On the relationship between macroprudential policy and other policies

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Abstract

Our note has two related, albeit separate, goals. First, we extend an interest rate policy rule by appending a financial variable to it. Our key assumption is that the relationship between that financial variable and output is uncertain. This is an important assumption because policymakers seek policy rules that are robust to economic relationships. This exercise allows us to discuss a number of issues pertaining to the connection between macroprudential and monetary policies. Second, we examine some of the incentives faced by countries in coordinating their macroprudential policies and, thus, in working towards global financial stability, an international public good. We assume that the probability of a financial crisis decreases as more countries opt for coordination. Moreover, the heterogeneity of expected net benefits implies that countries' willingness to coordinate differs. While coordination to achieve financial stability faces important challenges, it can be socially optimal.

Keywords: monetary policy, macroprudential policy, financial stability, public goods provision, non-cooperative games

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[1] The opinions presented in this paper are those of the authors and do necessarily reflect those of the Bank of Mexico.

Introduction

We first explore the problem of a policymaker with a macroprudential concern by including a financial variable in an otherwise ordinary interest rate policy rule. A key assumption is that the policymaker is uncertain about the relationship between the financial variable and output. As a related exercise, we consider a problem in which the policymaker is uncertain about the measurement error of the financial variable. Using a min max criterion (Hansen and Sargent, 2007), we assess the implications for robust policy rules under these two setups. In this context, we discuss a number of issues pertaining to the relationship between macroprudential and monetary policies.[2]

As a second and separate step, we assess the scope for the international coordination of macroprudential policies. A possible approach is to think of global financial stability as an international public good. In effect, it is for the most part non-rival and non-excludable and, thus, its provision entails international coordination. Accordingly, it faces important challenges.[3]

We think that there are three distinctive features of global financial stability as a public good. First, its provision is an uncertain undertaking.[4] This is apparent in our setting but it is not a general feature of public goods. Second, arguably, if more players opt for coordination, financial stability is more likely to be achieved. The probability of a financial crisis is therefore a decreasing function of the number of players coordinating. Third, benefits and costs depend on the type of player. Thus, each player's willingness to coordinate differs, which has implications for collective action (Olson (1965)).

In sum, our note explores how macroprudential policy relates to other policies; namely, to monetary policy and, separately, to macroprudential policies abroad. Since the methodologies we use are notably different, we divide our note into two separate sections.

On monetary and macroprudential policies

> *"[...] I have argued for robust monetary policy rules that recognize that we face considerable uncertainty about the correct underlying model of the economy. I believe that the same basic framework may be useful for thinking about macroprudential policy." (Plosser (2014)).*

To set the stage, we start with a streamlined model. Suppose that a policymaker faces the following problem:

$$\min_{y,\pi} w_y y^2 + w_\pi \pi^2 \qquad (1)$$

2 See Claessens (2015) for an overview of macroeconomic policy tools and Käfer (2014) for a literature review of the Taylor rule and financial stability.

3 One can more generally see its provision as a non-cooperative repeated game.

4 We use the word uncertain in this section in an ordinary way.

subject to:

$\pi = \lambda_y y + \beta E(\pi) + e$, where $\lambda_y > 0$ ("Phillips curve"); and

$y = \lambda_i i \ + u$, where $\lambda_i < 0$ ("IS curve").

where the w's are the relative weights associated with inflation and output gap volatility, y is the output gap, π denotes inflation (ie we assume that the inflation target is zero), i is the monetary policy rate, and e and u are uncorrelated and independently and identically distributed (iid) shocks. The assumption of iid shocks allows us to focus on a one period problem. On the timing of shocks, we assume that the policymaker observes them before taking a decision. We refer to the output gap, simply, as output.

This problem leads to the following policy rule:

$$i = \frac{\beta E(\pi)+e}{-\lambda_i} \frac{w_\pi \lambda_y}{(w_y + w_\pi \lambda_y^2)} + \frac{u}{-\lambda_i}. \qquad (2)$$

This is similar to an ordinary monetary policy rule as in Taylor (1993). In effect, all else being constant, a positive inflation shock (e) implies an increase in the policy rate (i). The strength of the policy response depends on the relative weight given to the variability of inflation (w_π) and on the effect of output on inflation (λ_y), given by the Phillips curve. The greater the inflation weight is, the stronger the interest rate response will need to be to accommodate a higher proportion of the shock towards output.

In general, the greater the effect of output on inflation (λ_y) is, the greater the interest rate response will need to be.[5] In such a case, it is optimal for output to adjust further. The strength of its response depends inversely on the effect that the policy rate has on output (λ_i), based on the IS curve. In short, with a larger $-\lambda_i$, it takes a smaller change of the interest rate to accommodate a given shock. All else being constant, a positive output shock leads to an increase in the interest rate. For similar reasons, the strength of this response depends inversely on λ_i.

