Central Bank Communication with a Financial Stability Objective*

David M. Arseneau†
Federal Reserve Board

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Abstract

An endogenous financial crisis is introduced into the canonical model used to study central bank transparency. The central bank is endowed with private information about the real economy and credit conditions which jointly determine financial vulnerabilities. An optimal choice is made regarding whether to communicate this information to the public. A key finding is that the optimal communication strategy depends on the state of the credit cycle and the composition of shocks driving the cycle. From a policy perspective, this raises the possibility that central bank communication in the presence of a financial stability objective faces a time inconsistency problem.

Keywords: Financial stability report, Information disclosure, Survey of economic projections, Time inconsistency problem, Transparency

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*The views expressed here are solely those of the authors and should not be interpreted as reflecting the views of the Board of Governors of the Federal Reserve System or of any other person associated with the Federal Reserve System.

†**Corresponding Author**. Board of Governors of the Federal Reserve System; 20th St. and Constitution Ave. NW; Washington, D.C. 20551; Phone: 202-452-2534. Email address: david.m.arseneau@frb.gov.

1 Introduction

Financial stability considerations have taken on an increasingly important role for central banks following the 2007-'08 global financial crisis. In many countries central banks now take a leadership role amongst domestic financial regulators in identifying, monitoring, and communicating with the public about emerging financial vulnerabilities.

In light of this new emphasis, it has now become standard practice for central banks to communicate views on potential financial vulnerabilities through the publication of a financial stability report (FSR). The specific content of these central bank FSRs differs widely from country to country, but, broadly speaking, they summarize current financial developments and provide an assessment of vulnerabilities that could potentially pose a threat to the stability of the domestic financial system.[1] In the United States, the Federal Reserve became the last major central bank to adopt this trend, publishing its first FSR in late-2018.

What explains this emerging trend in central bank communication? The motivation comes, at least in part, from a desire to provide enhanced transparency about how financial stability considerations shape central bank views and how those views, in turn, shape policy decisions.[2] At present, there exists a large literature, both theoretical and empirical, studying the value of central bank transparency in the context of traditional monetary policy. Geraats (2002) provides an extensive survey of this work. From the theoretical perspective, the standard framework builds on some variation of a small scale new Keynesian model in which the central bank enjoys an informational advantage over private agents.[3] Insights from this literature have been extremely influential in pushing central banks to be more open with the public about the conduct of monetary policy. However, because there is no role for financial stability these models are limited in what they have to say about post-crisis communication strategies. In this sense, the academic literature on optimal transparency has not kept pace with the practice of central banking.

This paper fills this gap in the literature. The model presented here builds on a simple game theoretic model of optimal monetary policy with asymmetric information similar to Kydland and Prescott (1977) and Barro and Gordon (1983). The main innovation is to introduce a role for

[1] See Osterloo and den Haan (2004), Cihak (2006), and Osterloo, den Haan, and Jong-A-Pin (2007), for a survey of FSRs across countries.

[2] Federal Reserve Chairman Jerome Powell in a May 2018 speech: "Public transparency and accountability around financial stability have become all the more important in light of the extraordinary actions taken by central banks during the global financial crisis." On the topic of FSRs, in particular, Federal Reserve Governor Lael Brainard in a December 2018 speech: "Last week, the Board released its first Financial Stability Report to help inform the public and promote transparency and accountability as we carry out our financial stability responsibilities."

[3] This framework includes the static models (or repeated play in one-period games) such as Backus and Driffill (1985), Canzoneri (1985), Cukierman and Liviatan(1991), Atkeson and Kehoe (2006), Geraats (2007), and Seibert (2009). Alternatively, Cukierman and Meltzer (1989), Faust and Svensson (2001, 2002), Jensen (2002), Walsh (2007), Westelius (2009), and Mertens (2011) use dynamic models either study optimal transparency explicitly or optimal monetary policy when the policymaker is better informed than the public.

financial stability by incorporating a crisis shock as in Svensson (2017). The crisis shock, in turn, is modeled with an endogenous probability determined by credit conditions as in Ajello, et al. (2018) and Gerdrup, et al. (2018), among others. The central bank is assumed to be better informed than the public in two dimensions: it has private information about the true state of the real economy (i.e., the output gap) as well as the true nature of credit conditions and associated vulnerabilities in the financial system. The question of interest for this paper is how do financial stability considerations shape the decision about whether or not to make this private information available to the public. More narrowly, the paper examines when and why a central bank might choose to publish a financial stability report.

In the model, the central bank observes the set of shocks in the initial period and then commits to one of four possible alternative strategies regarding the degree of communication it wants to pursue with the public: (1.) complete transparency about both the real side of the economy and credit conditions; (2.) retaining private information about credit conditions combined with transparency about the real economy; (3.) retaining private information about the real economy combined with transparent credit conditions; and, finally (4.) retaining all private information. The model is solved analytically for welfare under each of these four separate alternatives, allowing for a complete characterization of the optimal communication strategy over the entire parameter space. This characterization is presented in a series of propositions which are then used to support a number of policy implications discussed later in the paper.

One of the key insights is whether or not a central bank finds transparency regarding financial stability conditions consistent with the optimal communication strategy—as may be suggested by the decision to publish an FSR—depends importantly on the state of the credit cycle as well as the composition of shocks that are driving the cycle. To understand the intuition, consider that in the baseline framework absent financial stability considerations retaining private information is preferred to transparency because it allows the central bank to generate policy surprises to more effectively smooth fluctuations in inflation and output around their respective targets. The result that private information allows for more effective achieve *within-the-period stabilization* holds regardless of the configuration of shocks that hit the economy.

Introducing even the simplest financial vulnerabilities (i.e., a linear crisis probability function) alters this benchmark result. The macroprudential nature of monetary policy creates an incentive for the central bank to try to minimize the *level of financial fragilities* by pushing inflation higher than would otherwise be optimal in an effort to "lean against the wind" on credit conditions. Leaning against the wind provides insurance against the likelihood of a future crisis, but because leaning against the wind requires the central bank to tolerate a level of inflation that runs above its desired target, it comes at the cost of introducing *intertemporal volatility*. That said, as long as vulnerabilities are simple, the macroprudential nature of monetary policy is linear in the policy tool which has the implication that the degree of intertemporal volatility is invariant to the communication strategy. The optimal strategy in this case weighs the gains from within-the-period stabilization directly against the incentive to minimize the level of financial vulnerabilities with no consideration of intertemporal volatility. The resolution of this straightforward tradeoff turns out to be state dependant. Specifically, retaining private information remains optimal (as in the benchmark model) for most realizations of the supply shock. However, transparency emerges as the optimal communication strategy provided the supply shock is sufficiently adverse.[4]

When vulnerabilities are complex (i.e., a nonlinear crisis probability function) the macroprudential nature of monetary policy is no longer linear in the policy tool and intertemporal volatility is no longer invariant to the communication strategy. This significantly complicates the welfare comparison across strategies. The intuition is that when vulnerabilities are complex the central bank gains the ability exploit its private information to introduce policy surprises through macroprudential objectives. Unanticipated macroprudential policy affects real activity (just as is the case with traditional monetary policy surprises in the benchmark model) as well as the level of financial vulnerabilities and, hence, intertemporal volatility. Transparency shuts this channel down because perfect information implies all policy is perfectly anticipated in a rational expectations equilibrium. It turns out that whether or not the central bank can exploit its informational advantage for welfare gains in the face of complex vulnerabilities depends on the joint realization of supply and credit shocks. Moreover, it depends on whether this joint realization hits when the credit cycle is expanding or contracting. Generally speaking, the results show that transparency (i.e., publishing an FSR) tends to be consistent with the optimal communication strategy in early stages of an expanding credit cycle but becomes costly as the crisis probability rises. In contrast, when the credit cycle is contracting publishing an FSR is always consistent with the optimal strategy.

These theoretical results have a number of policy implications but two stand out as particularly important. First, the paper shows that central banks need to be extremely well informed about financial conditions to be in a position to communicate optimally with the public. Indeed, choosing the optimal communication strategy requires an understanding of not only whether the credit cycle is expanding or contracting at a given point in time, but it also requires complete knowledge of the composition of supply and credit shocks that are driving the cycle. Second, the state dependance of the optimal communication strategy implies that the choice to publish a financial stability report is likely subject to a time inconsistency problem. While it may be desirable to promote transparency about financial conditions through the publication of an FSR in early stages of the credit cycle, the

[4]It turns out that when vulnerabilities are simple the state dependance of the optimal communication strategy is driven entirely by the supply shocks. As discussed in Section 3.1, in this special case the realization of credit shocks turn out not to matter.

decision to do so may turn costly in later stages.

In terms of related literature, beyond the previous work on optimal transparency for traditional monetary policy highlighted above, this paper is related to two additional strands of the literature. First, it relates to recent work on the use of monetary policy to "lean against the wind" (LAW) on asset price movements.[5] As yet, there is no consensus as to whether or not central banks should pursue LAW policies (that is, conduct tighter monetary policy than would otherwise be justified for the purpose of enhancing financial stability). For example, Stein (2012), Giamabacorta and Signoretti (2014), Filardo and Rungcharoenkitkul (2016), Gerdrup et al. (2017), and Adrian and Liang (2018) argue in favor LAW policies, while Gourio, Kashyap, and Sim (2017) provide a more nuanced view. In contrast, Svensson (2016, 2017) argues that the costs of such policies strongly outweigh any benefit and this view that is supported by Ajello, et al (2017).

This paper makes a different, but related, point. It shows that financial stability concerns are important in shaping *central bank communication* rather than the conduct of monetary policy *per se*. In other words, even if the debate resolves in a way that suggests monetary policy should not directly pursue LAW policies, the results here highlight that financial stability considerations still play an important role in shaping the way central banks communicate with the public. To my knowledge, this is a point that has not been made elsewhere in the literature.

The second branch of related work is a small but growing empirical literature on the effectiveness of central bank communication through financial stability reports. Studies such as Osterloo and den Haan (2004), Cihak, et al. (2012), and Horvath and Vasko (2016) build on the empirical literature on monetary transparency (for example, Eijiffinger and Geraats, 2006 or Demertzis and Hughes Hallett, 2007) by focusing on measurement of how financial stability objectives shape transparency. Alternatively, Cihak (2006), Born, et al. (2014) and Correa, et al. (2017) analyze the impact of communication regarding stability issues to determine whether market participants actually value this communication. In contrast to these papers, the focus here is on how financial stability concerns alter optimal transparency in a theoretical framework. Again, to the best of my knowledge this is the first paper to address this question from a theoretical perspective.

The remainder of this paper is organized as follows. The model is presented in the next section and solved under four alternative information regimes. Section 3 presents the main analytical results in a series of propositions and Section 4 discusses some practical policy implications of these theoretical results. Finally, Section 5 concludes.

[5]See Smets (2014) for a survey of this literature as it relates to monetary policy. There is also a literature that studies the use of macroprudential policy to lean against the wind on credit conditions (see, for example, Bianchi (2011), Bianchi and Mendoza (2018), Biljanovska, Gornicka, and Vardoulakis (2019), Jeanne and Korinek (2010), Korinek and Simsek (2016), and Miao, Want, and Zhou (2015) among others). Optimal communication regarding macroprudential polices is an important area for future research, but beyond the scope of this paper.

2 Theoretical Framework

The model is a dynamic game played between two agents: a central bank and the private sector. There are two periods denoted by $t = \{1, 2\}$. In each period, the economy exists in either a normal or a crisis state, indexed by $s \in \{n, c\}$. Uncertainty stems from a sequence of supply shocks that hit the economy in both periods as well as from a credit shock that hits in the first period and helps to determine the likelihood of a crisis that, if realized, materializes in the second period.

Information Structure. All agents have rational expectations and fully understand the underlying structure of the economy, including the true nature of the crisis probability. However, the central bank directly observes both the supply shocks as well as the credit shock, whereas the private sector does not. Hence, the shocks are private information for the central bank.

This type of information asymmetry regarding the true state of the real economy is common in the transparency literature. The central bank is assumed to have a comparative advantage in identifying underlying shocks to output and inflation. For example, central banks have access to better information in the form of regulatory data which is not available to the public. They also employ a large and highly trained staff whose primary job it is to interpret these data. Regardless of the source of informational advantage, in this model the central bank makes a choice regarding whether or not to reveal its private information about the supply shocks to the public. It does so by publishing its forecast of real activity. Concretely, the Federal Reserve has been doing this since 2012 when it first began publishing its the Survey of Economic Projections (SEP).

The novel aspect of this paper comes from extending this informational advantage into financial conditions. In particular, we assume that, in addition to the real economy, the central bank is also better informed relative to the private sector regarding the true underlying state of the credit cycle. Hence, the central bank is better positioned to understand the true likelihood of a future crisis.

This is a strong assumption and, to be clear, there is nothing in the literature that supports the idea that central banks are necessarily better at predicting financial crisis than private market participants. Nevertheless, it is now standard practice for central banks to publicize their views on financial conditions and potential vulnerabilities by publishing Financial Stability Reports (FSRs). Presumably, the motivation behind publishing an FSR is that the central bank views the information it is providing through the public report as somehow beneficial to market participants and the broader public. This paper formalizes this idea in a very straightforward way by simply assuming the central bank has *complete knowledge* of financial vulnerabilities. The choice the central bank then faces is whether or not to to reveal its private information to the public.

Sequence of Events. A timeline for the sequence of events is depicted in Figure 1. The economy begins $t = 1$ in a normal state. At the beginning of the period, the central bank observes the period $t = 1$ supply shock, $\epsilon_1 \backsim N(0, \sigma_\epsilon^2)$, as well as an uncorrelated credit shock, $\omega \backsim N(0, \sigma_\omega^2)$.

