Monetary and Macroprudential Policy Coordination Among Multiple Equilibria*

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Abstract

The notion of a tradeoff between output and financial stabilization is based on monetary-macroprudential models with unique equilibria. Navigating among multiple equilibria leads to qualitatively different results. Monetary and macroprudential authorities have tools that impose externalities on each other's objectives. One of the tools (macroprudential) is coarse, while the other (monetary policy) is unconstrained. We find that this asymmetry always leads to multiple equilibria, and show that under economically relevant conditions the authorities prefer different equilibria. Giving the unconstrained authority a weight on "helping" the constrained authority ("leaning against the wind") now has unexpected effects: it *deepens* the coordination problem and worsens outcomes on both authorities' objectives.

Keywords: Macroprudential Policy, Multiple objectives, Financial stability, Leaning against the wind, Coordination game

JEL Classification: C72, E58, E61, G28

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1 Introduction

In various countries monetary and macroprudential policies are assigned to different authorities (Nier et al., 2011). Although the central bank is usually at least part, and sometimes chair, of macroprudential policy committees, the need to coordinate across authorities features prominently in such structures, especially as part of the macroprudential toolkit often resides at the bank regulator (Agur and Sharma, 2013). Moreover, even when monetary and prudential policy are entirely conducted within the central bank, separating walls are often in place within the institution (Goodhart, 2000). Indeed, when monetary policy centers primarily on inflation targeting, the objectives of monetary and macroprudential policies imply a separation, regardless of whether those policies are conducted within the same institution.

The separation of monetary and macroprudential policies raises the specter of coordination problems. In recent years, a rapidly growing body of empirical literature has shown that the monetary policy rate significantly affects bank risk taking incentives (Maddaloni and Peydró, 2011; Jiménez et al., 2014; Dell'Ariccia, Laeven and Suarez, 2017).[1] Monetary policy therefore imposes a direct externality on the financial stability objective of macroprudential policy. Such policy externalities point at a potential need for policy coordination. One might expect that a policy of "leaning against the wind" (hereafter: leaning), whereby monetary policy includes a financial stability objective, would facilitate coordination with macroprudential policy. Is it not easier to work together when authorities are closer to wanting the same things?

Obviously, when objectives are truly identical, there can be no problem in coordinating. But even supporters of leaning, such as Borio and White (2004), Rajan (2006), Disyatat (2010), Schularick and Taylor (2012), Stein (2014), Adrian and Liang (2018) and Borio et al. (2018) do not suggest that monetary policy makers should care about financial stability to the same extent as prudential authorities. The relevant question is whether introducing some degree of leaning facilitates coordination, as compared to a pure inflation targeting

[1] For further references on this literature, see Agur and Demertzis (2018).

regime.

To study the link between leaning and coordination, this paper develops a game that gives rise to multiple equilibria. We believe that multiplicity of equilibria is essential to coordination problems, and that the most natural way to think of such problems is in terms of success or failure at preventing (a probability of) bad equilibria. This stands in contrast to the existing literature, which primarily focuses on quantifying the net welfare gains of moving between different single equilibrium settings. To give an example, the comparison of a noncooperative to a cooperative Prisoners' Dilemma game is qualitatively straightforward, but can be quantitatively interesting (i.e., how *large* are the benefits from cooperating). But when instead of a simple Prisoners' Dilemma, the game is one with multiple equilibria, its outcomes become *qualitatively* interesting. Indeed, the *direction* of the relation between leaning and financial stability, usually taken for granted as positive, may be overturned with multiple equilibria.

The authorities in our game have tools that impose externalities on each other's main objectives. Each authority aims to minimize a quadratic loss function with its own tool, given shocks and the play of the other authority. If the tools are both entirely unconstrained, a single Nash Equilibrium emerges, which is socially optimal: it matches the policy of a social planner minimizing both objectives with both tools. However, we show that when one of the tools is constrained, there are *always* multiple Nash Equilibria. The multiplicity of equilibria is inherent to the combination of quadratic loss functions and one constrained tool. In reality, macroprudential policies face a variety of constraints, including limited or uncertain effectiveness, infrequent adjustment, arbitrage, and political economy problems (Lim et al., 2011; Galati and Moessner, 2013). Instead, monetary policy arguably has a greater degree of freedom. We believe that a game between an unconstrained and a constrained authority captures key elements of the monetary-macroprudential coordination problem.

In this context, we define leaning as introducing in the unconstrained authority's loss function a weight on "helping" the constrained authority, by jointly targeting its objective.

Our key result is that the introduction of such a weight has surprising implications, and can lead to the opposite of its intent. There are several steps towards this result.

First, multiplicity of equilibria is a cause of conflict. There are different policy combinations (i.e., relatively loose monetary policy and tight macroprudential policy, and vice versa) that are sustainable as Nash Equilibria. But comparing equilibria, the outcomes for the two authorities can be very different. Therefore, they can prefer different equilibria. We derive sufficient conditions for which authorities indeed prefer different Nash Equilibria. The main sufficient condition is that the effectiveness of tools depends on their distance from neutral policy, which has an empirical grounding, as we discuss.

Second, the ease of coordinating among equilibria may fall rather than rise in the extent of leaning. We define the coordination cost as the minimum utility transfer that would convince the least resistant authority to coordinate on another equilibrium. The relation between this coordination cost and leaning is driven by two countervailing effects. On the one hand, when the unconstrained authority focuses primarily on its main objective, it keeps its loss function limited for any play of the constrained authority. This limits the cost that the unconstrained authority experiences in switching between equilibria. On the other hand, the more similar the aims of the authorities become (i.e., through leaning), the closer they come to preferring the same equilibrium. In the corners of no leaning or sufficiently large leaning, one equilibrium Pareto dominates another and coordination is costless. Instead, intermediate degrees of leaning imply that the authorities still prefer different equilibria, but the gaps of outcomes (loss functions) between those equilibria are large. Thus, the relation between leaning and the coordination cost is hump-shaped.

Third, the "established tradeoff" - leaning limits financial imbalances at the cost of reduced output gap stabilization - is incomplete. Our game captures the established tradeoff when looking *within* Nash Equilibria. But when comparing *among* Nash Equilibria, the ability to coordinate matters. An equilibrium that the constrained authority dislikes, can be harder to circumvent when the unconstrained authority leans, because of the increased difficulty of coordinating. Hence, a leaning weight can perversely backfire, hurting the authority it was intended to help. Indeed, taking a uniform prior over multiple equilibria, we derive a clear-cut result: a small leaning weight always backfires, implying that a Pareto welfare loss ensues (worse performance on both objectives).

Galí (2014) also shows that leaning against the wind can backfire, although through a very different mechanism than ours. His setup centers on monetary policy only. Monetary policy's impact on rational asset bubbles is shown to be counterintuitive: a rational bubble can be spurred on by a rate hike, rather than counteracted.[2]

Calibrated models and empirical work instead take for granted that leaning improves financial stability and focus on the quantitative tradeoff: do the financial stability gains of leaning justify its cost from lost output gap stabilization? Various DSGE models with financial frictions use calibrations to consider the welfare implications of monetary policy rules with and without leaning.[3] Several of these papers explicitly model a macroprudential regulator. In Collard et al. (2017) a complete separation of monetary and macroprudential objectives is optimal. Instead, in Bodenstein, Guerrieri and LaBriola (2016), Carrillo et al. (2017) and Van der Ghote (2018) financial stability objectives for monetary policy are quantitatively found to be welfare-improving. Moreover, in Angelini, Neri and Panetta (2014) a lack of cooperation between the authorities results in excessive volatility of both the policy rate and capital requirements.[4] Econometric cost-benefit analyses are conducted by Svensson (2014, 2017a) and IMF (2015), who find that the benefits of leaning are small compared to its costs, whereas Filardo and Rungcharoenkitkul (2016) find large benefits to leaning.

[2]Brunnermeier and Koby (2017), Eggertsson, Juelsrud and Wold (2017) and Cavallino and Sandri (2018) also model monetary policy with non-standard effects, where below a threshold rate cuts become contractionary. Similarly, in Agur and Demertzis (2013) in response to a recession a leaning authority initially cuts rates deeper than an inflation targeter.

[3]See Svensson (2017b), Gerdrup et al. (2017), Loisel (2014) and references therein.

