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Rules versus Discretion in Central Bank Communication

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JEL Codes: D83, D84, E58,

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1 Introduction

For the past three decades, Central Bank communication has been recognized as a powerful instrument to help private agents to take better informed actions. However, Central Bank's and agents' interests are not always aligned. What should a Central Bank reveal to agents? Should the Central Bank commit to a set of rules for its communication?

The contribution of this paper is to answer these questions in a formal model of communication. We build on the model of speculative currency attacks of Morris and Shin (1998) and introduce a Central Bank that can send credible public signals about the state of fundamentals of the economy. Commitment is modeled as the ability of the Central Bank to choose a disclosure rule before observing the state.

We find that commitment plays a very specific role in Central Bank communication. Our results show that commitment is neither sufficient nor necessary for the Central Bank to achieve high payoffs, but instead it guarantees a minimum payoff that could not be assured in its absence.

This result provides a complementary theory for the importance of commitment for Central Banks. Traditionally, commitment has been argued to enable a player to achieve its highest payoff. For instance, Kydland and Prescott (1977) argue that commitment allows the policy maker to achieve a payoff greater than what would be possible without commitment; in Albanesi et al. (2003), commitment allows the Central Bank to select its most preferred equilibrium. In contrast, our model displays multiple equilibria in the game without commitment as well as in the game with commitment; moreover, the upper bound for the Central Bank's payoff is the same in both games. Commitment is beneficial only to the extent that it increases the lower bound of the set of equilibrium payoffs for the Central Bank.

The distinctive feature of our model is the presence of a continuum of speculators with private information and actions that are strategic complements. Strategic complementary is one source of multiple equilibria: attacking the currency is more likely to be profitable when other speculators are attacking. This the self-fulfilling crises aspect of our model. In the absence of commitment, there is an additional source of multiplicity. Speculators expect the Central Bank to follow a particular disclosure rule and, in equilibrium, the Central Bank conforms to these expectations. The Central Bank is thus subject to expectation traps. The combination of self-fulfilling crises and expectation traps leads to an *anything goes* result: both the Central Bank's most and least preferred allocations can be supported in equilibrium, and so can anything in between.

Commitment eliminates expectation traps but not self-fulfilling crises. In particular, even with commitment, the Central Bank is unable to implement its most preferred allocation without being subject to self-fulfilling crises. We show, however, that the least desirable allocations - which can be supported in equilibrium if the expectation trap issue is severe - can be avoided by the Central Bank if it commits to a particular disclosure rule.

In order to do so, we study the Central Bank's problem under commitment. We assume that if, for a given disclosure rule, there are multiple equilibria of the subgame played by speculators, then the Central Bank only cares about its lowest equilibrium payoff. This allows us to find a lower bound for the Central Bank's payoff.

We show that the Central Bank cannot improve upon an information structure that sends only two messages. Under the optimal information structure, the public signal works as an action recommendation: for each message, there is a unique action that speculators can take in equilibrium (in particular, speculators' behavior does not rely on their private information). Thus, speculators perfectly coordinate their actions and the Central Bank shuts down the possibility of self-fulfilling crises.

Our model is able to rationalize a negative empirical correlation between commitment and Central Bank "performance". Indeed, if Central Banks could freely adopt commitment technologies, only those who perform very poorly would choose to do so. The expected payoff of those Central Banks would increase, but, according to our model, it would still be inferior to those of Central Banks that choose to remain discretionary. We believe that this is of great important in policy debates and serves as a warning about the interpretation of empirical studies that make cross-section comparisons of Central Bank performance.[1]

[1] This self-selection mechanism resembles and could possibly justify the results in the empirical literature on inflation targeting. For example, Ball and Sheridan (2004) argue that rules (i.e., inflation targeting) were adopted by countries that were initially in a bad equilibrium (i.e., experienced high

This paper is organized as follows. In the remainder of this section, we review the literature. In Section 2, we describe the basic model. We solve the model when the Central Bank cannot commit to a disclosure rule in Section 3. In Section 4, we introduce commitment to the Central Bank's problem. We conclude in Section 5. Omitted proofs are in the Appendix.

Related Literature, Since the 1990's, communication has become an increasingly important instrument for Central Banks.[2] There has been a movement toward greater Central Bank transparency, which is not restricted to developed economies, and this has followed the trend of Central Bank independence (see, for example, Dincer and Eichengreen (2014)). This phenomenon has lead to an extensive, and growing, literature on Central Bank communication. Numerous works, mostly empirical, have tried to analyze the effects of Central Bank communication on economic outcomes.

As most of the empirical work is performed with a reduced-form empirical strategy, the mechanism through which Central Bank communication works is unclear. The empirical findings on the effects of communication on economic outcomes are at times conflicting and inconclusive.[3] Our paper suggests that, aside from methodological issues, knowing whether the Central Bank can commit to a disclosure rule is essential in order to understand and estimate the impact of communication.

This paper is related to the literature on self-fulfilling crises when payoffs are not common knowledge. The idea that small deviations from common knowledge can have a large impact on equilibrium outcomes dates back at least to Rubinstein's mail game (Rubinstein (1989)), and has gained great attention since Carlsson and van Damme (1993) and Morris and Shin (1998).

We build on the model of Morris and Shin (1998) to introduce a public signal

inflation before inflation targeting was implemented).

[2] Studying exchange rate interventions, Fratzscher (2008) argues that communication can sometimes substitute direct intervention, but direct intervention and the appropriate communication are complements.

[3] For instance, Jansen and De Haan (2007) find that the European Central Bank communication helps to anchor expectations, but their results are not consistently significant across time. See Blinder et al. (2008) for many examples in which the empirical literature has reached conflicting results.

that generates partial common knowledge. In different settings, the interaction between public and private signals in coordination games has been studied in Morris and Shin (2002), Hellwig (2002), Angeletos and Pavan (2007) and Angeletos et al. (2007).

