}$$

Rewriting everything in terms of γ delivers:

$$p_i = (1-\pi)\mathbb{E}[\theta] + \pi\mathbb{E}[\bar{p}] = (1-\pi)\left(\frac{z_i + \frac{\alpha}{\gamma}Z + \frac{\epsilon}{\gamma}U}{1+\frac{\alpha}{\gamma}+\frac{\epsilon}{\gamma}}\right) + \pi\left(\psi\left(w_S^{pvt}\left(\frac{z_i + \frac{\alpha}{\gamma}Z + \frac{\epsilon}{\gamma}U}{1+\frac{\alpha}{\gamma}+\frac{\epsilon}{\gamma}}\right) + w_S^{pub}Z + w_S^{Y}\left(\frac{\frac{\frac{\delta}{\gamma}}{1+\frac{\delta}{\gamma}}z_i + \frac{\frac{\alpha}{\gamma}\frac{\delta}{\gamma}}{\frac{\alpha}{\gamma}+\frac{\delta}{\gamma}}Z + \frac{\frac{\epsilon}{\gamma}\frac{\delta}{\gamma}}{\frac{\delta}{\gamma}-\frac{\epsilon}{\gamma}}U}{\frac{\frac{\delta}{\gamma}}{1+\frac{\delta}{\gamma}} + \frac{\frac{\alpha}{\gamma}\frac{\delta}{\gamma}}{\frac{\alpha}{\gamma}+\frac{\delta}{\gamma}} + \frac{\frac{\epsilon}{\gamma}\frac{\delta}{\gamma}}{\frac{\delta}{\gamma}-\frac{\epsilon}{\gamma}}}\right)\right) + (1-\psi)\left(w_{NS}^{pvt}\left(\frac{z_i + \frac{\alpha}{\gamma}Z + \frac{\epsilon}{\gamma}U}{1+\frac{\alpha}{\gamma}+\frac{\epsilon}{\gamma}}\right) + w_{NS}^{pub}Z + w_{NS}^{U}U\right)\right) \tag{1.5.20}$$

Comparing the coefficients of (1.5.20) and (1.4.3) we can solve for the equilibrium weights for the 'Non Sophisticated':

$$w_{NS}^{pvt} = \frac{(-1+\pi)\left(-\frac{\delta}{\gamma}^2 + (1-\frac{\alpha}{\gamma})\frac{\phi}{\gamma}(-1+\pi\psi) + \frac{\delta}{\gamma}(1+\frac{\alpha}{\gamma}+\frac{\phi}{\gamma})(-1+\pi\psi)\right)}{A(\frac{\delta}{\gamma},\frac{\alpha}{\gamma},\pi,\frac{\phi}{\gamma},\psi)} \tag{1.5.21}$$

$$w_{NS}^{pub} = \frac{\left((1+\frac{\alpha}{\gamma})\frac{\phi}{\gamma} + \frac{\delta}{\gamma}(1+\frac{\alpha}{\gamma}+\frac{\phi}{\gamma})\right)(-1+\pi)(-1+\pi\psi)}{-A(\frac{\delta}{\gamma},\frac{\alpha}{\gamma},\pi,\frac{\phi}{\gamma},\psi)} \tag{1.5.22}$$

$$w_{NS}^{U} = \frac{\frac{\delta}{\gamma}(1+\frac{\alpha}{\gamma}+\frac{\delta}{\gamma})\frac{\phi}{\gamma}(-1+\pi\psi)}{-A(\frac{\delta}{\gamma},\frac{\alpha}{\gamma},\pi,\frac{\phi}{\gamma},\psi)} \tag{1.5.23}$$

where

$$A(\frac{\delta}{\gamma},\frac{\alpha}{\gamma},\pi,\frac{\phi}{\gamma},\psi) = -(1+\frac{\alpha}{\gamma})\frac{\phi}{\gamma}(1+\frac{\alpha}{\gamma}-\pi)(-1+\pi\psi) - \frac{\delta}{\gamma}(1+\frac{\alpha}{\gamma}^2 + \frac{\alpha}{\gamma}(2+2\frac{\phi}{\gamma}-\pi) - \frac{\phi}{\gamma}(-2+\pi) - \pi(-1+\pi\psi) + \frac{\delta}{\gamma}^2(1+\frac{\alpha}{\gamma}+\frac{\phi}{\gamma}-\pi-\frac{\alpha}{\gamma}\pi\psi - \frac{\phi}{\gamma}\pi\psi)$$

Appendix E: Loss Function for the Second Model

Using the facts that $w_S^{pvt} + w_S^{pub} + w_S^Y + w_S^U = 1$ and $w^p vt_{NS} + w_{NS}^{pub} + w_{NS}^U = 1$ we can rewrite the loss function in the following way:

$$
\begin{aligned}
L(z_i, Z, Y, U, \psi) = & \left((w_{1,S} - \frac{1}{1+\frac{\alpha}{\gamma}+\frac{\delta}{\gamma}})(w_{2,S} - \frac{\frac{\alpha}{\gamma}}{1+\frac{\alpha}{\gamma}+\frac{\delta}{\gamma}})(w_{3,S} - \frac{\frac{\delta}{\gamma}}{1+\frac{\alpha}{\gamma}+\frac{\delta}{\gamma}})w_{4,S} \right)\psi \\
& \left(-\frac{1}{(w_{3,S} - \frac{\frac{\delta}{\gamma}}{1+\frac{\alpha}{\gamma}+\frac{\delta}{\gamma}})w_{4,S}} - \frac{1}{(w_{2,S} - \frac{\frac{\alpha}{\gamma}}{1+\frac{\alpha}{\gamma}+\frac{\delta}{\gamma}})w_{4,S}} - \frac{1}{(w_{2,S} - \frac{\frac{\alpha}{\gamma}}{1+\frac{\alpha}{\gamma}+\frac{\delta}{\gamma}})(w_{3,S} - \frac{\frac{\delta}{\gamma}}{1+\frac{\alpha}{\gamma}+\frac{\delta}{\gamma}})} - \right. \\
& \frac{\frac{1}{\frac{\alpha}{\gamma}}}{(w_{1,S} - \frac{1}{1+\frac{\alpha}{\gamma}+\frac{\delta}{\gamma}})(w_{3,S} - \frac{\frac{\delta}{\gamma}}{1+\frac{\alpha}{\gamma}+\frac{\delta}{\gamma}})} - \frac{\frac{1}{\frac{\alpha}{\gamma}}}{(w_{1,S} - \frac{1}{1+\frac{\alpha}{\gamma}+\frac{\delta}{\gamma}})w_{4,S}} - \frac{\frac{1}{\frac{\alpha}{\gamma}}}{(w_{3,S} - \frac{\frac{\delta}{\gamma}}{1+\frac{\alpha}{\gamma}+\frac{\delta}{\gamma}})w_{4,S}} - \\
& \frac{\frac{1}{\frac{\delta}{\gamma}}}{(w_{1,S} - \frac{1}{1+\frac{\alpha}{\gamma}+\frac{\delta}{\gamma}})(w_{2,S} - \frac{\frac{\alpha}{\gamma}}{1+\frac{\alpha}{\gamma}+\frac{\delta}{\gamma}})} - \frac{\frac{1}{\frac{\delta}{\gamma}}}{(w_{1,S} - \frac{1}{1+\frac{\alpha}{\gamma}+\frac{\delta}{\gamma}})w_{4,S}} - \frac{\frac{1}{\frac{\delta}{\gamma}}}{(w_{2,S} - \frac{\frac{\alpha}{\gamma}}{1+\frac{\alpha}{\gamma}+\frac{\delta}{\gamma}})w_{4,S}} - \\
& \frac{\frac{1}{\frac{\epsilon}{\gamma}}}{(w_{1,S} - \frac{1}{1+\frac{\alpha}{\gamma}+\frac{\delta}{\gamma}})(w_{2,S} - \frac{\frac{\alpha}{\gamma}}{1+\frac{\alpha}{\gamma}+\frac{\delta}{\gamma}})} - \frac{\frac{1}{\frac{\epsilon}{\gamma}}}{(w_{1,S} - \frac{1}{1+\frac{\alpha}{\gamma}+\frac{\delta}{\gamma}})(w_{3,S} - \frac{\frac{\delta}{\gamma}}{1+\frac{\alpha}{\gamma}+\frac{\delta}{\gamma}})} - \\
& \left. \frac{\frac{1}{\epsilon}}{(w_{2,S} - \frac{\alpha}{\gamma+\alpha+\delta})(w_{3,S} - \frac{\delta}{1+\frac{\alpha}{\gamma}+\frac{\delta}{\gamma}})} + \frac{2cov(U,Y)}{(w_{1,S} - \frac{1}{1+\frac{\alpha}{\gamma}+\frac{\delta}{\gamma}})(w_{2,S} - \frac{\frac{\alpha}{\gamma}}{1+\frac{\alpha}{\gamma}+\frac{\delta}{\gamma}})} \right) + \\
& \left((w_{1,U} - \frac{1}{1+\frac{\alpha}{\gamma}+\frac{\epsilon}{\gamma}})(w_{2,U} - \frac{\frac{\alpha}{\gamma}}{1+\frac{\alpha}{\gamma}+\frac{\epsilon}{\gamma}})(w_{3,U} - \frac{\frac{\epsilon}{\gamma}}{1+\frac{\alpha}{\gamma}+\frac{\epsilon}{\gamma}}) \right) + \\
& (1-\psi)\left(-\frac{1}{w_{2,U} - \frac{\frac{\alpha}{\gamma}}{1+\frac{\alpha}{\gamma}+\frac{\epsilon}{\gamma}}} - \frac{1}{w_{3,U} - \frac{\frac{\epsilon}{\gamma}}{1+\frac{\alpha}{\gamma}+\frac{\epsilon}{\gamma}}} - \frac{1}{w_{1,U} - \frac{1}{1+\frac{\alpha}{\gamma}+\frac{\epsilon}{\gamma}}} - \right. \\
& \left. \frac{\frac{1}{\frac{\alpha}{\gamma}}}{w_{3,U} - \frac{\frac{\epsilon}{\gamma}}{1+\frac{\alpha}{\gamma}+\frac{\epsilon}{\gamma}}} - \frac{\frac{1}{\frac{\epsilon}{\gamma}}}{w_{1,U} - \frac{1}{1+\frac{\alpha}{\gamma}+\frac{\epsilon}{\gamma}}} - \frac{\frac{1}{\frac{\epsilon}{\gamma}}}{w_{2,U} - \frac{\frac{\alpha}{\gamma}}{1+\frac{\alpha}{\gamma}+\frac{\epsilon}{\gamma}}} \right)
\end{aligned}
\tag{1.5.24}
$$

Appendix F: Proofs of the Propositions

Proposition 1 We are interested in the loss function for a restricted set of values of the parameters: $0 < \pi < 1$, $0 < \psi < 1$, $\delta > 0$, $\alpha > 0$, $\gamma > 0$. In this case a substitution shows that $L(z_i, Z, Y, \psi = 1) - L(z_i, Z) = \pi^2 \left(\frac{\frac{\alpha}{\gamma}+\frac{\delta}{\gamma}}{(\frac{\alpha}{\gamma}+\frac{\delta}{\gamma}+1)(\frac{\alpha}{\gamma}+\frac{\delta}{\gamma}-\pi+1)^2} - \frac{\frac{\alpha}{\gamma}}{(\frac{\alpha}{\gamma}+1)(\frac{\alpha}{\gamma}-\pi+1)^2} \right) < 0$ whenever $\frac{\alpha}{\gamma} > \frac{1}{4}\sqrt{9-8\pi} - \frac{1}{4}$.