As is usually understood, a positive inflation shock combined with a negative output shock – commonly interpreted as an aggregate supply curve shift – is normally not accommodated. Based on the policy rule, the effects of both shocks on the interest rate would tend to cancel out.

Taylor (1993 and 1999) proposes this type of monetary policy rule on positive and normative grounds. There are a number of issues associated with monetary policy rules, including, measuring the output gap, the conditions under which the price level is determined and welfare considerations. We stop short of analysing the use of more than one instrument; ie we do not consider the *Tinbergen principle* (Blinder (1998)). Although these issues are important in their own right, we do not explore them further here (see Woodford (2003)).

Monetary policy rules have been extended in a number of directions. For example, some authors (Ball (1999), Bernanke and Gertler (1999), and Cúrdia and Woodford (2010)) have proposed the inclusion of a financial variable, such as the

[5] The incidence of variable λ_y – which captures the effect of inflation shocks on the interest rate – depends on the relationship between w_y and $w_\pi \lambda_y^2$. If we assume similar weights, one would expect to have $1 > \lambda_y^2$ and, hence, a positive incidence.

exchange rate, asset prices, credit and other financial spreads. In many cases, their rationale has been to account for financial stability concerns.[6]

One can motivate this type of extension in, at least, two different ways. First, as a way of recognising that the interest rate affects the economy's financial stability. This is more of a positive approach. Second, as a way of incorporating macroprudential concerns in an otherwise ordinary monetary policy rule, which is more of a normative approach. In effect, there is a potential role for monetary policy in averting the accumulation of systemic risks, or managing them, if and when they materialise (Freixas et al (2015)).

Consider then the following problem, which extends (1):

$$\min_{y,\pi,z} w_y y^2 + w_\pi \pi^2 + w_z z^2 \tag{3}$$

subject to:

$\pi = \beta E(\pi) + \lambda_y y + e$, where $\lambda_y > 0$ ("Phillips curve");

$y = \lambda_i i \ + u$, where $\lambda_i < 0$ ("IS curve"); and

$z = \lambda_z y \ + w$, where $\lambda_z > 0$ ("Financial relation").

We added a financial variable as part of the policymaker's objective function, and of a relation that entails the financial variable, output, and the financial shock w. Similarly, we assume that w is observed by the policymaker before it takes a decision, and that it is an iid process, uncorrelated with e and u. We do not take a stance on a concrete financial variable. In fact, there is no consensus on a financial variable that could reliably be part of a policy rule.

This problem implies the following policy rule:

$$i = \frac{(\beta E(\pi)+e)}{-\lambda_i}\frac{w_\pi \lambda_y}{(w_y+w_\pi\lambda_y^2+w_z\lambda_z^2)} + \frac{u}{-\lambda_i} + \frac{w}{-\lambda_i}\frac{w_z\lambda_z}{(w_y+w_\pi\lambda_y^2+w_z\lambda_z^2)} \tag{4}$$

We next highlight some of its main features. First, its response to an inflation shock has the same sign as in (2); however, its relative magnitude depends on $w_z\lambda_z^2$. Thus, the presence of a financial stability concern affects how such a policy rule reacts to shocks that could be unrelated to the financial variable. Second, it responds to an output shock as in (2). In this particular case, the presence of the financial stability variable has no implications for the policymaker's reaction. Third, a given positive financial shock leads to an increase in the interest rate. The strength of such a response depends on the relative weight given to its variability in the objective function (w_z), as well as on the effect of output on inflation (λ_y) and the effect of the financial variable (λ_z). All responses depend inversely on the relationship between output and the interest rate ($-\lambda_i$).

Seeking robust monetary rules

In this subsection, we assume a central case in which the policymaker is *uncertain* about the relationship between output and the financial variable. Specifically, the policymaker is uncertain about the value of λ_z. It only knows the variable's interval,

[6] While this approach sheds some light upon the relationship between monetary and macroprudential policies, we do not wish to propose a stance on macroprudential governance.

given by $[\lambda_0, \lambda_1]$. This assumption is motivated by the view of various authors who have expressed concerns about the state of our knowledge of macroprudential policy (Hansen (2013) and Freixas et al (2015)).

One way of dealing with concerns about ambiguity has been put forward by Hansen and Sargent (2007), who propose a robustness approach using a min max operator.[7] One of the general motivations for using such an approach has been the evidence pertaining to ambiguity aversion as, for instance, supported by the existence of the *Ellsberg paradox* (Ellsberg (1961)).

This approach has, nonetheless, brought about an intense debate. For instance, Sims (2001) argues that the robustness approach fails to satisfy the *sure-thing principle*. He advocated instead a Bayesian approach.[8] In the context of monetary policy, Svensson (2007) objected to the robustness approach on the grounds that it assigns too much weight to a possible state of nature.[9] Still, such an approach assumes from the outset that the policymaker knows very little about the model's features.