In particular, our paper contributes to the literature on the role of policy choices in coordination games, as in Angeletos et al. (2006).Breaking the uniqueness result in Morris and Shin (1998), Angeletos et al. (2006) point out that policy interventions without commitment convey information about the fundamentals, allowing agents to coordinate their actions and leading to multiple equilibria. Our model shares this feature but, by restricting attention to communication policies, we are able to find all equilibrium payoffs for the Central Bank and to show how severe expectation traps can be. Moreover, we show how commitment alleviates - but not completely eliminates - the threat that posed by multiplicity.

This paper also relates to the literature on Bayesian persuasion, pioneered by Kamenica and Gentzkow (2011). They study the optimal signal structure from the perspective of a sender who wants to influence a rational Bayesian receiver to take the sender's preferred action. We address this question of information design in the context of a coordination model in which the sender faces a continuum of privately informed receivers. In our model, not only the sender faces more than one receiver, but it is also restricted to sending the same message to all of them. In a similar setting, Goldstein and Huang (2016) characterize the optimal policy for a sender who is restricted to announcing a threshold state of fundamentals below which the status quo is abandoned.[4] In our model, this is equivalent to restricting the Central Bank to sending only two signals. In simultaneous and independent work, Inostroza and Pavan (2019) study Bayesian persuasion in coordination games. They characterize the optimal information structure from the sender's perspective and, as we show in Section 4, find that it coordinates private agents "*on the same course of action*." In our paper, we analyze the distinction between what the sender can achieve with and without commitment, while they focus on policy with commitment.

[4] They also restrict speculators' strategies to cutoff rules.

2 Model

We extend the model of speculative currency attacks of Morris and Shin (1998) by introducing Central Bank communication. Our model features a Central Bank that can send strategic public signals about the state of fundamentals before speculators decide whether to attack the currency peg or not.

2.1 Actions and payoffs

The state of fundamentals is represented by θ, which is uniformly distributed over $[0, 1]$. The exchange rate is initially pegged by the Central Bank at e^*, and its value in the absence of intervention is given by $f(\theta)$. We assume that $f(\cdot)$ is continuous and strictly increasing, with $e^* \geq f(\theta)$ for all θ. A continuum of speculators of measure one has to simultaneously decide whether to attack the peg.

A speculator attacks the peg by selling short one unit of the currency at a cost $t > 0$. The payoff to a speculator that attacks when the peg is abandoned is $e^* - f(\theta) - t$, whereas the payoff when the peg is defended is $-t$. The payoff of not attacking is zero. We assume that it is not profitable for speculators to attack if fundamentals are strong enough ($e^* - f(1) - t < 0$).

The Central Bank derives a value $v > 0$ from maintaining the currency peg. There is a cost $c(\alpha, \theta)$ to defend the peg, where α is the mass of speculators who attack. The cost $c(\cdot, \cdot)$ is continuous, strictly increasing in α and strictly decreasing in θ. Hence, the payoff from defending the peg is $v - c(\alpha, \theta)$, and the payoff from abandoning the peg is zero. We assume that the Central Bank abandons the peg if sufficiently many speculators attack ($c(1, 1) > v$), or if the fundamentals are sufficiently weak ($c(0, 0) > v$).

Let $\underline{\theta}$ be the solution to $v = c(0, \theta)$ and $\overline{\theta}$ be the solution to $e^* - f(\theta) - t = 0$. We assume that $\underline{\theta} < \overline{\theta}$.[5] When the state is common knowledge, the parameters $\underline{\theta}$ and $\overline{\theta}$ define the regions where speculators have a dominant strategy: if $\theta \in [0, \underline{\theta}]$, attacking is a dominant strategy; if $\theta \in (\overline{\theta}, 1]$, not attacking is a dominant strategy. If $\theta \in (\underline{\theta}, \overline{\theta}]$, it is only profitable to attack if sufficiently many speculators do so.

[5] This condition holds for a large v and a small t.

Let $a(\cdot)$ denote the critical size of attack that induces the Central Bank to abandon the peg. We have that for $\theta \leq \underline{\theta}$, $a(\theta) = 0$, and for $\theta > \underline{\theta}$, $a(\theta)$ is the solution to $v = c(a, \theta)$. Note that, given our assumptions on $c(\cdot, \cdot)$, we have that $a(\cdot)$ is continuous in θ and strictly increasing if $\theta > \underline{\theta}$.

2.2 Information

Speculators cannot directly observe θ. Each speculator i observes a private signal x_i, where

$$x_i = \theta + \varepsilon_i.$$

The idiosyncratic noise ε_i is drawn from a distribution with a continuous probability density function $g(\cdot)$, and cumulative distribution function $G(\cdot)$. Each ε_i is independent and identically distributed across speculators, and independent of θ. We assume that support$(g) = [-\varepsilon, \varepsilon]$, $\varepsilon > 0$, and, as in Morris and Shin (1998), that $2\varepsilon < \min\{\underline{\theta}, 1 - \overline{\theta}\}$.

The Central Bank can observe θ and send a public signal y. When the Central Bank cannot commit to a disclosure rule (Section 3), it observes the realized state and sends y, an interval such that $\theta \in y$. When the Central Bank commits to a disclosure rule (Section 4), it chooses a partition $\{y_n\}$ of the state space, $[0, 1]$, and speculators observe the element y_n that contains θ.

3 No commitment

This section analyzes the model when the Central Bank cannot commit to a communication policy. We first characterize all possible equilibrium payoffs for the Central Bank, and then discuss the issues of self-fulfilling crises and expectation traps.

3.1 Timing

The game without commitment has three stages. In the first stage, nature draws θ and the Central Bank observes the realized state. In the second stage, the Central Bank sends a public signal y. Speculators observe the public signal and their own private signals and simultaneously decide whether to attack the peg or not. In the third stage, the Central Bank observes the size of the attack and decides whether to maintain the peg or to abandon it. The last stage of the game is straightforward, and the Central Bank abandons the peg if only if the size of the attack is greater than $a(\theta)$.