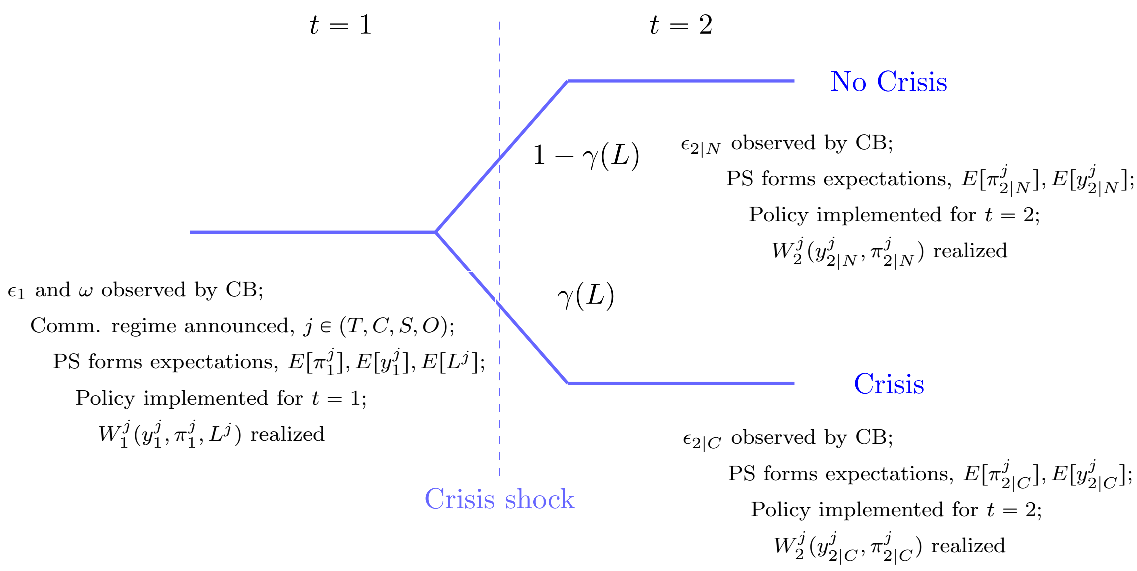

Figure 1: Model timeline

After observing these initial shocks, the central bank credibly commits to one of four possible communication strategies, indexed by $j \in \{T, C, S, O\}$. At the two extremes, a strategy of complete transparency, $j = T$, is characterized by the central bank revealing all its private information to the public while a strategy of complete opacity, $j = O$, means that all information is held private. The other two strategies address the middle ground. When $j = C$, information about the credit shock is held private, but the supply shock is made public. The opposite is true when $j = S$; the supply shock is private, but the credit shock is public.

Private agents form expectations conditional on available information under the announced communication strategy and the central bank sets its policy instrument for the initial period, π_1, taking these expectations as given.

The optimal policy response determines the output gap. A generic expression for the output gap in period t, conditional on state s, is given by

$$y_{t|s} = \overline{y} + \theta(\pi_{t|s} - E[\pi_{t|s}]) + \epsilon_{t|s} \tag{1}$$

where: $E[\pi_{t|s}]$ denotes private sector expectations of period t inflation in state s, and $\theta > 0$ is a parameter that governs the sensitivity of the output gap to unanticipated monetary policy (i.e., the slope of the Phillips curve). The equation says that a central bank, which chooses $\pi_{t|s}$ as its policy instrument, can influence real activity by generating inflation surprises, such that $\pi_{t|s} - E[\pi_{t|s}] \neq 0$. Note that because the economy is always in a normal state in $t = 1$, the output gap in the initial period is not state dependant, so we can denote it as simply as y_1.

Moving into the second period, as in Svensson (2017), the economy experiences a crisis with some probability. If a crisis occurs the private sector incurs a fixed welfare cost, denoted $\Gamma > 0$. The fixed cost of a crisis is assumed for analytic tractability. Alternative approaches might include modeling a crisis as shift in the distribution of supply shock such that $\epsilon_{2|c}$ is drawn from a distortion with a lower mean or, alternatively a higher variance. The former is observationally equivalent to a fixed cost of a crisis, so there is nothing lost here. Allowing for a higher variance in a crisis state would be interesting but it greatly complicates the analytic results presented in Section 3.

Following Ajello, Laubach, Lopez-Salido, and Nakata (2018), the crisis probability, denoted $\gamma(L)$, is an endogenous function of the state of the credit cycle, L, given by

$$L = \hat{L} + \phi_y y_1 + \phi_\pi \pi_1 + \omega \tag{2}$$

where: $\hat{L}$ is some equilibrium level of credit issuance; ω is the credit shock; and $\phi_y > 0$ and $\phi_\pi < 0$ are parameters. The equation says that the credit cycle expands as the output gap expands and as inflation declines. This general framework builds on a body of literature that establishes excess credit growth as a determinate of financial crises.[6]

For the moment, the specific functional form for the crisis probability, $\gamma(L)$, is left unspecified except to say that $\partial\gamma/\partial L > 0$, so the likelihood of a crisis is increasing in the amount of credit available in the economy. At the same time, it is decreasing in inflation, $(\partial\gamma/\partial L)(\partial L/\partial\pi_1) < 0$.

While the functional form for the crisis probability is common knowledge for all agents, the central bank has private information over the credit cycle, L, because it directly observes both ϵ_1, which enters implicitly through π_1 and y_1, and ω. This information asymmetry drives a wedge between the true state of financial vulnerabilities, $\gamma(L)$, and private sector expectations of those vulnerabilities, $E[\gamma(L)]$. As a result, it also drives a wedge between the central bank's understanding of the degree to which monetary policy leans against the wind on financial vulnerabilities, $(\partial\gamma(L)/\partial L)(\partial L/\partial\pi_1)$, relative to public perceptions, $E[(\partial\gamma(L)/\partial L)(\partial L/\partial\pi_1)]$. As will become clear, this information wedge plays an important role in determining the optimal communication strategy.

Central Bank Loss Function. The central bank loss function in period t conditional on state s is quadratic over deviations in output from its equilibrium level, $\hat{y}$, and inflation from its target, τ. Specifically, we have that

$$W_{t|s} = -\frac{1}{2}\alpha(\pi_{t|s} - \tau)^2 - \frac{1}{2}\beta(y_{t|s} - \hat{y})^2 \tag{3}$$

where: α and β are parameters which determine the weight the central bank puts on inflation

[6]See, for example, Reinhart and Rogoff (2008), Schularick and Taylor (2012), Anundsen, et al. (2016), and Jorda, Schularick, and Taylor (2016).

stabilization relative to output stabilization.

Optimal Policy Problem. The central bank takes private expectations as given and chooses the sequence of inflation, π_1, $\pi_{2|c}$, and $\pi_{2|n}$, in order to maximize the discounted expected two-period objective function

$$W = W_1 + \delta(\gamma W_{2|c} + (1-\gamma)W_{2|n}) \tag{4}$$

where: $\delta \in (0,1)$ is the discount factor of the central bank.

The first order condition for optimal inflation in $t = 1$ is given by

$$\pi_1 = \frac{1}{\alpha + \beta\theta^2}\left[\alpha\tau + \beta\theta^2 E[\pi_1] - \beta\theta\epsilon_1 + \delta\frac{\partial\gamma}{\partial\pi_1}(E[W_{2|c}] - E[W_{2|n}])\right] \tag{5}$$

Similarly, optimal inflation in $t = 2$ for state $s \in (c, n)$ can be written as

$$\pi_{2|s} = \frac{1}{\alpha + \beta\theta^2}\left[\alpha\tau + \beta\theta^2 E[\pi_{2|s}] - \beta\theta\epsilon_{2|s}\right] \tag{6}$$

At this point, completing the optimal policy problem requires backward induction to solve the second period problem which can then be used to obtain the solution for the optimal policy in $t = 1$. In total, we need expressions for inflation, $\pi_{t|s}$, the output gap, $y_{t|s}$, the state of the credit cycle, L, the incremental crisis probability, $\partial\gamma/\partial\pi_1$, and the expected cost of a crisis, $E[W_{2|c}] - E[W_{2|n}]$.

All of these depend importantly on private inflation expectations, $E[\pi_{t|s}]$, as well as expectations regarding the degree to which monetary policy leans against the wind, $E[\partial\gamma/\partial\pi_1]$. These expectations, in turn, depend on the announced communication strategy. In what follows, the model is solved separately under each of the four strategies, $j \in \{T, C, S, O\}$.

2.1 Transparency

The central bank makes its private information regarding the supply shocks, ϵ_1, $\epsilon_{2|n}$, $\epsilon_{2|c}$, available to the public by publishing its forecast for real activity through the SEP, for example. Similarly, the credit shock, ω, is made public by publishing the state of the credit cycle through an FSR. This communication strategy is broadly consistent with the current practice of the Federal Reserve as of late-2018. All variables under a strategy of transparency are denoted with the superscript $j = T$.

Expectations are rational, so transparency implies that inflation surprises are not possible, that is $\pi^T_{t|s} = E[\pi^T_{t|s}]\ \forall\ t$ and s. Optimal inflation in state s in period $t = 2$ is given by $\pi^T_{2|s} = \tau - (\beta\theta/\alpha)\epsilon_{2|s}$. Similarly, $E[y^T_{t|s}] = y^T_{t|s}\ \forall\ t$ and s and output in period $t = 2$ is given by $y^T_{2|s} = \overline{y} + \epsilon_{2|s}$.

Once the crisis shock is revealed there is no remaining uncertainty. The central bank adjusts inflation optimally in response to the crisis shock, but transparency implies that this response is perfectly anticipated by the public. Hence, monetary policy does not affect the output gap.

Substituting these expressions into the second period welfare function and taking the difference across the two states yields the expected cost of a crisis under transparency.

$$E[W_{2|c}^T] - E[W_{2|n}^T] = -\Gamma < 0 \tag{7}$$

We can now turn to the solution of the first period problem. As above, transparency implies $E[\pi_1^T] = \pi_1^T$ and $E[y_1^T] = y_1^T$. Furthermore, the credit shock, ω, is public information. This means that the private sector knows the true state of the credit cycle, $E[L^T] = L^T$, as well as the true crisis probability, γ^T, and the degree to which monetary policy leans against the wind on these vulnerabilities, $E\left[\partial\gamma^T/\partial\pi^T\right] = \partial\gamma^T/\partial\pi^T$.

Accordingly, we can express optimal inflation in the first period as

$$\pi_1^T = \tau - \frac{\beta\theta}{\alpha}\epsilon_1 - \frac{\delta}{\alpha}\frac{\partial\gamma^T}{\partial\pi^T}\Gamma$$

The last term on the right hand side captures the effect of the financial stability objective on optimal monetary policy. Recalling that $\partial\gamma^T/\partial\pi^T < 0$, the financial stability motive generates a precautionary incentive for the central bank to push inflation higher. Doing so trades off the cost of pushing inflation above target in period $t = 1$ against the benefit of marginally decreasing the likelihood of a crisis owing to a tightening of the credit cycle. The strength of this channel is governed by the expected cost of a crisis, Γ, as well as the effectiveness of monetary policy to lean against the wind, $\partial\gamma^T/\partial\pi^T$.

As with the second period solution, inflation surprises are not possible under transparency, so $y_1^T = \overline{y} + \epsilon_1$. All told, total expected welfare under transparency is given by:

$$E[W^T] = -\frac{1}{2}\frac{1}{\alpha}\left[\beta(\alpha + \beta\theta^2)(1+\delta)\sigma_{\epsilon_n}^2 + \left(\delta\frac{\partial\gamma^T}{\partial\pi_1^T}\Delta^T\right)^2\right] - \delta\gamma^T\Gamma \tag{8}$$

Welfare is comprised of three separate terms. The first is standard and captures discounted losses that accrue within the period from the sequence of supply shocks. The last two terms are new and capture losses associated with financial vulnerabilities. The term related to $\delta(\partial\gamma^T/\partial\pi_1^T)\Gamma$ captures the idea that any marginal adjustment to monetary policy in $t = 1$ changes the degree to which monetary policy leans against the wind on the credit cycle and therefore has implications for intertemporal volatility. Finally, the term related to $\delta\gamma^T\Gamma$ captures the direct welfare costs associated with the possibility of a crisis emerging in $t = 2$.

2.2 Private Information about the Credit Shock

The central bank chooses to make its information on the supply shocks, $\epsilon_{t|s}\ \forall\ t, s$, public but chooses to keep information about the credit shock, ω, private. This strategy can be thought of as loosely consistent with Federal Reserve practice from 2012 to late-2018 after the Fed began to publish the SEP, but before it began publishing its FSR. All variables under this strategy are denoted with the superscript $j = C$.

As long as the central bank publicizes the supply shock, the solutions for $y^C_{2|s}$ and $\pi^C_{2,s}$ are identical to $y^T_{2|s}$ and $\pi^T_{2,s}$ above. As a result, expected welfare across the two states, as well as the anticipated cost of a crisis, are the same, so $E[W^C_{2|c}] = E[W^T_{2|c}]$, $E[W^C_{2|n}] = E[W^T_{2|n}]$.

However, turning to the solution to the first period problem, private information over the credit cycle introduces an information gap related to financial vulnerabilities. To see this, consider that $L^C_1 - E[L^C_1] = \phi_y(y^C_1 - E[y^C_1]) + \phi_\pi(\pi^C_1 - E[\pi^C_1]) + \omega$. In turn, this implies $\gamma(L^C_1) \neq E[\gamma(L^C_1)]$ and $\partial\gamma^C/\partial\pi^C \neq E[\partial\gamma^C/\partial\pi^C]$.