[4]De Paoli and Paustian (2017) and Cecchetti and Kohler (2014) bring in the dimension of a first-mover advantage. In De Paoli and Paustian (2017) having a macroprudential authority as first-mover welfare-dominates coordination. Instead, Cecchetti and Kohler (2014) find that a first-mover setup is inferior to coordination, and sometimes even to a noncooperative simultaneous-moves game.

There is also a literature that "microfounds" the externality that monetary policy may impose on the macroprudential regulator's objective, but does not consider coordination problems. A large variety of transmission channels from monetary policy to bank risk have been modeled.[5] Freixas, Martin and Skeie (2011), Cesa-Bianchi and Rebucci (2017) and Agur and Demertzis (2018) investigate the optimal response of prudential regulation to the impact of such transmission channels from (exogenous) monetary policy.[6]

The next section presents our setup, which Section 3 solves for the case of unconstrained tools. Section 4 then delves into the case of constrained tools, and shows that these lead to multiple equilibria. Section 5 identifies when this leads to conflict among the authorities. Section 6 defines the coordination cost and derives its relation to leaning. Section 7 considers the welfare implications. Section 8 concludes.

2 Game setup

We call the two authorities MA (monetary authority) and REG (macroprudential regulator). MA and REG focus on minimizing gaps, which represent cyclical states. In particular, MA's main objective is to minimize y, which we refer to as the output gap.[7] The gap that REG cares about is denoted by f, which can be thought of as a "financial gap", derived from a "financial cycle", like the output gap relates to the business cycle (Drehmann, Borio and Tsatsaronis, 2012; Borio, 2014).

[5] These include: the incentives of banks to monitor (Dell'Ariccia, Laeven and Marquez, 2014); the screening of borrowers by banks (Dell'Ariccia and Marquez, 2006); the skewness of bank returns (Valencia, 2014); the impact on information asymmetries (Loisel, Pommeret and Portier, 2012; Drees, Eckwert and Várdy, 2013; Dubecq, Mojon and Ragot, 2015); the incentives of bank loan officers or asset managers whose incentives deviate from profit maximization (Acharya and Naqvi, 2012; Morris and Shin, 2016); the impact on nominal contracts between banks and creditors that cannot be made state-contingent (Allen, Carletti and Gale, 2014); and moral hazard when policy rates are used as a bailout mechanism (Diamond and Rajan, 2012; Farhi and Tirole, 2012).

[6] This paper is also related to the literature on the optimal transparency of monetary policy communication, which essentially considers a coordination problem between a central bank and market participants (Morris and Shin, 2002; Svensson, 2006). In addition, coordination problems between authorities with unequal tools feature prominently in the literature on monetary-fiscal interactions (Slobodyan, 2018).

[7] Absent supply shocks, output gap stabilization also implies inflation stabilization (Blanchard and Galí, 2007).

The monetary policy rate is r, and the neutral rate is defined as $r = 0$. Hence, a negative r implies a rate cut relative to the neutral rate, and a positive r is a tightening relative to the neutral rate. We apply a similar formulation to m, the tool of REG, which is aimed at limiting deviations in the financial cycle. We let $m = 0$ represent the neutral stance, where positive (negative) m stands for tight (loose) macroprudential policy.[8]

Business and financial cycles are subject to shocks: ε_y and ε_f. These shocks represent the values that, respectively, y and f would take, if policies are neutral ($r = 0$ and $m = 0$).

The output gap is given by

$$y\left(\underset{+}{\varepsilon_y}, \underset{-}{m}, \underset{-}{r}, \underset{+}{f(\bullet)}\right) \tag{1}$$

while the financial gap is

$$f\left(\underset{+}{\varepsilon_f}, \underset{-}{m}, \underset{-}{r}, \underset{+}{y(\bullet)}\right) \tag{2}$$

Here we allow real and financial cycles to be interlinked (y and f affect each other positively), but the correlation is less than one. Hence, $\frac{\partial y}{\partial f} < 1$ and $\frac{\partial f}{\partial y} < 1$. Given $\frac{\partial y}{\partial f} < 1$ and $\frac{\partial f}{\partial y} < 1$, terms can be replaced such that the above expressions can be written to

$$Y\left(\underset{+}{\varepsilon_y}, \underset{+}{\varepsilon_f}, \underset{-}{m}, \underset{-}{r}\right) \tag{3}$$

$$F\left(\underset{+}{\varepsilon_f}, \underset{+}{\varepsilon_y}, \underset{-}{m}, \underset{-}{r}\right) \tag{4}$$

where from $\frac{\partial y}{\partial f} < 1$ and $\frac{\partial f}{\partial y} < 1$ we also have that $\frac{\partial Y}{\partial \varepsilon_y} > \frac{\partial Y}{\partial \varepsilon_f}$ and $\frac{\partial F}{\partial \varepsilon_f} > \frac{\partial F}{\partial \varepsilon_y}$.

We write the optimization problems of, respectively, MA and REG as

$$\min_r \left\{\lambda Y^2 + (1 - \lambda) F^2\right\} \tag{5}$$

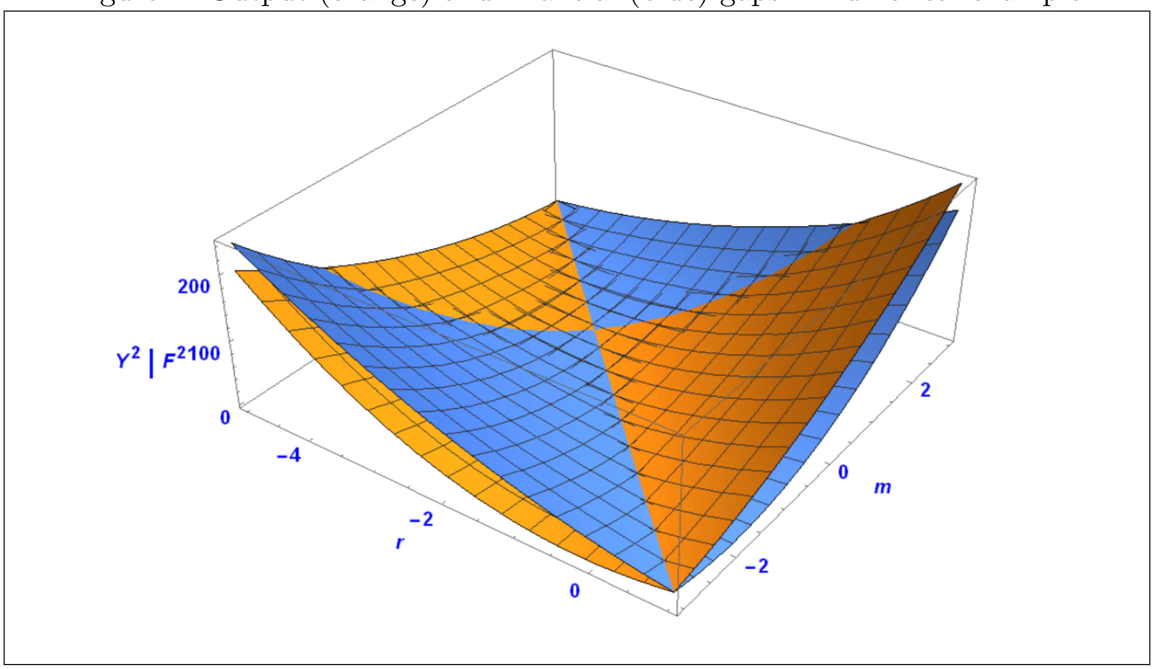
[8] The focus here is therefore on containing the *cyclical* aspect of financial imbalances, as opposed to *structural* aspects: i.e., a countercyclical capital requirement rather than the base level of capital requirements, or a time-varying LTV rather than structural housing market policies.

$$\min_{m} \left\{ \omega F^2 + (1-\omega) Y^2 \right\} \tag{6}$$

where we let $\lambda \in \left(\frac{1}{2}, 1\right]$ and $\omega \in \left(\frac{1}{2}, 1\right]$, as well as $\left|\frac{\partial Y}{\partial r}\right| > \left|\frac{\partial Y}{\partial m}\right|$ and $\left|\frac{\partial F}{\partial m}\right| > \left|\frac{\partial F}{\partial r}\right|$: each authority has a dominant objective, and its tool has the dominant impact on that objective. Here, $\lambda = 1$ implies that MA focuses only Y, whereas $\lambda < 1$ implies leaning: MA weighs the financial gap as part of its mandate. To keep the initial setup general, we also allow for REG to have a weight on Y in (6), although this will turn out to be of little relevance in the analysis (ω could be set to 1, without losing the main tradeoffs).