3.2 Equilibrium

We take the Central Bank's behavior in the last stage of the game as given and focus on its communication strategy. A strategy for the Central Bank is a function Y such that $Y(\theta)$ is a closed interval with $\theta \in Y(\theta)$ for all θ, i.e., the range of fundamentals disclosed by the Central Bank must include the realized state.[6] A typical public signal is denoted by y.

A strategy for a speculator is a function π such that, for every private signal x and every public signal y, $\pi(x, y)$ determines the probability of attacking the peg.

In the absence of commitment, the game between Central Bank and speculators can be interpreted as a signaling game in which θ is the Central Bank's type. The equilibrium concept in this section is the Perfect Bayesian Equilibrium (PBE) with symmetric strategies for the speculators.

Definition 1. *The strategy profile* (Y, π) *is a PBE if*

1. *for all* $\theta \in [0, 1]$, $Y(\theta)$ *maximizes the Central Bank's payoff given* π*;*
2. *for every pair of signals* (x, y)*, there exist beliefs* $\phi(\cdot|x, y)$ *about* θ *such that* $\pi(x, y)$ *maximizes the speculator's expected payoff given* ϕ *and that other speculators are using* π*;*

[6] The restriction to closed interval is made only for simplicity.

3. *for each signal y such that $\{\theta : Y(\theta) = y\} \neq \emptyset$, $\phi(\cdot|x, y)$ is given by Bayes' rule, conditional on x and $Y(\theta) = y$;*

4. *for each signal y such that $\{\theta : Y(\theta) = y\} = \emptyset$,*

$$\textit{support}(\phi(\cdot|x, y)) \subset [x - \varepsilon, x + \varepsilon] \cap y.$$

The no-commitment assumption is explicit in the first condition of the definition: the public signal $Y(\theta)$ must maximize the Central Bank's payoff for each realization of θ. Condition 2 states that following π must be optimal for each speculator given posterior beliefs ϕ and the other speculators' strategy, π. The last two conditions impose restrictions on the speculators' posterior beliefs. Beliefs must follow Bayes' rule on the path of play (condition 3), and off-path they must be consistent with private and public signals (condition 4).

In Proposition 1 below, we characterize all possible equilibrium outcomes for the currency peg. We first argue that, if θ is in one of the dominance regions, $[0, \underline{\theta}]$ or $(\overline{\theta}, 1]$, then the fate of the peg is uniquely determined by the fundamentals: if $\theta \leq \underline{\theta}$, the Central Bank finds it optimal to unilaterally abandon the peg; if $\theta > \overline{\theta}$, the Central Bank can prevent attacks by simply disclosing θ, and therefore the peg is maintained in any PBE.

Outside the dominance regions, however, the peg is subject to self-fulfilling crises: for any subset A of $(\underline{\theta}, \overline{\theta}]$, there is a PBE in which the peg is abandoned in A and maintained in its complement, $(\underline{\theta}, \overline{\theta}] \setminus A$. In order to prove this claim, we construct an equilibrium in which speculators expect the Central Bank to fully reveal the state; any deviation is discouraged by pessimistic beliefs and a higher likelihood of attacks. With common knowledge that $\theta \in (\underline{\theta}, \overline{\theta}]$, there can either be a coordinated attack and currency devaluation, or all speculators refrain from attacking and the peg is maintained.[7]

Proposition 1 (PBE outcomes). *In any PBE, the currency peg is abandoned if $\theta \leq \underline{\theta}$, and it is maintained without attacks if $\theta > \overline{\theta}$. Furthermore, for every $A \subset (\underline{\theta}, \overline{\theta}]$, there exits a PBE in which the peg is abandoned in A and maintained in $(\underline{\theta}, \overline{\theta}] \setminus A$.*

[7] There are equilibria in which the Central Bank does not fully disclose the state. In order to prove our results, characterizing every equilibrium with full disclosure suffices.

Proof: The first part of the proposition follows directly from the arguments in the text. For the second part, let $A \subset (\underline{\theta}, \overline{\theta}]$ and $\tilde{A} = [0, \underline{\theta}] \cup A$. In what follows, we construct an equilibrium in which the public signal reveals the true state and speculators attack if and only if $\theta \in \tilde{A}$. The peg is thus abandoned in $\tilde{A}$ and maintained in $[0,1] \setminus \tilde{A}$.

Let a generic public signal be denoted by $y = [\underline{y}, \overline{y}]$. Consider beliefs ϕ given by

$$\phi(\theta|x, y) = \begin{cases} 1, & \text{if } \theta = \max\{x - \varepsilon, \underline{y}\} \\ 0, & \text{otherwise} \end{cases}, \tag{1}$$

and a strategy profile (Y, π) given by

$$\begin{aligned} Y(\theta) &= \{\theta\} \quad \forall \theta, \\ \pi(x, y) &= \begin{cases} 1, & \text{if } \begin{cases} \underline{y} = \overline{y} \in \tilde{A}, \text{ or} \\ \underline{y} < \overline{y} \text{ and } \max\{x - \varepsilon, \underline{y}\} \le \overline{\theta} \end{cases} \\ 0, & \text{otherwise} \end{cases}. \end{aligned}$$

We claim that this strategy profile is a PBE supported by the beliefs described in (1).

Consider speculator i's problem. When $\underline{y} = \overline{y} = \theta$, given the aggregate strategy π, it is only profitable for i to attack if $\underline{y} \in \tilde{A}$, which means that π is optimal on the path of play. Now consider off path signals with $\underline{y} < \overline{y}$. When $\underline{y} > \overline{\theta}$, speculator i knows that $\theta > \overline{\theta}$ and attacking is indeed not profitable. If $\underline{y} \le \overline{\theta}$ and $x_i \le \overline{\theta} + \varepsilon$, then i believes that $\theta = \max\{x_i - \varepsilon, \underline{y}\} \le \overline{\theta}$. Speculator i also believes that every other speculator received a private signal below $\overline{\theta} + \varepsilon$, and that, following π, they all attack. Hence, attacking is profitable. Finally, when $\underline{y} \le \overline{\theta}$ and $x_i > \overline{\theta} + \varepsilon$, speculator i knows that $\theta > \overline{\theta}$, and it is not profitable to attack. Therefore, π is optimal for i, given ϕ and that every other speculator follows π.