One can use this framework to assess policies that minimise the loss under the most adverse scenario with respect to those features of the model that a policymaker is uncertain about. For us, it also provides a way of skeptically appending a financial variable to a policy rule in an attempt to reconcile different views about the role of monetary policy for macroprudential ends.[10]

In this context, we assume that the policymaker solves the following problem:

$$\min_{y,\pi,z} \max_{\lambda_z} w_y y^2 + w_\pi \pi^2 + w_z z^2 \tag{5}$$

subject to:

$\pi = \beta E(\pi) + \lambda_y y + e$, where $\lambda_y > 0$ ("Phillips curve");

$y = \lambda_i i + u$, where $\lambda_i < 0$ ("IS curve"); and

$z = \lambda_z y + w$, where $\lambda_z \in [\lambda_0, \lambda_1]$ ("Financial relationship").

7 The distinction between risk and uncertainty can be attributed to Knight (1921). In fact, at times, it is referred to as Knightian uncertainty. Relatedly, Keynes (1921) introduced the concept of irreducible uncertainty.

The min max operator was proposed in Wald (1945) and subsequently developed by Savage (1951), who proposed a min max regret approach. The min max operator in economics has been used in three related approaches: Hansen and Sargent (2007), Gilboa and Schmeidler (1989), and Epstein and Wang (1994).

8 The *sure-thing principle* can be intuitively explained as follows. If you prefer A to B knowing that an event C will take place, and still prefer A to B knowing that event C will not take place, then you should prefer A to B without knowing anything about event C.

9 Such a view contrasts somewhat with the following remark: "This may come as a surprise to some of you, but I am not a fine-tuner. I think that the objective of the Federal Reserve ought to be to avoid a very bad outcome, and so my concerns are primarily with tail risks on both sides of our mandate." (Bernanke, transcript of FOMC meeting of June 24–25 2008).

10 Our problem is based on Barlevy (2011) who analysed the implications of robustness in the context of an ordinary monetary policy problem. Giannoni (2002 and 2007), for his part, studies robustness in general monetary models.

Hence, the agent is pessimistic about how the coefficient λ_z affects its objective function.[11] As a result, it minimises the objective function assuming the worst case scenario for the effect of output on the financial variable. One can also see this problem as an agent with a malevolent nature, who will respond as mischievously as possible to the policymaker's decisions (Hansen and Sargent (2007)).

The problem can be rewritten as:

$$\min_{\pi,z} \max_{\lambda_z} w_y(z-w)^2/\lambda_z^2 + w_\pi \pi^2 + w_z z^2 \qquad (5')$$

subject to:

$\pi = \beta E(\pi) + \lambda_y y + e$, where $\lambda_y > 0$ ("Phillips curve");

$y = \lambda_i i + u$, where $\lambda_i < 0$ ("IS curve"); and

$\lambda_z \in [\lambda_0, \lambda_1]$.

As a first relevant case, suppose that zero belongs to $[\lambda_0, \lambda_1]$; ie, the policymaker is uncertain even about the sign of the relationship between the financial variable and output. In this case, the optimal choice of λ_z is zero. This implies that the optimal policy rule obtained from (5) is exactly as in (2), which supports overlooking the financial variable when deciding the interest rate in the face of substantial ambiguity about its effect.

One can also interpret this result in the context of the clean versus lean debate. In effect, if there is much uncertainty about how output and the financial variable correlate, to the extent that the sign is unknown, the optimal rule implies that the financial variable should be ignored. This is in line with what is known as the Bernanke, Svensson and Greenspan approach. In effect, as has been argued: "[...] monetary policy is too blunt a tool to be routinely used to address possible financial imbalances." (Bernanke (2011)).

For the next case, we assume that zero does not belong to the interval. Specifically, assume that $\lambda_0 > 0$. In this case, the optimal choice of λ_z is equal to λ_0. This can be seen by considering the first stage of the optimisation problem in (5'), as follows:

$$\max_{\lambda_z} w_y(z-w)^2/\lambda_z^2 + w_\pi \pi^2 + w_z z^2$$

subject to:

$\lambda_z \in [\lambda_0, \lambda_1]$.

Solving the minimisation part of the problem leads to the following policy rule:

$$i = \frac{\beta E(\pi)+e}{-\lambda_i} \frac{w_\pi \lambda_y}{(w_y + w_\pi \lambda_y^2 + w_z \lambda_0^2)} + \frac{u}{-\lambda_i} + \frac{w}{-\lambda_i} \frac{w_z \lambda_0}{(w_y + w_\pi \lambda_y^2 + w_z \lambda_0^2)}. \qquad (6)$$

We then can ponder how the presence of uncertainty changes the policy rule in (4). Interestingly, the concern for robustness not only affects how the policymaker would react to financial shocks but also to inflation shocks. In effect, it diminishes the strength of the response to an inflation shock. This result is parallel to the *attenuation*

[11] While we are assuming that the policymaker confronts some uncertainty, another possibility is to assume that economic agents face uncertainty and that the policymaker is certain about the model of the economy (Hansen and Sargent (2007)).

principle (Brainard (1967)), which implies that if the policymaker is unsure about an effect, then it should proceed only gradually.