Propositions 2–5 We are interested in the loss function for a restricted set of values of the parameters: $\frac{\alpha}{\gamma} > \frac{1}{4}\sqrt{9-8\pi} - \frac{1}{4}$, $0 < \pi < 1$, $0 < \psi < 1$, $\delta > 0$. Now:

$$L(z_i, Z, Y, \psi) - L(z_i, Z) = \frac{\frac{\delta}{\gamma}\pi^2\psi(\frac{\alpha}{\gamma}^2(\frac{\delta}{\gamma}^2(\psi-1)^2 + \frac{\delta}{\gamma}((-3\pi^2+4\pi+5)\psi^2 - 2\pi\psi^3 + 2(2\pi-5)\psi+2)}{(\frac{\alpha}{\gamma}+1)(\pi\psi-1)^2(\frac{\alpha}{\gamma}+\frac{\delta}{\gamma}+1)(\alpha-\pi+1)^2(\frac{\alpha}{\gamma}+\frac{\delta}{\gamma}-\pi\psi+1)^2}$$
$$\frac{(\pi^2\psi^4 + 2\pi(\pi^2-3)\psi^3 + (-8\pi^2+8\pi+6)\psi^2 + 2(3\psi-5)\psi+1)) + 2\frac{\alpha}{\gamma}^3}{(\frac{\alpha}{\gamma}+1)(\pi\psi-1)^2(\frac{\alpha}{\gamma}+\frac{\delta}{\gamma}+1)(\frac{\alpha}{\gamma}-\pi+1)^2(\frac{\alpha}{\gamma}+\frac{\delta}{\gamma}-\pi\psi+1)^2}$$
$$\frac{(\frac{\delta}{\gamma}(\psi-1)^2 + ((-\pi^2+2\pi+2)\psi^2 - \pi\psi^3 + (\pi-4)\psi+1)) + \frac{\alpha}{\gamma}^4(\psi-1)^2}{(\frac{\alpha}{\gamma}+1)(\pi\psi-1)^2(\frac{\alpha}{\gamma}+\frac{\delta}{\gamma}+1)(\frac{\alpha}{\gamma}-\pi+1)^2(\frac{\alpha}{\gamma}+\frac{\delta}{\gamma}-\pi\psi+1)^2}$$
$$\frac{\frac{\alpha}{\gamma}(\pi-1)\psi(-\frac{\delta}{\gamma}^2(\pi\psi+\psi-2) + \frac{\delta}{\gamma}(2\pi(\pi+1)\psi^2 - (7\pi+3)\psi+6)}{(\frac{\alpha}{\gamma}+)(\pi\psi-1)^2(\frac{\alpha}{\gamma}+\frac{\delta}{\gamma}+1)(\frac{\alpha}{\gamma}-\pi+1)^2(\frac{\alpha}{\gamma}+\frac{\delta}{\gamma}-\pi\psi+1)^2}$$
$$\frac{-4(\psi-1)(\pi^2\psi^2 - 3\pi\psi+2)) + (\pi-1)^2\psi^2(\pi\psi-1)^2)}{(\frac{\alpha}{\gamma}+1)(\pi\psi-1)^2(\frac{\alpha}{\gamma}+\frac{\delta}{\gamma}+1)(\frac{\alpha}{\gamma}-\pi+1)^2(\frac{\alpha}{\gamma}+\frac{\delta}{\gamma}-\pi\psi+1)^2}$$

$L(z_i, Z, Y, \psi) - L(z_i, Z)$ is continuous and differentiable in ψ. There are at most two $\psi \in (0,1)$ s.t. $\frac{\delta(L(z_i,Z,Y,\psi)-L(z_i,Z))}{\delta\psi} = 0$, and $\frac{\delta(L(z_i,Z,Y,\psi)-L(z_i,Z))}{\delta\psi}\Big|_{\psi=0} > 0$. This, plus 1 and the Intermediate Value Theorem imply that there is only one ψ s.t. $L(z_i, Z, Y, \psi) - L(z_i, Z) = 0$.

If if $\psi > \bar{\psi} = \frac{\frac{\alpha}{\gamma}-\pi+1}{\frac{\alpha}{\gamma}-\pi^2+1} - \sqrt{\frac{\frac{\alpha}{\gamma}\pi^2 - 2\frac{\alpha}{\gamma}\pi + \frac{\alpha}{\gamma} + \pi^2 - 2\pi + 1}{\left(\frac{\alpha}{\gamma}-\pi^2+1\right)^2}}$, some tedious algebra shows that, independently of δ, $L(z_i, Z, Y, \psi) - L(z_i, Z) < 0$.

When $\psi < \bar{\psi}$, $L(z_i, Z, Y, \psi) - L(z_i, Z) > 0$ iff $\delta > k(\frac{\alpha}{\gamma}, \pi, \psi)$. When $\psi \in (0, \bar{\psi})$, $\frac{\delta k(\frac{\alpha}{\gamma},\pi,\psi)}{\delta\psi} > 0$. $k(\frac{\alpha}{\gamma}, \pi, \psi) > 0$ iff $\psi > \underline{\psi}$, where $\underline{\psi}$ is the ψ that solves $\psi^3(\frac{\alpha}{\gamma}^2\pi - 2\frac{\alpha}{\gamma}\pi^2 + 2\frac{\alpha}{\gamma}\pi + \pi^3 - 2\pi^2 + \pi) + \psi^2\left(2\frac{\alpha}{\gamma}^2\pi^2 - 2\frac{\alpha}{\gamma}^2\pi - \frac{\alpha}{\gamma}^3 - 3\frac{\alpha}{\gamma}^2 + 3\frac{\alpha}{\gamma}\pi^2 - 3\frac{\alpha}{\gamma} - \pi^2 + 2\pi - 1\right) + \psi\left(-3\frac{\alpha}{\gamma}^2\pi + 2\frac{\alpha}{\gamma}^3 + 6\frac{\alpha}{\gamma}^2 - 4\frac{\alpha}{\gamma}\pi + 4\frac{\alpha}{\gamma}\right) - \frac{\alpha}{\gamma}^3 - \frac{\alpha}{\gamma}^2 = 0$, which has only one solution in $(0,1)$. This implies that, when $\psi \in (0, \underline{\psi})$, $L(z_i, Z, Y, \psi) - L(z_i, Z) > 0$ $\forall\delta$, and when $\psi \in (\underline{\psi}, \bar{\psi})$ for a higher precision level δ, a higher accessibility level ψ is required in order to have $L(z_i, Z, Y, \psi) - L(z_i, Z) < 0$.

Proposition 6–8 We are interested in the loss function for a restricted set of values of the parameters: $0 < \pi < 1$, $0 < \psi < 1$, $\delta > \epsilon > 0$, $\alpha > 0$, $\gamma > 0$ In this case, a substitution shows that $L(z_i, Z, Y, U, \psi) - L(z_i, Z, Y, \psi) < 0$ if $\frac{\alpha}{\gamma} > \frac{1}{4}\sqrt{9 - 8\pi} - \frac{1}{4}$.

$L(z_i, Z, Y, U, \psi) - L(z_i, Z, U) = 0$ has three real solutions $\psi = 0, \psi = \psi^*, \psi = \psi^{**}$.For our set of values of the parameter, only one, ψ^*, is in $(0, 1)$. We can also show that $\frac{\delta\psi^*(\delta)}{\delta\delta} > 0$. This shows that the minimum accessibility threshold needed for the release of both signals to be beneficial increases with the precision of the technical signal Y.

Chapter 2

Monetary/Fiscal Interactions with Forty Budget Constraints

2.1 Introduction

At least since Sargent and Wallace [1981], it has been understood that monetary and fiscal authorities are bound together by a common budget constraint, and that this constraint forces some (implicit or explicit) coordination across the two actors. More recently, a large literature on the fiscal theory of the price level has developed to study the implications of the way this coordination takes place,[1] and the potential role that de jure separate budget constraints between a nation's central bank and its Treasury might have,[2] with an eye to political-economy stories where this separation might affect the bargaining power of the different players.[3] These papers have focused on the

[1]This literature started with Leeper [1991], Sims [1994], and Woodford [1994]. More recent contributions that have emphasized the alternation between different regimes include Davig and Leeper [2007], Davig and Leeper [2010] , Chung et al. [2007], Bianchi and Melosi [2014], Bianchi et al. [2019], and Bianchi et al. [2020]. Cochrane [2011, 2017, 2019, 2020] has argued that active fiscal rules provide a more convincing source of determinacy within new Keynesian models than active monetary policy rules.

[2]The separation of the budget constraints plays a prominent role in Sims [2001b,a], Bassetto and Messer [2013], Hall and Reis [2015] and Reis [2017].