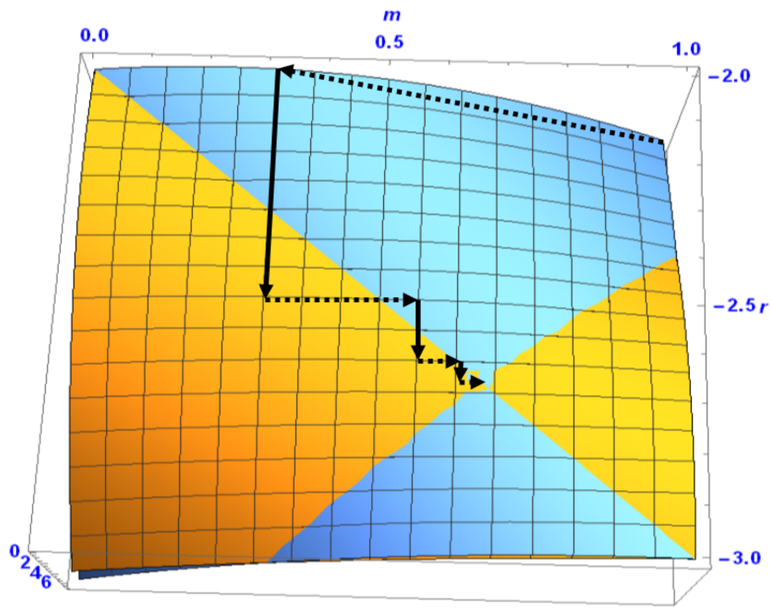
3 Unconstrained tools

Figure 1: Output (orange) and financial (blue) gaps in numerical example



As a benchmark case, we first let both tools be unconstrained: r and m can be set to any value by the authorities. We let $r, m \in \mathbb{R}$. Denote the optimal responses by $r^*(m)$ and $m^*(r)$. Call the socially optimal policy setting (i.e., what a single authority with two tools would implement) $\widehat{r}$ and $\widehat{m}$. Note that $r, m \in \mathbb{R} \Rightarrow \exists (r, m) : Y^2 = 0 \wedge F^2 = 0$, as there are two unconstrained tools for two targets. That is, there exists a combination $(\widehat{r}, \widehat{m})$

Figure 2: Play towards the single Nash Equilibrium with unconstrained tools (REG is dashed arrows, MA is unbroken arrows)



which is unambiguously the social optimum (without a need to define the welfare function, given that both the output and financial gaps are completely closed). A social planner with unconstrained tools would always implement $(\widehat{r}, \widehat{m})$. But can the noncooperative Nash Equilibrium replicate this first-best outcome?

Proposition 1 establishes the relation between $(\widehat{r}, \widehat{m})$ and the Nash game with unconstrained tools. It shows that the unique Nash Equilibrium is always socially optimal.

Figures 1 and 2 graph a numerical example, derived from for an analytically solved specific-form that is described in Appendix B. Figure 1 depicts both Y^2 and F^2 relative to r and m. The blue plane is F^2 and the orange plane is Y^2. In regions where F^2 is greater than Y^2 the blue plane is higher, and vice versa. Here one can gauge that there is one crossing point, where $Y^2 = F^2 = 0$. That crossing point is $(r, m) = (-2.67, 0.67)$ in this example. Figure 2 pivots Figure 1 upside down (looking in from "below"), and zooms in on the Nash Equilibrium. Figure 2 shows how, starting from a given point outside of the Nash

Equilibrium (here, $(r, m) = (-2, 1)$) play would always progress towards the single, socially optimal Nash Equilibrium.

Proposition 1 *With unconstrained tools, the simultaneous moves game always has a single Nash Equilibrium. That Nash Equilibrium attains the social optimum, as* $Y^2 = 0$ *and* $F^2 = 0$.

Proof. In Appendix A. ■

4 Constrained tools

We now consider $m \in \mathbb{Z}$. This is the simplest type of constraint to consider in our setting, namely a constraint on the precision of the macroprudential tool. That is, m is a coarse tool, which can only be approximately calibrated, as represented by a restriction to the space of integers ($\mathbb{Z}$).

The optimization problem of MA is still as in (5). However, the optimization problem of REG now becomes

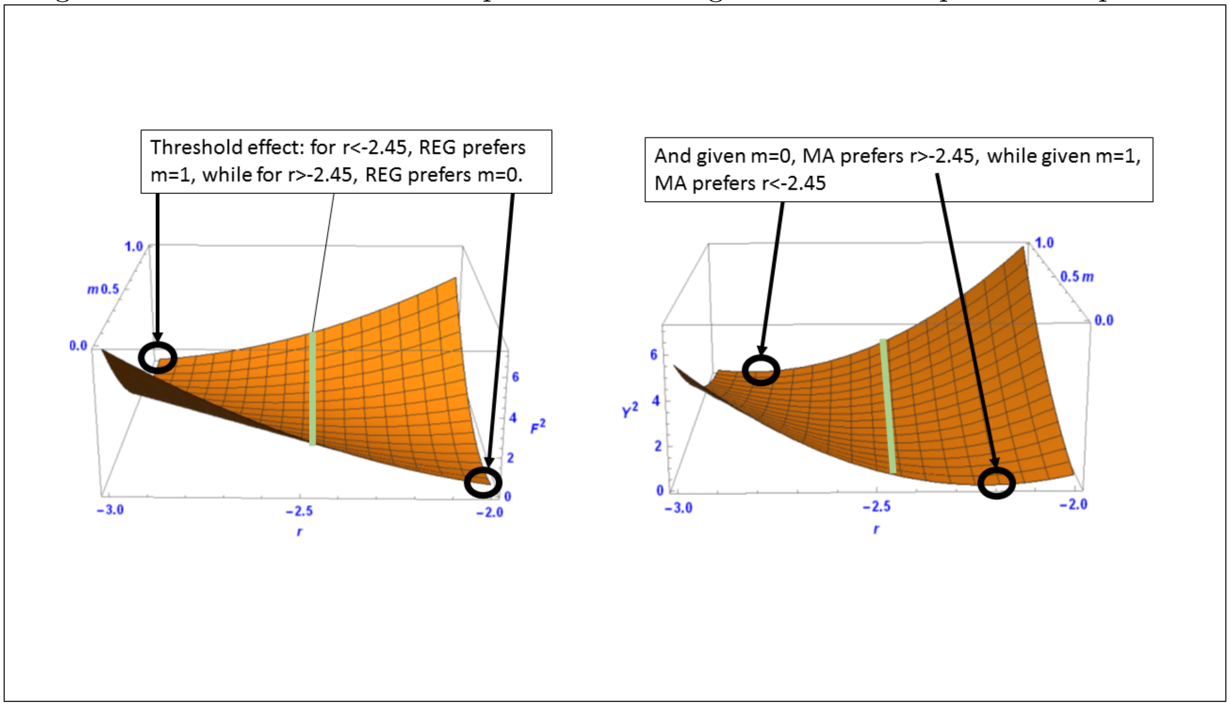
$$\min_{m=\ldots-2,-1,0,1,2,\ldots} \left\{ \omega F^2 + (1-\omega) Y^2 \right\} \tag{7}$$

Proposition 2 *The simultaneous moves game described by (5) and (7) always gives rise to multiple Nash Equilibria.*

Proof. In Appendix A. ■

Figure 3 provides a representation of the emergence of multiple Nash Equilibria with constrained tools, derived from the quantified example in Appendix B. In that example, the optimal policy of REG takes a simple threshold form: set tight policy ($m = 1$) whenever $r < -2.45$ and set neutral policy ($m = 0$) when $r > -2.45$. Moreover, as shown in Figure 3, if $m = 1$ then MA's optimal policy is to set $r^* < -2.45$, while if $m = 0$ then $r^* > -2.45$. That is, both points are sustainable as Nash Equilibria: combinations of relatively looser monetary policy and tighter macroprudential policy, and vice versa, are mutually reinforcing, making for optimal play for each authority given the play of the other.

Figure 3: How constrained macroprudential tools give rise to multiple Nash Equilibria



5 Conflict among the authorities

Multiplicity of equilibria does not necessarily imply a conflict among authorities. If both authorities prefer the same equilibrium (or one is indifferent and the other has a strict preference) then coordination is easy: cheap talk can eliminate Pareto dominated equilibria. Therefore, it is important to understand if and when authorities have genuinely conflicting preferences, and face a real problem in coordinating among the two equilibria. We now refer to *two* equilibria, because we have introduced the notion that Pareto dominated equilibria are eliminated. With two authorities, there can be at most two equilibria that are not Pareto dominated.