Nonetheless, we underscore that it is not always the case that the agent would attenuate or augment its response to a shock to the financial variable, both in absolute terms and relative to the model under certainty.

Being more specific, the response to a shock depends on how $w_z\lambda_0(1-w_z\lambda_0)/(-\lambda_i)$ and $w_y + w_\pi\lambda_y^2$ compare to each other. We note that the first expression is a parabola as a function of λ_0. So, if $w_z\lambda_0(1-w_z\lambda_0)/(-\lambda_i) > (<)\, w_y + w_\pi\lambda_y^2$, then one would have a less (more) than proportional response.

Relative to the model with certainty in (3), the kind of response depends on how $\lambda_0(w_y + w_\pi\lambda_y^2 + w_z\lambda_z^2) - \lambda_z w_z\lambda_0^2$ and $(\lambda_z w_y + \lambda_z w_\pi\lambda_y^2)$ compare to each other. Note that λ_z is only known in the model with certainty. Similarly, $\lambda_0(w_y + w_\pi\lambda_y^2 + w_z\lambda_z^2) - \lambda_z w_z\lambda_0^2$ is a parabola with respect to λ_0. Hence, if $\lambda_0(w_y + w_\pi\lambda_y^2 + w_z\lambda_z^2) - \lambda_z w_z\lambda_0^2 < (>)(\lambda_z w_y + \lambda_z w_\pi\lambda_y^2)$, the response is then attenuated (augmented). This last case underscores that the *attenuation principle* is not a general result (as also emphasised by Giannoni (2002)). It depends on a plethora of factors, such as the structure of the model, the parameters and variables that the agent is uncertain about, among other factors.

To provide a more concrete interpretation in this context, consider the following expressions:

$$\lambda_0(w_y + w_\pi\lambda_y^2 + w_z\lambda_z^2) - \lambda_z w_z\lambda_0^2 \tag{7}$$

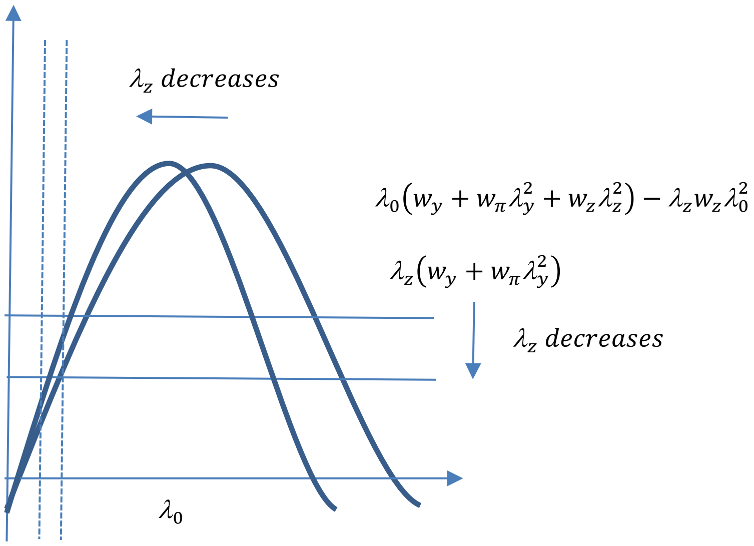
$$\lambda_z(w_y + w_\pi\lambda_y^2) \tag{8}$$

We will focus on the case in which λ_0 is small.[12] If λ_0 is sufficiently small, the rule calls for an attenuated response. One can think of the difference $\lambda_z - \lambda_0$ as a measure of relative uncertainty.[13] It depends on the impact of output on the financial variable, based on the value of the parameter in the model with certainty, in (3), and the lower bound of the interval of λ_z in model (5).

12 As a second case, its holds when λ_0 is sufficiently large. But since it is the lower bound of the interval, we stick to the first case.

13 Note that $-\log(\lambda_z - \lambda_0)$ is the entropy of a uniform distribution with parameters $[\lambda_0, \lambda_z]$. In a robustness setup under continuous-time, the distance between models is measured by their relative entropy.

Characterisation of the attenuated and augmented responses | Graph 1



The intuition underlying the model is as follows. The policymaker assesses the magnitude of the possible effect (λ_z) relative to the uncertainty outcome ($\lambda_z - \lambda_0$). If its magnitude is large relative to its uncertainty, the response will be augmented. We interpret this as an effect that is too important to be possibly ignored. However, if its magnitude is small relative to its uncertainty, the response will be attenuated. In this case, the policymaker's *ambiguity aversion* dominates.

If the knowledge of λ_z were only somewhat uncertain, one could find some support for leaning against wind. Although one might be uncertain about the relationship between output and the financial variable, there could be a basis for using the policy rate for macroprudential ends. In this case, λ_z is relevant with an acceptable level of uncertainty.