[3]The analysis of monetary-fiscal games is the subject of a smaller literature. Bassetto [2002] provides theoretical underpinnings for the fiscal theory of the price level, but he does not describe the objectives that lead fiscal and monetary authorities to choose their strategies. A few papers that have

interaction between a single fiscal and a single monetary authority. This is because currency issue and monetary policy is typically done by a national central bank, even in federal countries, and the relationship between the national central bank and the Treasury occurs at the level of the central government.

In this chapter, we revisit monetary/fiscal interaction in the context of the Eurozone. While monetary policy is conducted under the control of the European Central Bank (ECB), the European Union has been until now a minor fiscal player with limited revenues and has mostly relied on transfers from the national governments, that retain the ultimate power to tax in their jurisdiction. Moreover, the budgetary interaction between these national governments and the ECB is mediated by the national central banks (NCBs) of each member country, each with its own separate budget. This distinction has taken particular significance since the ECB engaged in quantitative easing (QE), purchasing large amounts of debt issued by national governments. Given the very heterogeneous risks of default across Eurozone countries, a simple pooling of all assets, income, and losses at the level of the ECB would represent an implicit insurance offered by the citizens of the more stable countries to those that are most likely to default. Realizing this, QE has been structured so that each NCB retains 90% of the risk arising from movements in the price of their country's bonds.[4] We then ask the following question: if monetary and fiscal policy are inevitably intertwined by their common budget constraint, under what assumptions is there truly a wall between the budgets of each nation within the Eurozone? Is there still the potential for losses and gains to spill over from one country to another in potentially unintended ways?

Sims [2001a] characterized the ECB as a "model E" central bank, where there is a stark separation with fiscal authorities and a presumption of no fiscal backing, to contrast it with "model F" central banks (like the Federal Reserve System), where lines are more blurred. Once the Eurosystem (formed by the ECB and its member NCBs) started engaging in large-scale purchases of government debt, our findings suggest that the conditions under which the separation of the budgets of each country holds are quite restrictive. In practice taxpayer risks are pooled to a greater extent than it would be

attempted such a description are Niemann [2011], Barthelemy and Plantin [2018], and Camous and Matveev [2022].

[4] The appendix contains a more extensive description of the specific arrangements about income and loss pooling across the Eurosystem.

the case de jure. We distinguish between two broad cases. First, if the Eurozone excess reserves do not command a special liquidity premium, but rather pay the same interest rate as other nominally risk-free assets, then separation can be enforced to the extent that the ECB can prevent each NCB from operating with arbitrarily negative capital and it can also prevent each national Treasury from recapitalizing its NCB with assets that represent pure bookkeeping entries, such as the Federal Reserve's gold certificates. Second, when excess reserves command a liquidity premium and pay a correspondingly lower interest rate, even prohibition of negative capital is not sufficient to avoid that a default by one country spills over to the taxpayers of other countries through the budget constraints of their NCBs, beyond the small percentage that has been agreed ex ante.

Our chapter emphasizes the role of the Target 2 system in representing the link in the budget constraints across countries. In this, we join the literature that has discussed the role of Target 2 within the Eurozone, alternatively criticizing it[5] or defending it.[6] Critics of the Target 2 system worry about the consequences of Target 2 imbalances in the event of a breakup of the European Monetary Union, wondering whether those imbalances would ever be repaid; they also have studied the relationship between movements in Target 2 balances, international capital movements within the Eurozone, and current-account imbalances across countries. Compared to previous work, our analysis focuses entirely on quantitative easing, but it concentrates its attention to the role of the budget constraint of the *fiscal* authorities, in addition to monetary authorities. Cast in this light, the Target 2 system is simply one manifestation of the link in the budget constraint of the monetary authority, which is supposed to act at the European level, and that of the national Treasuries, that are supposed to remain independent. We thus highlight how fragile this arrangement looks from the perspective of studies of monetary/fiscal interactions, and how a similar link would inevitably emerge in different ways as long as the ECB faces national fiscal authorities and purchases their debt in the conduct of its monetary policy.

[5] See e.g. Sinn and Wollmershäuser [2011], Sinn [2018, 2020], and Perotti [2020]

[6] See e.g. De Grauwe and Ji [2012], Whelan [2014]

2.2 The setup

Our model starts from Bassetto and Messer [2013], whose notation we follow. As in their paper, the model is stylized and based on an economy that features flexible prices and special assumptions about preferences, but this is done purely for simplicity and does not affect the central message of our chapter. Most of our equations are based on present-value relations that would be true under much more general circumstances.

The economy features a continuum of private households that live in one of two countries, A and B. Each one of the two countries has its own Treasury and a national central bank (NCB), but the two NCBs are joined in a currency union which we call the Eurosystem. Assuming only two countries has no effect other than simplifying notation. We abstract from the budget of the European Union, who would be a separate player. In practice the budget of the EU is small relative to that of the national governments; the important assumption here is that we do not allow transfers from the EU to national governments to depend on the creditor/debtor position of national treasuries and central banks. While the European Stability and Growth Pact in principle allows for fines, these have never been applied and, to the best of our knowledge, nothing in European law allows for targeted transfers based on the creditor/debtor position vis-à-vis the Eurosystem. Other arrangements, such as the European Stability Mechanism (ESM), may be a more relevant source of pooling of fiscal revenues, but they remain limited and are not the focus of our analysis anyway. However, it might be worth noting that such mechanisms would be one way in which the imbalances that we identify in our analysis are eventually resolved if the tension arising from keeping them implicit within the budget of the central banks becomes untenable. Finally, we also abstract from the budget of the European Central Bank (ECB), since our considerations can be cast purely in terms of the relation between NCBs. In practice, the Target 2 balances that play a prominent role in what follows are mediated through the ECB rather than being bilateral positions.

The Treasury of each of the two countries issues one-period bonds.[7] Country A's debt is safe, while country B's debt is potentially subject to default. We denote by γ_t the

[7] Bassetto and Messer [2013] analyze long-term bonds, since their emphasis is on interest-rate risk. Since we are interested in default risk instead, we neglect them.

(exogenous) probability that country B's debt will be defaulted in period $t+1$, and we assume an exogenous haircut δ upon each default. B_t^i is the nominal amount of one-period bonds that are issued by country i's Treasury in period t and need to be repaid in period $t+1$, and R_t^i is the promised nominal interest rate between periods t and $t+1$. To repay its debts, country i's Treasury has the power to levy (lump-sum) taxes on the residents of the country; let T_t^i be their nominal amount in period t. The Treasury also receives transfers S_t^i from its NCB, with $S_t^i < 0$ corresponding to a recapitalization of the NCB by the Treasury. We abstract from government spending.[8]

On a period-by-period basis, the budget constraint for country i's Treasury is given by the following:

$$B_{t-1}^i(1-\delta\mathbb{1}) = \frac{B_t^i}{1+R_t^i} + S_t^i + T_t^i, \tag{2.2.1}$$

where $\mathbb{1}$ is an indicator function that takes the value of 1 for country B if the country defaults at t and zero otherwise.[9] At each period t, the left-hand side of equation (2.2.1) represents the Treasury's repayment commitments: B_{t-1}^i to the holders of debt, scaled down by δ if default occurs. The right-hand side represents the sources of funds: taxes from the private sector seigniorage transfers from the central bank to Treasury, and new issuance of debt.

In this theoretical section, we focus on the monetary-policy and quantitative easing roles of the central bank and we thus neglect other assets and liabilities that are not connected to it.[10] As a whole, the Eurosystem has liabilities in the form of currency and reserves, and assets in the form of loans to banks and government bonds. In our model, we abstract from banks, so both reserves and loans are directly with the Eurozone residents. We distinguish between currency and reserves because the former pays a zero nominal interest rate. In normal times, when the nominal risk-free interest rate is positive, the spread between the nominal interest rate and the zero rate on currency is a source of profits for the Eurosystem. Reserves may pay an interest rate, which we normally think of being positive, but can also be negative, both in principle

[8]Equivalently, we assume that public goods are perfect substitutes for private consumption, in which case transfers and spending are equivalent, as long as the nonnegativity constraint on private consumption is not binding, which we assume.

[9]$\mathbb{1}$ is always zero for country A.

[10]One example is foreign-currency reserves. Quantitatively, we concentrate on the larger items of the balance sheet.

and in practice.

We adopt the following notation:

- M_{t-1} represents currency outstanding at the beginning of period t issued by the Eurosystem as a whole, and M^i_{t-1}, with $i \in \{A, B\}$ is the amount of the liability allocated to the NCBs of countries A and B.

- X_{t-1} represents reserves outstanding at the beginning of period $t-1$, with a similar split denoted by X^i_{t-1}.

- A_{t-1} represents loans to private households, which are then also split into A^i_{t-1}.

- $\bar{B}^i_{t-1}$ represents holdings by the Eurosystem of government bonds issued by country i. To keep notation simple, we assume here that each NCB only purchases the bonds of its country. This can be generalized; what is important for our analysis is that the NCB of each country purchases a disproportionate amount of the bonds of its Treasury, which is a key characteristic of the current QE program in the Eurosystem and is supposed to limit the mutualization of default risk.

- Finally, τ^i_{t-1} represents the Target 2 balance of the NCB of country i.

Government bonds of countries A and B carry a different interest rate due to default risk. We assume that private citizens cannot default on their loans from the Eurosystem. Since our emphasis is on the assets and liabilities of the central bank, in this version we abstract from the liquidity role that government debt may play, and simply assume that country A's risk-free debt pays the same rate of return as private securities. In particular, this will imply that, in the equilibrium we will describe, this interest rate exceeds the growth rate (which we will normalize to zero). We will include a discussion of liquidity services of government debt in future versions.[11] We assume that reserves pay interest at the rate R^X_t; reserves may or may not provide liquidity services, so in equilibrium we will obtain $R^X_t \leq R^A_t$.

[11] Allowing governments to reap seigniorage from being able to issue debt at low interest rates would not interact with our considerations, except that we usually would expect governments not to default while the interest rate that they pay is below the growth rate of the economy, so that the burden of debt service remains effectively negative.

A central role in our chapter is played by the budget constraints of the NCBs, but for now we start with the budget constraint of the Eurosystem as a whole. The flow budget constraint is

$$M_t - M_{t-1} + \frac{X_t}{1+R_t^X} - X_{t-1} = \frac{\bar{B}_t^A + A_t}{1+R_t^A} + \frac{\bar{B}_t^B}{1+R_t^B} - A_{t-1} - \bar{B}_{t-1}^A - \bar{B}_{t-1}^B(1-\delta I_t) + S_t^A + S_t^B. \tag{2.2.2}$$

On the left-hand side of equation (2.2.2), the Eurosystem raises funds by issuing new currency or reserves beyond those previously issued. On the right-hand side, the new funds are used to purchase new government securities of either country (beyond rolling over principal and interest), or to transfer seigniorage to either government.