Recalling that ϵ_1 is public information, we can run the expectations operator through the central bank's first order condition for π^C_1 to get an expression for private sector inflation expectations. This can be substituted back into the central bank's first order condition for π^C_1, yielding the following expression for optimal inflation,

$$\pi^C_1 = \tau - \frac{\beta\theta}{\alpha}\epsilon_1 - \frac{\delta}{\alpha}\frac{1}{\alpha + \beta\theta^2}\left(\alpha\frac{\partial\gamma^C}{\partial\pi^C} + \beta\theta^2 E\left[\frac{\partial\gamma^C}{\partial\pi^C}\right]\right)\Gamma$$

Solving for the optimal inflation surprise, we have $\pi^C_1 - E[\pi^C_1] = -(\alpha/(\alpha + \beta\theta^2))(\partial\gamma^C/\partial\pi^C - E\left[\partial\gamma^C/\partial\pi^C\right])\Gamma$, so that output is given by

$$y^C_1 = \overline{y} + \epsilon_1 - \frac{\delta\theta}{\alpha + \beta\theta^2}\left(\frac{\partial\gamma^C}{\partial\pi^C} - E\left[\frac{\partial\gamma^C}{\partial\pi^C}\right]\right)\Gamma$$

As long as information about the credit shock remains private, the central bank has the ability to introduce unanticipated inflation even if the supply shock is publicized. This channel operates through the degree to which monetary policy leans against the wind. For example, if the public expects more precautionary inflation than the central bank is willing to deliver (which is the case when $E[|\partial\gamma/\partial\pi^C|] > |\partial\gamma/\partial\pi^C|$ given that $\partial\gamma/\partial\pi^C < 0$) the resulting negative monetary surprise will be contractionary for output while the opposite is true for $E[|\partial\gamma/\partial\pi^C|] < |\partial\gamma/\partial\pi^C|$.

All told, expected welfare is given by

$$E[W^C] = -\frac{1}{2}\frac{1}{\alpha}\beta(\alpha + \beta\theta^2)(1+\delta)\sigma^2_{\epsilon_n} \tag{9}$$
$$-\frac{1}{2}\frac{1}{\alpha}\left[(\delta\Gamma)^2 \frac{1}{\alpha+\beta\theta^2}\left(\alpha\left(\frac{\partial\gamma^C}{\partial\pi^C}\right)^2 + \beta\theta^2\left(E\left[\frac{\partial\gamma^C}{\partial\pi^C}\right]\right)^2\right)\right] - \delta\gamma^C\Gamma$$

Comparing this expression to equation (8) above, private information about the credit shock differs from transparency in two respects. First, given that the state of the credit cycle differs across the two communication regimes, the relative level of financial vulnerabilities will potentially differ across the two regimes, that is, $\gamma(L^T) \neq \gamma(L^C)$. Additionally, the possibility that $\partial\gamma^C/\partial\pi^C \neq E[\partial\gamma^C/\partial\pi^C] \neq \partial\gamma^T/\partial\pi^T$ allows for differences in intertemporal volatility across the two regimes.

2.3 Private Information about the Supply Shock

The central bank makes the credit shock, ω, public but chooses to keep information on the supply shocks, $\epsilon_{t|s}\ \forall\ t, s$, private. This strategy sheds light on how financial stability considerations affect existing results regarding optimal transparency regarding the real side of the economy. Variables under this regime are denoted with the superscript $j = S$.

When the central bank maintains private information over the supply shock, the private sector forms expectations of period $t = 2$ inflation in state $s \in (c, n)$ based on its knowledge of the distribution of shocks that hit the economy in each state. That is, $E[\pi^S_{2|s}] = \tau - (\beta\theta/\alpha)E[\epsilon_{2|s}]$, where $E[\epsilon_{2|n}] = 0$.

Taking private expectations as given, inflation in period $t = 2$ for state $s \in (c, n)$, is given by

$$\pi^S_{2|s} = \tau - \frac{\beta\theta}{\alpha+\beta\theta^2}\epsilon_{2|s}$$

In this case, the inflation surprise is given by $\pi^S_{2|s} - E[\pi^S_{2|s}] = -(\beta\theta/(\alpha+\beta\theta^2))\epsilon_{2|s}$. In either state the central bank is able to use its private information about the supply shock to introduce unanticipated monetary policy to help smooth output fluctuations, where the output gap is given by the following expression.

$$y_{2|s} = \overline{y} + \frac{\alpha}{\alpha+\beta\theta^2}\epsilon_{2|s}$$

Substituting these expressions into the second period welfare function for the crisis and normal states, respectively, and taking the difference between the two results in an expression for the expected cost of a crisis when the supply shock is private information:

$$\Delta^S \equiv E[W^S_{2|c}] - E[W^S_{2|n}] = -\Gamma < 0$$

Moving to the first period problem and noting that $E[\epsilon_1] = 0$, private inflation expectations are given by $E[\pi_1^S] = \tau - (\delta/\alpha)E[\partial\gamma^S/\partial\pi^S]\Gamma$, whereas actual inflation is

$$\pi_1^S = \tau - \frac{\beta\theta}{\alpha+\beta\theta^2}\epsilon_1 - \frac{\delta}{\alpha}\frac{1}{\alpha+\beta\theta^2}\left(\alpha\frac{\partial\gamma^S}{\partial\pi^S} + \beta\theta^2 E\left[\frac{\partial\gamma^S}{\partial\pi^S}\right]\right)\Gamma$$

In this case, there are two potential sources of unanticipated inflation. The first is standard and comes from the fact that the private sector does not have the same information set as the central bank with respect to the supply shock, ϵ_1. The second stems from an information gap that arises between the degree to which the private sector believes monetary policy will be used to lean against the wind on financial vulnerabilities relative to what the central bank actually does. To better understand this second channel, consider that even though the realization of ω is made public, imperfect information about supply shock implies that actual state of the credit cycle will differ from private expectations; that is, $L_1^S - E[L_1^S] = \phi_y(y_1^S - E[y_1^S]) + \phi_\pi(\pi_1^S - E[\pi_1^S])$. In turn, this implies $\gamma(L_1^S) \neq E[\gamma(L_1^S)]$ and $\partial\gamma^S/\partial\pi^S \neq E[\partial\gamma^S/\partial\pi^S]$.

In the first period, unanticipated inflation has the following implication for output

$$y_1^S = \overline{y} + \frac{\alpha}{\alpha+\beta\theta^2}\epsilon_1 - \frac{\delta\theta}{\alpha+\beta\theta^2}\left(\frac{\partial\gamma^S}{\partial\pi^S} - E\left[\frac{\partial\gamma^S}{\partial\pi^S}\right]\right)\Gamma$$

Putting this all together, expected welfare is given by

$$E[W^S] = -\frac{1}{2}\frac{1}{\alpha}\beta(\alpha+\beta\theta^2)(1+\delta)\left(\frac{\alpha}{\alpha+\beta\theta^2}\right)^2\sigma_{\epsilon_n}^2 \tag{10}$$
$$-\frac{1}{2}\frac{1}{\alpha}\left[(\delta\Gamma)^2\frac{1}{\alpha+\beta\theta^2}\left(\alpha\left(\frac{\partial\gamma^S}{\partial\pi^S}\right)^2 + \beta\theta^2\left(E\left[\frac{\partial\gamma^S}{\partial\pi^S}\right]\right)^2\right)\right] - \delta\gamma^S\Gamma$$

Note that expected welfare under private information about the supply shock, equation (10), has a similar functional from as expected welfare under private information about the credit shock, equation (9), with the key exception that the costs associated with the sequence of supply shocks is strictly lower in equation 10 (i.e., $(\alpha/(\alpha+\beta\theta^2))^2 - 1 < 0$).

2.4 Opacity

Finally, under complete opacity all information is kept private. This communication strategy can be loosely interpreted as consistent with Federal Reserve policy in the pre-Bernanke era. Variables under this regime are denoted with the superscript $j = O$.

The form of the solution for all the variables under a strategy of opacity is identical to the case of private information over the supply shock. That said, relative to private information over the supply shock, opacity introduces additional information asymmetry into the credit cycle. To see this, consider that $L_1^O - E[L_1^O] = \phi_y(y_1^O - E[y_1^O]) + \phi_\pi(\pi_1^O - E[\pi_1^O]) + \omega$, which differs from $L_1^S - E[L_1^S]$ insofar as the private sector is uninformed about the realization of ω. This means that $\gamma^O \neq \gamma^S$ and $\partial\gamma^O/\partial\pi^O \neq E[\partial\gamma^S/\partial\pi^S]$.

3 The Optimal Communication Strategy

In order to say more about the optimal communication strategy the functional from for the crisis probability needs to be specified. A piecewise linear function which is flexible enough to allow for simple nonlinearities but does so in a way that preserves analytic tractability.

The crisis probability is given by

$$\gamma(L) = \begin{cases} 1 & \text{for } \overline{L} \leqslant L \\ \lambda L & \text{for } \underline{L} \leqslant L < \overline{L} \\ 0 & \text{for } L < \underline{L} \end{cases}$$

where $\underline{L}$ and $\overline{L}$ are exogenously given thresholds for the state of the credit cycle.

Using this functional form, a set of analytical results is derived and stated below in a series of propositions which detail the optimal communication strategy regarding supply and credit shocks across the entire parameter space of the model.

The first result addresses the benchmark case in which financial stability concerns *do not enter* into the central bank's policy problem.

Proposition 1 *When $L < \underline{L}$ so that $\gamma(L) = 0 \ \forall \ L$, financial vulnerabilities are irrelevant. The optimal communication strategy is to keep information about the supply shock private.*

Proof. See Appendix A. ■

Absent financial stability concerns, the only objective is to smooth within-the-period fluctuations in output and inflation that result from the sequence of supply shocks. As long as information about these shocks is held private, the central bank retains the ability to use unanticipated monetary policy to more effectively smooth these fluctuations. In contrast, if the information is made public rational private agents can perfectly forecast policy actions and any policy leverage over the output gap is lost. This result is well known from the existing literature (as surveyed, for example, in Geraats, 2002) and is simply restated here to serve as a benchmark for the analysis that follows.

The remainder of this section focuses on cases in which financial stability concerns *do enter* into the central bank's policy problem. Vulnerabilities are assumed to take one of two forms: (1.) simple (characterized by a linear crisis probability); or (2.) complex (characterized by a nonlinearity owing to a kink in the crisis probability function).

3.1 Simple Vulnerabilities

Vulnerabilities are simple when financial stability concerns enter the optimal policy problem linearly; i.e., when $\underline{L} \leqslant L < \overline{L}$, so that $\gamma(L) = \lambda L \ \forall \ L$. In this case, the central bank faces two potentially competing objectives when setting optimal policy. There is the baseline *within-the-period stabilization* objective (introduced in Proposition 1 in absence of financial vulnerabilities) and, in addition, the central bank must also internalize the effect of the optimal policy response on financial vulnerabilities in an effort to *minimize the level of financial fragilities*.

The next proposition presents the optimal communication strategy with regard to the credit and supply shocks, separately.

Proposition 2 *When financial vulnerabilities are simple:*

(i.) The central bank is indifferent to the communication strategy regarding the credit shock.

(ii.) The optimal communication strategy regarding the supply shock is state dependant and contingent on the underlying realization of the supply shock itself.

(a.) Retaining private information is optimal if ϵ_1 *is such that* $(1+\delta)\Psi\sigma_\epsilon^2 + \delta\lambda\Omega\Gamma\epsilon_1 > 0$, *where* $\Psi \equiv -(1/2)(\beta/\alpha)(\alpha+\beta\theta^2)((\alpha/(\alpha+\beta\theta^2)))^2 - 1) > 0$ *and* $\Omega \equiv \frac{\beta\theta^2}{\alpha+\beta\theta^2}(\phi_y - \phi_\pi \frac{\beta\theta}{\alpha}) > 0$.

(b.) Transparency is optimal if $(1+\delta)\Psi\sigma_\epsilon^2 + \delta\lambda\Omega\Gamma\epsilon_1 \leqslant 0$.

Proof. See Appendix B. ■

Indifference regarding communication about the credit shock reflects the fact that the ability of the central bank to lean against the wind is linear in the policy instrument (i.e., $\partial\gamma/\partial\pi$ is constant). Linearity implies the private sector can perfectly anticipate the optimal policy response regardless of whether it knows the true underlying state of the credit cycle. In other words, when vulnerabilities are simple, private information about the credit shock has no value to the central bank.

When it comes to supply shocks, however, even simple vulnerabilities have important consequences for optimal communication. Intuitively, as demonstrated by Proposition 1, retaining private information facilitates output and inflation stabilization relative to transparency. This is captured by the term $(1+\delta)\Psi\sigma_\epsilon^2 > 0$. However, the policy response under private information affects financial conditions differently relative to transparency and this, in turn, has implications for the likelihood of a crisis across the two strategies. This is captured by the term $\delta\lambda\Omega\Gamma\epsilon_1 \lesseqgtr 0$. We know $\delta\lambda\Omega\Gamma > 0$, so whether private information is costly or beneficial through its effect on financial conditions depends entirely on the realization of ϵ_1.

Suppose an adverse supply shock hits, so that $\epsilon_1 < 0$. The optimal response under transparency calls for higher inflation which is perfectly anticipated by the private sector and hence has no impact on output. The gains from stabilization are limited, but higher inflation leads to a decline in credit which reduces the crisis probability. Compare this to the optimal response under private information. Here, the optimal policy also calls for higher inflation, although not as high as under transparency. The muted inflation response owes to the fact that the central bank is able to use unanticipated inflation as a tool to influence the output gap. In other words, the information asymmetry allows the central bank to more effectively achieve smoothing of output fluctuations with a smaller increase in inflation above its target. At the same time, the muted inflation response implies that credit (and, hence, the crisis probability) falls by less than is the case under transparency. This cost is captured by the term $\delta\lambda\Omega\Gamma\epsilon_1 < 0$, given that $\epsilon_1 < 0$. All told, if the supply shock is sufficiently adverse, such that $(1+\delta)\Psi\sigma_\epsilon^2 + \delta\lambda\Omega\Gamma\epsilon_1 < 0$, the gains from committing to transparency in order to achieve a lower crisis probability outweigh the loss associated with inefficient output and inflation stabilization.

Notice that this tradeoff between communication strategies only exists for adverse supply shocks. The reason is that for a favorable shock, $\epsilon_1 > 0$, the optimal policy response calls for lower inflation which leads to a deterioration of financial stability conditions. Private information is unambiguously preferred because by allowing for more effective output and inflation stabilization, the resulting muted decline in inflation raises the crisis probability by a smaller amount relative to transparency.