In this vein, Stein (2013) argues that: "[...] while monetary policy may not be quite the right tool for the job, it has one important advantage relative to supervision and regulation –namely that it gets in all of the cracks." One possible interpretation of the tool not being quite right is the presence of uncertainty, while an interpretation of its advantage is the magnitude of the effect resulting from its reach.

The approach of Freixas et al (2015) is related. They argue for using the interest rate for macroprudential ends while a better understanding of how other macroprudential policies really work is gained. More generally, this points to the relevance of learning more about macroprudential policy and, in tandem, about the potential importance of monetary models incorporating a macroprudential extension.

Evidently, uncertainty about a specific parameter is only one of the features of a model deemed relevant by a policymaker. There might be other aspects to be concerned with. In the next subsection, we consider the case of a financial variable that comprises a measurement error which the policymaker is concerned with.

Measurement error in the financial variable

We explore a problem in which the financial variable has a measurement error. Specifically, the policymaker observes $\hat{z}$, instead of the financial variable z, with a measurement error $\hat{z} = z + \epsilon$. As a result, it solves the following problem:

$$\min_{y,\pi,z} \max_{\epsilon} w_y y^2 + w_\pi \pi^2 + w_z \hat{z}^2$$

subject to:

$\pi = \beta E(\pi) + \lambda_y y + e$, where $\lambda_y > 0$ ("Phillips curve");

$y = \lambda_i i \ + u$, where $\lambda_i < 0$ ("IS curve");

$\hat{z} = z + \epsilon$, where $\epsilon \in [\epsilon_0, \epsilon_1]$; and

$z = \lambda_z y + w$, where $\lambda_z > 0$ ("Financial relation").

We assume that the measurement error is uncorrelated with shocks. In addition, we assume that $E(\epsilon) = 0$ and $cov(\epsilon, y) = 0$. The latter assumption allows for an unbiased estimator of λ_z. In short, the financial variable z is observed with an error, which the policymaker is uncertain about.

The solution to the problem: $\max_\epsilon w_y y^2 + w_\pi \pi^2 + w_z \hat{z}^2$ is a function of ϵ_0, ϵ_1 and z. To solve it, we further assume that the interval $[\epsilon_0, \epsilon_1]$ is symmetric with respect to zero. Accordingly, we have that if $\hat{z} > 0$, then $\epsilon^* = \epsilon_1$, and if $\hat{z} < 0$, then $\epsilon^* = \epsilon_0$, which implies the following policy rule:

$$i = \frac{\beta E(\pi)+e}{-\lambda_i} \frac{w_\pi \lambda_y}{(w_y + w_\pi \lambda_y^2 + w_z \lambda_z^2)} + \frac{u}{-\lambda_i} + \frac{w+\epsilon_0}{-\lambda_i} \frac{w_z \lambda_z}{(w_y + w_\pi \lambda_y^2 + w_z \lambda_z^2)}, \text{ if } \hat{z} < 0;$$

$$i = \frac{\beta E(\pi)+e}{-\lambda_i} \frac{w_\pi \lambda_y}{(w_y + w_\pi \lambda_y^2 + w_z \lambda_z^2)} + \frac{u}{-\lambda_i} + \frac{w+\epsilon_1}{-\lambda_i} \frac{w_z \lambda_z}{(w_y + w_\pi \lambda_y^2 + w_z \lambda_z^2)}, \text{ if } \hat{z} > 0.$$

This rule leads to an intermittent interest rate policy with respect to z. We see two possible interpretations. One is that it accounts for an unobserved regime-switching variable captured by the change in the sign of $\hat{z}$. A second is that the rule is too erratic with respect to z. This can be seen as being supportive of the clean approach. As is well known, this approach posits that financial imbalances are too hard to identify in real time (Blanchard, Dell'Ariccia and Mauro (2010)).[14, 15]

On a related matter, Kocherlakota (2016) explores policy rules in which inflation involves an uncertain measurement error.[16] He conceives the implementation of monetary policy as a principal-agent problem, possibly having a rule as part of their contract. He argues that an uncertain measurement error is, by and large, non-contractual. He refers to such a variable as nonrulable; ie it cannot be part of a sensible policy rule. Kocherlakota characterises his solution in terms of the inflation record vis-à-vis the level of measurement uncertainty. He concludes that using a policy rule that

[14] A related measurement difficulty also takes place, for example, in the case of credit. Albeit the importance of credit for financial stability is well documented, the key distinction between excessive credit growth due to a shift in demand or supply remains. Freixas et al (2015) underscore that the latter case is associated with longer and deeper financial crises.

[15] The extent to which monetary policy affects credit is also an issue. Romer and Romer (1990), for example, argue that it has a limited influence.