The economy starts at time 0 with some initial stock of bonds, money, and excess reserves, described by $(B_{-1}^i, \bar{B}_{-1}^i, A_{-1}, A_{-1}^i, X_{-1}, X_{-1}^i, M_{-1}, M_{-1}^i)_{i=A,B}$.

We relegate the household problem to the appendix. For our purposes, the key equation that emerges in a competitive equilibrium is the consolidated present value budget constraint of the government, which is also known as the government debt valuation equation in the literature on the fiscal theory of the price level:

$$\begin{aligned} &B_{-1}^A - \bar{B}_{-1}^A - A_{-1} + (B_{-1}^B - \bar{B}_{-1}^B)(1-\delta I_0) + M_{-1} + X_{-1} = \\ &T_0^A + T_0^B + M_0 \frac{R_0^A}{1+R_0^A} + X_0 \left(\frac{1}{1+R_0^X} - \frac{1}{1+R_0^A} \right) \\ +&E_0 \sum_{s=1}^{\infty} z_{0,s} \left[T_s^A + T_s^B + M_s \frac{R_s^A}{1+R_s^A} + X_s \left(\frac{1}{1+R_s^X} - \frac{1}{1+R_s^A} \right) \right]. \end{aligned} \tag{2.2.3}$$

In equation (2.2.3), $z_{0,s}$ is the nominal stochastic discount factor between periods 0 and s. This equation states that the liabilities of the Eurozone as a whole at the beginning of period 0 must be equal to the present value of taxes levied by all the governments in the union, plus the present value of all the seigniorage revenues arising from the fact that cash and reserves may pay a lower interest rate than implied by the stochastic discount factor due to their liquidity provision. This equation emerges from market clearing and from the transversality condition of the households: if government liabilities were not matched by appropriate tax revenues, debt would explode over time, and households would find it optimal to spend some of their exploding wealth rather than continuing to purchase ever-increasing amounts of government bonds (or money).

2.3 The present-value budget constraint of the Eurosystem

Using the no-arbitrage relations emerging among asset prices in a competitive equilibrium, we can similarly sum forward the budget constraint of the Eurosytem, equation (2.2.2), and we obtain the following:

$$\begin{aligned}&\bar{B}^A_{-1} + A_{-1} + \bar{B}^B_{-1}(1-\delta I_0) - M_{-1} - X_{-1} + M_0 \frac{R^A_0}{1+R^A_0} + X_0\left(\frac{1}{1+R^X_0} - \frac{1}{1+R^A_0}\right)\\ &+E_0 \sum_{s=1}^{\infty} z_{0,s}\left[M_s \frac{R^A_s}{1+R^A_s} + X_s\left(\frac{1}{1+R^X_s} - \frac{1}{1+R^A_s}\right)\right]\\ &=S^A_0 + S^B_0 + E_0 \sum_{s=1}^{\infty} z_{0,s}(S^A_s + S^B_s) + \lim_{s\to\infty} E_0[z_{0,s}(\bar{B}^A_{s-1} + \bar{B}^B_{s-1}(1-I_{s-1}))].\end{aligned} \tag{2.3.1}$$

The left-hand side of (2.3.1) represents the assets of the Eurosystem as of time 0: its holdings of government bonds and private debt, plus the present value of seigniorage revenues. The right-hand side represents the disposition. The first part is standard, and represents the present value of seigniorage transfers to governments. The final term represents the fact that nothing prevents the Eurosystem from accumulating exploding amounts of government debt. While private households would never do that, as they would rather increase their consumption, the central bank is not an agent maximizing its consumption and nothing prevents a policy of indefinite accumulation.[12] If the Eurosystem faced a single fiscal authority, a Modigliani-Miller theorem would be at work and this position would be irrelevant. To better illustrate it, consider the consolidated present-value budget constraint of the fiscal authorities of the Eurozone:

$$\begin{aligned}&B_{A,-1} + B_{B,-1}(1-\delta I_0) = T^A_0 + T^B_0 + S^A_0 + S^B_0 + E_0 \sum_{s=1}^{\infty} z_{0,s}\left[T^A_s + T^B_s + S^A_s + S^B_s\right]\\ &+\lim_{s\to\infty} E_0[z_{0,s}(\bar{B}_{A,s-1} + \bar{B}_{B,s-1}(1-\delta I_{s-1}))].\end{aligned} \tag{2.3.2}$$

[12]Throughout our analysis, we assumed that $\lim_{s\to\infty} E_0[z_{0,s}A_{s-1}] = 0$. Since we impose a lower bound on the private-sector real net debt position, this is equivalent to ruling out a situation in which the private sector accumulates an explosive amount of government debt financed by exploding loans from the central bank.

Notice that the limit in (2.4.1) only contains bonds held by the Eurosystem, because the limit is zero for all holdings by private actors. Whether the central bank remits its profits to the Treasury or keeps them in ever-increasing amounts of debt is irrelevant from the perspective of equations (2.3.1) and (2.4.1), as well as for all the other competitive-equilibrium conditions, which only depend on the bonds in the hands of the private households. Of course, in practice the net position of the central bank might matter in political-economy models in which there is a conflict between the fiscal and monetary authorities. These equations are useful to understand the policy implications of the fiscal authorities' attempt to directly or indirectly seize some of the assets of the central bank. A recent example of such a policy in the Eurosystem is the proposal to cancel some of the debt held by the Eurosystem that the countries accumulated in their fight against COVID. To the extent that this leads to lower future remittances or a lower limit accumulation of assets by the Eurosystem, the proposal would be neutral, but it is rather viewed as a way of pressuring the Eurosystem to increase seigniorage revenues (and thereby inflation). Similarly, during the Great Depression, the Treasury seized the gold of the Federal Reserve System, replacing it with "gold certificates," an asset bearing no interest and an indefinite maturity.[13]

While there are many historical examples of policies of redistribution of assets between fiscal and monetary authorities, what is unique about the Eurosystem is the fact that many different countries are participating, which raises the possibility that the indefinite accumulation of assets may be asymmetric across countries. To address this, we now consider the present-value budget constraints of national central banks and national Treasuries within the Eurosystem.

2.4 The budget constraints of national Treasuries and Central Banks

Splitting the budget constraint of each national Treasury is straightforward, owing to the weak links across different fiscal authorities in the Eurozone. Summing (2.2.1)

[13]It is worth noting that these gold certificates are not an entitlement to gold, so that they do not necessarily appreciate at the same rate as gold. The Federal Reserve System carries them on the book at their historical value.

forward, we obtain

$$B_{i,-1}(1-\delta I_0) = T_0^i+S_0^i+E_0\sum_{s=1}^{\infty} z_{0,s}\left[T_s^i + S_s^i\right]+\lim_{s\to\infty} E_0[z_{0,s}(\bar{B}_{i,s-1}(1-\delta I_{s-1}))], \quad i = A, B, \tag{2.4.1}$$

with the usual proviso that $I_t \equiv 0$ for country A by assumption.[14] Equation (2.4.1) assumes that the Treasury of country i does not participate in the market for country j's debt, or at least that its position does not explode, similar to the position of the private sector.

The flow budget constraint of country i's NCB is given by

$$M_t^i - M_{t-1}^i + \frac{X_t^i - \tau_t^i}{1+R_t^X} - X_{t-1}^i + \tau_{t-1}^i = \frac{\bar{B}_{i,t}}{1+R_t^i} + \frac{A_t^i}{1+R_t^A} - \bar{B}_{i,t-1}(1-\delta I_t) - A_{t-1}^i + S_t^i. \tag{2.4.2}$$

We consider the allocation of cash and purchases of private securities to be part of "ordinary monetary policy," and are split between the two NCBs according to an exogenous capital key α^i. In contrast, the composition of liabilities between reserves and the Target 2 balance depends on the counterparty of asset purchases conducted by the Eurosystem. When the Eurosystem buys an asset from a resident of country i, the NCB of country i issues new reserves. To the extent that this asset is purchased by the NCB of country $j \neq i$, the NCB of country i is compensated by a matching Target 2 credit. To be concrete, if the NCB of country B purchases one unit of government bonds of country B from residents of country A in period t, it acquires an asset worth $1/(1 + R_t^B)$ and a matching Target 2 liability worth the same. The NCB of country A acquires a Target 2 credit worth $1/(1 + R_t^B)$ and a matching liability in the form of extra reserves. We have imposed that Target 2 balances pay the same rate as reserves, as is the case in practice.[15]

[14] We neglect bonds issued by the European Union and other arrangements such as the ESM. These are a further potentially important source of mutual insurance, but are not at the heart of our research question, and they all implicitly or explicitly include limits that would ensure that the transversality condition is satisfied.

[15] More precisely, the interest rate on Target 2 balances is tied to the ECB's Main refinancing rate, which is the bottom of the corridor system. In our analysis, we neglect the technical details that lead to the emergence of a corridor of interest rates.

Rolling forward equation (2.4.2), we obtain

$$\begin{aligned}&\bar{B}_{i,-1}(1-\delta I_0)+A^i_{-1}-M^i_{-1}-X^i_{-1}+\tau^i_{-1}+M^i_0\frac{R^A_0}{1+R^A_0}+X^i_0\left(\frac{1}{1+R^X_0}-\frac{1}{1+R^A_0}\right)\\&+E_0\sum_{s=1}^{\infty}z_{0,s}\left[M^i_s\frac{R^A_s}{1+R^A_s}+(X^i_s-\tau^i_s)\left(\frac{1}{1+R^X_s}-\frac{1}{1+R^A_s}\right)\right]\\&=S^i_0+E_0\sum_{s=1}^{\infty}z_{0,s}S^i_s+\lim_{s\to\infty}E_0[z_{0,s}(\bar{B}_{i,s-1}(1-\delta I_{s-1})+\tau^i_s)].\end{aligned} \tag{2.4.3}$$

We wish to study the consequences on this budget constraint of a default by country B's Treasury in period 0. Such a default causes a shortfall in the assets of country i's CB on the right-hand side.