3.2 Complex Vulnerabilities.

Vulnerabilities are complex when stability concerns enter nonlinearly into the policy problem; i.e., when L is such that either: (a.) $L \leqslant \underline{L}$, so $\gamma(L) = 0$; or (b.) $\underline{L} < L < \overline{L}$ so $\gamma(L) = \lambda L, \forall\ L$. For simplicity, assume the joint distribution of ϵ_1 and ω is such that $L(\epsilon_1, \omega)$ falls in the region $L(\epsilon_1, \omega) \leqslant \underline{L}$ with probability $1 - \sigma$ and in the region $\underline{L} < L(\epsilon_1, \omega) \leqslant \overline{L}$ with probability σ. This piecewise linear crisis probability function is depicted in Figure 2.

When vulnerabilities are complex, asymmetric information alters the tradeoff between within-the-period stabilization and the incentive to minimize the crisis probability. The reason is that the nonlinearity in the crisis probability generates in an information gap between the actual and expected degree to which the central bank leans against the wind on credit conditions. That is, with asymmetric information $\partial\gamma/\partial\pi_1^j \neq E[\partial\gamma/\partial\pi_1^j]$ for $j \in \{C, S, O\}$. This information gap does two things relative to the case of perfect transparency: it alters the optimal amount of precautionary inflation, which has implications for the level of financial fragilities, and it affects intertemporal volatility, which arises as a result of the crisis shock. All told, the optimal policy with complex vulnerabilities trades off the standard *within-the-period stabilization objective* (introduced in

Proposition 1 in absence of financial vulnerabilities), the incentive to *minimize the level of financial fragilities* (introduced in Proposition 2 with simple vulnerabilities), and the incentive to *minimize intertemporal volatility.*

In what follows, we show in a series of propositions how these three channels interact with one another to shape the optimal communication strategy with regard to both credit and supply shocks, respectively, over the entire parameter space of the model.

3.2.1 The Credit Shock

In order to focus attention on communication about the credit shock assume that the central bank makes all of its information about the supply shock fully available to the public.

Characterizing the optimal communication strategy requires two steps. The first establishes the feasibility of different parts of the parameter space. Owing to the kink in the crisis probability function feasibility differs depending on whether the credit cycle is expanding (approaching the kink from below) or contracting (approaching from above). Feasibility conditional on each of these two possibilities is presented in Propositions 3 and 4, respectively. The second step is to characterize the optimal strategy over the feasible part of the parameter space. This is done in Proposition 5.

Proposition 3 *When the credit cycle is expanding, so that L^j for $j \in (C, T)$ approaches $\underline{L}$ from below, for any combination of supply and credit shocks, $f(\epsilon_1, \omega) \equiv (\phi_y - \frac{\beta\theta}{\alpha}\phi_\pi)\epsilon_1 + \omega$, there exists a threshold, $\overline{f}_-^T \equiv \underline{L} - \hat{L} - \phi_y \hat{y} - \phi_\pi \tau$, defined by the point at which $L^T(\epsilon_1, \omega) = \underline{L}$, such that:*

(i.) $L^T(\epsilon_1, \omega), L^C(\epsilon_1, \omega) \leqslant \underline{L}$ *is a feasible part of the parameter space if* $f(\epsilon_1, \omega) \leqslant \overline{f}_-^T$*;*

(ii.) $L^C(\epsilon_1, \omega) \leqslant \underline{L} < L^T(\epsilon_1, \omega)$ *is feasible if* $\overline{f}_-^T < f(\epsilon_1, \omega) \leqslant \overline{f}_-^T - \frac{\delta}{\beta\theta}\sigma\lambda(\phi_y\theta + \phi_\pi)\Omega\Gamma$*;*

(iii.) $L^T(\epsilon_1, \omega) \leqslant \underline{L} < L^C(\epsilon_1, \omega)$ *is not a feasible part of the parameter space;*

(iv.) and, $\underline{L} < L^T(\epsilon_1, \omega), L^C(\epsilon_1, \omega)$ *is feasible if* $\overline{f}_-^T - \frac{\delta}{\beta\theta}\sigma\lambda(\phi_y\theta + \phi_\pi)\Omega\Gamma < f(\epsilon_1, \omega)$.

Proof. See Appendix C. ∎

Establishing feasibility when the credit cycle is expanding amounts to identifying the most binding constraint as L^j approaches $\underline{L}$ from below. When $\underline{L}$ is approached from below, the optimal monetary response under either information strategy leads to an outcome in which $L^C < L^T$. This is a direct consequence of the information gap. Private information implies $E[\partial\gamma/\partial\pi^C] = \sigma\lambda(\phi_y\theta + \phi_\pi) < \partial\gamma/\partial\pi^C = 0$ whereas under transparency we have $E[\partial\gamma/\partial\pi^T] = \partial\gamma/\partial\pi^T = 0$. That is, imperfect information generates an incentive for the central bank to introduce additional precautionary inflation that is not necessary under transparency. As a result, $\pi^C > \pi^T$ and $y^T > y^C$, both of which in turn imply $L^C < L^T$. With this understanding, the intuition behind Proposition 3 is simple. The feasibility of each region of the parameter space simply reflects the fact that $L^T \leqslant \underline{L}$ is the more binding constraint relative to $L^C \leqslant \underline{L}$ when $\underline{L}$ is approached from below.

Proposition 4 *When the credit cycle is contracting, so that L^j for $j \in (C,T)$ approaches $\underline{L}$ from above, there exists a threshold, $\overline{f}^T_+ \equiv \underline{L} - \hat{L} - \phi_y \bar{y} - \phi_\pi \tau + \phi_\pi(\delta/\alpha)\lambda(\phi_y\theta + \phi_\pi)\Gamma$, defined by the point at which $L^T = \underline{L}$, such that:*

(i.) $L^T(\epsilon_1,\omega), L^C(\epsilon_1,\omega) \leqslant \underline{L}$ is feasible if $f(\epsilon_1,\omega) \leqslant \overline{f}^T_+ + \frac{\delta}{\beta\theta}(1-\sigma)\lambda(\phi_y\theta + \phi_\pi)\Omega\Gamma$;

(ii.) $L^C(\epsilon_1,\omega) \leqslant \underline{L} < L^T(\epsilon_1,\omega)$ is not a feasible part of the parameter space;

(iii.) $L^T(\epsilon_1,\omega) \leqslant \underline{L} < L^C(\epsilon_1,\omega)$ is feasible if $\overline{f}^T_+ + \frac{\delta}{\beta\theta}(1-\sigma)\lambda(\phi_y\theta + \phi_\pi)\Omega\Gamma < f(\epsilon_1,\omega) \leqslant \overline{f}^T_+$;

(iv.) and, $\underline{L} < L^T(\epsilon_1,\omega), L^C(\epsilon_1,\omega)$ is a feasible part of the parameter space if $\overline{f}^T_+ < f(\epsilon_1,\omega)$.

Proof. See Appendix D. ■

In contrast, when $\underline{L}$ is approached from above, private information implies $\partial\gamma/\partial\pi^C = \lambda(\phi_y\theta + \phi_\pi) < E[\partial\gamma/\partial\pi^C] = \sigma\lambda(\phi_y\theta + \phi_\pi)$ whereas under transparency we have $E[\partial\gamma/\partial\pi^T] = \partial\gamma/\partial\pi^T = \lambda(\phi_y\theta+\phi_\pi)$. In this case, the information gap allows the central bank to exploit private expectations in the sense that it does not need to introduce as much precautionary inflation as called for given the true state of financial vulnerabilities. The result is that $\pi^C < \pi^T$ and $y^T < y^C$, both of which push L^C higher relative to L^T. Hence, when $\underline{L}$ is approached from above the more binding constraint is $\underline{L} \leqslant L^T$ and it is this constraint that shapes feasibility.

Now that we have established feasibility, the following proposition summarizes the optimal communication strategy regarding the credit shock.

Proposition 5 *The optimal communication strategy regarding the credit shock is state dependent and contingent on the underlying shocks, (ϵ_1,ω), driving the credit cycle.*

i. Transparency is optimal when: $L^T(\epsilon_1,\omega), L^C(\epsilon_1,\omega) \leqslant \underline{L}$, $L^T(\epsilon_1,\omega) \leqslant \underline{L} < L^C(\epsilon_1,\omega)$, or $\underline{L} < L^T(\epsilon_1,\omega), L^C(\epsilon_1,\omega)$;

ii. Private information is optimal when $L^C(\epsilon_1,\omega) \leqslant \underline{L} < L^T(\epsilon_1,\omega)$.

Proof. See Appendix E. ■

The assumption of full information over the supply shock removes any potential welfare gain from within-the-period stabilization. This simplification means that the optimal communication strategy trades off the incentive to *minimize the level of financial fragilities* with the incentive to *minimize intertemporal volatility.* The proposition shows that the resolution of this tradeoff varies with the level of credit.

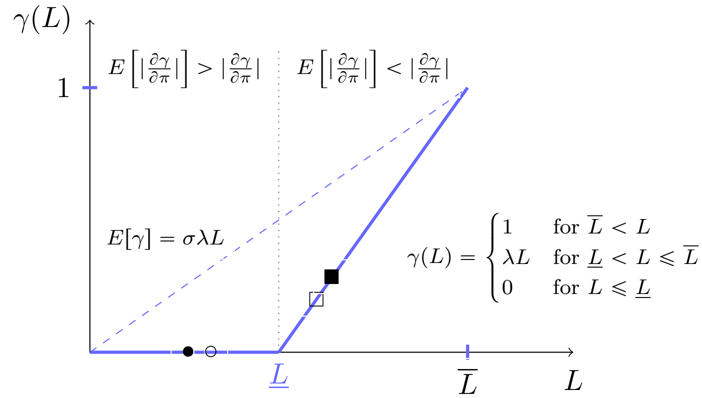

Figure 2: Piecewise linear crisis probability function.

For low levels of credit (i.e., realizations of $f(\epsilon_1, \omega)$ such that $L^C, L^T < \underline{L}$, depicted in Figure 2 by the solid and hollow dots, respectively, to the left of the kink) there is no difference in the crisis probability, so the optimal strategy is simply that which minimizes intertemporal volatility. In this part of the parameter space, imperfect information implies $0 = |\partial\gamma/\partial\pi^C| < |E[\partial\gamma/\partial\pi^C]|$ meaning that the central bank is forced to introduce some precautionary inflation to partially accommodate private expectations. However, doing so introduces intertemporal volatility through the crisis shock (i.e., the central bank is forced to insure the economy against an outcome that it knows will never happen, but the public nevertheless believes is possible). Transparency eliminates this additional welfare cost, as $|E[\partial\gamma/\partial\pi^T]| = \partial\gamma/\partial\pi^T = 0$.

However, when the credit cycle is expanding so that L^j approaches $\underline{L}$ from below, the welfare gains from transparency decline. To see this, consider that higher realizations of ϵ_1 and ω such that $L^C < \underline{L} < L^T$ (depicted in Figure 2 with L^C and L^T as the solid dot and the hollow square, respectively) alter the tradeoff in two ways. First, as L^T moves to the right of the kink more expansive credit under transparency results in a higher crisis probability. In addition, because $0 = |\partial\gamma/\partial\pi^C| < |E[\partial\gamma/\partial\pi^C]| < |\partial\gamma/\partial\pi^T|$, the information gap now works in favor of private information private because optimal policy under transparency calls for more precautionary inflation which results in higher intertemporal volatility. Together, these two forces imply that for this part of the parameter space transparency ceases to be optimal.

For higher realizations of ϵ_1 and ω such that $\underline{L} < L^T, L^C$ (depicted in Figure 2 with L^C and L^T as the solid and hollow squares, respectively) retaining private information remains beneficial because it lowers intertemporal volatility, but these gains are more than offset by losses associated with a higher crisis probability, as in this part of the parameter space $L^C > L^T$. All told, transparency reemerges as the optimal communication regime. Moreover, when the credit cycle contracts so that L^j approaches $\underline{L}$ from above, the gains from transparency increase. Smaller realizations of ϵ_1 and ω

such that $L^T < \underline{L} < L^C$ (depicted in Figure 2 with L^C as the solid square and L^T as the hollow dot, respectively), mean that transparency not only delivers more efficient intertemporal stabilization relative to private information, it also minimizes financial fragilities.

3.2.2 The Supply Shock

In contrast to the previous section, assume here that the central bank makes all of its information about the credit shock available to the public in order to focus attention on communication about the supply shock. The next three propositions provide a complete characterization of the optimal communication strategy regarding the supply shock over the entire parameter space of the model.