To facilitate the comparison of equilibria, we need to introduce some notation. Let Y_1 and Y_2 denote the value of Y in equilibria 1 and 2, respectively, and similarly for F_1 and F_2. What the authorities care about, then, is the squared values in the equilibria, denoted by (Y_1^2, F_1^2) in equilibrium 1 and (Y_2^2, F_2^2) in equilibrium 2. When either $Y_1^2 > Y_2^2 \wedge F_1^2 < F_2^2$ or $Y_2^2 > Y_1^2 \wedge F_2^2 < F_1^2$, there is the potential for conflict among authorities, as the output gap is smaller in one equilibrium, and the financial gap is smaller in the other equilibrium.

However, to identify a precise set of conditions that imply conflict, we need to narrow down the set of constraints on the macroprudential tool. Essentially, REG's optimization problem in (7), with $m \in \mathbb{Z}$, is too coarse to derive the sufficient conditions for conflict. For example, consider some specific-form (like the example in Appendix B), which yields a solution for $\widehat{m}$, which happens to be 0.9. Then, even if both $m = 0$ and $m = 1$ are Nash Equilibria, it is quite likely that both authorities will prefer $m = 1$, as it happens to be much closer to the social optimum. The constraint $m \in \mathbb{Z}$ is useful as an initial approximation for constrained macroprudential policy, allowing the derivation of Proposition 2, but is aribtrary. When we ask about the potential for conflicting preferences, the most relevant case is that of a tool that is symmetrically constrained around the social optimum. In the example of $\widehat{m} = 0.9$, a symmetric constraint could be choosing between $m = 0.8$ and $m = 1$.

We let m^- and m^+, respectively, denote the feasible values of m below and above $\widehat{m}$, with $m^+ - \widehat{m} = \widehat{m} - m^-$ implying the constraints are symmetric. Then, REG's optimization problem is written to

$$\min_{m=\{m^-,m^+\}} \left\{\omega F^2 + (1-\omega) Y^2\right\} \tag{8}$$

Using (8), we are able to show that multiplicity of equilibria always leads to a conflict of preferences under the following set of three (sufficient but not necessary) conditions:

- 1. **Linear separability of shocks**: ε_y and ε_f are intercept shocks, which is standard in most macroeconomic models.

  2. **A marginal leaning weight:** we focus on $\lambda = 1 - \nu$ with $\nu \to 0^+$, where ν can be seen as the introduction of a marginal weight on financial stability objectives for MA. Moreover, we let $\omega = 1$.

     – This facilitates our qualitative analysis without the need to specify a welfare function, because $Y_1^2 > Y_2^2 \wedge F_1^2 < F_2^2$ or $Y_2^2 > Y_1^2 \wedge F_2^2 < F_1^2$ then implies conflicting preferences among the authorities.

3. **Nonlinearity between targets and tools:** the response of output and financial gaps to, respectively, r and m, is not perfectly linear. That is, $\frac{\partial^2 Y\left(\varepsilon_y,\varepsilon_f,m,r\right)}{\partial r^2}$ and $\frac{\partial^2 F\left(\varepsilon_y,\varepsilon_f,m,r\right)}{\partial m^2}$ are either positive or negative. There are several arguments to suspect such nonlinearity in reality:

   - **The impact of a marginal change in a tool weakens in its distance from neutral policy.** For examle, a policy rate cut can have different implications depending on the level from which the rate is cut. Several studies have found empirically that as interest rates get lower, their impact on bank lending and on the real economy weakens (Eggertsson, Juelsrud and Wold, 2017; Heider, Saidi and Schepens, 2017; Hong and Kandrac, 2018). Similarly, the impact of prudential policy changes can depend on its starting level. Once prudential regulation reaches the point where further tightening significantly reduces bank charter values, it can perversely spur risk taking (Hellmann, Murdock and Stiglitz, 2000; Perotti, Ratnovski and Vlahu, 2011). A loosening of macroprudential policy is also likely to have a declining impact, as prudential limits cease to bind beyond a certain point.
   - **The impact that the tools can have on each other.** There is empirical evidence highlighting that monetary and macroprudential policies are both more effective when they move in the same direction, than when they move in opposite directions (Bruno, Shim and Shin, 2015). The impact of one tool on the transmission of another is also common in the literature on the relationship between bank capital and monetary transmission (Van den Heuvel, 2002; Angelini, Neri and Panetta, 2014).
   - **Nonlinearity due to the economic environment.** One can think of the situation in many advanced economies during 2010-2015, for instance, where the risks of raising versus lowering interest rates were deeemed asymmetric (Summers, 2015).

Proposition 3 *Under the three properties outlined above, MA and REG prefer different Nash Equilibria.*

Proof. In Appendix A. ■

6 Coordination cost

The previous section identified sufficient conditions for conflicting preferences among the authorities. The next step is to define an expression that summarizes the *depth* of conflict. How far apart are authorities? How difficult would it be to sit together and coordinate on a different outcome? One could imagine that if one authority is only slightly better off under an equilibrium that makes the other a lot worse off, a small degree of altruism (or public pressure) could suffice to make the minimally affected authority move. But the more that minimally affected authority has to give up in terms of its objectives, the less inclined it will be to agree to a coordinated outcome.

We identify the extent of disagreement between MA and REG with this coordination cost expression

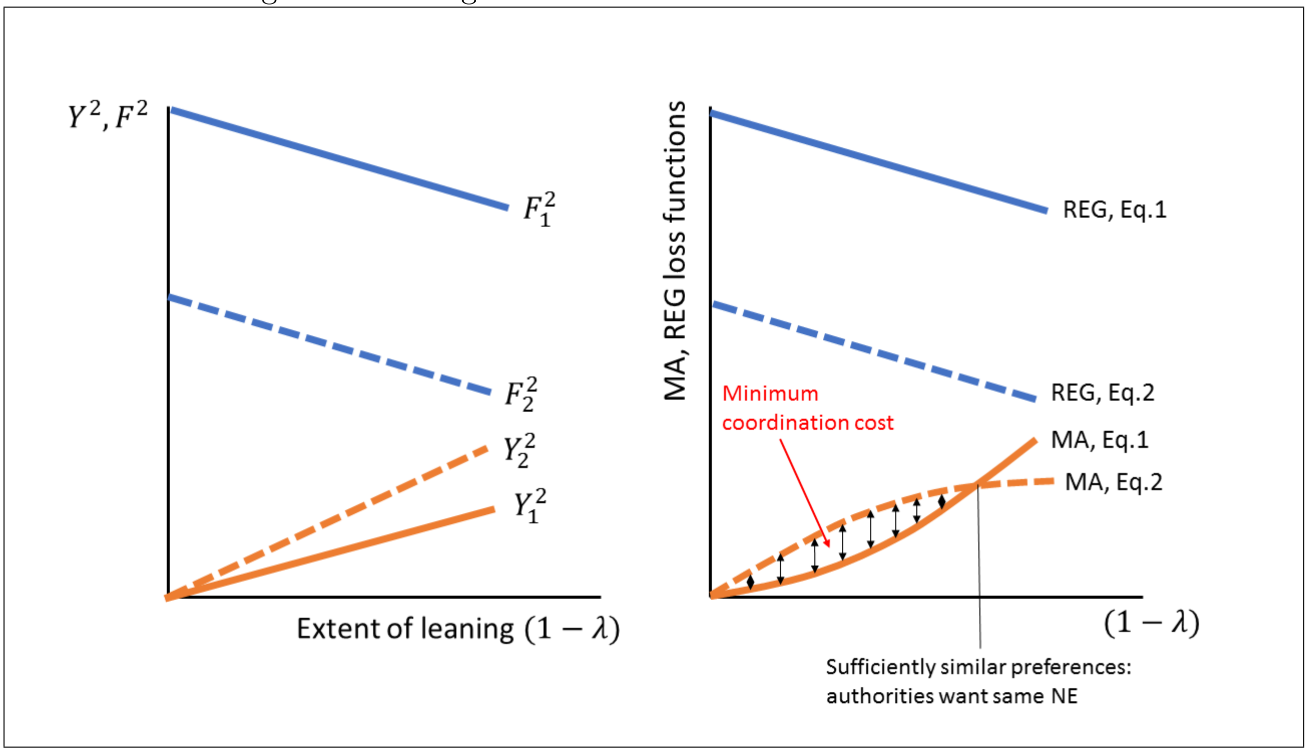
$$C = \min\left\{\left|\left[\lambda Y_1^2 + (1-\lambda)F_1^2\right] - \left[\lambda Y_2^2 + (1-\lambda)F_2^2\right]\right|, \left|\left[\omega F_1^2 + (1-\omega)Y_1^2\right] - \left[\omega F_2^2 + (1-\omega)Y_2^2\right]\right|\right\} \tag{9}$$

One can see (9) as a means to quantify what one authority would have to minimally "offer" the other in order to move. If there were some means to transfer utility between authorities, then the coordination cost is the minimum utility transfer required.