Consider first the case in which central bank reserves do not provide special liquidity, so that they pay the same rate of return as other nominal risk-free claims: $R^X_t = R^A_t$. If the Eurosystem as a whole controls the evolution of monetary policy, and it does not react by altering the path of seigniorage on cash, there are only two possibilities:

- **The Intended Adjusted Mechanism**. Faced with a smaller net worth, and correspondingly smaller current and future profits, country B's NCB reduces the present value of the stream of remittances to the Treasury of country B. Ceteris paribus, this will force the Treasury to raise taxes on country i's residents, keeping the credit risk confined to country B. If the default is sufficiently large so as to make the left-hand side of equation (2.4.3) negative, this might require negative values of S_t in some periods: this would correspond to a recapitalization of the NCB by its Treasury. What would such a recapitalization entail in practice? How willing would a government that has just defaulted on its debt be to find the resources for this to happen?

- **Alternative Shenanigans**. A government in default might be tempted to continue to receive its transfers from its NCB, and let the NCB operate with smaller and eventually negative capital. In the absence of a lower bound on the Target 2 liability, the NCB is able to operate in this regime indefinitely, relying on the explosive limit on the right-hand side as a source of funding for its seigniorage transfers even when its assets have fallen in value. An equivalent alternative would be for the Treasury to recapitalize its NCB with non-interest bearing assets of infinite maturity, such as the "gold certificates" (or the more-recently discussed "platinum coin.") Such an arrangement would avoid the embarrassment of taking money out of a NCB that has negative book value, but would not alter the economic problem, since these assets would not generate income and would thus not appear in the economically relevant budget constraint. This prospect causes a conundrum for country A's central bank. Since Target 2 liabilities sum to zero within the Eurosystem, an exploding liability for country B implies an exploding asset for country A, which detracts from the present value of seigniorage transfers that country A's CB can remit to its own Treasury. This is the most transparent manifestation of the fact that there is effectively a single common budget constraint, and a need to coordinate remittance policies. If country B refuses to undergo what we labeled as the "intended adjusted mechanism," it remains unclear in the current circumstances how country A could force an adjustment. If country A insisted on maintaining its stream of seigniorage transfers, the inevitable forces of the budget constraint would force an increase in seigniorage (and the accompanying higher inflation).

Next, consider how the conclusion that we reached above changes when reserves play a liquidity role, so that $R_t^X < R_t^A$. To further simplify the proof, assume the slightly stronger condition $(1 + R_t^X)/(1 + R_t^A) < \theta < 1$, that is, the value of liquidity services provided by reserves have a uniform lower bound. Suppose that, following a default by country B in period 0, country B's NCB does not alter any of its policies, but simply relies on rolling over an increased Target 2 liability. Using equation (2.4.2), we observe that the change in the Target 2 position in period t will be given by

$$\varDelta\tau_t^i = -\bar{B}_{B,-1}\delta \prod_{s=0}^{t}(1 + R_t^X). \qquad (2.4.4)$$

From the household optimality conditions, we obtain

$$\frac{1}{1 + R_t^A} = E_t z_{t,t+1} \Longrightarrow (1 + R_t^X) E_t z_{t,t+1} < \theta.$$

Using the law of iterated expectations, it then follows that

$$\lim_{t\to\infty} E_0 z_{0,t} \varDelta\tau_t^i = 0 : \qquad (2.4.5)$$

in this case, a policy of indefinite rollover does not even lead to an explosive path for Target 2 balances! Depending on the specific value of R_t^X, it may lead to a balance that is growing slower than the private rate of interest, or even shrinking in real terms. How is this possible? Equation (2.4.3) provides the answer: in this case, the NCB earns seigniorage profits in the amount of $\frac{1}{1+R_t^X} - \frac{1}{1+R_t^A}$ on its Target 2 *liabilities*, so that higher liabilities effectively shift seigniorage from country A to country B. Of course, unless country A reduces its own seigniorage redistribution, the present value of the Eurosystem as a whole is not in balance, so that some other adjustment will need to take place. This example illustrates once more how the presence of a common budget constraint causes makes it difficult to define where fiscal risk arises upon a country's default.

2.5 Some Numerical Illustrations

(Check final version)

In this section we explore some numerical implications of the model under alternative scenarios. In the current version, we focus on plausible scenarios that are fairly favorable to the central bank, in that the present value of seigniorage profits is large compared to the size of the default.

We take the period to be 1 year. We consider an economy in which consumption grows at a constant rate, so that the real interest rate on government debt and private assets is also constant and equal to 2%. We assume that the economy grows at 1% per year, and we study paths in which the central bank successfully keeps inflation stable at 2%.

We follow the official profit distribution rule of Bank of Italy and apply it to both country A and country B. Specifically, accounting profits are distributed to the Treasury for 60% and retained as reserves for 40%.

Country A and country B are treated symmetrically, except for two aspects:

- Country B is subject to a one-time possibility of default in period 2, while country A never defaults.

- Country B represents 15% of the GDP of the currency union, roughly the size of Italy in the Eurozone.

Symmetry implies that the demand for cash and bank reserves (after adjusting for size) is the same in the two countries.

To compute seigniorage, we posit a log-log demand for cash given by

$$M_t/(P_tY_t) = \phi \left(R^A\right)^\lambda,$$

with $\phi = 0.0096$ and $\lambda = -0.61$, and Y_t is real GDP. This is chosen so that cash over GDP is 6% when the nominal interest rate is 5% and 4.5% when the nominal rate is 8%, in line with the historical experience of the United States.

Similarly, we assume that reserves are given by

$$X_t/(P_tY_t) = \phi^X \left(\frac{1+R^A}{1+R_t^X} - 1\right)^\lambda.$$

We use the same value of λ as for cash, and we choose $\phi^X = 0.0045$ so that in the initial steady state the central bank has assets in the amount 25% of GDP. On the liability side, in addition to cash (about 6.8% of GDP), the central bank has about 7.4% of GDP of bank reserves.[16]

We start the economy from the asset position that the central bank would have in a steady state in which it only bought private assets. In period 0, the CB engages in "quantitative easing," purchasing government bonds of both countries in the amount of 25% of GDP; this is a one-time purchase and is then reabsorbed through growth and inflation over time. As mentioned in the model, each national CB buys the bonds of its own government.

Country B may or may not default in period 2 (it will not default in any other period). We set the probability of default at 2%; our results are not sensitive to this parameter. Upon default, country B imposes a 50% haircut on its debt, which represents thus a loss of 12.5% of GDP for the CB. This is a fairly benign scenario: the CB starts with a net reserve position of about 11% of GDP, so it barely reaches negative capital. Furthermore, given the relatively low real interest rate, the present value of seigniorage is large, at 31% of GDP (26% coming from cash and 5% from bank reserves).

[16]The balance of assets minus liabilities represents accumulated reserves.

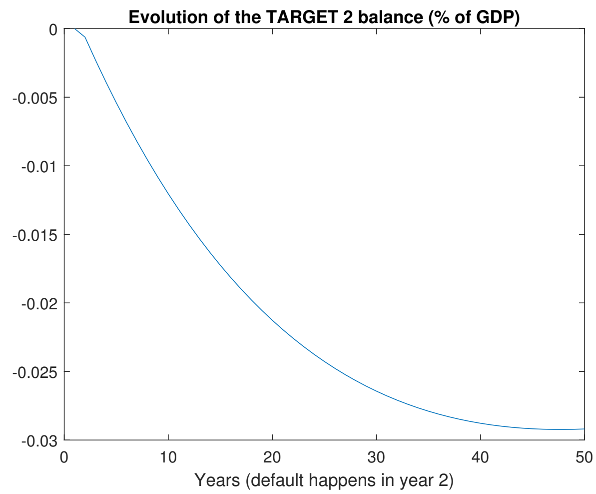

Figure 2.5.1: Target2

Even in this benign scenario, 9% of the fiscal cost of the default is born by the taxpayers of country A. To understand how this happens, Figure 2.5.1 shows the evolution of country B's Target 2 balance. In our experiment, the effect of default on the Target 2 balance is limited on impact. In our environment, Target 2 imbalances emerge over time. In the absence of a default, the CB would be using some of its profits to reabsorb the reserves issued through quantitative easing. When a default occurs, the missing interest payments on the defaulted debt reduce the resources available to reabsorb reserves, leaving the Eurosystem with more bank reserves than would have happened otherwise. Since bank reserves pay the same interest rate in both countries and we assumed symmetry, some of the greater reserves will transfer to banks in country A, so that country B incurs a Target 2 liability. As we previously discussed, in this environment a Target 2 liability is a way for the CB of country B to appropriate a greater part of the seigniorage raised by the Eurosystem, leading to some mutualization of risk.

We considered two alternative scenarios. First, suppose that QE is larger, at 50% of GDP. While in the baseline case the CB incurs losses only in the period of default and starts earning profits from its net interest margin immediately in the period after default, in this case the net interest payments remain negative for 38 years. In the initial years, the net position of the CB of country B is paying interest on reserves and Target 2 liabilities that exceeds its interest earnings on assets, even though the interest rate on the latter is higher. Without an interest rate differential, the CB of country

B would be engaging in a Ponzi scheme and the Target 2 liability would explode. Nonetheless, the seigniorage earned from cash as well as the lower interest rate paid on reserves and Target 2 liabilities compared to assets eventually is enough to restore balance and bring the CB back to profitability. The length of the period in which the CB of country B has negative capital implies a greater temptation for its government to engage in creative accounting and thereby attempt to seize an even greater share of seigniorage.

Finally, suppose that in period 1, prior to a default, the Treasury of country B raids the reserves of its central bank. In this case, the proportion of costs shifted to the taxpayers of country A rises to 16%, and the Target 2 balance reaches a minimum of -18% of GDP.

It is worth noting that, even in this last experiment, the movement in the Target 2 balance is not as large as the one that we already observed in the data. This is likely to be the case because of the symmetry assumption: the prospect of a default is not accompanied by movements of bank deposits across countries.