[16] In fact, he assumes that a component of inflation has an uncertain measurement error.

involves a component of inflation with an uncertain measurement error is only warranted if the inflation record is poor relative to the referred uncertainty.

In this context, a macroprudential goal implemented by extending a policy rule with a financial variable, whose measurement is uncertain, has significant implications. For instance, we could interpret Kocherlakota's (2016) result as a forewarning. This is particularly the case for emerging market economies that have no more than a satisfactory inflation record, and in which introducing a macroprudential mandate could lead to a decline in the inflation record. Still, there might be specific cases in which a central bank might prefer to be subject to an explicit policy rule. More generally, as Freixas et al (2015) have underlined, a macroprudential policy mandate would be difficult to implement in practice since it lacks a generally accepted measurable target.

Final remarks pertaining the first part

Using a robustness approach to assess the implications of including a macroprudential concern in a standard monetary policy rule is a useful approach. In fact, it sheds some light on the relationship between macroprudential and monetary policies. For instance, it is useful to assess some of the conditions under which a monetary rule could be a function of a financial variable.

In this context, it is worth recalling three of our motivations in appending a financial variable to a monetary policy rule. First, there is as a recognition that monetary policy affects financial stability. This is important since monetary policy is not only relevant for the time dimension of systemic risk but also for the cross-sectional one since it affects all financial intermediaries (Stein (2013)).

Second, the incorporation of a macroprudential concern into a standard monetary policy rule poses a challenge given that our understanding of how best to implement macroprudential policy is progressing. Thus, policymakers could decide to modify monetary policy by introducing a macroprudential rationale while learning more about implementation and potential implications (Freixas et al (2015)).

Third, it could be a way of reconciling different views of the role of monetary policy in a macroprudential policy framework. We think that this approach could be useful in considering a framework that unifies a number of approaches on the use of monetary policy for macroprudential ends.

On the international coordination of macroprudential policies

> "[…] cooperation is a fair-weather phenomenon." (Schwartz (2000))

In this section, we explore a number of aspects relating to the international coordination of macroprudential policies. To that end, we draw results from two strands of the economic literature.

The first strand is the provision of public goods (Morrissey et al (2002)), which underscores the challenges that collective action entails (Olson (1965)). The literature on public goods offers useful elements to understand some of the factors leading to, or perhaps eluding, coordination. The logic of collective action can help us consider the incentives that different types of agent have in reaching a coordination equilibrium.

The second strand is game theory (Gibbons (1992) and Mailath et al (2006)). In this strand, a public good is achieved in the absence of a government, giving place to a non-cooperative game. Three other features stand. First, achieving financial stability is a risky endeavor. Second, one can plausibly assume that as more economies opt to coordinate, the benefits and probability of maintaining financial stability increase. Thus, the expected aggregate net benefits of coordination are endogenous to the number of agents involved. Third, given agents' characteristics; in particular, the net benefits they can expect, their incentives to coordinate can differ markedly. One could more generally see this problem as a non-cooperative repeated game.

Game with deterministic benefits

To set the stage, we start with a simple setup in which a large number of countries are considering whether to coordinate in the provision of an international public good. In this case, there is no risk and each player faces the same constant unit benefits and costs. The only decision each one has to take is whether to coordinate or not.

If player i decides to coordinate, its pay-off is then given by:

$$(B \cdot n)/N \ + \ B/N \qquad (1)$$

where B is the benefit that each player provides when coordinating, n is the number of players that opt to coordinate, and N is the total number of players. Note that the total benefits $B \cdot (n+1)$ are equally shared among all countries (N) regardless of their decision. In addition, C is the unit cost, which is borne by each individual country that decides to coordinate.

Accordingly, if player i decides not to coordinate, its pay-off is given by:

$$(B \cdot n)/N \qquad (2)$$

Naturally, if it decides not to coordinate, it incurs in no cost. However, since the good is non-rival and non-excludable, the player still obtains its proportional share of the benefits. This choice, in effect, would make the player a free-rider.

A player would opt for coordination if the pay-off in (1) is greater than (2). This happens if and only if:

$$B/N \ > \ C \qquad (3)$$

Hence, it would do so if the individual cost is sufficiently small relative to the benefit. This inequality highlights a well-known result, collective action is harder to achieve in large groups (Olson (1965)). In effect, the larger N is, the less likely it is that (3) will hold.

Moreover, to see under what conditions coordination will be socially optimal, it is illustrative to analyse the social planner's welfare problem. Hence, the provision of the public good will lead to an increase in welfare of $N(B-C)$ relative to the no coordination equilibrium. To obtain this result, we add the individual benefits in (1) of all N players, assuming that all players opt to coordinate (ie, $n = N$).

Full participation will be welfare-enhancing provided that $B > C$. Thus, even if we have that $B/N < C$, a situation in which countries acting individually will *not* coordinate, we have that $B > C$ and, thus, the coordination equilibrium would be welfare-enhancing. This is a standard result in the provision of public goods.[17]

Game with stochastic benefits

We tweak this model in three ways. First, we assume that there are risks involved in the provision of the public good. Achieving financial stability is, after all, an uncertain undertaking. Hence, there is a positive probability that financial stability might not be achieved, albeit reasonable efforts are made to attain it.