Now we show that the Central Bank has no profitable deviation from strategy Y. Since the peg is not attacked on $(\overline{\theta}, 1]$, there can only be a profitable deviation if $\theta \le \overline{\theta}$. A deviation for the Central Bank at θ is public signal $y' = [\underline{y}', \overline{y}']$, such that $\underline{y}' < \overline{y}'$, and $\theta \in y'$. However, according to π, speculators still attack the peg whenever they observe such a public signal. This proves that there is no profitable deviation for the Central Bank and that Y is optimal.

Since ϕ satisfies conditions 3 and 4 of Definition 1, the profile (Y, π) constitutes a PBE. $\square$

Note that the PBE constructed in the proof of Proposition 1 satisfies the intuitive criterion of Cho and Kreps (1987). As argued above, only types in $[0, \overline{\theta}]$ could benefit from a deviation. However, if the speculators know that $\theta \leq \overline{\theta}$, they can coordinate on attacking the currency peg and, in this case, a deviation is not profitable for such a type.

From Proposition 1, we know that, for any $m \in [\underline{\theta}, \overline{\theta}]$, we can find an equilibrium in which the peg is attacked if and only if $\theta \leq m$. In this case, the Central Bank's expected payoff is

$$\int_m^1 (v - c(0, \theta))\, d\theta, \tag{2}$$

which is strictly decreasing in m, for $m > \underline{\theta}$. The expected payoff in (2) can reach any value in

$$\mathcal{V}^{NC} = \left[\int_{\overline{\theta}}^1 v - c(0, \theta) d\theta, \int_{\underline{\theta}}^1 v - c(0, \theta) d\theta \right],$$

that is, for any $\nu \in \mathcal{V}^{NC}$, there is a PBE in which the Central Bank's expected payoff is ν. Moreover, the first part of Proposition 1 implies that expected payoffs outside of $\mathcal{V}^{NC}$ are not achievable. Thus we have characterized all possible equilibrium payoffs for the Central Bank.

Proposition 2 (PBE payoffs). *In any PBE, the Central Bank's expected payoff is an element of $\mathcal{V}^{NC}$. Conversely, for any $\nu \in \mathcal{V}^{NC}$, there exists a PBE in which the Central Bank's expected payoff is ν.*

3.3 Discussion

We have taken a standard model of speculative currency attacks and added to it an informed Central Bank that cannot commit to a disclosure rule. Our model exhibits a multiplicity problem that is inherent to games of coordination, an implication of the strategic complementarity in the speculators' actions. For a given communication policy and beliefs about the fundamentals, there is more than one equilibrium strategy for speculators. The strategy played in equilibrium is determined by speculators' expectations about what others are doing: this is the self-fulfilling nature of equilibria in coordination games.

The introduction of policy without commitment adds another source of multiplicity. The equilibrium is also determined by what speculators expect the policy to be. The Central Bank is thus subject to expectation traps, as is clear from the equilibrium constructed in the proof of Proposition 1. Speculators expect the Central Bank to fully disclose the state, and any deviation is met with an aggressive attacking strategy. The Central Bank finds it optimal to conform to speculators' expectations, and follows a full disclosure policy that opens up the possibility of self-fulfilling crises.

Proposition 2 shows how severe the issue of expectation traps can be. Both the speculators' and the Central Bank' most preeferred outcomes can be achieved in equilibrium. In the former, the peg is attacked whenever a coordinated attack is profitable. In the latter, there are no attacks whenever the Central Bank does not unilaterally abandon the peg. These two extreme cases determine the bounds for the Central Bank's expected payoff in any PBE, and Proposition 2 shows that any payoff in between is possible in equilibrium.

4 Commitment

In this section, we allow the Central Bank to commit to a disclosure rule before observing θ. Since expectation traps are no longer an issue, the Central Bank can design a public signal structure in order to steer speculators' beliefs in the "right" direction. The self-fulfilling aspect of the game, however, persists, and it poses limits to what the Central Bank can achieve. For example, just as in the previous section, the Central Bank's most preferred allocation is an equilibrium outcome, but that can only be achieved if speculators coordinate on the best equilibrium strategy for the Central Bank.

Our goal is to show that commitment allows the Central Bank to set a higher lower bound for its equilibrium payoff. For this purpose, we focus on the worst equilibrium for the Central Bank, in which speculators follow the strategy that minimizes the Central Bank's payoff (or, equivalently, the strategy that maximizes their own payoffs).[8] Therefore, we are interested in finding a communication policy that maximizes the Central Bank's payoff when speculators follow their most aggressive (subgame perfect) strategy. We find that the optimal disclosure rule eliminates self-fulfilling crises in equilibrium and that it ensures a lower bound for the Central Bank's payoff that could not be guaranteed without commitment.

4.1 Public information

In contrast to the previous section, the Central Bank commits to a disclosure rule before observing θ. As in the Bayesian persuasion literature, an interpretation of the disclosure rule is that an independent and credible Central Bank commits to an information acquisition procedure and to publicly releasing its findings.

The Central Bank can partition the space of fundamentals and announce in which interval the realization of θ lies. We denote a partition[9] of $[0,1]$ by $Y = \{y_n\}_{n=1}^N$, where

$$y_1 = [0, m_1], y_2 = (m_1, m_2], ..., y_n = (m_{n-1}, m_n], ..., y_N = (m_{N-1}, 1],$$

for $N > 1$. When the public signal $y = y_n$ is sent, it becomes common knowledge that $\theta \in y_n$. When $N = 1$, we let $y_1 = [0,1]$, which means that the public signal is uninformative.