Proposition 6 *When the credit cycle is expanding, so that L^j for $j \in (S,T)$ approaches $\underline{L}$ from below, there exists a threshold supply shock, $\overline{\epsilon}_- \equiv \frac{\delta}{\beta\theta}\sigma\lambda(\phi_y\theta + \phi_\pi)\Gamma < 0$, defined by the point at which $L^S(\epsilon_1,\omega) = L^T(\epsilon_1,\omega)$ conditional on $L^T, L^S \leqslant \underline{L}$, such that:*

- *(i.) $L^T(\epsilon_1,\omega), L^S(\epsilon_1,\omega) \leqslant \underline{L}$ is feasible if $\epsilon_1 \leqslant \overline{\epsilon}_-$ and $f(\epsilon_1,\omega) \leqslant \overline{f}^T_- + \Omega(\epsilon_1 - \overline{\epsilon}_-)$, or, alternatively, if $\epsilon_1 > \overline{\epsilon}_-$ and $f(\epsilon_1,\omega) \leqslant \overline{f}^T_-$;*
- *(ii.) $L^S(\epsilon_1,\omega) \leqslant \underline{L} < L^T(\epsilon_1,\omega)$ is not feasible if $\overline{\epsilon}_- \leqslant \epsilon_1$, but is feasible if $\epsilon_1 > \overline{\epsilon}_-$ and $\overline{f}^T_- < f(\epsilon_1,\omega) \leqslant \overline{f}^T_- + \Omega(\epsilon_1 - \overline{\epsilon}_-)$;*
- *(iii.) $L^T(\epsilon_1,\omega) \leqslant \underline{L} < L^S(\epsilon_1,\omega)$ is feasible if $\epsilon_1 \leqslant \overline{\epsilon}_-$ and $\overline{f}^T_- + \Omega(\epsilon_1 - \overline{\epsilon}_-) \leqslant \overline{f}^T_-$, but is not feasible if $\epsilon_1 > \overline{\epsilon}_-$;*
- *(iv.) and, $\underline{L} < L^T(\epsilon_1,\omega), L^S(\epsilon_1,\omega)$ is feasible if $\epsilon_1 \leqslant \overline{\epsilon}_-$ and $\overline{f}^T_- < f(\epsilon_1,\omega)$, or, alternatively, if $\epsilon_1 > \overline{\epsilon}_-$ and $\overline{f}^T_- + \Omega(\epsilon_1 - \overline{\epsilon}_-) < f(\epsilon_1,\omega)$.*

Proof. See Appendix F. ■

As above, feasibility is dictated by the more binding constraint across information strategies. The complication here is that when there is private information over the supply shock, the incentive to stabilize output and inflation within the period means that the optimal policy response could lead to either higher or lower credit relative to transparency depending on the realization of the supply shock. For example, when L^j approaches $\underline{L}$ from below and the supply shock is sufficiently small such that $\epsilon_1 \leqslant \overline{\epsilon}_-$, the optimal policy response under the two regimes calls for $\pi^S < \pi^T$ and $y^S > y^T$. Under private information this response minimizes fluctuations of inflation and output around their respective targets but, as a byproduct, also pushes up the level of credit so that $L^S > L^T$. For this reason, conditioning on $\epsilon_1 \leqslant \overline{\epsilon}_-$, $L^S \leqslant \underline{L}$ is the more binding constraint that shapes feasibility over the remaining parameter space. In contrast, if the supply shock is sufficiently large such that $\epsilon_1 > \overline{\epsilon}_-$ the optimal policy results in $\pi^S > \pi^T$ and $y^S < y^T$ which implies $L^S < L^T$. In this case, $L^T \leqslant \underline{L}$ is the more binding constraint which then shapes feasibility.

Proposition 7 *When the credit cycle is contracting, so that* L^j *for* $j \in (S, T)$ *approaches* $\underline{L}$ *from above, there exists a threshold supply shock,* $\bar{\epsilon}_+ \equiv -\frac{\delta}{\beta\theta}(1-\sigma)\lambda(\phi_y\theta + \phi_\pi)\Gamma > 0$*, defined by the point at which* $L^S(\epsilon_1, \omega) = L^T(\epsilon_1, \omega)$ *conditional on* $\underline{L} < L^T(\epsilon_1, \omega), L^S(\epsilon_1, \omega)$*, such that:*

(i.) $L^T(\epsilon_1, \omega), L^S(\epsilon_1, \omega) \leqslant \underline{L}$ *is feasible if* $\epsilon_1 \leqslant \bar{\epsilon}_+$ *and* $f(\epsilon_1, \omega) \leqslant \overline{f}^T_+ + \Omega(\epsilon_1 - \bar{\epsilon}_+)$ *or, alternatively, if* $\epsilon_1 > \bar{\epsilon}_+$ *and* $f(\epsilon_1, \omega) \leqslant \overline{f}^T_+$*;*

(ii.) $L^S(\epsilon_1, \omega) \leqslant \underline{L} < L^T(\epsilon_1, \omega)$ *is not feasible* $\epsilon_1 \leqslant \bar{\epsilon}_+$*, but is feasible if* $\epsilon_1 > \bar{\epsilon}_+$ *and* $\overline{f}^T_+ < f(\epsilon_1, \omega) \leqslant \overline{f}^T_+ + \Omega(\epsilon_1 - \bar{\epsilon}_+)$*;*

(iii.) $L^T(\epsilon_1, \omega) \leqslant \underline{L} < L^S(\epsilon_1, \omega)$ *is feasible if* $\epsilon_1 \leqslant \bar{\epsilon}_+$ *and* $\overline{f}^T_+ + \Omega(\epsilon_1 - \bar{\epsilon}_+) < f(\epsilon_1, \omega) \leqslant \overline{f}^T_+$*, but is not feasible if* $\epsilon_1 > \bar{\epsilon}_+$*;*

(iv.) and, $\underline{L} < L^T(\epsilon_1, \omega), L^S(\epsilon_1, \omega)$ *is feasible if* $\epsilon_1 \leqslant \bar{\epsilon}_+$ *and* $\overline{f}^T_+ < f(\epsilon_1, \omega)$*, or, alternatively, if* $\epsilon_1 > \bar{\epsilon}_+$ *and* $\overline{f}^T_+ + \Omega(\epsilon_1 - \bar{\epsilon}_+) < f(\epsilon_1, \omega)$*.*

Proof. See Appendix G. ■

A similar logic applies when the credit cycle is contracting. When L^j approaches $\underline{L}$ from above and the supply shock is such that $\epsilon_1 \leqslant \bar{\epsilon}_+$, the optimal policy response under the two regimes calls for $\pi^T < \pi^S$ and $y^T > y^S$, so that $L^T > L^S$. Conditioning on $\epsilon_1 \leqslant \bar{\epsilon}_-$, $\underline{L} < L^T$ is the more binding constraint which shapes feasibility. In contrast, if the supply shock is sufficiently large such that $\epsilon_1 > \bar{\epsilon}_+$ the optimal policy results in $\pi^T > \pi^S$ and $y^T < y^S$ which implies $L^T < L^S$. In this case, $L^S \leqslant \underline{L}$ is the more binding constraint which then shapes feasibility.

The following proposition describes the optimal policy across each of the four different parts of the parameter space conditional on whether $\underline{L}$ is approached from below or above.

Proposition 8 *The optimal communication strategy regarding the supply shock is state dependent and contingent on the underlying shocks,* (ϵ_1, ω)*, driving the credit cycle.*

(i.) When $L^T, L^S \leqslant \underline{L}$*, private information is the optimal strategy if* $(1-\delta)\Psi\sigma^2_\epsilon > \delta\varpi_1\Phi\Gamma^2$ *where* $\varpi_1 \equiv \sigma^2\beta\theta^2/(\alpha + \beta\theta^2) > 0$*, otherwise transparency is optimal;*

(ii.) When $L^S \leqslant \underline{L} < L^T$*, private information is optimal;*

(iii.) When $L^T \leqslant \underline{L} < L^S$*, private information is the optimal strategy if* $(1+\delta)\Psi\sigma^2_\epsilon > \delta\varpi_3\Phi\Gamma^2 + \delta\lambda(\underline{L} + \lambda\Omega(\epsilon_1 - \bar{\epsilon}_i))\Gamma$ *where* $\varpi_3 \equiv \sigma^2\beta\theta^2/(\alpha + \beta\theta^2) > 0$ *and* $\bar{\epsilon}_i = \bar{\epsilon}_-$ *or* $\bar{\epsilon}_+$ *if* $\underline{L}$ *is approached from below or above, respectively. In all other cases, transparency is optimal;*

(iv.) When $\underline{L} < L^T, L^S$*, private information is the optimal strategy if* $(1+\delta)\Psi\sigma^2_\epsilon + \delta\varpi_4\Phi\Gamma^2 > \delta\Gamma\lambda\Omega(\epsilon_1 - \bar{\epsilon}_+)$*, where* $\varpi_4 \equiv (1-\sigma^2)\beta\theta^2/(\alpha + \beta\theta^2) > 0$*. Otherwise, transparency is optimal.*

Proof. See Appendix H. ■

When it comes to the supply shock, the optimal communication strategy balances three objectives: achieving within-the-period stabilization, minimizing the level of financial fragilities, and minimizing intertemporal volatility. The within-the-period stabilization objective always resolves in favor of retaining private information, but the later two objectives change notably with the composition of supply and credit shocks driving the credit cycle, $L(\epsilon_1, \omega)$. This complicates the description of the optimal communication strategy.

For low levels of credit (i.e., realizations of $f(\epsilon_1, \omega)$ such that $L^C, L^T < \underline{L}$) there is no difference in the crisis probability, so the optimal communication strategy trades off the within-the-period and intertemporal stability objectives. Intuitively, imperfect information allows the central bank to more efficiently smooth output and inflation volatility with in the period (captured by the term $(1-\delta)\Psi\sigma_\epsilon^2$). However, because $0 = |\partial\gamma/\partial\pi^C| < |E[\partial\gamma/\partial\pi^C]|$ in this part of the parameter space the optimal policy also requires the central bank to introduce some precautionary inflation. In doing so, this increases intertemporal volatility (captured by the term $\delta\varpi_1\Phi\Gamma^2$) relative to a regime of transparency in which $|E[\partial\gamma/\partial\pi^T]| = \partial\gamma/\partial\pi^T = 0$. The proposition states that the optimal strategy resolves in favor of the regime that minimizes these two conflicting objectives.

Across both regimes, the optimal policy response to the supply shock determines the relative level of credit. Although this does not matter for the crisis probability in this part of the parameter space (i.e., $L^T, L^S \leqslant \underline{L}$, so $\gamma(L^T) = \gamma(L^S) = 0$), it does matter for which constraint is more binding as credit expands.

As highlighted in Proposition 6, the optimal policy response to sufficiently negative supply shocks such that $\epsilon_1 \leqslant \bar{\epsilon}_-$ leads to a situation in which $L^S \leqslant \underline{L}$ is the more binding constraint. In this case, as credit expands with higher realizations of $f(\epsilon_1, \omega)$, an outcome in which $L^T < \underline{L} < L^S$ emerges (depicted in Figure 2 with L^S and L^T as the solid square and the hollow dot, respectively). In this part of the parameter space, retaining private information now trades off the benefit of more efficient within-the-period against not only the costs associated with increased intertemporal volatility (owing to the necessity of introducing precautionary inflation), but also with the costs associated with more fragile financial conditions (captured by the term associated with $\delta\lambda(\underline{L} + \lambda\Omega(\epsilon_1 - \bar{\epsilon}_i))\Gamma)$.

Alternatively, if the supply shock is more favorable such that $\epsilon_1 > \bar{\epsilon}_-$, the optimal policy response implies that $L^T \leqslant \underline{L}$ is the more binding constraint as L^j approaches $\underline{L}$ from below. Higher realizations of $f(\epsilon_1, \omega)$ lead to an outcome in which $L^S < \underline{L} < L^T$ (depicted in Figure 2 with L^S and L^T as the solid dot and the hollow square, respectively). In this case, private information minimizes both within-the-period volatility and the level of financial fragility (i.e., $0 = \gamma(L^S) < \gamma(L^T)$). Moreover, because we have $0 = |\partial\gamma/\partial\pi^S| < |E[\partial\gamma/\partial\pi^S]| < |\partial\gamma/\partial\pi^T| = |E[\partial\gamma/\partial\pi^T]|$ in this part of the parameter space, the information gap under private information actually leads to less precautionary inflation and intertemporal volatility relative to transparency. With all three forces acting in the same direction, there is no tradeoff as private information is unambiguously the optimal regime for this part of the parameter space.

For higher realizations of ϵ_1 and ω such that $\underline{L} < L^T, L^C$ private information minimizes both within-the-period and intertemporal volatility for the same reasons as above (i.e., $|\partial\gamma/\partial\pi^S| < |E[\partial\gamma/\partial\pi^S]|$ implies that less precautionary inflation is necessary relative to transparency). On the other hand, whether or not private information minimizes the level of financial fragilities depends on how optimal policy responds to the supply shock. As highlighted in Proposition 7, the optimal policy response to a sufficiently negative supply shock in this part of the parameter space such that $\epsilon_1 \leqslant \bar{\epsilon}_+$ leads to a situation in which $\underline{L} < L^T < \underline{L^S}$ (depicted in Figure 2 with L^S and L^T as the solid and the hollow square, respectively). If the shock is large enough, the costs associated with greater financial fragility under private information (captured by the term $\delta\Gamma\lambda\Omega(\epsilon_1 - \bar{\epsilon}_+)$) could outweigh the gains from more efficient within-the-period and intertemporal stabilization relative to a regime of transparency. In contrast, if $\epsilon_1 > \bar{\epsilon}_+$, the optimal policy response leads to $L^S < \underline{L^T}$ (depicted in Figure 2 with L^S and L^T as the hollow and the solid square, respectively) and retaining private information is the optimal strategy.

Finally, when the credit cycle contracts so that L^j approaches $\underline{L}$ from above, whether smaller realizations of ϵ_1 and ω lead to a region in which $L^T < \underline{L} < L^S$ or $L^S < \underline{L} < L^T$ depends on the realization of ϵ_1 relative to $\bar{\epsilon}_+$. Proposition 8 describes the implications for the optimal communication policy in either state of the world.

4 Policy Implications

These results have important policy implications, especially in light of the considerable resources currently devoted by central banks to improving communication about their financial stability objectives. These implications are state below.

The first two focus on how financial stability considerations shape the value of transparency about the real and financial side of the economy, respectively.

Implication 1 *Even in their simplest form, financial stability considerations significantly alter the benchmark policy prescription regarding optimal communication about the real side of the economy.*

The policy prescription from the benchmark model (captured by Proposition 1) suggests that absent financial stability concerns optimal communication involves keeping information about the supply shock private. In contrast, Proposition 2 establishes that this does not necessarily carry over when the monetary authority has a financial stability objective. Even simple vulnerabilities force the central bank to internalize how the monetary policy response to a supply shock shapes the likelihood of a crisis. This means that whether or not the benchmark policy prescription carries over is state dependant and conditional on the realization of the supply shock in $t = 1$. Indeed, Proposition 2 shows transparency can be optimal provided the supply shock is not too bad.