Second, we assume that the probability of a financial crisis is a function of the number of players opting to coordinate. That is, the more players opting to coordinate, the smaller the probability of a financial crisis.

Third, we assume that there are two types of player, characterised by the benefit and cost each one gets if it decides to coordinate or not, as well as the impact that each one has on the probability of achieving global financial stability.

Thus, if player i of type j decides to coordinate, its expected pay-off is:

$(F_1(n_1, n_2)n_1 + F_2(n_1, n_2)n_2)/N + F_j\ (n_1, n_2)/N - C_j(n_1, n_2)$,

with probability $p(n_1, n_2)$; and

$(S_1(n_1, n_2)n_1 + S_2(n_1, n_2)n_2)/N + S_j\ (n_1, n_2)/N - C_j(n_1, n_2)$,

with probability $1 - p(n_1, n_2)$;

where $j = 1$ or 2, n_j is the number players of type j opting for coordination, N_j is the total number of players of type j, and N is the total number of players (ie, $N_1 + N_2 = N$).

On the other hand, if a player decides not to coordinate, its pay-off is given by:

$(F_1(n_1, n_2)n_1 + F_2(n_1, n_2)n_2)/N$, with probability $p(n_1, n_2)$; and (5)

$(S_1(n_1, n_2)n_1 + S_2(n_1, n_2)n_2)/N$, with probability $1 - p(n_1, n_2)$.

We associate the pay-off $F_j(n_1, n_2)$ with a financial crisis. Thus, $p\ (n_1, n_2)$ is presumed to be "small" (in line with Reinhart and Rogoff (2009)). Correspondingly, we think of $S_j(n_1, n_2)$ as the pay-off associated with a state of financial stability. Naturally, we assume that $F_j(n_1, n_2) \ll S_j(n_1, n_2)$; ie there are significant costs associated with a financial crisis. Furthermore, we assume the following properties:

$\frac{\partial F_j}{\partial n_1} > \frac{\partial F_j}{\partial n_2} > 0$; (6)

$\frac{\partial S_j}{\partial n_1} > \frac{\partial S_j}{\partial n_2} > 0$; and,

$\frac{\partial p}{\partial n_1} < \frac{\partial p}{\partial n_2} < 0$.

17 These types of problem have been studied at least since Lloyd (1833). See also Hardin (1968), Ferroni and Mody (2002) and Morrissey et al (2002).

In short, type 1 players have a greater influence in the determination of the expected benefits of coordination. All in all, the expected benefits, individual and collective, depend on the type and the number of agents that opt for coordination.

To see some of the factors that drive the decision to opt for coordination, consider its expected benefits. To simplify our notation, we omit the variables on which F, S, p and C depend.

An agent of type j will opt for coordination if:

$$\left[(F_1 n_1 + F_2 n_2)/N \; + F_j/N\right]p + \left[(S_1 n_1 + S_2 n_2)/N \; + S_j/N\right](1-p) - C_j$$

is greater than:

$$[(F_1 n_1 + F_2 n_2)/N\,]p + [(S_1 n_1 + S_2 n_2)/N\,](1-\;p).$$

This is the case if and only if the following inequality holds:

$$\left[F_j/N\,\right]p + \left[S_j/N\,\right](1-\;p) > C_j. \qquad (7)$$

This leads to the following implications, all else being equal. First, coordination is more likely the larger the values of F_j and S_j are (ie the smaller the costs of a financial crisis and the greater the benefits of financial stability), and the smaller the costs C_j. Second, in general, the larger the group the harder it is to observe a higher degree of coordination, in parallel with the original case in (3) but not if F_j and S_j increase sufficiently fast as n_1 and n_2 increase. Third, one is more likely to observe greater coordination if $\partial p/\partial n_j < 0$, as we have assumed. Note that the role of p is central, since each player faces financial uncertainty regardless of its decision to coordinate. Finally, all else being equal, type 1 players have more incentives to coordinate than type 2 players as inequality (7) is more likely to hold in their case.[18]

Olson (1965) distinguishes between three types of player, two of which have an interpretation in our context. If intermediate types, for instance, were to withdraw their contribution, this would lead to a notable decrease in the supply of the public good. In our model, this type is similar to 1. On the other hand, latent types are players that could withhold their contribution without causing a notable reduction in the public good. In our model, these are similar to 2.[19] In our case, such features are captured by the properties of (6).

One could think of type 1 players as having a significant presence in the global financial system, possibly because of the presence of their banks abroad or of foreign banks in their economies. One could think of type 2 agents as playing a smaller role in the global financial system. In general, they are not as financially open. Importantly, type 2 players might have stronger incentives not to coordinate.