Given the assumption that the Central Bank commits to a choice of Y before learning the true state θ, there is no *strategic learning*, i.e., the choice of Y does not change the speculators' beliefs about what the Central Bank knows. Since the common prior is uniform, the posterior distribution of θ given a private signal x

[8] This equivalence follows from Lemma 2 and Lemma A.1 in Appendix A.3.

[9] In this exposition, we restrict the analysis to partitions with a finite number of intervals. Our results still hold if partitions can have a countable number of intervals.

and a public signal y has probability density function $\phi(\theta|x, y)$, where[10]

$$\phi(\theta|x, y_n) = \begin{cases} \frac{g(x-\theta)}{G(x-m_{n-1})-G(x-m_n)}, & \text{if } \theta \in y_n \\ 0, & \text{otherwise} \end{cases}. \tag{3}$$

4.2 Equilibrium

We solve this game by backward induction. In the last stage, the Central Bank abandons the peg if and only if the size of the attack is greater than $a(\theta)$. As in the previous section, we take the Central Bank's strategy in the last stage of the game as given. In the second stage, speculators observe the public signal and their own private signals. Anticipating the Central Bank's behavior in the last stage, they simultaneously decide whether to attack the currency peg or not. In the first stage, the Central Bank chooses a partition Y. If there are multiple equilibria in the second stage of the game, we assume that the Central Bank only cares about its lowest equilibrium payoff.[11]

More formally, suppose that the Central Bank chooses a partition $Y = \{y_n\}_{n=0}^{N}$. Let $p_n = m_n - m_{n-1}$ be the probability that θ lies in the interval y_n of the partition. Now consider the subgame that follows the disclosure of $y = y_n$. Denote by V_n the infimum of the Central Bank's equilibrium payoffs when $y = y_n$,[12] and let $V(Y) = \sum_{n=1}^{N} p_n V_n$. The Central Bank's problem is to choose Y in order to maximize $V(Y)$.

As before, let $\pi(x, y)$ be speculators' selling strategy.[13] When all speculators follow $\pi(\cdot, \cdot)$, the size of the attack at θ is given by

$$s(\theta, \pi) = \int_{\theta-\varepsilon}^{\theta+\varepsilon} \pi(x, y(\theta)) g\,(x-\theta)\,dx,$$

[10] There is a finite number of pairs (x, y) that fully reveal θ: when $y = y_n$ and $x = m_n + \varepsilon$, we have $\mathbb{P}(\theta = m_n|y = y_n, x = m_n + \varepsilon) = 1$; likewise, when $y = y_1$ and $x = -\varepsilon$, then $\mathbb{P}(\theta = 0|y = y_1, x = -\varepsilon) = 1$. For all other pairs (x, y), the conditional density of θ is given by (3).

[11] When there is no ambiguity, we say equilibrium when we mean the equilibrium of the subgame that follows the choice of Y.

[12] Such infimum always exists as the Central Bank has the option to abandon the peg, so the equilibrium payoff is bounded below by 0.

[13] For simplicity, we omit the dependence of π on the partition choice Y.

where $y(\theta)$ is the public signal sent according to Y. Thus, the event in which the peg is abandoned is given by

$$A(\pi) = \{\theta : s(\theta, \pi) \geq a(\theta)\},$$

and the expected payoff from attacking the currency given a pair of signals (x, y) is

$$u_y(x, \pi) = \int_{A(\pi)} [e^* - f(\theta)]\phi(\theta|x, y)d\theta - t. \tag{4}$$

In equilibrium, $\pi(x, y) = 1$ if $u_y(x, \pi) > 0$, and $\pi(x, y) = 0$ if $u_y(x, \pi) < 0$.

4.3 Equilibrium properties

Before finding the optimal policy for the Central Bank, we first characterize the speculators' most aggressive strategies for any partition choice Y. In Proposition 3, we show that such strategies will take the form of cutoff rules on their private signals. That is, given a partition Y and a public signal y, speculators attack if and only if their private signal is below some cutoff k.

Let X_y denote the set of possible private signals when the public signal is y.[14] For $k \in [-\varepsilon, 1 + \varepsilon]$, let the indicator function I_k be defined as

$$I_k(x) = \begin{cases} 1, & \text{if } x < k \\ 0, & \text{if } x \geq k \end{cases}.$$

We say that speculators follow a cutoff rule I_k in the subgame that follows the disclosure of public signal y if $\pi(x, y) = I_k(x)$ for all $x \in X_y$. In this case, we replace $\pi(\cdot, y)$ by $I_k(\cdot)$ when it is clear that we are referring to the strategy conditional on public signal y.

Suppose that the state is θ and that speculators follow the cutoff rule I_k after they observe public signal $y(\theta)$. In Appendix A.1, we show that there will be a threshold θ_k which is the largest value of θ at which the Central Bank finds it optimal to abandon the peg. We also show that θ_k is continuous and increasing in

[14] I.e., $X_{y_1} = [-\varepsilon, m_1 + \varepsilon]$ and, for $n > 1$, $X_{y_n} = (m_{n-1} - \varepsilon, m_n + \varepsilon]$.

k, and that $k - \theta_k$ is strictly increasing in k.

Since the currency peg is abandoned if and only if $\theta \leq \theta_k$, the payoff function $u_y(k, I_k)$ is given by

$$u_y(k, I_k) = \int_{k-\varepsilon}^{\theta_k} [e^* - f(\theta)]\phi(\theta|k, y)d\theta - t, \tag{5}$$

for all $k \in X_y$.

In order to characterize the speculators' payoffs when a cutoff strategy is used, we make the following assumption.