Implication 2 *The value to a central bank of transparency about the credit shock derives from the complexity of financial vulnerabilities.*

This follows directly from Propositions 2 and 5. Disclosing private information about the state of the credit cycle is only useful when there is an information gap between the actual vulnerabilities, which, in this stylized model, are directly observed by the central bank, and the public perception of those vulnerabilities. For such a gap to exist, it must be that the vulnerabilities are sufficiently complexity that the private sector cannot easily infer them on its own. This is captured in our analytic results through a simple nonlinearity in the crisis probability. To this end, the model suggests that the reason more central banks have chosen to begin publishing Financial Stability Reports is that they play a potentially valuable role of minimizing information gaps that arise given the complexity of the financial side of the economy.

The next two policy implications focus on when and why publishing a Financial Stability Report might be valuable to a central bank.

Implication 3 *Publishing an FSR is consistent with the optimal communication strategy in early stages of an expanding credit cycle, but becomes costly as the crisis probability rises. In contrast, publishing an FSR is always consistent with the optimal strategy when the credit cycle is contracting.*

This follows directly from Proposition 5. It highlights that by choosing to publish an FSR, the central bank risks putting the economy in a position where a crisis actually becomes a more acute event relative to an alternative in which information about the credit cycle is held as private information. Moreover, the risk of this happening is greatest at a critical point in the credit cycle where financial vulnerabilities rise from very low levels (i.e., when credit expands from the left to the right of the kink in crisis probability function). By the same token, the proposition also makes it clear that publishing an FSR is a robust strategy provided the credit cycle is contracting.

Implication 4 *The value of providing transparency about credit conditions is increasing in the size of the information gap between the central bank and the public regarding financial vulnerabilities.*

As can be seen in Figure 2, provided $L^C \leqslant \underline{L}$ the size of the information gap regarding financial vulnerabilities is measured by σ, whereas if $\underline{L} < L^C$ it is measured by $1 - \sigma$.[7] With this in mind, the implication comes from the proof of Proposition 5 which derives analytic expressions for

[7] When $L^C \leqslant \underline{L}$, we have $\partial\gamma/\partial\pi^C - E[\partial\gamma/\partial\pi^C] = -\sigma\lambda(\phi_y\theta + \phi_\pi) > 0$ and the information gap is increasing in σ. In contrast, when $L^C > \underline{L}$, $\partial\gamma/\partial\pi^C - E[\partial\gamma/\partial\pi^C] = (1-\sigma)\lambda(\phi_y\theta + \phi_\pi) < 0$ so that the gap is increasing in $1 - \sigma$.

$E[W^C] - E[W^T]$ for each of the four possible regions of the parameter space. It is easy to see that $\partial(E[W^C] - E[W^T])/\partial\sigma < 0$ for $L^C \leqslant \underline{L}$ and $\partial(E[W^C] - E[W^T])/\partial\sigma > 0$ for $\underline{L} < L^C$. In light of this, the model suggests that minimizing the information gap over financial vulnerabilities is a key motivation for why central banks choose to publish Financial Stability Reports (i.e., the goal of communicating about the credit shock is to minimize $\partial\gamma/\partial\pi^C - E[\partial\gamma/\partial\pi^C]$ and σ is a sufficient statistic for this when $L^C \leqslant \underline{L}$ while $1-\sigma$ is a sufficient statistic when $\underline{L} < L^C$).

The final two policy implications focus on the state dependance of optimal communication about both the real and financial side of the economy in the presence of financial vulnerabilities.

Implication 5 *The financial stability objective implies that the optimal communication strategy regarding either the real or the financial side of the economy is heavily state dependant and potentially differs depending on wether the credit cycle is expanding or contracting.*

Propositions 2, 5, and 8 all highlight the fact that optimal communication in the presence of a financial stability objective is conditional on a large number of factors, including: (1.) the overall level of credit (i.e., L^j relative to $\underline{L}$); (2.) whether the credit cycle is expanding or contracting (i.e., whether L^j is approaching $\underline{L}$ from below or above); and (3.) the underlying composition of shocks that are driving the credit cycle (i.e., it needs to be able to differentiate whether the credit cycle is driven by ϵ_1 or ω). This level of detail necessary to implement the optimal communication strategy raises a number of practical considerations. In particular, communicating optimally about complex vulnerabilities is likely to be an extremely difficult task for central banks. Even in this stylized model it is not enough for the central bank to simply have better information than the private sector about credit conditions (as discussed earlier, this is an already speculative assumption). It also needs to understand whether the credit cycle is expanding or contracting and it needs to be able to differentiate whether the financial cycle is driven by real or financial shocks.

Finally, state-dependance of the optimal communication regime has one more important implication for policy makers.

Implication 6 *The optimal communication strategy regarding either the real or financial side of the economy is likely to suffer from a time inconsistency problem.*

In this model, the time inconsistency problem is ruled by the timing assumptions, but the potential for it to emerge is easy to understand. As noted in Section 2, in this setup the central bank observes ϵ_1 and ω prior to announcing a communication regime. Consider an alternative in which, the central bank has to announce a communication regime prior to observing the shocks.[8]

[8] It would be straightforward to show this formally. I chose not to do this because it would lengthen the paper with only a limited gain given that the intuition behind the potential for a time inconsistency problem seems clear from

With regard to the decision to publish an FSR, for example, it would be *ex ante* optimal to do so provided $E[f(\underline{\epsilon}_1, \omega)] \leqslant \overline{f}_-^T$. However, if the actual realization of $f(\epsilon_1, \omega)$ is sufficiently large such that an outcome in which $L^C(\epsilon_1, \omega) \leqslant \underline{L} < L^T(\epsilon_1, \omega)$ emerges, Proposition 5 says that such a strategy would turn out to be suboptimal *ex post.* In principle, the central bank could renege on its promise to make the credit shock public, but in practice the cost of doing this is likely to be prohibitively high. Once a central bank goes down the road of publicly commenting on real or financial developments, as long as the private sector finds value in that communication, it would be impractical to simply stop doing it. Hence, a decision like publishing the Survey of Economic Projections, or example, or a Financial Stability Report is likely to be a one way street.

5 Conclusion

This paper examines how financial stability concerns affect optimal central bank communication. It introduces an endogenous crisis shock into an otherwise standard two period game-theoretic model of optimal central bank transparency. The analysis focuses on the circumstances under which a central bank finds it optimal to communicate its private information about the real and financial side of the economy to the public. From a practical point of view, the paper seeks to understand when and why a central bank finds it useful to publish a financial stability report, as so many have opted to do in the post-financial crisis era.

The main results show that the financial stability objective significantly complicates the optimal choice of communication regime. Whether or not a central bank finds it beneficial to promote transparency about either the real side or the financial side of the economy depends importantly on the state of the credit cycle. In particular, the level of credit matters as does whether the credit cycle is expanding or contracting, and, in addition, the composition of the underlying shocks driving the credit cycle matters as well. In other words, the central bank needs to be extremely well informed in order to communicate optimally in the presence of financial vulnerabilities.

The model suggests the prime motivation for publishing a financial stability report is to minimize the information gap regarding financial vulnerabilities. However, owing to the state dependance of the optimal communication regime, the choice to do so is likely subject to a time inconsistency problem. A consequence could be that choosing to publish a financial stability report may be beneficial in early stages of the credit cycle, but may turn costly at later stages.

Looking forward, the model here is relatively simple in order to facilitate analytic solutions as well as straightforward comparisons to the existing literature. Nevertheless, it abstracts from a

the state dependant nature of the optimal communication strategy. That said, one argument in favor of including the formal analysis is that doing so would highlight that the time inconsistency problem only will only arise for *ex post* realizations of shocks that are sufficiently far from the means of their respective distributions. This is potentially an interesting point to make from a policy perspective.

number of potentially important issues. The information asymmetry here is stark in that the central bank has prefect information and its communication is fully credible. These assumptions could be relaxed to allow for the possibility that effective communication with the public about financial fragilities takes time as the central bank builds its credibility and reputation for identifying noisy vulnerabilities.[9] Beyond that, the way the central bank talks about financial market developments is likely to change endogenously over the business/financial cycle.[10] Finally, the model abstracts from political economy issues that may arise, for example, due to multiple competing macroprudential authorities. These are all important areas left for future research.

[9]See Moscarini (2007) and Frankel and Kartik (2018) for models of central bank competence.

[10]For example, in delivering a financial stability assessment it is likely that a central bank would try to internalize the possibility that drawing attention to an emerging vulnerability of which the public may be ill-informed runs the risk of bring about the very panic that the public release of the assessment is designed to prevent.

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A Proof of Proposition 1.

When $\gamma(L) = \partial\gamma/\partial\pi = 0 \; \forall \; L$, the difference between expected welfare under private information about the supply shock, equation (10), and transparency, equation (8), is given by $E[W^S] - E[W^T] = \Psi\sigma_\epsilon^2$, where $\Psi \equiv -\frac{1}{2}\frac{\beta}{\alpha}(\alpha + \beta\theta^2)[(\alpha/(\alpha + \beta\theta^2))^2 - 1] > 0$. Hence, private information is always preferred to transparency. ■

B Proof of Proposition 2.

The proof is in two parts. We first show that private information over the credit shock has no value when the crisis probability is linear. We then establish the conditions under which is optimal to reveal private information over the supply shock.

Part i. When $\gamma(L) = \lambda L \; \forall \; L$, we have $\partial\gamma/\partial\pi = E[\partial\gamma/\partial\pi] = \lambda(\phi_y\theta + \phi_\pi) < 0 \; \forall \; L$. In this case, the difference between expected welfare under private information about the credit shock, equation (9), and transparency, equation (8), is given by $E[W^C] - E[W^T] = -\delta(\gamma(L^C) - \gamma(L^T))\Gamma$.

Substituting in the values of L^C and L^T and using the fact that $\partial\gamma/\partial\pi = E[\partial\gamma/\partial\pi]$, we have

$$E[W^C] - E[W^T] = -\delta\frac{\lambda(\phi_y\theta + \phi_\pi)}{\alpha + \beta\theta^2}\left(\frac{\partial\gamma}{\partial\pi^C} - E\left[\frac{\partial\gamma}{\partial\pi^C}\right]\right)\Gamma = 0$$

In other words, the linear probability implies there is no value to keeping private information about the credit shock, so the central bank is indifferent to the communication strategy.

Part ii. The difference between expected welfare under private information, equation (10), and transparency, equation (8), is given by

$$E[W^S] - E[W^T] = (1 + \delta)\Psi\sigma_\epsilon^2 - \delta(\gamma(L^S) - \gamma(L^T))\Gamma$$

where: Ψ is defined in Appendix A.

Substituting in the equilibrium values of L^S and L^T, respectively, we can rewrite this as

$$E[W^S] - E[W^T] = (1 + \delta)\Psi\sigma_\epsilon^2 + \delta\lambda\frac{\beta\theta^2}{\alpha + \beta\theta^2}\left(\phi_y - \phi_\pi\frac{\beta\theta}{\alpha}\right)\Gamma\epsilon_1 \gtrless 0$$

The first term is strictly positive while the sign of the second term depends on ϵ_1.

Let $\Omega \equiv \frac{\beta\theta^2}{\alpha+\beta\theta^2}(\phi_y - \phi_\pi\frac{\beta\theta}{\alpha}) > 0$. Retaining private information is optimal for realizations of ϵ_1 such that $(1 + \delta)\Psi\sigma_\epsilon^2 + \delta\lambda\Omega\Gamma\epsilon_1 > 0$, while transparency is optimal if $(1 + \delta)\Psi\sigma_\epsilon^2 + \delta\lambda\Omega\Gamma\epsilon_1 \leqslant 0$. ■

C Proof of Proposition 3.

When the credit cycle is expanding so that $L^j = \underline{L}$ for $j \in (T, C)$ approach $\underline{L}$ from below we have that $E[\partial\gamma/\partial\pi^C] = \sigma\lambda(\phi_y\theta + \phi_\pi) < \partial\gamma/\partial\pi^C = 0$ under private information whereas under transparency $E[\partial\gamma/\partial\pi^T] = \partial\gamma/\partial\pi^T = 0$.

We can use this to solve for the threshold configuration of shocks, ϵ_1 and ω, such that $L^j = \underline{L}$ for $j \in (T, C)$ under the optimal policy. The thresholds for transparency and private information, respectively, are

$$f(\epsilon_1, \omega) = \underline{L} - \hat{L} - \phi_y\hat{y} - \phi_\pi\tau \equiv \overline{f}_-^T$$

and

$$f(\epsilon_1,\omega)=\underline{L}-\hat{L}-\phi_y\hat{y}-\phi_\pi\tau-\frac{\delta}{\beta\theta}\sigma\lambda(\phi_y\theta+\phi_\pi)\Omega\Gamma\equiv\overline{f}_-^C$$

where: $f(\epsilon_1,\omega)=(\phi_y-\frac{\beta\theta}{\alpha}\phi_\pi)\epsilon_1+\omega$ and Ω is defined in Appendix B.

Note that $\overline{f}_-^C=\overline{f}_-^T-\frac{\delta}{\beta\theta}\sigma\lambda(\phi_y\theta+\phi_\pi)\Omega\Gamma$. Recalling $\phi_\pi<0$ and $\phi_y\theta+\phi_\pi<0$, we have $\overline{f}_-^T<\overline{f}_-^C$ so for L^j approaching $\underline{L}$ from below the more binding constraint is $L^T\leqslant\underline{L}$.