6.1 The impact of leaning on coordination

We can now analyze how the coordination cost is impacted by the extent of leaning. That is, how does C vary with λ? Proposition 4 shows that the coordination cost is lowest in the corners where there is no leaning at all, or where authorities are sufficiently similar. In between, coordination is harder. In particular, the relationship between the extent of leaning and the coordination cost is hump shaped. This is summarized in Figures 4 and 5.

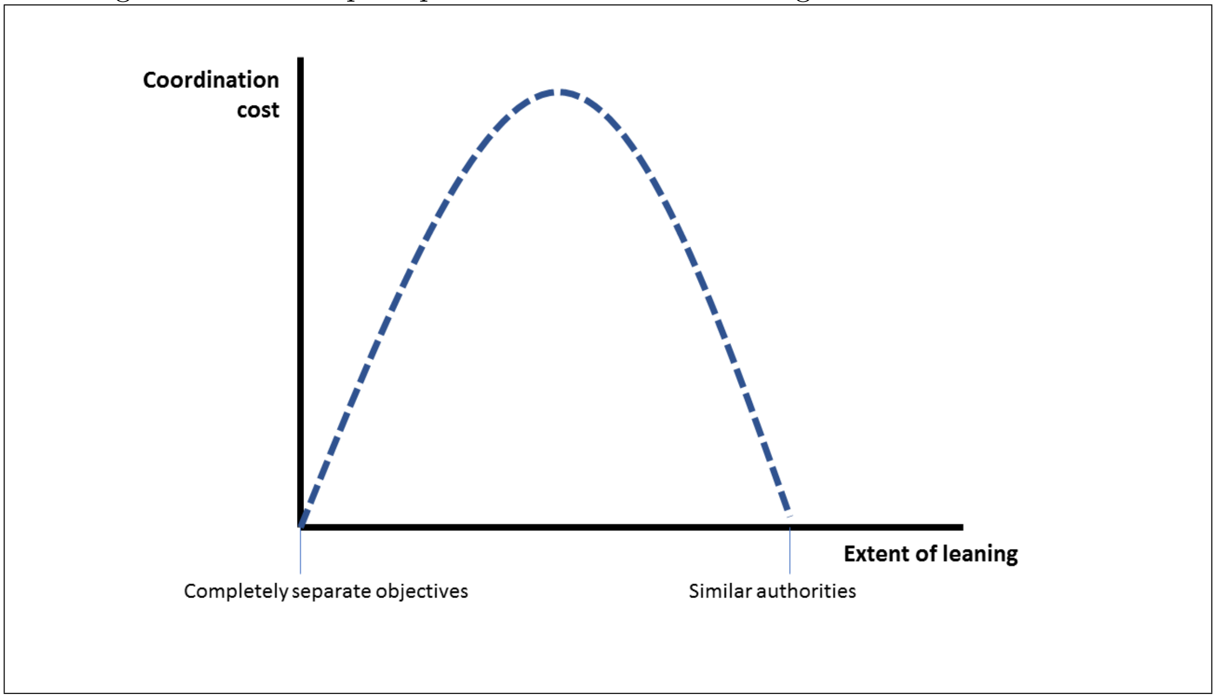
Figure 4: Leaning and the loss functions of MA and REG



The left pane of Figure 4 represents the conflict between real and financial objectives, as in Proposition 3. At $\lambda = 1$ (no leaning), MA always closes the output gap. But for any, $\lambda < 1$, the output gap is larger in one equilibrium (NE2), while the financial gap is larger in the other (NE1). As long as MA's weight on the output gap dominates, it will prefer NE1. But at some point, when MA's weight on financial objectives becomes large enough, it will switch to preferring NE2. This is represented in the right pane of Figure 4.

This implies a hump-shaped relation between leaning and coordination cost, shown in Figure 5 and proven in Proposition 4. Starting from no leaning, the introduction of a small weight on leaning always increases the coordination cost. The reason is that for a small weight, the MA certainly still prefers the equilibrium with the lower output gap (here, NE1). Leaning reduces the financial gap and increases the output gap in each equilibrium. Because output gaps widen as MA leans more, the coordination cost first rises in leaning.

Figure 5: The hump-shaped relation between leaning and coordination costs



However, MA's preferences also move closer to those of REG. Eventually, the convergence of preferences "overtakes" the divergence of equilibrium outcomes, and coordination cost declines in leaning, until it reaches zero again. We call the point at which authorities' preferences are sufficiently similar that they prefer the same equilibrium, $\lambda = \widehat{\lambda}$.

In sum, in terms of coordination, the problematic cases occur when authorities are different enough from each other that they prefer different equilibria, but not so different from each other that coordination costs are small, because one authority is always close to achieving its target. This happens when the leaning parameter is in the intermediate range.

Proposition 4 *For the same set of conditions outlined for Proposition 3, the coordination cost C is hump-shaped in the extent of leaning, $(1-\lambda)$, with $C = 0$ at the corners of no leaning ($\lambda = 1$) and sufficiently similar preferences ($\lambda = \widehat{\lambda}$).*

Proof. In Appendix A. ■

6.2 Non-equivalence of the authorities

Our analysis has centered on λ, and the relation between leaning and coordination problems. But would a similar comparison apply to ω, whereby a pure regulatory focus on financial imbalances ($\omega = 1$) eliminates coordination problems? That is not the case, because of the asymmetry of tools, m and r. The interest rate is modeled as a precision tool, whereas macroprudential policy is coarse. But such an asymmetry between the tools implies that Proposition 4's result on λ has no equivalent for ω. That is, $\omega \to 1 \nRightarrow F^2 = 0$, and therefore there is no general-form, qualitative statement on the relation between C and ω.

7 Social welfare implications

Without defining a welfare function, we can nonetheless discuss the impact of leaning on the most conservative definition of welfare changes: Pareto improvements. Here, a Pareto welfare improvement comes about whenever both Y^2 and F^2 are lower for a change in λ. We qualitatively compare $\lambda = 1$ (inflation targeting) and $\lambda < 1$ (leaning). It is obvious that Y^2 is always lowest at $\lambda = 1$ (since r is then always adjusted to effectuate $Y^2 = 0$). Hence, the welfare comparison can center on F^2: if $\lambda < 1$ implies a higher value of F^2 than does $\lambda = 1$, then $\lambda < 1$ unambiguously (Pareto) worsens social welfare.

7.1 Leaning and social welfare

The trade-off here is as follows. On the one hand, leaning lowers F^2 *within* each Nash Equilibrium. That is, within equilibria, the trade-off between leaning and inflation targeting takes the "traditional" form, whereby leaning implies a loss on output gap stabilization, but gains on financial stabilization. Formally, $\frac{\partial F_1^2}{\partial \lambda} > 0$ and $\frac{\partial F_2^2}{\partial \lambda} > 0$, because for any given m, $r^*(m)$ attains a lower F^2 when λ is smaller (by (5)). This is seen in Figure 4. On the other hand, leaning can make it harder to coordinate *among* Nash Equilibria, and therefore increases the likelihood of landing on the worse of F_1^2, F_2^2. This statement can be made more specific by assuming a uniform prior over Nash Equilibria: absent successful coordination, each equilibrium is equally likely to occur. This allows us to speak of $E\left[F^2\right]$. If authorities fail to coordinate, then

$$E\left[F^2\right] = \frac{F_1^2 + F_2^2}{2} \tag{10}$$

Since the aim of leaning is to reduce financial imbalances, we refer to a situation wherein $E\left[F^2\right]$ rises in the extent of leaning as "backfiring leaning". That is:

$$\frac{\Delta E\left[F^2\right]}{\Delta \lambda} < 0$$

which means that, starting from $\lambda = 1$, and then introducing a weight on leaning (a reduction of λ by $\Delta\lambda$) would increase $E\left[F^2\right]$. Backfiring leaning implies that leaning lowers social welfare in a Pareto sense, because it raises both output and financial gaps. This is seen in Figures 6 and 7.