Assumption 1. *Let the public signal be y. For any pair of private signals x_1 and x_2, with $x_1 < x_2$, $\Phi(\theta|x_2, y) \leq \Phi(\theta|x_1, y)$ for all θ, where $\Phi(\theta|x, y)$ is the cumulative distribution function of θ conditional on signals x and y.*

This assumption means that the distribution of θ conditional on y and x_2 first-order stochastically dominates the distribution of θ conditional on y and x_1. It is satisfied, for example, if the idiosyncratic noise on $[-\varepsilon, \varepsilon]$ follows a concave or a truncated normal distribution. Assumption 1 leads to the following lemma.

Lemma 1. *Suppose that Assumption 1 is satisfied. When the aggregate strategy is given by I_k, the payoff from attacking the currency, $u_y(x, I_k)$, is decreasing in the private signal x.*

Proof: See Appendix A.2. □

A consequence of Lemma 1 is that if $u_y(k, I_k) = 0$, then following I_k is an equilibrium strategy for speculators that observe the public signal y. As the next lemma shows, characterizing the Central Bank's payoff will be closely related to the existence of cutoff strategies for each realization of the public signal.

Lemma 2. *For a given public signal y,*

i. if $u_y(k, I_k) < 0$ for all $k \in X_y$, then, in any equilibrium, $\pi(x, y) = 0$ for all $x \in X_y$;

ii. if $u_y(k', I_{k'}) \geq 0$ for some $k' \in X_y$, then, in the worst equilibrium for the Central Bank, speculators use the cutoff rule I_k after observing y, where $k = \sup\{k' \in X_y : u_y(k', I_{k'}) \geq 0\}$.

Proof: See Appendix A.3. □

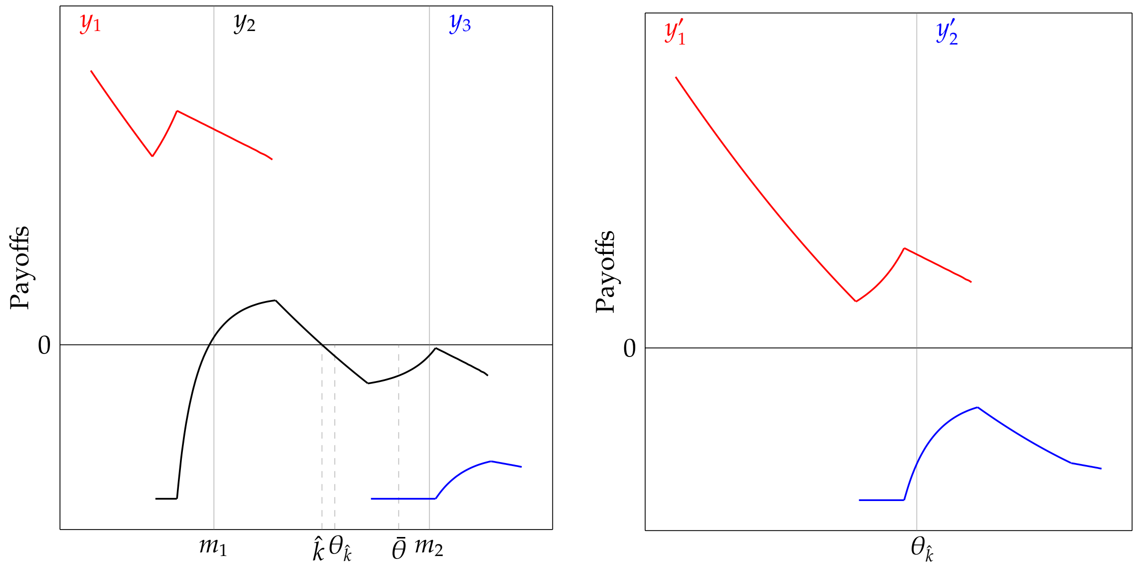
We are now able to characterize the equilibrium strategy that minimizes the Central Bank's payoff in the proposition below, which follows directly from Lemma 2.

Proposition 3 (**Strategies in the worst equilibrium for the Central Bank).** *Consider a partition $Y = \{m_n\}_{n=0}^{N}$. The equilibrium strategy that minimizes the Central Bank's payoff is as follows: for all n such that $m_n \leq \overline{\theta}$, speculators always attack the currency if $y = y_n$; likewise, for all n such that $m_{n-1} \geq \overline{\theta}$, speculators never attack the currency if $y = y_n$. Lastly, if n is such that $m_{n-1} < \overline{\theta} < m_n$, speculators never attack if $u_{y_n}(k, I_k) < 0$ for all $k \in X_{y_n}$; otherwise, speculators follow I_{k_n} after observing y_n, where $k_n = \sup\{k' \in X_{y_n} : u_{y_n}(k', I_{k'}) \geq 0\}$.*

4.4 No loss of generality in two-interval partitions

In this subsection, we show that the Central Bank chooses, without loss of generality, a partition with two elements. Proposition 3 provides the intuition for this result. If there are several n such that $m_n \leq \overline{\theta}$, then the Central Bank can group all these y_n into a single interval without changing its payoff. Likewise, if there are several n such that $m_{n-1} \geq \overline{\theta}$, the Central Bank can group these y_n together. This implies that we can restrict attention to partitions with at most three intervals.