As long as $f(\epsilon_1,\omega)\leqslant\overline{f}_-^T$ is satisfied, it must also be true that $f(\epsilon_1,\omega)\leqslant\overline{f}_-^C$ holds, so $L^T,L^C\leqslant\underline{L}$ is a feasible part of the parameter space. An outcome in which $L^C\leqslant\underline{L}<L^T$ is also feasible provided $\overline{f}_-^T<f(\epsilon_1,\omega)\leqslant\overline{f}_-^C$ because it is the case that $\overline{f}_-^T<\overline{f}_-^C$ but this also necessarily implies that $L^T\leqslant\underline{L}<L^C$ is not a feasible part of the parameter space when $\underline{L}$ is approached from below. Finally, $L^T,L^C>\underline{L}$ is feasible as long as $\overline{f}_-^C<f(\epsilon_1,\omega)$ because when this constraint is satisfied it must also be the case that $\overline{f}_-^T<f(\epsilon_1,\omega)$. ■

D Proof of Proposition 4.

When the credit cycle is contracting so that $L^j=\underline{L}$ for $j\in(T,C)$ approach $\underline{L}$ from above we have that $E[\partial\gamma/\partial\pi^C]=\sigma\lambda(\phi_y\theta+\phi_\pi)>\partial\gamma/\partial\pi^C=\lambda(\phi_y\theta+\phi_\pi)$ under private information whereas under transparency $E[\partial\gamma/\partial\pi^T]=\partial\gamma/\partial\pi^T=\lambda(\phi_y\theta+\phi_\pi)$.

The threshold configuration of shocks, ϵ_1 and ω, such that $L^j=\underline{L}$ for $j\in(T,C)$ under the optimal policy yields the following thresholds for transparency and private information, respectively

$$f(\epsilon_1,\omega)=\underline{L}-\hat{L}-\phi_y\overline{y}-\phi_\pi\tau+\phi_\pi(\delta/\alpha)\lambda(\phi_y\theta+\phi_\pi)\Gamma\equiv\overline{f}_+^T$$

and

$$f(\epsilon_1,\omega)=\underline{L}-\hat{L}-\phi_y\overline{y}-\phi_\pi\tau-\frac{\delta}{\alpha+\beta\theta^2}\lambda(\phi_y\theta+\phi_\pi)[\sigma\theta(\phi_y-\frac{\beta\theta}{\alpha}\phi_\pi)-(\phi_y\theta+\phi_\pi)]\Gamma\equiv\overline{f}_+^C$$

where: $f(\epsilon_1,\omega)$ is defined in Appendix C.

Note that $\overline{f}_+^T=\overline{f}_-^T+\phi_\pi(\delta/\alpha)\lambda(\phi_y\theta+\phi_\pi)\Gamma$ and $\overline{f}_+^C=\overline{f}_-^C+\frac{\delta}{\alpha+\beta\theta^2}\lambda(\phi_y\theta+\phi_\pi)^2\Gamma$. We can use this to write $\overline{f}_+^T-\overline{f}_+^C=\overline{f}_-^T-\overline{f}_-^C+\phi_\pi(\delta/\alpha)\lambda(\phi_y\theta+\phi_\pi)\Gamma-\frac{\delta}{\alpha+\beta\theta^2}\lambda(\phi_y\theta+\phi_\pi)^2\Gamma$ which simplifies to

$$\overline{f}_+^T-\overline{f}_+^C=-(1-\sigma)\lambda(\phi_y\theta+\phi_\pi)\frac{\delta}{\beta\theta}\Omega\Gamma>0$$

where: Ω is defined in Appendix B. We have $\overline{f}_+^T>\overline{f}_+^C$, so $L^T>\underline{L}$ is the more binding constraint when L^j approaches $\underline{L}$ from above.

As long as $\overline{f}_+^T<f(\epsilon_1,\omega)$ is satisfied, it must also be true that $\overline{f}_+^C<f(\epsilon_1,\omega)$ holds, so $\underline{L}<L^T,L^C$ is a feasible part of the parameter space. An outcome in which $L^T\leqslant\underline{L}<L^C$ is also feasible provided $\overline{f}_+^C<f(\epsilon_1,\omega)<\overline{f}_+^T$ because $\overline{f}_-^T<\overline{f}_-^C$ but this also necessarily implies that $L^C\leqslant\underline{L}<L^T$ is not a feasible part of the parameter space when $\underline{L}$ is approached from above. Finally, $L^T,L^C\leqslant\underline{L}$ is feasible as long as $f(\epsilon_1,\omega)\leqslant\overline{f}_+^C$ because this also necessarily implies $f(\epsilon_1,\omega)\leqslant\overline{f}_+^T$ is satisfied. ■

E Proof of Proposition 5.

The difference between expected welfare under private information about the credit shock, equation (9), and transparency, equation (8), is given by

$$E[W^C] - E[W^T] = -\frac{1}{2}\frac{\delta^2}{\alpha}\left[\frac{1}{\alpha+\beta\theta^2}\left(\alpha\left(\frac{\partial\gamma}{\partial\pi_1^C}\right)^2 + \beta\theta^2\left(E\left[\frac{\partial\gamma}{\partial\pi_1^C}\right]\right)^2\right) - \left(\frac{\partial\gamma}{\partial\pi^T}\right)^2\right]\Gamma^2 \qquad \text{(E1)}$$
$$- \left(\gamma(L^C) - \gamma(L^T)\right)\delta\;\Gamma$$

where we have used the fact that $\Delta^T = -\Gamma < 0$.

Region 1. When $L^T, L^C \leqslant \overline{L}$, we have that $\gamma(L^C) = \gamma(L^T) = 0$ and $\partial\gamma/\partial\pi^C = \partial\gamma/\partial\pi^T = 0$. At the same time, $E[\partial\gamma/\partial\pi] = \sigma\lambda(\phi_y\theta + \phi_\pi) < 0$, so that equation (E1) reduces to

$$E[W^C] - E[W^T] = -\delta\varpi_1\Phi\Gamma^2 < 0$$

where: $\varpi_1 = \frac{\sigma^2\beta\theta^2}{\alpha+\beta\theta^2} > 0$ and $\Phi = \frac{1}{2}\frac{\delta}{\alpha}\left[\lambda(\phi_y\theta + \phi_\pi)\right]^2 > 0$. In this part of the parameter space, transparency is the optimal communication strategy.

Region 2. When $L^C \leqslant \underline{L} < L^T < \overline{L}$, $\gamma(L^C) = 0$ and $\partial\gamma/\partial\pi^C = 0$, while $\gamma(L^T) = \lambda L^T$ and $\partial\gamma/\partial\pi^T = \lambda(\phi_y\theta + \phi_\pi)$. Finally, $E[\partial\gamma/\partial\pi] = \sigma\lambda(\phi_y\theta + \phi_\pi)$, so that equation (E1) reduces to

$$E[W^C] - E[W^T] = \delta\varpi_2\Phi\Gamma^2 + \delta\gamma(L^T)\Gamma > 0$$

where: $\varpi_2 = \frac{\alpha+(1-\sigma^2)\beta\theta^2}{\alpha+\beta\theta^2} > 0$. Private information is the optimal communication strategy.

Region 3. When $L^T \leqslant \underline{L} < L^C < \overline{L}$, $\gamma(L^T) = 0$ and $\partial\gamma/\partial\pi^T = 0$, while $\gamma(L^C) = \lambda L^C$ and $\partial\gamma/\partial\pi^C = \lambda(\phi_y\theta + \phi_\pi) < 0$. Finally, $E[\partial\gamma/\partial\pi] = \sigma\lambda(\phi_y\theta + \phi_\pi) < 0$. Equation (E1) reduces to

$$E[W^C] - E[W^T] = -\delta\varpi_3\Phi\Gamma^2 - \delta\gamma(L^C)\Gamma < 0$$

where $\varpi_3 = \frac{\alpha+\sigma^2\beta\theta^2}{\alpha+\beta\theta^2} > 0$. In this part of the parameter space, transparency is the optimal communication strategy.

Region 4. When $\underline{L} \leqslant L^T, L^C$, $\gamma(L^T) = \lambda L^T$, $\gamma(L^C) = \lambda L^C$ and $\partial\gamma/\partial\pi^T = \partial\gamma/\partial\pi^C = \lambda(\phi_y\theta + \phi_\pi)$, while $E[\partial\gamma/\partial\pi] = \sigma\lambda(\phi_y\theta + \phi_\pi)$. Moreover, as long as $\overline{L} \leqslant L^T, L^C$, we have that $y^C - y^T = (-\delta\theta/(\alpha+\beta\theta^2))(1-\sigma)\lambda(\phi_y\theta+\phi_\pi)\Gamma > 0$ and $\pi^C - \pi^T = (\delta/\alpha)(1-\sigma)\lambda(\phi_y\theta+\phi_\pi)(\beta\theta^2/(\alpha+\sigma\beta\theta^2))\Gamma < 0$, which means it must be the case that $L^C > L^T$.

In this part of the parameter space, equation (E1) reduces to

$$E[W^C] - E[W^T] = \delta\varpi_4\Phi\Gamma^2 - \delta\left(\gamma(L^C) - \gamma(L^T)\right)\Gamma$$

where: $\varpi_4 = \frac{(1-\sigma^2)\beta\theta^2}{\alpha+\beta\theta^2} > 0$.

The first term is positive while the second is negative. Substitute in the solutions for L^C and L^T under the optimal policy along with the definitions of ϖ_4 and Φ to get

$$E[W^C] - E[W^T] = (\delta\lambda\Gamma)^2\frac{\theta}{\alpha+\beta\theta^2}(1-\sigma)(\phi_y\theta+\phi_\pi)\left[\frac{1}{2}\frac{\beta\theta}{\alpha}(\phi_y\theta+\phi_\pi)(1+\sigma) + \left(\phi_y - \frac{\beta\theta}{\alpha}\phi_\pi\right)\right] < 0$$

The term outside the brackets is negative, so the sign of the entire expression depends on the term inside the brackets, which can be rewritten as $[(1 + \frac{1}{2}\frac{\beta\theta^2}{\alpha}(1+\sigma))\phi_y - \frac{1}{2}\frac{\beta\theta}{\alpha}(1-\sigma)\phi_\pi] > 0$. The entire expression is negative, so transparency is the optimal strategy. ■

F Proof of Proposition 6.

When the credit cycle is expanding so L^j approaches $\underline{L}$ from below for $j \in (T, S)$, we have that $E[\partial\gamma/\partial\pi^S] = \sigma\lambda(\phi_y\theta + \phi_\pi) < \partial\gamma/\partial\pi^S = 0$ under private information whereas $E[\partial\gamma/\partial\pi^T] = \partial\gamma/\partial\pi^T = 0$ under transparency.

Using this to solve for the threshold configuration of shocks, ϵ_1 and ω, such that $L^j = \underline{L}$ for $j \in (T, C)$ shows that the threshold for transparency is the same as in Appendix C; that is, $f(\epsilon_1, \omega) = \underline{L} - \hat{L} - \phi_y\hat{y} - \phi_\pi\tau \equiv \overline{f}_-^T$, where $f(\epsilon_1, \omega) = (\phi_y - (\beta\theta/\alpha)\phi_\pi)\,\epsilon_1 + \omega$. On the other hand, the threshold for $L^S = \underline{L}$ is given by

$$g(\epsilon_1, \omega) = \underline{L} - \hat{L} - \phi_y\hat{y} - \phi_\pi\tau - \frac{\delta\theta}{\alpha + \beta\theta^2}\sigma\lambda(\phi_y\theta + \phi_\pi)\Gamma(\phi_y - \frac{\beta\theta}{\alpha}\phi_\pi) \equiv \overline{f}_-^S$$

where: $g(\epsilon_1, \omega) = \frac{\alpha}{\alpha+\beta\theta^2}(\phi_y - \frac{\beta\theta}{\alpha}\phi_\pi)\epsilon_1 + \omega$.

Note that $g(\epsilon_1, \omega) = f(\epsilon_1, \omega) - \Omega\epsilon_1$ where $\Omega > 0$ is defined in Appendix B. Additionally, we have that $\overline{f}_-^S = \overline{f}_-^T - \frac{\delta}{\beta\theta}\sigma\lambda(\phi_y\theta + \phi_\pi)\Gamma\Omega > \overline{f}_-^T$. Taken together, this implies that when L^j approaches $\underline{L}$ from below, whether private information or transparency imposes the more binding constraint for the sequence of shocks ϵ_1 and ω such that $L^j \leqslant \underline{L}$ depends on the realization of ϵ_1. In particular, let $\overline{\epsilon}_- \equiv \frac{\delta}{\beta\theta}\sigma\lambda(\phi_y\theta + \phi_\pi)\Gamma < 0$, be a threshold shock defined by the point at which $L^S(\epsilon_1, \omega) = L^T(\epsilon_1, \omega)$ conditional on $L^T, L^S \leqslant \underline{L}$.

If $\epsilon_1 \leqslant \overline{\epsilon}_-$, we have that $L^S \geqslant L^T$ and the more binding constraint is $L^S \leqslant \underline{L}$. In this case, as long as $g(\epsilon_1, \omega) \leqslant \overline{f}_-^S$ it must also be that $f(\epsilon_1, \omega) \leqslant \overline{f}_-^T$, implying that $L^T, L^S \leqslant \underline{L}$ is a feasible part of the parameter space. An outcome in which $L^S \leqslant \underline{L} < L^T$ is not feasible when $\epsilon_1 \leqslant \overline{\epsilon}_-$ but $L^T \leqslant \underline{L} < L^S$ is provided $\overline{f}_-^T + \Omega(\epsilon_1 - \overline{\epsilon}_-) < f(\epsilon_1, \omega) < \overline{f}_-^T$ is also satisfied. This later constraint ensures $\overline{f}_-^S < g(\epsilon_1, \omega)$ and $f(\epsilon_1, \omega) \leqslant \overline{f}_-^T$ are jointly satisfied. Finally, $L^T, L^S > \underline{L}$ is feasible provided the least binding constraint is satisfied when $\underline{L}$ is approached from below. That is, as long as $\overline{f}_-^T < f(\epsilon_1, \omega)$ is satisfied it must also be that $\overline{f}_-^S < g(\epsilon_1, \omega)$ is satisfied.