Proposition 5 provides a benchmark result for backfiring leaning, when conflicting preferences cannot be overcome and only Pareto-dominated equilibria can be eliminated.

Proposition 5 *If authorities fail to coordinate when $C > 0$ (one authority needs to be made worse off to make the other better off), then there exists as $\lambda' \in (1, \lambda_S]$ such that a change from $\lambda = 1$ to $\lambda \in (1, \lambda')$ always Pareto worsens welfare* $\left(\frac{\Delta E\left[F^2\right]}{\Delta \lambda} < 0 \text{ and } \frac{\Delta E\left[Y^2\right]}{\Delta \lambda} < 0\right)$.

Proof. In Appendix A. ■

7.2 First-best

Section 3 showed that under unconstrained tools the two separate authorities could replicate the social planner's solution. For the case of constrained tools, we have not considered the social planner's solution. That is because we have not gone down the path of specifying a welfare function. Under constrained tools and conflicting preferences, which equilibrium is better from a welfare perspective, the one preffered by MA or the one preferred by REG,

Figure 6: Leaning backfires over full possible range

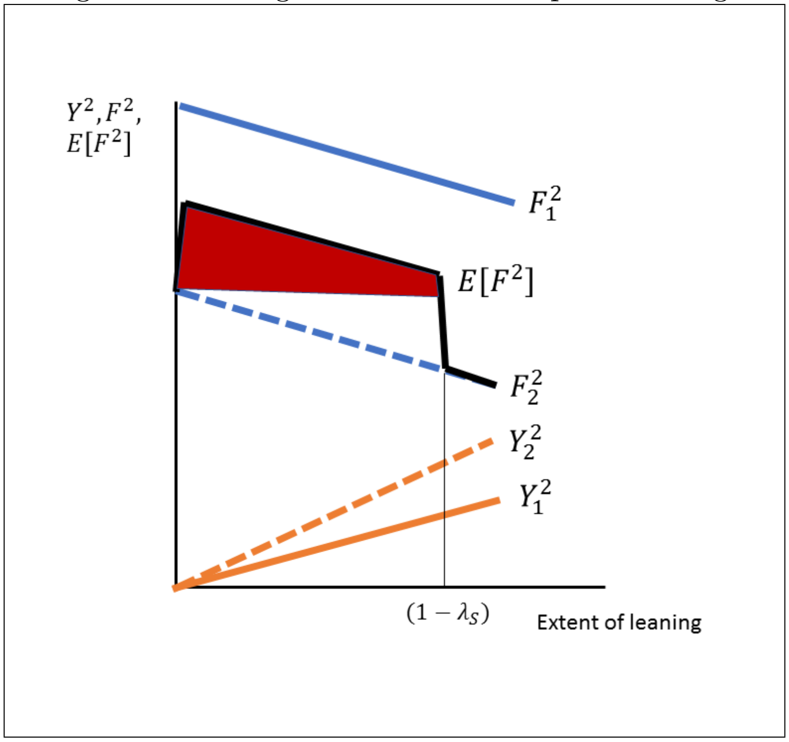
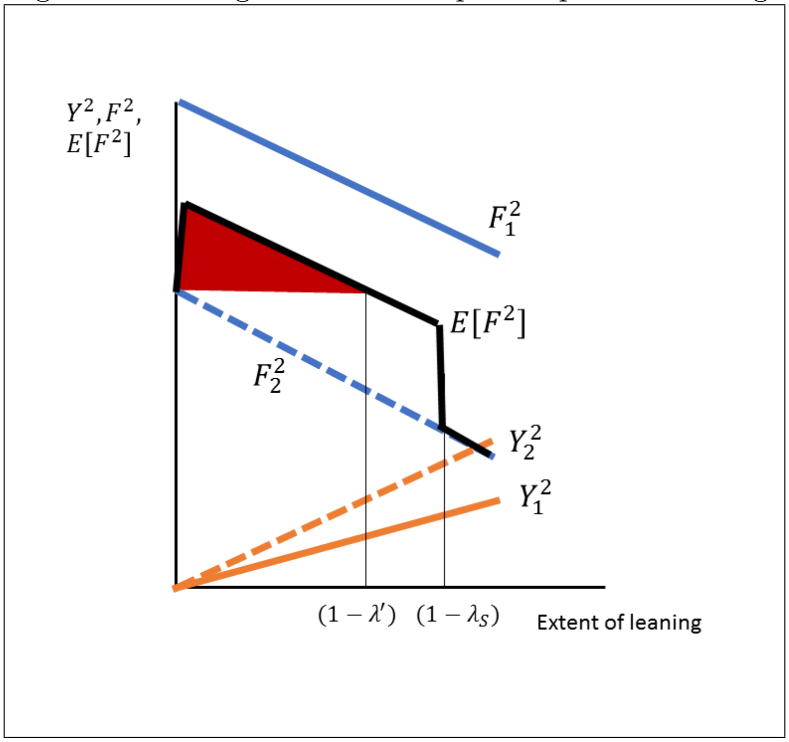


Figure 7: Leaning backfires over part of parameter range



cannot be answered without a welfare function. However, for present purposes, what matters is the knowledge that the two equilibria are different, and therefore, barring a knife-edge case, social welfare would always be higher in one of them. The inability to coordinate can impose costs, by bringing about the possibility that a lower welfare equilibrium wins out. For this, we need not quantify which equilibrium has the lower welfare.

8 Conclusions

The debate on whether monetary policy should engage in "leaning against the wind" is usually framed in terms of a cost-benefit analysis. Is a leaning central bank's hampered ability to stabilize the output gap and inflation outweighed by its financial stability benefits?

This paper takes a different angle. Rather than asking about relative costs and benefits *within* equilibria, it considers the costs of coordinating *between* equilibria. It is when uncoordinated policies can give rise to different equilibria that coordination is likely to matter most. In this perspective, coordination is not a fine-tuning exercise for a smooth return to steady states, but a means to avoid bad equilibria, in which one authority may be slightly better off, while the other is a lot worse off.

This paper comes to a fairly clear-cut conclusion on the merits of leaning when there are multiple equilibria. Starting from traditional objectives (i.e., output gap stabilization) the introduction of a weight on financial stability makes coordination harder. If the weight on financial stability is small, leaning always backfires, and ends up lowering rather than raising financial stability.

Appendix A: Proofs

Proof of Proposition 1. The uniqueness of the Nash Equilibrium follows from $\lambda \in \left(\frac{1}{2}, 1\right]$, $\omega \in \left(\frac{1}{2}, 1\right]$, $\left|\frac{\partial Y}{\partial r}\right| > \left|\frac{\partial Y}{\partial m}\right|$, and $\left|\frac{\partial F}{\partial m}\right| > \left|\frac{\partial F}{\partial r}\right|$ (i.e., each authority's tool has a first-order impact on its relatively dominant objective). These imply that $\frac{dr^*(m)}{dm} < 0$ and $\frac{dm^*(r)}{dr} < 0$ are monotonic. Hence, there can be only one crossing point of the reaction functions. At that crossing point, both authorities cannot do better given the play of the other authority. This can only be at $Y^2 = 0 \wedge F^2 = 0$. Any point $Y^2 > 0$ would optimally see MA adjusting r, and any point with $F^2 > 0$, would optimally see REG adjusting m. ■

Proof of Proposition 2. Consider the unconstrained socially optimal policy setting $(\widehat{r}, \widehat{m})$ and find the closest feasible values within $m \in \mathbb{Z}$ to $\widehat{m}$. Call these m^- (closest below) and m^+ (closest above). If

$$
\begin{aligned}
& [\omega F\left(\varepsilon_f, \varepsilon_y, m^+, r^*\left(m^+\right)\right)^2 + (1-\omega)\, Y\left(\varepsilon_y, \varepsilon_f, m^+, r^*\left(m^+\right)\right)^2 \\
< \;& \omega F\left(\varepsilon_f, \varepsilon_y, m^-, r^*\left(m^+\right)\right)^2 + (1-\omega)\, Y\left(\varepsilon_y, \varepsilon_f, m^-, r^*\left(m^+\right)\right)^2] \\
& \wedge[\omega F\left(\varepsilon_f, \varepsilon_y, m^-, r^*\left(m^-\right)\right)^2 + (1-\omega)\, Y\left(\varepsilon_y, \varepsilon_f, m^-, r^*\left(m^-\right)\right)^2 \\
< \;& \omega F\left(\varepsilon_f, \varepsilon_y, m^+, r^*\left(m^-\right)\right)^2 + (1-\omega)\, Y\left(\varepsilon_y, \varepsilon_f, m^+, r^*\left(m^-\right)\right)^2]
\end{aligned}
$$

then there will be multiple Nash Equilibria: given that REG plays m^+, the optimal response of MA is to set a r^* such that m^+ is optimal for REG; instead, given that REG plays m^-, the optimal response of MA is to set a r^* such that m^- is optimal for REG.