Consider a partition $Y = \{[0, m_1], (m_1, m_2], (m_2, 1]\}$ with $m_1 < \overline{\theta} < m_2$. If there are no attacks in y_2, then the Central Bank can choose $Y' = \{[0, m_1], (m_1, 1]\}$ and obtain the same payoff. Otherwise, it follows from Proposition 3 that there is a cutoff $\hat{k} = \sup\{k \in X_{(m_1,m_2]} : u_{(m_1,m_2]}(k, I_k) \geq 0\}$ such that, in the worst equilibrium for the Central Bank, a speculator attacks after observing $y_2 = (m_1, m_2]$ and $x \leq \hat{k}$. This leads to a threshold $\theta_{\hat{k}} \in (m_1, m_2]$ such that the Central Bank abandons the peg if and only if $\theta \leq \theta_{\hat{k}}$. Cutoff $\hat{k}$ and threshold $\theta_{\hat{k}}$ are depicted in Figure 1(a). The curves represent the payoff functions $u_y(k, I_k)$, and we can see that $u_{y_2}(k, I_k)$ crosses zero at the cutoff $\hat{k}$. Now consider the alternative partition $Y' = \{[0, \theta_{\hat{k}}], (\theta_{\hat{k}}, 1]\}$, with public signals y'_1 and y'_2. The payoff functions under partition Y' are depicted in Figure 1(b). We can prove that $u_{y'_1}(k, I_k) > 0$ for all k, therefore speculators attack the currency after observing y'_1, and the peg is abandoned. Moreover, we can also show that $u_{y'_2}(k, I_k) < 0$ for all k, which implies that speculators refrain from



(a) $P = \{[0, m_1], (m_1, m_2], (m_2, 1]\}$.

(b) $P' = \{[0, \theta_{\hat{k}}], (\theta_{\hat{k}}, 1]\}$.

Figure 1: Two-signal structure without loss of generality. The curves depict the payoff function $u_y(k, I_k)$.

attacking after observing y'_2. Thus, the peg is still abandoned if $\theta \leq \theta_{\hat{k}}$, but the currency is defended at the lowest possible cost for $\theta > \theta_{\hat{k}}$. Since it is cheaper for the Central Bank to maintain the peg with Y', this partition is preferred to Y. This result is formalized in Proposition 4 below .

In order to prove Proposition 4, we use Lemma A.3 (in Appendix A.4), which is an application of the law of total expectation. In that lemma, we show that moving an interval of the partition to the right - that is, increasing the lower bound m_{n-1} or the upper bound m_n - will not increase the payoff $u_{(m_{n-1}, m_n]}(k, I_k)$. This implies that $u_{(\theta_{\hat{k}}, 1]}(k, I_k) < 0$ for all $k \in X_{(\theta_{\hat{k}}, 1]}$. By Proposition 3, there are no attacks when $y = (\theta_{\hat{k}}, 1]$.

Proposition 4 (No loss of generality in two-interval partitions). *For any partition* $Y = \{y_n\}_{n=1}^{N}$, *there exists* $Y' = \{y'_n\}_{n=1}^{N'}$ *with* $N' = 2$, *such that* $V(Y') \geq V(Y)$.

Proof: See Appendix A.4.

4.5 Characterization of the optimal signal structure

Proposition 4 allows us to restrict attention to partitions of two intervals. When $N = 2$, the Central Bank's problem is equivalent to choosing m such that speculators will learn whether $\theta \leq m$ or $\theta > m$. Given the choice of m, they observe the public signal $y \in \{y_L, y_H\}$, drawn as follows:

$$y = \begin{cases} y_L, & \text{if } \theta \in [0, m] \\ y_H, & \text{if } \theta \in (m, 1] \end{cases} .$$

From now on, we refer to y_L and y_H as the *low* and the *high* public signals, respectively.

For the sake of exposition, let us consider the benchmark environment where there is no public signal. As in Morris and Shin (1998), there is a unique equilibrium where speculators use a cutoff strategy I_{k^*}, leading to a threshold θ_{k^*} such that the peg is abandoned if and only if $\theta \leq \theta_{k^*}$. Following the reasoning that leads to Proposition 4, consider the choice of $m = \theta_{k^*}$. In the worst equilibrium for the Central Bank, there is a coordinated attack in $[0, \theta_{k^*}]$, and speculators refrain from attacking in $(\theta_{k^*}, 1]$. We can in fact show that this is the unique equilibrium with partition choice $Y = \{[0, \theta_{k^*}], (\theta_{k^*}, 1]\}$.[15] Thus, as in the game without a public signal, the peg is abandoned if and only if $\theta \leq \theta_{k^*}$.

A few observations are in order. First, note that no speculator attacks the currency when $\theta > \theta_{k^*}$, whereas without the public signal some speculators would still attack the currency for some $\theta > \theta_{k^*}$. Thus, the Central Bank is strictly better off with the introduction of the public signal, since it minimizes the cost of maintaining the peg. Moreover, speculators are also strictly better off now that no one attacks when the peg is maintained, and they all attack when the peg is abandoned.

We also claim that choosing $m > \theta_{k^*}$ is strictly dominated by $m = \theta_{k^*}$, since a higher m either increases the region where the peg is abandoned, or it makes it more costly to defend the peg (or both). This follows from the aforementioned Lemma A.3, which implies that $u_{y_L}(k^*, I_{k^*}) \geq u_{[0,1]}(k^*, I_{k^*}) = 0$. Therefore, speculators will use a cutoff strategy in y_L that will lead to a threshold above θ_{k^*}. Any improvement over $m = \theta_{k^*}$ must be in the direction of reducing m.

[15] See Lemma A.4 in Appendix A.5.

Starting from $m = \theta_{k^*}$, as m decreases, the Central Bank is strictly better off as long as the equilibrium is still unique: reducing m will increase the range of fundamentals where the peg is not attacked. However, reducing m also leads to an increase in $u_{y_H}(k, I_k)$, and eventually it will cross 0 from below for some $k \in X_{y_H}$. When this happens, there is an equilibrium with speculators attacking in y_H, making the Central Bank worse off. Thus, the Central Bank wants to reduce m up to the limit where the equilibrium is still unique. This result is formalized in Proposition 5.

Before presenting the proposition, we define M as

$$M = \{m \in [0, 1] : \text{ in any equilibrium, there is no attack if } \theta \in y_H = (m, 1]\}.$$

Note that $M \neq \emptyset$ because $\overline{\theta} \in M$. We also define $\underline{m}$ as

$$\underline{m} = \inf M.$$

Now we are ready to characterize the optimal partition.