In contrast, if $\epsilon_1 > \overline{\epsilon}_-$, we have that $L^T > L^S$ and the more binding constraint is $L^T \leqslant \underline{L}$. In this case, $L^T, L^S \leqslant \underline{L}$ is a feasible part of the parameter space as long as $f(\epsilon_1, \omega) \leqslant \overline{f}_-^T$, which necessary implies $g(\epsilon_1, \omega) \leqslant \overline{f}_-^S$ is also satisfied. An outcome in which $L^S \leqslant \underline{L} < L^T$ is feasible provided $\epsilon_1 > \overline{\epsilon}_-$ and $\overline{f}_-^T < f(\epsilon_1, \omega) < \overline{f}_-^T + \Omega(\epsilon_1 - \overline{\epsilon}_-)$. The later constraint ensures $g(\epsilon_1, \omega) \leqslant \overline{f}_-^S$ and $\overline{f}_-^T < f(\epsilon_1, \omega)$ are jointly satisfied. As long as $\epsilon_1 > \overline{\epsilon}_-$, $L^T \leqslant \underline{L} < L^S$ is not a feasible part of the parameter space. Finally, if $\overline{f}_-^S < g(\epsilon_1, \omega)$ is satisfied it must also be true that $\overline{f}_-^T < f(\epsilon_1, \omega)$, implying that $\underline{L} < L^T, L^S$ is feasible. ■

G Proof of Proposition 7.

When the credit cycle is contracting so L^j approaches $\underline{L}$ from above for $j \in (T, S)$, we have that $\lambda(\phi_y\theta + \phi_\pi) = \partial\gamma/\partial\pi^S < E[\partial\gamma/\partial\pi^S] = \sigma\lambda(\phi_y\theta + \phi_\pi)$ under private information whereas $\lambda(\phi_y\theta + \phi_\pi) = \partial\gamma/\partial\pi^T = E[\partial\gamma/\partial\pi^T]$ under transparency.

The resulting threshold configuration of shocks, ϵ_1 and ω, such that $L^j = \underline{L}$ for $j \in (T, C)$ shows that the threshold for transparency is the same as in Appendix D; that is, $f(\epsilon_1, \omega) = \underline{L} - \hat{L} - \phi_y\hat{y} - \phi_\pi\tau + \phi_\pi(\delta/\alpha)\lambda(\phi_y\theta + \phi_\pi)\Gamma \equiv \overline{f}_+^T$, where $f(\epsilon_1, \omega) = (\phi_y - (\beta\theta/\alpha)\phi_\pi)\,\epsilon_1 + \omega$. On the other hand, the threshold for $L^S = \underline{L}$ is given by

$$g(\epsilon_1,\omega) = \underline{L} - \hat{L} - \phi_y \hat{y} - \phi_\pi \tau - \frac{\delta}{\alpha+\beta\theta^2}\lambda(\phi_y\theta+\phi_\pi)\Gamma\left(\theta\sigma(\phi_y - \frac{\beta\theta}{\alpha}\phi_\pi) - (\phi_y\theta+\phi_\pi)\right) \equiv \overline{f}_+^S$$

where, as in Appendix F, $g(\epsilon_1,\omega) = \frac{\alpha}{\alpha+\beta\theta^2}(\phi_y - \frac{\beta\theta}{\alpha}\phi_\pi)\epsilon_1 + \omega = f(\epsilon_1,\omega) - \Omega\epsilon_1$.

Note that $\overline{f}_+^T = \overline{f}_+^S - \frac{\delta}{\beta\theta}(1-\sigma)\lambda(\phi_y\theta+\phi_\pi)\Gamma\Omega > \overline{f}_+^S$. When L^j approaches $\underline{L}$ from above, whether private information or transparency imposes the binding constraint for the sequence of shocks such that $L^j \geqslant \underline{L}$ depends on the realization of ϵ_1. Let $\overline{\epsilon}_+ \equiv -\frac{\delta}{\beta\theta}(1-\sigma)\lambda(\phi_y\theta+\phi_\pi)\Gamma > 0$, be a threshold shock defined by the point at which $L^S(\epsilon_1,\omega) = L^T(\epsilon_1,\omega)$ conditional on $\underline{L} < L^T, L^S$.

If $\epsilon_1 \leqslant \overline{\epsilon}_+$, we have that $L^S < L^T$ implying that $\underline{L} < L^T$ is the more binding constraint when $\underline{L}$ is approached from above. In this case, as long as $g(\epsilon_1,\omega) \leqslant \overline{f}_-^S$ it must also be that $f(\epsilon_1,\omega) \leqslant \overline{f}_-^T$, implying that $L^T, L^S \leqslant \underline{L}$ is a feasible part of the parameter space. An outcome in which $L^S \leqslant \underline{L} < L^T$ is not feasible when $\epsilon_1 \leqslant \overline{\epsilon}_+$ but $L^T \leqslant \underline{L} < L^S$ is provided $\overline{f}_+^T + \Omega(\epsilon_1 - \overline{\epsilon}_+) < f(\epsilon_1,\omega) < \overline{f}_+^T$ is also satisfied. This later constraint ensures $\overline{f}_+^S < g(\epsilon_1,\omega)$ and $f(\epsilon_1,\omega) \leqslant \overline{f}_+^T$ are jointly satisfied. Finally, $L^T, L^S > \underline{L}$ is feasible provided $\overline{f}_+^T < f(\epsilon_1,\omega)$, which ensures $\overline{f}_+^S < g(\epsilon_1,\omega)$ is also satisfied provided $\epsilon_1 \leqslant \overline{\epsilon}_+$.

On the other hand, if $\epsilon_1 > \overline{\epsilon}_+$, we have that $L^S > L^T$ so that $\underline{L} < L^S$ is the more binding constraint when $\underline{L}$ is approached from above. As long as $f(\epsilon_1,\omega) \leqslant \overline{f}_+^T$, which necessary implies $g(\epsilon_1,\omega) \leqslant \overline{f}_+^S$ is also satisfied, $L^T, L^S \leqslant \underline{L}$ is a feasible part of the parameter space. An outcome in which $L^S \leqslant \underline{L} < L^T$ is feasible provided $\overline{f}_+^T < f(\epsilon_1,\omega) < \overline{f}_+^T + \Omega(\epsilon_1 - \overline{\epsilon}_+)$ is also satisfied. This later constraint ensures $g(\epsilon_1,\omega) \leqslant \overline{f}_+^S$ and $\overline{f}_+^T < f(\epsilon_1,\omega)$ are jointly satisfied. As long as $\epsilon_1 > \overline{\epsilon}_+$, $L^T \leqslant \underline{L} < L^S$ is not a feasible part of the parameter space. Finally, in this case $L^T, L^S > \underline{L}$ is feasible provided $\overline{f}_+^S < g(\epsilon_1,\omega)$, which ensures $\overline{f}_+^T < f(\epsilon_1,\omega)$ is also satisfied provided $\epsilon_1 > \overline{\epsilon}_+$. ■

H Proof of Proposition 8.

The difference between expected welfare under private information about the supply shock, equation (10), and expected welfare under transparency, equation (8), is given by

$$\begin{aligned} E[W^S] - E[W^T] = (1+\delta)\Psi\sigma_\epsilon^2 \\ -\frac{1}{2}\frac{\delta^2}{\alpha}\left[\frac{1}{\alpha+\beta\theta^2}\left(\alpha\left(\frac{\partial\gamma}{\partial\pi_1^S}\right)^2 + \beta\theta^2\left(E\left[\frac{\partial\gamma}{\partial\pi_1^S}\right]\right)^2\right) - \left(\frac{\partial\gamma}{\partial\pi_1^T}\right)^2\right]\Gamma^2 \\ -\delta\left(\gamma(L^S) - \gamma(L^T)\right)\Gamma \end{aligned} \tag{H1}$$

where $\Psi > 0$ is defined in Appendix A.

Region 1. When $L^T, L^S \leqslant \overline{L}$, we have that $\gamma(L^S) = \gamma(L^T) = 0$ and $\partial\gamma/\partial\pi^S = \partial\gamma/\partial\pi^T = 0$. At the same time, $E[\partial\gamma/\partial\pi] = \frac{1}{2}\lambda(\phi_y\theta+\phi_\pi) < 0$, so equation (H1) reduces to

$$E[W^S] - E[W^T] = (1+\delta)\Psi\sigma_\epsilon^2 - \delta\varpi_1\Phi\Gamma^2 \ \substack{> \\ <}\ 0$$

where $\varpi_1 = \frac{\sigma^2\beta\theta^2}{\alpha+\beta\theta^2} > 0$ and $\Phi = \frac{1}{2}\frac{\delta}{\alpha}\left[\lambda(\phi_y\theta+\phi_\pi)\right]^2 > 0$.

The first term is strictly positive while the second is negative. Retaining private information is the optimal communication strategy if $(1+\delta)\Psi\sigma_\epsilon^2 > \delta\varpi_1\Phi\Gamma^2$. Alternatively, transparency is optimal if $(1+\delta)\Psi\sigma_\epsilon^2 > \delta\varpi_1\Phi\Gamma^2$.

Region 2. When $L^S \leqslant \overline{L} < L^T$, $\gamma(L^S) = 0$ and $\partial\gamma/\partial\pi^S = 0$, while $\gamma(L^S) = \lambda L^S$ and $\partial\gamma/\partial\pi^S = \lambda(\phi_y\theta + \phi_\pi)$. Finally, $E[\partial\gamma/\partial\pi] = \frac{1}{2}\lambda(\phi_y\theta+\phi_\pi)$. Equation (H1) reduces to

$$E[W^S] - E[W^T] = (1+\delta)\Psi\sigma_\epsilon^2 + \delta\varpi_2\Phi\Gamma^2 + \delta\gamma(L^T)\Gamma > 0$$

where: $\varpi_2 = \frac{\alpha+(1-\sigma^2)\beta\theta^2}{\alpha+\beta\theta^2} > 0$. Private information is the optimal communication strategy.

Region 3. When $L^T \leqslant \overline{L} < L^S$, $\gamma(L^T) = 0$ and $\partial\gamma/\partial\pi^T = 0$, while $\gamma(L^S) = \lambda L^S$ and $\partial\gamma/\partial\pi^S = \lambda(\phi_y\theta+\phi_\pi) < 0$. Finally, $E[\partial\gamma/\partial\pi] = \frac{1}{2}\lambda(\phi_y\theta+\phi_\pi) < 0$. Equation (H1) reduces to

$$E[W^S] - E[W^T] = (1+\delta)\Psi\sigma_\epsilon^2 - \delta\varpi_3\Phi\Gamma^2 - \delta\gamma(L^S)\Gamma \ \substack{> \\ <}\ 0$$

where $\varpi_3 = \frac{\alpha+\sigma^2\beta\theta^2}{\alpha+\beta\theta^2} > 0$.

The first term is strictly positive, while the second and third terms are both negative, so private information is optimal if $(1+\delta)\Psi\sigma_\epsilon^2 > \delta\varpi_2\Phi\Gamma^2 + \delta\gamma(L^S)\Gamma$ and transparency is optimal if $(1+\delta)\Psi\sigma_\epsilon^2 \leqslant \delta\varpi_2\Phi\Gamma^2 + \delta\gamma(L^S)\Gamma$.

We can substitute in the value of L^S to get $\gamma(L^S) = \lambda(\hat{L} + \phi_y\hat{y} + \phi_\pi\tau + g(\epsilon_1,\omega) - \frac{\delta}{\alpha+\beta\theta^2}\lambda(\phi_y\theta + \phi_\pi)((\phi_y\theta+\phi_\pi) - \sigma\theta(\phi_y - \frac{\beta\theta}{\alpha}\phi_\pi)))$. Note that this term is bounded below by $g(\epsilon_1,\omega) = \overline{f}_+^S$ where $L^S = \underline{L}$ so that $\gamma(L^S) = 0$ and bounded above by $f(\epsilon_1,\omega) = \overline{f}_-^T$ where $L^T = \underline{L}$.

Region 4. When $\overline{L} \leqslant L^T < L^S$, $\gamma(L^T) = \lambda L^T$, $\gamma(L^S) = \lambda L^S$ and $\partial\gamma/\partial\pi^T = \partial\gamma/\partial\pi^S = \lambda(\phi_y\theta+\phi_\pi)$, while $E[\partial\gamma/\partial\pi] = \frac{1}{2}\lambda(\phi_y\theta+\phi_\pi)$. Equation (H1) reduces to

$$E[W^C] - E[W^T] = (1+\delta)\Psi\sigma_\epsilon^2 + \delta\varpi_4\Phi\Gamma^2 - \delta\left(\gamma(L^S) - \gamma(L^T)\right)\Gamma \ \substack{> \\ <}\ 0$$

where: $\varpi_4 = \frac{(1-\sigma^2)\beta\theta^2}{\alpha+\beta\theta^2} > 0$.

The first and second terms are strictly positive, while the third depends on L^S relative to L^T. If $\epsilon_1 > \overline{\epsilon}_+$ (where $\overline{\epsilon}_+ \equiv -\frac{\delta}{\beta\theta}(1-\sigma)\lambda(\phi_y\theta+\phi_\pi)\Gamma > 0$ as defined in Appendix G) then $L^T > L^S$ and private information is the optimal strategy.

On the other hand, if $\epsilon_1 \leqslant \overline{\epsilon}_+$, we have $L^S > L^T$. In this case transparency is optimal provided $\epsilon_1 \leqslant \overline{\epsilon}_+ - \frac{1}{\delta\lambda\Gamma\Omega}\left[(1+\delta)\Psi\sigma_\epsilon^2 + \delta\varpi_4\Phi\Gamma^2\right]$. That is, the supply shock needs to be sufficiently negative such that the welfare loss associated with the higher level of credit under private information exceeds the gains from within the period and intertemporal stabilization. If $\epsilon_1 > \overline{\epsilon}_+ - \frac{1}{\delta\lambda\Gamma\Omega}\left[(1+\delta)\Psi\sigma_\epsilon^2 + \delta\varpi_4\Phi\Gamma^2\right]$ private information is optimal. ■