2.6 Conclusions

This chapter shows that, while 'on paper', within QE programs, each NCB should retain 90% of the risk arising from movements in the price of their bonds, in practice, assessing the real risk sharing principle is extremely complicated. The chapter starts by rigorously spelling out the budget constraints of the entirety of the institutional actors of the Eurozone. We then highlight the key role of the TARGET2 system, that ends up acting as a link between the budget constraints of the Eurozone Treasuries, that instead are supposed to be fully independent. Finally, we show how this link implies that, under plausible scenarios, a significantly larger fraction of the risk ends up being mutualized. Key message of the chapter is that, given this potential spillover of losses, it is crucial for the Eurozone to coordinate remittance policies at the central level.

Appendix A: The Household Problem

In each country i the representative consumer's preferences are given by[17]

$$u(c_0^i) + v(\omega_0^i) - \phi y_0^i + E_0 \sum_{t=1}^{\infty} \beta^t [u(c_t^i) + v(\omega_t^i) - \phi y_t^i],$$

where c_t is consumption of residents of country i in period t that is paid out of cash, ω_t^i is consumption paid out of reserves, and y_t^i is labor supplied in period t.[18] There is a technology with constant returns to scale that produces one unit of either consumption good for each unit of time worked.

In each period, each household cannot consume what it produces, but it rather has to purchase its consumption from an anonymous market; in some markets only cash is accepted, and in others only reserves, so that the following constraints must hold:

$$m_t^i \geq P_t c_t^i$$

and

$$x_t^i \geq P_t \omega_t^i$$

where m_t^i and x_t^i are money and reserve balances held by the individual household.

Capital markets are integrated, so that households can save in bonds of either country, borrow from the central bank, or invest in state-contingent private securities α_t. Define w_t as the nominal wealth in the hands of households at the beginning of period t and ω_t its net asset position against other households. We have

$$w_t = b_{A,t-1} - a_{t-1} + b_{B,t-1}(1 - \delta I_t) + m_{t-1} + x_{t-1} + P_{t-1}(y_{t-1} - c_{t-1} - \omega_{t-1}) + \alpha_t. \quad (2.6.1)$$

The different time subscripts represent the fact that public bonds are nominally risk free (other than for the event of a default), so that their promised repayment in period

[17] Bassetto and Messer [2013] allow for periods in which the discount factor is greater than one, so that the zero bound on nominal interest rates may be binding for a central bank that attempts to target stable prices. We neglect this element here. While Bassetto and Messer lump required reserves with cash and assume no liquidity role for excess resrves, for our purposes it is better to separate the two and lump together all reserves, that may provide a liquidity role separate from that of cash.

[18] Lowercase variables represent choices by the households, while uppercase variables represent choices by a government agency, either the Treasury or a central bank.

t is set in period $t-1$, while α_t is contingent on time-t shocks (and consequently so is w_t).

Defining $z_{t,s}$ as the stochastic discount factor between periods t and s (representing the intertemporal prices in the market for private loans), the wealth of the households evolves according to the following equation:

$$\begin{aligned}&E_t\left[z_{t,t+1}\left(w_{t+1}-b_t^A+a_t-b_t^B(1-\delta I_{t+1})-m_t-x_t-P_t(y_t-c_t-z_t)\right)\right]\\&+\frac{b_t^A-a_t}{1+R_t^A}+\frac{b_t^B}{1+R_t^B}+m_t+\frac{x_t}{1+R_t^X}+T_t\leq w_t\end{aligned} \tag{2.6.2}$$

Households are also subject to a lower bound on real wealth $w_t/P_t \geq \underline{w}$, which is not binding in any period, but prevents Ponzi schemes.

The necessary and sufficient conditions for household optimality require

$$u'(c_t)=\phi(1+R_t^A), \tag{2.6.3}$$

$$v'(\omega_t)=\phi\frac{1+R_t^A}{1+R_t^X}, \tag{2.6.4}$$

$$z_{t,t+1}=\frac{\beta P_t(1+R_{t+1}^A)}{P_{t+1}(1+R_t^A)}, \tag{2.6.5}$$

$$E_t z_{t,t+1}=\frac{1}{1+R_t^A}\implies 1=\beta E_t\left[\frac{P_t(1+R_{t+1}^A)}{P_{t+1}}\right], \tag{2.6.6}$$

$$\frac{1}{1+R_t^B}=\beta E_t\left[z_{t,t+1}(1-\delta I_{t+1})\right], \tag{2.6.7}$$

and the present-value budget constraint

$$\begin{aligned}&w_0\geq T_0+m_0\frac{R_0^A}{1+R_0^A}+x_0\left(\frac{1}{1+R_0^X}-\frac{1}{1+R_0^A}\right)\\&+\sum_{s=1}^{\infty}z_{0,s}\left[T_s+m_s\frac{R_s^A}{1+R_s^A}+x_s\left(\frac{1}{1+R_s^X}-\frac{1}{1+R_s^A}\right)+P_{s-1}(y_{s-1}-c_{s-1}-\omega_{s-1})\right],\end{aligned} \tag{2.6.8}$$

where no arbitrage implies $z_{0,s} := \prod_{t=1}^{s} z_{t-1,t}$.

The competitive equilibrium conditions are the same as above, plus market clearing, which requires $y_t = c_t + \omega_t$ and that the household demand for government bonds is equal to their supply. Using market clearing, in equilibrium equations (2.6.8) and (2.6.1) yield (2.2.3) in the main text.

Appendix B: A brief overview of ECB's monetary policy operations: implementation and risk sharing agreements

Most of the Eurosystem's monetary policy operations are carried out in a decentralised way, however their implementation and risk sharing agreements differ from program to program.

During standard open market operations (MROs, LTROs, fine tuning, and structural operations) and non-standard longer term refinancing operations (TLTROs and three years LTROs) each NCB collects bids for central bank liquidity from local institutions and manages the collateral provided (the ECB provides a list of eligible assets) keeping them in their balance sheets. Despite their decentralized nature, the risk associated with all these refinancing operations is fully shared among the Eurosystem's NCBs in proportion to their capital key (article 32.4 of the ESCB Statute).

In quantitative easing programs (the Asset Purchase Programme started in 2014 and the recent Pandemic Emergency Purchase Programme), the Eurosystem expands its global balance sheet buying asset-backed securities (ABSPP), covered bonds (CBPP3), corporate sector bonds (CSPP), and public sector securities (PSPP and PEPP).

The PSPP (approximately 85% of the whole APP) and the PEPP are, in terms of magnitude, the most relevant. Under the PSPP and the PEPP the Eurosystem buys sovereign bonds from euro-area governments according to each country's NCB share of the ECB's capital ('capital key'), and securities from european institutions and national agencies. Purchases are carried out by both the ECB (20% of the total), and each of the NCBs (the remaining 80%). NCBs focus exclusively on their home market, and thus hold only their own country's debt. From a risk sharing perspective, PSPP and PEPP are different from open market operations, as the sovereign bonds default risk is not shared: each NCB bears in full the risk on the bonds it has on its balance sheet, that represent the 90% of the total sovereign bonds purchased (the other 10% is held by the ECB). In terms of profits, when it comes to compute the monetary income to be pooled and shared, these holdings are considered to bear interest at the marginal rate used by the Eurosystem for MROs, any extra profit remains therefore to the NCB.

Chapter 3

Optimal Communication Strategy for Central Banks

3.1 Introduction

Central banks' communication problems have been widely studied in recent years, especially following the financial crisis. This is because central banks communication is considered a fundamental tool to improve the effectiveness of 'unconventional' monetary policies.

In particular, there is a long-term debate going on around the welfare effects of the so called 'Delphic forward guidance'[1]. This is the tool used by central banks to share superior information regarding economic conditions. The aim is to reduce the agents' uncertainty, to guide their expectations, and ease their decision making process (Tarkka and Mayes [2000]). Two crucial features of this type of forward guidance are precision and credibility. Existing literature has widely analysed the optimal precision level of central banks' communication casting doubts on whether maximizing the precision of the information released is incontrovertibly welfare enhancing. In particular, Morris and Shin [2002a] show that, when agents have strategic motives, maximizing the precision of the public information released can be detrimental. Later studies (Svensson

[1] Campbell et al. [2012] calls "Delphic forward guidance" the case in which a Central Bank's aim is to transmit superior information regarding the economy to the agents.

[2006] and Cornand and Heinemann [2008]) further contributed to the debate challenging the findings of Morris and Shin [2002a].

Regarding the second feature, credibility, most of the literature praises its maximisation as fundamental in order to maximise the efficacy of communication (Blinder [2000] and Goy et al. [2018]). It has been shown how being completely credible plays a crucial role in reducing the costs of disinflation (Ball [1995], and Erceg and Levin [2003]) and in avoiding speculative attacks to the currency (Blinder [2000]). However, the literature has not yet explored how the conclusions change once we consider that a central bank can employ both these two features jointly in order to manipulate welfare. In this chapter I provide a theoretical framework that allows to achieve that. I extend the static model developed in Morris and Shin [2002a] to allow for an additional feature of the release of public signal: alongside precision, the Central Bank can also choose the level of credibility of the signal it releases to the economy. The results coming from this the model are interesting and in contrast with both standard economic practice and the main theoretical findings in the existing literature. I prove that, in order to maximize welfare, credibility should not be blindly maximised, but carefully tailored to the precision achievable. Furthermore, I show that, conditional on setting credility at its welfare-maximising level, a central bank should always release its signal with maximum precision. This result contrasts the main finding in Morris and Shin [2002a], who argue that in some instances it may be optimal to set the precision of the signal to 0 (i.e. not releasing the signal at all). The intuition behind my finding is that, when agents have strategic motives, it is the second feature of communication, namely credibility, that should be used as a tool to endogenously discourage the overweighting of public signals, as it leads to larger welfare gains. I also show that using credibility drastically increases the number of situations in which the sender can induce welfare gains. As while manipulating precision can be useful uniquely when the public signal's maximum precision is lower than the private one's (a setting which is not very unrealistic, Svensson [2006]), fine tuning credibility allows to achieve welfare gains also when a sender is releasing superior information.

3.2 The Model

The model is a game that induces strategic behavior in the spirit of the "beauty contest", and closely follows the one developed in Morris and Shin [2002a]. It is a one-period model with two types of agents: a central bank and a continuum of firms indexed by the unit interval $[0, 1]$. The economy is ruled by an underlying hidden state of the world $x \in R$, drawn at the beginning of the period from an improper uniform distribution.