All in all, the type of a player is key to the decision to coordinate. This defines a situation that is markedly different from one in which the net benefits are deterministic. Relative to (3), whether collective action takes place will depend on the extent to which the net expected benefits increase as more agents opt to coordinate.

18 Assuming that differences in costs do not offset differences in benefits due to their types.

19 On a related note, the presence of a dominant type is similar to Olson's (1965) third type, which has two features. First, compared to other players, the units of public good it can provide are significantly greater. Second, the benefits it gets are therefore greater; in fact, it is in its own interest to unilaterally provide the public good. If the equilibrium is such that the dominant player opts for "coordinating"; then the bulk of the public good will be provided.

In this context, it is also illustrative to look at the welfare gains by considering the central planner's solution to the game. Such a gain is relative to the no coordination equilibrium. To calculate it, we add the expected individual benefits for both types of player, assuming that all of them opt for coordination.

$$[F_1N_1 + F_2N_2]p(N_1, N_2) + [S_1N_1 + S_2N_2]\big(1 - p\,(N_1, N_2)\big) - N_1C_1 - N_2C_2.$$

The welfare gain is positive provided that:

$$[F_1N_1 + F_2N_2]p(N_1, N_2) + [S_1N_1 + S_2N_2]\big(1 - p\,(N_1, N_2)\big) > N_1C_1 + N_2C_2. \qquad (8)$$

Since $F_j, S_j,\ C_j$ and p are not constant, inequality (8) is more likely to hold, particularly if type 1 players coordinate, relative to the model with deterministic benefits, as in (3).

Of course, we assume that certain properties of F, S, C and p make agents more likely to coordinate. They capture the idea that, in general, the more agents that opt to coordinate, the greater the expected net unit benefit associated with financial stability.

Although we see such properties as plausible, we think that the following questions naturally arise. First, what factors determine them? Second, what is done and what could be done to enhance such properties? Are players doing something, perhaps inadvertently, that is contrary to their benefit? All these considerations have a bearing on the likelihood and sustainability of coordination.

In this context, we succinctly describe a number of factors that could influence the determination of the referred properties, including the achievement of a coordination equilibrium. First, at a basic level, having the same accounting and financial conventions will be advantageous to coordination. For instance, the International Financial Reporting Standards (IFRS) are an effort in this direction. They, however, have not been free from challenges (Financial Times (2009)).

Second, a reason why there is a strong case for coordination is the presence of regulatory arbitrage (Boyer and Kempf (2016)). Macroprudential policy without coordination could lead to less effective policies as agents engage in regulatory arbitrage. Evidently, this could be seen as spillover effects. Conversely, this arbitrage might imply an increase in external risk factors. These effects can be seen as spillbacks.

Third, the implementation of risk management frameworks, such as the Basel capital requirements (Basel III), the liquidity coverage ratio (LCR), and the net stable funding ratio (NFSR) are central initiatives (BIS (2011, 2013 and 2014, respectively)). One could argue that financial stability is more certain as more economies implement adequate risk management frameworks.

In addition, evidence put forward by Rey (2013) and Borio (2012), among others, provide us with further reasons for macroprudential policy coordination. Both papers underscore the growing influence of global factors in economies' financial states. We believe that this is particularly relevant for small open economies, making common policy responses more likely and viable.

Final remarks pertaining the second part

There are a number of difficulties in achieving a welfare-enhancing equilibrium in games (Nash (1950)). The provision of global public goods is a particularly interesting case. There are various circumstances under which coordination could be welfare-enhancing but agents acting rationally opt for not doing so. This could have dramatic implications. In a sense, Olson (1965) was less concerned about understanding how coordination took place than about its pervasive absence.

Understanding what characteristics and actions would make coordination more likely and less fragile is valuable. Of course, one general aspect of the games we described is that they are repeated. Thus, understanding how they are maintained is as important as understanding how they are achieved.

On a closely related note, we did not explicitly consider the temporal dimension of a financial crisis. This is important since financial crises are generally infrequent (Reinhart and Rogoff (2009)). While coordinating to minimise the probability of a financial crisis entails periodic costs, its key benefits occur in states of nature with a low probability of occurrence (ie avoiding a crisis).

This could have implications for the incentives faced by government officials with a relatively short planning horizon. Some might decide to "gamble" by not coordinating, hoping that no financial crisis would take place within their term. Hence, there might be a political economy dimension to coordination.

Crucially, international institutions and fora, such as the BIS, the G20 and the IMF, among others, play a key role in making coordination equilibria more likely. As our results highlight, achieving coordination is unlikely but doing so is in general socially optimal.

In sum, our contention is that for stronger coordination to strengthen global financial stability, we need to reassess the benefits of such coordination and, in tandem, the costs of a financial crisis. Macroprudential policy coordination has to be supported by the realisation that it is in our economies' best interest to coordinate. Not doing so could eventually bring about significant and enduring costs.

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