Since $r^*(m)$ represents optimal play by MA for a given m, it is necessarily true that

$$
Y\left(\varepsilon_y, \varepsilon_f, m^+, r^*\left(m^+\right)\right)^2 < Y\left(\varepsilon_y, \varepsilon_f, m^-, r^*\left(m^+\right)\right)^2
$$

and

$$
Y\left(\varepsilon_y, \varepsilon_f, m^-, r^*\left(m^-\right)\right)^2 < Y\left(\varepsilon_y, \varepsilon_f, m^+, r^*\left(m^-\right)\right)^2
$$

Hence, the first condition in this proof can be rewritten to: there will be multiple Nash Equilibria when

$$\begin{aligned} [F\left(\varepsilon_f, \varepsilon_y, m^+, r^*\left(m^+\right)\right)^2 &< F\left(\varepsilon_f, \varepsilon_y, m^-, r^*\left(m^+\right)\right)^2] \\ \wedge[F\left(\varepsilon_f, \varepsilon_y, m^-, r^*\left(m^-\right)\right)^2 &< F\left(\varepsilon_f, \varepsilon_y, m^+, r^*\left(m^-\right)\right)^2] \end{aligned}$$

From $F(\varepsilon_f, \varepsilon_y, \widehat{m}, \widehat{r}) = 0$ it follows that $F(\varepsilon_f, \varepsilon_y, \widehat{m}, r^*(m^+)) > 0$, which implies that REG will optimally set m^+ when $r = r^*(m^+)$, i.e.,

$$[F\left(\varepsilon_f, \varepsilon_y, m^+, r^*\left(m^+\right)\right)^2 < F\left(\varepsilon_f, \varepsilon_y, m^-, r^*\left(m^+\right)\right)^2]$$

and similarly $F(\varepsilon_f, \varepsilon_y, \widehat{m}, r^*(m^-)) < 0$ implies that REG will set m^- when $r = r^*(m^-)$, i.e.,

$$[F\left(\varepsilon_f, \varepsilon_y, m^-, r^*\left(m^-\right)\right)^2 < F\left(\varepsilon_f, \varepsilon_y, m^+, r^*\left(m^-\right)\right)^2]$$

■

Proof of Proposition 3. Consider the class of functional forms for which shocks are linearly separable

$$\begin{aligned} Y(\varepsilon_y, \varepsilon_f, m, r) &= \Theta_y(\varepsilon_y, \varepsilon_f) + \widetilde{Y}(m, r) \\ F(\varepsilon_y, \varepsilon_f, m, r) &= \Theta_f(\varepsilon_y, \varepsilon_f) + \widetilde{F}(m, r) \end{aligned}$$

and, therefore,

$$\begin{aligned} Y(\varepsilon_y, \varepsilon_f, m, r)^2 &= \Theta_y^2 + \widetilde{Y}(m, r)^2 + 2\Theta_y \widetilde{Y}(m, r) \\ F(\varepsilon_y, \varepsilon_f, m, r)^2 &= \Theta_f^2 + \widetilde{F}(m, r)^2 + 2\Theta_f \widetilde{F}(m, r) \end{aligned}$$

By Proposition 1, $(\widehat{r}, \widehat{m})$ is the social optimum under unconstrained tools, at which

$Y^2 = F^2 = 0$. Hence, we already know that

$$\frac{\partial^2 Y(\varepsilon_y, \varepsilon_f, m, r)^2}{\partial r^2} > 0, \text{ with } \frac{\partial Y(\varepsilon_y, \varepsilon_f, m, r)^2}{\partial r} = 0 \text{ at } r = \widehat{r}$$
$$\frac{\partial^2 F(\varepsilon_y, \varepsilon_f, m, r)^2}{\partial m^2} > 0, \text{ with } \frac{\partial F(\varepsilon_y, \varepsilon_f, m, r)^2}{\partial m} = 0 \text{ at } m = \widehat{m}$$

However, as we are considering a symmetric constraint $m^+ - \widehat{m} = \widehat{m} - m^-$, the key question is in which direction (above or below $\widehat{m}$) output and financial gaps increase *faster*. This is a question about the *third derivatives* of Y^2 and F^2. Since Y^2 and F^2 are always convex, the issue at hand is whether that convexity is tilted in a particular direction. In particular, let $(r^*(m^-), m^-)$ be the first Nash Equilibrium (subscript 1) and $(r^*(m^+), m^+)$ be the second (subscript 2), and write Y and F shorthand for $Y(\varepsilon_y, \varepsilon_f, m, r)$ and $F(\varepsilon_y, \varepsilon_f, m, r)$, respectively. Then, by $\frac{dr^*(m)}{dm} < 0$ (i.e., $m > \widehat{m} \Rightarrow r < \widehat{r}$ and vice versa),

$$\frac{\partial^3 Y^2}{\partial r^3} > 0 \wedge \frac{\partial^3 F^2}{\partial m^3} > 0 \Rightarrow Y_1^2 > Y_2^2 \wedge F_1^2 < F_2^2 \tag{11}$$
$$\frac{\partial^3 Y^2}{\partial r^3} < 0 \wedge \frac{\partial^3 F^2}{\partial m^3} < 0 \Rightarrow Y_1^2 < Y_2^2 \wedge F_1^2 > F_2^2 \tag{12}$$

Here,

$$\frac{\partial^3 Y^2}{\partial r^3} = \left[2\frac{\partial^3 \widetilde{Y}(m,r)}{\partial r^3}\left[\Theta_y + \widetilde{Y}(m,r)\right] + 6\frac{\partial \widetilde{Y}(m,r)}{\partial r}\frac{\partial^2 \widetilde{Y}(m,r)}{\partial r^2}\right]$$
$$\frac{\partial^3 F^2}{\partial m^3} = \left[2\frac{\partial^3 \widetilde{F}(m,r)}{\partial m^3}\left[\Theta_f + \widetilde{F}(m,r)\right] + 6\frac{\partial \widetilde{F}(m,r)}{\partial m}\frac{\partial^2 \widetilde{F}(m,r)}{\partial m^2}\right]$$

where however $\left[\Theta_y + \widetilde{Y}(m,r)\right] \approx 0$, and $\left[\Theta_f + \widetilde{F}(m,r)\right] \approx 0$ in the vicinity of $(\widehat{r}, \widehat{m})$, since at $(\widehat{r}, \widehat{m})$ per definition $\widetilde{Y}(m,r) = -\Theta_y$ and $\widetilde{F}(m,r) = -\Theta_f$. Indeed, we can consider $\frac{\partial^3 Y^2}{\partial r^3}$ and $\frac{\partial^3 F^2}{\partial m^3}$ *at* $(\widehat{r}, \widehat{m})$ for this analysis, ensuring these terms are zero. Therefore, we can focus on

$$\frac{\partial^3 Y^2}{\partial r^3} = 6\frac{\partial \widetilde{Y}(m,r)}{\partial r}\frac{\partial^2 \widetilde{Y}(m,r)}{\partial r^2} \tag{13}$$

$$\frac{\partial^3 F^2}{\partial m^3} = 6\frac{\partial \widetilde{F}(m,r)}{\partial m}\frac{\partial^2 \widetilde{F}(m,r)}{\partial m^2} \tag{14}$$

where $\frac{\partial \widetilde{Y}(m,r)}{\partial r} < 0$ and $\frac{\partial \widetilde{F}(m,r)}{\partial m} < 0$. Hence, $\frac{\partial^2 \widetilde{Y}(m,r)}{\partial r^2} > 0$ and $\frac{\partial^2 \widetilde{F}(m,r)}{\partial m^2} > 0$ imply (11), while $\frac{\partial^2 \widetilde{Y}(m,r)}{\partial r^2} < 0$ and $\frac{\partial^2 \widetilde{F}(m,r)}{\partial m^2} < 0$ imply (12). ■