Each firm i takes a single action a_i chosen in order to maximize the following utility function:

$$u_i(a_i, a_{-i}, x) = -((1-\pi)(a_i - x)^2 + \pi(L_i - \bar{L})) \qquad (3.2.1)$$

where

$$L_i \equiv \int_0^1 (a_j - a_i)^2 \, \mathrm{d}j \quad \text{and} \quad \bar{L} \equiv \int_0^1 L_j \, \mathrm{d}j$$

This utility function has two parts. The first one, is a standard quadratic payoff in the difference between the action and the realised state of the world. The second part is the 'beauty contest' term: the utility of firm i decreases, according to some weight π, when the distance between her action and the average action profile of the whole population ($\bar{a}$) increases. Firms have therefore a strategic motive: an incentive to second-guess what the other firms will do.
The central bank acts as a benevolent social planner whose goal is to maximise social welfare. Social welfare is defined as the normalised average of the firms' utilities:

$$W \equiv \frac{1}{1-r} \int_0^1 u_i(a_i, a_{-1}, x) \, \mathrm{d}i = -\int_0^1 (a_i - x)^2 \, \mathrm{d}i \qquad (3.2.2)$$

Note that the strategic motive cancels out: the central bank cares only about the ability of the firms to track the fundamental. In order to achieve its goal, the central bank releases a signal $Z \in R$ regarding the state of the world x. Z is publicly observed, however, it will not only feature a certain precision level, but also a credibility level: only a fraction p of the firms 'believe' it i.e. consider Z to be informative. Therefore, while the fraction p of 'Believers' realises Z's precision to be $\alpha_B > 0$, the remaining 'Non Believers' interpret it as pure noise ($\alpha_{NB} = 0$).

The information set regarding x available to each firm i is composed of two elements:

alongside the aforementioned central bank's signal Z, there is a private source of information z_i, that has precision γ.

$$Z = x + \frac{1}{\alpha_j}\nu \quad \text{and} \quad z_i = x + \frac{1}{\gamma}\epsilon_i \tag{3.2.3}$$

Where $j = \{B, NB\}$, ν and ϵ are i.i.d. $\mathcal{N}(0,1)$.

I solve the model by backward induction: first, I analyze the firms' problem finding their optimal action a_i^*, then I solve the Central Bank's communication problem.

3.3 The firms' problem

Given their utility function, each firm i's optimal strategy is determined by the following first-order condition:

$$\sigma_i(\alpha, p, Z, z_i) = \pi E_i(x) + (1-\pi)E_i(\bar{a}) \tag{3.3.1}$$

Notice that, while the social planners' aim is to keep all firms' action as close as possible to the state of the world x, each firm i's action is determined not only by the expected value of x, but also by the expected value of the average action in the economy $\bar{a}$. A firm that considers the central bank's signal Z informative (i.e. 'Believer') forms her expectation regarding x in the following way:

$$E_B(x) = \frac{\gamma}{\alpha+\gamma}z_i + \frac{\alpha}{\alpha+\gamma}Z \tag{3.3.2}$$

The remaining fraction $1-p$ of 'Non Believers', in order to form their expectation over x, use the private signal only, as they think Z is pure noise. Therefore:

$$E_{NB}(x) = z_i \tag{3.3.3}$$

In order to have an explicit formula for $E_i(\bar{a})$, and therefore to solve for an equilibrium, I proceed by 'guess and verify'. The guess is that the optimal strategy for both the types of firms will be a linear combination of the public and the private signal:

$$\sigma_i(\alpha, p, Z, z_i) = \lambda_j z_i + (1-\lambda_j)Z \tag{3.3.4}$$

Where $j = B, NB$.

In equilibrium, we will have two sets of weights: one for the 'Believers' (λ_B), and one for the 'Non Believers' (λ_{NB}). Notice also that, although a 'Non Believer' considers Z to be uninformative regarding x, she will still use it when setting her action as she knows that a fraction p of the firms are 'Believers' and thus rely on Z to forecast x (Z is a coordination device). The two types of firm will therefore form the following expectation regarding $\bar{a}$:

$$\begin{aligned} E_B(\bar{a}) = p[\lambda_B \underbrace{(\frac{\gamma}{\alpha+\gamma} z_i + \frac{\alpha}{\alpha+\gamma} Z)}_{E_i(z_j)=E_i(x)} + (1-\lambda_B)Z] + \\ (1-p)[\lambda_{NB} \underbrace{(\frac{\gamma}{\alpha+\gamma} z_i + \frac{\alpha}{\alpha+\gamma} Z)}_{E_i(z_j)} + (1-\lambda_{NB})Z] \end{aligned} \tag{3.3.5}$$

$$E_{NB}(\bar{a}) = p[\lambda_B \underbrace{z_i}_{E_i(z_j)=E_i(x)} + (1-\lambda_B)Z] + (1-p)[\lambda_{NB} \underbrace{z_i}_{E_i(z_j)} + (1-\lambda_{NB})Z] \tag{3.3.6}$$

Substituting in 3.3.1, a 'Believer''s optimal action will be:

$$\begin{aligned} \sigma_B(\alpha, p, Z, z_i) = (1-\pi)\left[\frac{\gamma z_i + \alpha Z}{\alpha+\gamma}\right] + \pi\Bigg[p\Bigg(\lambda_B(\frac{\gamma z_i + \alpha Z}{\alpha+\gamma}) + (1-\lambda_B)Z\Bigg) + \\ (1-p)\Bigg(\lambda_{NB}\frac{\gamma z_i + \alpha Z}{\alpha+\gamma} + (1-\lambda_{NB})Z\Bigg)\Bigg] \end{aligned} \tag{3.3.7}$$

While a 'Non Believer' optimal action will be:

$$\sigma_{NB}(\alpha, p, Z, z_i) = (1-\pi)z_i + \pi\Bigg[p\Bigg(\lambda_B z_i + (1-\lambda_B)Z\Bigg) + (1-p)\Bigg(\lambda_{NB} z_i + (1-\lambda_{NB})Z\Bigg)\Bigg] \tag{3.3.8}$$

Equating the coefficients of 3.3.4 and 3.3.7 and 3.3.8, and solving for the optimal weights λ_B^* and λ_{NB}^* delivers :

$$\lambda_B^* = \frac{\gamma(1-\pi)}{\alpha(p-1)\pi + \alpha + \gamma(1-\pi)} \quad \text{and} \quad \lambda_{NB}^* = \frac{(1-\pi)(\alpha+\gamma)}{\alpha(p-1)\pi + \alpha + \gamma(1-\pi)} \tag{3.3.9}$$

Note that the 'Non-Believers' assign a higher weight than the 'Believers' to the private signal, as they consider it to be the only relevant piece of information to track the fundamental x. Both λ_B^* and λ_{NB}^* are decreasing in: the precision of the public signal (α), the fraction of agents that believe it (p), and the strategic motive (π).

3.4 The central bank's problem

In order to maximise social welfare, the central bank chooses precision α, and credibility p of its signal Z.
Substituting the firms' optimal action in the expected welfare formula allows to retrieve an explicit formula for social welfare. The problem of the central bank therefore reads:

$$\max_{p,\alpha} E(W) = \max_{p,\alpha} -E(\int_0^1 (a_i - x)^2 \,\mathrm{d}i) = \max_{p,\alpha} -(p[\frac{\gamma(\pi-1)^2}{(\alpha(p-1)\pi+\alpha-\gamma\pi+\gamma)^2}+ \frac{\alpha((p-1)\pi+1)^2}{(\alpha(p-1)\pi+\alpha-\gamma\pi+\gamma)^2}]+ (1-p)[\frac{(\pi-1)^2(\alpha+\gamma)^2}{\gamma(\alpha(p-1)\pi+\alpha-\gamma\pi+\gamma)^2}+\frac{(\alpha p^2\pi^2)}{(\alpha+\gamma-\gamma\pi+\alpha(-1+p)\pi)^2}]) \tag{3.4.1}$$

Through this explicit expression it is possible to assess how the welfare effects produced by the release of the central bank's signal Z changes according to any credibility level p and precision α.

3.5 Social welfare and credibility

Morris and Shin [2002a] shows how, when the strategic motive is particularly strong (i.e. π particularly high), and when the central bank cannot be too precise in its communication (i.e. maximum precision level achievable $\bar{\alpha}$ is low with respect to γ), setting $\alpha = 0$ (i.e. no release of public information), is consistent with welfare maximization. This is because the release of Z produces two effects: an informative effect, which allows firms to have a better forecast of the state of the world, improving therefore welfare, but also a negative misweighting effect. The misweighting effect consists in the fact that firms would put too much effort in trying to match the strategy of their competitors (by putting too much weight on the public signal that has the same realisation for everyone) thereby amplifying too much the noise of the public signal. When $\bar{\alpha}$ is not high enough, the second effect dominates the first one, and withholding the information is preferable. However, here I show that when considering also the credibility dimension, this result changes.

Proposition 1. *No release of information is never optimal. For any possible set of values of π, α, and γ, there is always a degree of credibility $1 \geq p > 0$ such that releasing information is strictly better than not releasing it. (Proof in Appendix)*

This is because, through imperfect credibility ($p < 1$), the central bank can tackle the misweighting effect arising from the strategic motive.

The intuition behind this result works as follows. Once we add the credibility dimension, the misweighting effect arising after the introduction of the public signal Z becomes twofold. For what concerns the 'Believers', everything works exactly as explained in Morris and Shin [2002a]. However, among the 'Non-Believers', the misweighting effect acts in the opposite direction. Since they do not consider Z to be informative, they tend to discard it when setting the expected value over x, overweighting therefore the private signal z_i. This leads to an over-amplification of z_i's noise for this category of agents.