Proof of Proposition 4. This is a graphical proof, based on Figure 4. Figure 4 provides a correct representation in the following respects. First, under the conditions for Proposition 3, preferences conflict, which means that one Nash Equilibrium has a higher F^2 and the other a higher Y^2, for any $\lambda < 1$ (and at $\lambda = 1$, Y^2 is always zero by (5)). Since, $\omega = 1$ in the properties of Proposition 3, the regulator's loss function is identical to F^2 in the respective equilibria. Moreover, for λ arbitrarily close to 1, MA certainly continues to prefer the equilibrium with the lower Y^2, whereas for $\lambda \to 0$ it would certainly prefer the other equilibrium. Hence, there exists a crossing point of the MA's loss functions under the respective equilibria, $\widehat{\lambda}$, which implies that one loss function is convex in λ (for the equilibrium preferred at λ near 1), while the other is concave. Next, note that as the two authorities are identical except for the fact that MA possesses an unconstrained tool and REG a constrained tool, MA will always come closer to its objective (lower value in loss function) than REG. Hence, C in equation (9) is represented by the distance between the two MA lines in the right pane of Figure 4. The combination of a concave and a convex line with two crossing points (at $\lambda = 1$ and $\lambda = \widehat{\lambda}$) implies the hump-shape in Figure 5. ■

Proof of Proposition 5. This is seen directly from Figures 6 and 7. Starting from $C = 0$ at $\lambda = 1$, a decrease of λ always implies $C > 0$ (Proposition 4), and therefore a rise in $E[F^2]$ from $\min\{F_1^2, F_2^2\}$ to $\frac{F_1^2+F_2^2}{2}$. Subsequently, λ' can be either equal to λ_S (as in Figure 6) or larger than λ_S (as in Figure 7). ■

Appendix B: Analytical example used to derive Figures 1, 2 and 3

We use a linear functional form, to derive a quantifiable example for our charts.

$$y = \varepsilon_y - \beta_1 r - \beta_2 m + \rho_1 f \quad (15)$$

$$f = \varepsilon_f - \gamma_1 r - \gamma_2 m + \rho_2 y \quad (16)$$

with $\beta_1, \beta_2, \gamma_1, \gamma_2 > 0$ and $\rho_1, \rho_2 \in (0, 1)$. This can be written to

$$Y = \frac{\varepsilon_y + \rho_1 \varepsilon_f - (\beta_1 + \rho_1 \gamma_1) r - (\beta_2 + \rho_1 \gamma_2) m}{(1 - \rho_1 \rho_2)} \quad (17)$$

$$F = \frac{\varepsilon_f + \rho_2 \varepsilon_y - (\gamma_1 + \rho_2 \beta_1) r - (\gamma_2 + \rho_2 \gamma_2) m}{(1 - \rho_1 \rho_2)} \quad (18)$$

When $r, m \in \mathbb{R}$, the reaction functions of the two authorities follow from the first-order conditions to their respective optimization problems, (5) and (6). That is, $r^*(m)$ and $m^*(r)$ follow from, respectively,

$$\frac{d}{dr}\left[\lambda Y^2 + (1 - \lambda) F^2\right] = 0 \Leftrightarrow \frac{dY}{dr} + \frac{1 - \lambda}{\lambda}\frac{dF}{dr} = 0 \quad (19)$$

$$\frac{d}{dm}\left[\omega F^2 + (1 - \omega) Y^2\right] = 0 \Leftrightarrow \frac{dF}{dm} + \frac{1 - \omega}{\omega}\frac{dY}{dm} = 0 \quad (20)$$

The analytical solutions for $r^*(m)$ and $m^*(r)$ are rather long expressions (available on request), but the expression for the Nash Equilibrium is extremely simple. A Nash Equilibrium occurs for a pair (r, m) for which

$$\frac{dY}{dr} + \frac{1 - \lambda}{\lambda}\frac{dF}{dr} = \frac{dF}{dm} + \frac{1 - \omega}{\omega}\frac{dY}{dm} = 0 \quad (21)$$

This is found be replacing $m^*(r)$ into $r^*(m)$ (or vice versa) and solving. In this case, there is a unique solution, which is

$$r^{NE} = \frac{\beta_2\varepsilon_f - \gamma_2\varepsilon_y}{\beta_2\gamma_1 - \beta_1\gamma_2} \tag{22}$$

$$m^{NE} = \frac{\beta_1\varepsilon_f - \gamma_1\varepsilon_y}{\beta_1\gamma_2 - \beta_2\gamma_1} \tag{23}$$

Implementing these in (17) and (18) gives $Y = 0$ and $F = 0$, and therefore the Nash Equilibrium is socially optimal: $\left(r^{NE}, m^{NE}\right) = (\widehat{r}, \widehat{m})$.

We now consider a constrained macroprudential tool. In this example, we will consider that there are only two settings for m, namely tight ($m = 1$) and neutral ($m = 0$). The MA's optimization is unchanged compared to (19). REG's problem can now be written as

$$\begin{aligned} m^* &= 1 \Leftrightarrow \omega\left(\frac{\varepsilon_f + \rho_2\varepsilon_y - (\gamma_1 + \rho_2\beta_1)\, r - (\gamma_2 + \rho_2\gamma_2)}{(1-\rho_1\rho_2)}\right)^2 \\ &\quad + (1-\omega)\left(\frac{\varepsilon_y + \rho_1\varepsilon_f - (\beta_1 + \rho_1\gamma_1)\, r - (\beta_2 + \rho_1\gamma_2)}{(1-\rho_1\rho_2)}\right)^2 \\ &> \omega\left(\frac{\varepsilon_f + \rho_2\varepsilon_y - (\gamma_1 + \rho_2\beta_1)\, r}{(1-\rho_1\rho_2)}\right)^2 \\ &\quad + (1-\omega)\left(\frac{\varepsilon_y + \rho_1\varepsilon_f - (\beta_1 + \rho_1\gamma_1)\, r}{(1-\rho_1\rho_2)}\right)^2 \end{aligned} \tag{24}$$

That is, it is a comparison of the value of (6) for $m = 1$ and $m = 0$. The solution takes the form

$$m^* = 1 \Leftrightarrow r < \overline{r} \tag{25}$$

There is a value, $\overline{r}$, given by parameters, which acts as a threshold. If the interest rate is below this threshold then REG sets tight policy, and if the interest rate is above this threshold, then it sets loose policy.

For this example, we use the following parameter values: $\lambda = 1$, $\omega = 0.75$, $\varepsilon_y = -5$, $\varepsilon_f = 0$, $\beta_1 = 2$, $\beta_2 = 0.5$, $\gamma_1 = 0.5$, $\gamma_2 = 2$, $\rho_1 = 0.5$, $\rho_2 = 0.5$.

With unconstrained tools, Figures 1 and 2 highlight the emergence of a single, socially optimal Nash Equilibrium. We can calculate this Nash Equilibrium using (22) and (23) as

$\left(r^{NE}, m^{NE}\right) = (-2.67, 0.67)$ (and hence, in the notation used in the general form, we indeed have $m^{+} = 1$ and $m^{-} = 0$).

With constrained macroprudential policy, the above parameterization gives the following for (25):

$$m^{*} = 1 \Leftrightarrow r < -2.45 \tag{26}$$

That is, if $r < -2.45$ it is optimal for REG to set $m = 1$, while for $r > -2.45$ it is optimal to set $m = 0$ (and $r = -2.45$ is a knife-edge where REG is indifferent). This is shown in Figure 3.

Moreover, from (19) we now get that

$$r^{*} = -2.89 \text{ if } m = 1; r^{*} = -2.22 \text{ if } m = 0 \tag{27}$$

Taken together, these imply the existence of two Nash Equilibria, namely at

$$\left(r^{NE}, m^{NE}\right) = \begin{cases} (-2.89, 1) \\ (-2.22, 0) \end{cases} \tag{28}$$

The reason is that given tight macroprudential policy, the optimal interest rate ($r^{*} = -2.89$) is below the constraint ($r < -2.45$) for which $m^{*} = 1$ and the tight policy is optimal for REG. But given loose policy by REG, the optimal interest rate ($r^{*} = -2.22$) is above the constraint ($r > -2.45$) for which $m^{*} = 0$ and thus the loose policy is optimal for REG. Both combinations (tight macroprudential policy with a lower policy rate; loose macroprudential policy with a higher policy rate) are sustainable as Nash Equilibria.

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