When the central bank increases the credibility of its signal worsens the misweighting behaviour of the 'Believers', but improves the 'Non Believers" one, as Z's importance as coordination device, and therefore the weight assigned to it, increases. Fine tuning the credibility level of its signal allows the sender (Central Bank) to endogenously modify the optimal weighting of information (recall the form of λ^*_B and λ^*_{NB}), minimising the overall misweighting effect and making it smaller than the informative effect. It can be shown that:

Proposition 2. *Central bank's optimal credibility level p^* is given by* $\min(\frac{(\pi^2-1)(\alpha+\gamma)}{\pi(\alpha(\pi-1)+2\gamma(\pi-2))}, 1)$

This proposition shows that, for a broad range of values of the strategic motive ($\pi \in (2-\sqrt{3}, 1)$), unless the Central Bank can be precise enough ($\frac{\alpha}{\gamma} > \frac{\pi^2-4\pi+1}{\pi-1}$), full credibility is not desirable. It should be noted that this precision threshold $\frac{\pi^2-4\pi+1}{\pi-1}$ can be extremely elevated. For instance, when $\pi = 0.7$, a realistic value according to existing literature (e.g. Krugman [2001]), the threshold takes the value of 4.4, implying that unless the central bank can release information 4.4 times more precise than the private one agents already have, full credibility is not desirable.

This result is surprising and particularly relevant in terms of policy implications. In fact, one of the biggest critiques to Morris and Shin [2002a] is given by the fact that, in order for their 'no release' result to be interesting from a policy perspective, the precision level of the public information should be less than one eight of the private

one. This seems extremely unlikely in a central bank communication scenario (Svensson [2006]). Proposition 2 claims that fine tuning the credibility of the communication (i.e. $p^* < 1$) is welfare enhancing even when the Central Bank can improve the firms' knowledge of the hidden state of the world ($\bar{\alpha} > \gamma$).
Moreover, I can show that:

Proposition 3. *Conditional on setting the optimal credibility level, maximising the precision of the communication ($\alpha = \bar{\alpha}$) is always optimal.*

This last Proposition shows how, once a central bank manages to fine tune the credibility of its communication, choosing the precision level is a trivial exercise, as it should always be maximised. This result highlights how credibility is indeed first order important: once this dimension is correctly taken into account, studying optimal precision turns out to be less interesting.

3.6 A numerical example

In this section I illustrate the findings of the model through a numerical example. I set the strategic motive $\pi = 0.7$, and I also assume that the Central Bank can give the audience a more precise information than their private one regarding x, as I set $\frac{\bar{\alpha}}{\gamma} = 1.25$. I computationally solve for the welfare maximising precision α^* and credibility p^* levels (i.e. the solution to $\max p, \alpha E[W]$).

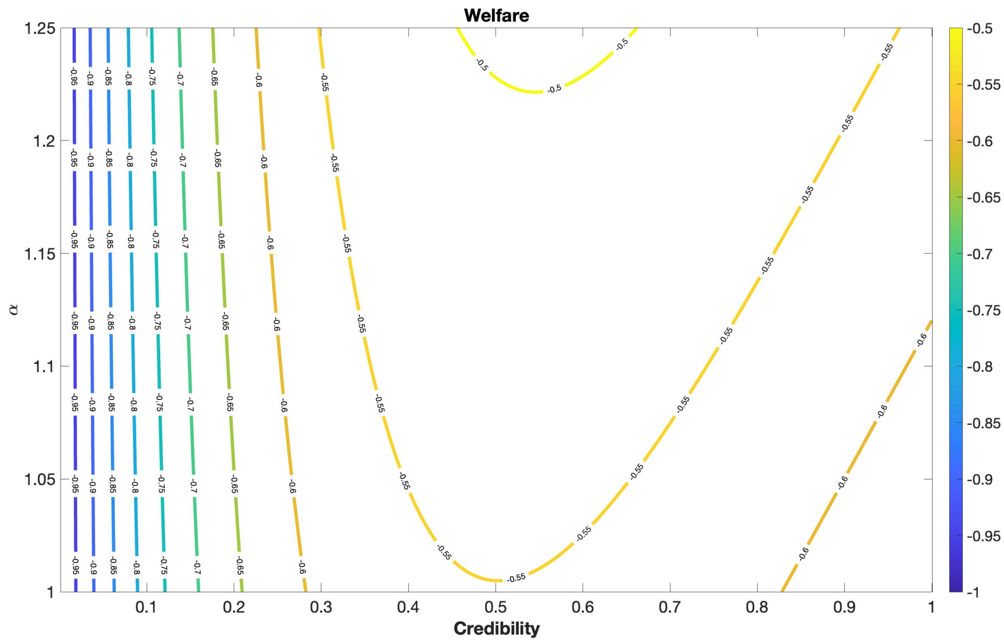

Figure 3.6.1: Welfare maximization credibility and precision level

Figure 3.6.1 summarises the findings of the chapter. The curves represent welfare contours in the credibility (p)-precision (α) space. It is clear how, in this simple numerical example, the central bank maximizes welfare by maximising the precision level of its signal, but also by keeping its credibility at a rather low level ($p^*(\bar{\alpha}) = 0.53$).

3.7 Conclusions

In this chapter I show that both standard economic practice and existing theoretical findings on optimal public information release might not be consistent with welfare maximization. I use a static model to show that, when releasing public information in a beauty contest environment in which agents have access to private information, while it is true that precision should always be maximized, maximizing credibility may not be optimal. This is because the most desirable way to tackle the detrimental effects produced by the coordination motive is not using precision (i.e. shutting down the public information channel), as theoretical literature suggests, but manipulating credibility.

Using the credibility channel rather than the precision one increases also the range of situations in which a sender (in this case the central bank) can improve welfare. In fact, Morris and Shin [2002a] show that manipulating precision increases welfare uniquely when the public signal is significantly less precise than the private one , which is an unlikely assumption in most settings Svensson [2006]. Here I show that changing the credibility level can lead to welfare improvements also when public signal is more precise than the private one.

Appendix

Proposition 1 Define the Loss function of the economy $E[L(\alpha,p,\pi,\gamma)] = -E[W(\alpha,p,\pi,\gamma)]$. We need to show that $\forall\ \pi$, and $\frac{\alpha}{\gamma}$, it is always possible to find a $p \in (0,1]$ s.t. $E[L(\alpha,p,\pi,\gamma)] < E[L(\alpha=0,p,\pi,\gamma)]$:

$$E[L(\alpha,p,\pi,\gamma)] - E[L(\alpha=0,p,\pi,\gamma)] = \frac{-\alpha^2(p-1)(\pi-1)^2 - \alpha\gamma\left(p^2(\pi-2)\pi + p(\pi-1)^2 - 2(\pi-1)^2\right) + \gamma^2(\pi-1)^2}{\gamma(\alpha(p-1)\pi+\alpha-\gamma\pi+\gamma)^2} - \frac{1}{\gamma} < 0 \tag{3.7.1}$$

Tedious algebra shows that: when $\frac{\alpha}{\gamma} \geq 1$, independently of π, this is verified $\forall p \in (0,1]$. when $0 < \frac{\alpha}{\gamma} < 1$, and $0 < \pi \leq \frac{\alpha+\gamma}{2\gamma}$, then $E[L(\alpha,p,r,\gamma)] < E[L(\alpha=0,p,r,\gamma)]\ \forall$ $p \in (0,1]$. Vice versa, when $\frac{\alpha+\gamma}{2\gamma} < \pi < 1$, $E[L(\alpha,p,r,\gamma)] < E[L(\alpha=0,p,r,\gamma)]$ iff $0 < p \leq \frac{\alpha\pi^2-\alpha+\gamma\pi^2-\gamma}{\alpha\pi^2+\gamma\pi^2-2\gamma\pi}$. Where $\frac{\alpha\pi^2-\alpha+\gamma\pi^2-\gamma}{\alpha\pi^2+\gamma\pi^2-2\gamma\pi} > 0\ \forall\ \alpha > 0$ and $\pi \in (\frac{\gamma+\alpha}{2\gamma},1)$.

Proposition 2–3

$$\frac{dE[L(\alpha,p,\pi,\gamma)]}{dp} = -\frac{\alpha(\pi-1)(\alpha+\gamma)\left(\alpha(\pi-1)((p-1)\pi-1)+\gamma\left(2p(\pi-2)\pi-\pi^2+1\right)\right)}{\gamma(\alpha(-p\pi+\pi-1)+\gamma(\pi-1))^3} \tag{3.7.2}$$

$\frac{dE[L(\alpha,p,\pi,\gamma)]}{dp} = 0$ when $p^* = \frac{(\alpha+\gamma)(\pi^2-1)}{\pi(\alpha\pi-\alpha+2\gamma\pi-4\gamma)}$.
And $\left.\frac{d^2E[L(\alpha,p,\pi,\gamma)]}{dp^2}\right|_{p=\frac{(\alpha+1)(\pi-1)(\pi+1)}{\pi(\alpha\pi-\alpha+2\pi-4)}} = \frac{2\alpha(\alpha+1)^2(\pi-1)^3\left(\pi^2-2\pi-3\right)(\alpha-\pi+2)}{(\alpha(\pi-1)+2(\pi-2))^2} > 0$ since $\alpha > 0$, and $1 > \pi > 0$.
p^* is increasing in α and when $\alpha \leq \frac{1-4\pi+\pi^2}{-1+\pi}$, then $p^* < 1$.
It can also be shown that:

$$\frac{dE[L(\alpha,p,\pi,\gamma)]}{d\alpha} = \frac{p\left(\alpha\left(\left(p^2-1\right)\pi^3+\left(-2p^2+p+1\right)\pi^2-p\pi+\pi-1\right)+\gamma(\pi-1)\left(p(\pi-2)\pi-\pi^2+1\right)\right)}{(\alpha(p-1)\pi+\alpha-\gamma\pi+\gamma)^3} \tag{3.7.3}$$

And:

$$\left.\frac{dE[L(\alpha,p,\pi,\gamma)]}{d\alpha}\right|_{p=p^*} = \frac{(\pi-2)(\pi+1)^2}{4\pi(\alpha-\gamma(\pi-2))^2} < 0 \tag{3.7.4}$$

This shows that precision should always be maximised.

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Statement of Conjoint work

Note on the joint work in Gherardo Gennaro Caracciolo's thesis "Essays on unconventional monetary policies".

Chapter 1, "Parole, parole, parole: The Importance of Central Bank Communication", is single-authored by Gherardo Gennaro Caracciolo.

Chapter 2, "Monetary/Fiscal interaction with Forty Budget Constraints", is co-authored work between Gherardo Gennaro Caracciolo and Marco Bassetto, and each author contributed equally.

Chapter 3, "Optimal Communication Strategy for Central Banks", is singleauthored by Gherardo Gennaro Caracciolo.