Proposition 5 (Optimal partition). *$V(Y) \leq \overline{V}$ for any partition Y, where*

$$\overline{V} = \lim_{m \downarrow \underline{m}} V(Y^m),$$

and thus the Central Bank can achieve a payoff arbitrarily close to $\overline{V}$.

Proof: See Appendix A.5. □

As argued above, the Central Bank reduces m as long as there are no attacks in $(m, 1]$. It turns out that, for a sufficiently small $m \in M$, the equilibrium is also unique if $y = y_L$, when every speculator attacks the peg.[16] Therefore, speculators perfectly coordinate their actions, attacking if and only if they observe y_L.

Note that an equilibrium only exists if $\underline{m} \in M$. However, the Central Bank can achieve a payoff arbitrarily close to $\overline{V}$ and, for $m \in M$ close enough to $\underline{m}$, speculators always coordinate on the public signal. Thus, in the next subsection, we abstract from this existence issue and, when referring to the optimal partition, we mean a

[16] This follows from Lemma A.4 and Lemma A.5 in the Appendix.

partition Y^m with m close to $\underline{m}$.

4.6 Discussion

The main results in this section are Propositions 4 and 5. In Proposition 4, we show that, despite having access to a broad message space, the Central Bank cannot improve upon a simple two-message rule. The key to this result is that committing to such a disclosure rule leads to a unique equilibrium, whereas a more informative communication strategy generates multiple equilibria, some of which have worse outcomes for the Central Bank.

In Proposition 5, the optimal partition was found by assuming that the Central Bank only cares about its lowest equilibrium payoff. Nevertheless, for any $m \in [\underline{\theta}, \underline{m}]$, there is an equilibrium in which speculators do not attack if $\theta \geq m$. It follows that any payoff in the interval $\mathcal{V}^C = \left[\int_{\underline{m}}^1 v - c(0,\theta)d\theta, \int_{\underline{\theta}}^1 v - c(0,\theta)d\theta\right]$ can be achieved in equilibrium, and therefore the Central Bank cannot improve upon the best allocation of the game without commitment. However, any choice of m in $[\underline{\theta}, \underline{m}]$ opens up the possibility of self-fulfilling crises and payoffs in $\mathcal{V}^C$ cannot be guaranteed. What we show in Proposition 5 is that the Central Bank can guarantee itself a payoff arbitrarily close to $\int_{\underline{m}}^1 v - c(0,\theta)d\theta$ by appropriately shutting down the possibility of self-fulfilling crises. In contrast, when the Central Bank cannot commit to a disclosure rule, its payoff can be as low as $\int_{\underline{\theta}}^1 v - c(0,\theta)d\theta$.

The public signal under commitment can be interpreted as a recommendation from the Central Bank to speculators about which action they should take. Indeed, y_L could be interpreted as an ”attack” recommendation, whereas y_H means ”do not attack”. Naturally, in equilibrium, those recommendations are followed by speculators. Interestingly, speculators ignore their own private signals.

In order to improve beliefs about the fundamentals when $y = y_H$, the Central Bank commits to acknowledging bad states, i.e., $\theta \leq m$. By disclosing that fundamentals are bad and allowing for a coordinated attack if $y = y_L$, the Central Bank is able to pool intermediate and good states together, minimizing the cost of defending the peg in y_H. The optimal threshold will be the lowest m such that expectations about θ are good enough to prevent attacks if $y = y_H$. Reducing m any further opens up the possibility of self-fulfilling crises, even if the public signal is y_H.

Even though it is without loss of generality to assume that $N = 2$, the Central Bank could be arbitrarily precise when fundamentals are bad. It is only when fundamentals are "not too bad" that the Central Bank must be vague, since, as long as y_H remains the same, its payoff does not change. This vagueness is used by the Central Bank to make speculators uncertain about whether the state is intermediate ($\theta \in (m, \overline{\theta})$, where a coordinated attack is profitable) or good ($\theta \geq \overline{\theta}$, where attacking is never profitable), thus preventing them from attacking.

Another feature of the equilibrium is its Pareto efficiency. Efficiency is achieved because the public signal allows for perfect coordination among speculators. In contrast, the game without public information is not Pareto efficient since there are θ at which some speculators attack the currency but the Central Bank defends the peg. The game without commitment admits both efficient and inefficient equilibria.[17]

5 Conclusion

In this paper, we study how important for a Central Bank is the ability to commit to a communication policy. We show that the Central Bank's most preferred allocation can be supported in an equilibrium of the game without commitment, but so are other allocations that yield lower payoffs. We find that commitment is not enough for the Central Bank to achieve its most preferred allocation, but it can guarantee an intermediate payoff that may be preferable to what it would get without commitment. Moreover, we show that the most profitable way for the Central Bank to guarantee itself a minimum payoff is to commit to a disclosure rule that eliminates the possibility of self-fulfilling crises.

Our results point out to a novel role for commitment: multiplicity may still exist, but with commitment the lower bound for the Central Bank's payoff is higher than the one without commitment. This distinctive feature of our model has two

[17] For instance, the equilibrium constructed in the proof of Proposition 1 is Pareto efficient. On the other hand, the allocation of the game without a public signal (discussed at the beginning of Subsection 4.5) is inefficient but can be supported in an equilibrium in which the Central Bank always sends the uninformative public signal $y = [0, 1]$ (provided that $k^* + \varepsilon < \overline{\theta}$).

empirical implications that we discuss below.

First, high performing Central Banks have little incentive to adopt commitment technologies. Low performing Central Banks, however, have reasons to pursue commitment and then to follow a disclosure rule as the one characterized in Section 4. An implication of this result is that, empirically, one could observe a negative correlation between commitment and Central Bank performance: Central Banks with a good performance absent commitment choose to remain discretionary, while Central Banks with inferior performance adopt commitment technologies in order to achieve an intermediate payoff, but still inferior to those of high performing Central Banks.

Second, we find that commitment is useful because it allows the Central Bank to adopt a disclosure rule that eliminates self-fulfilling crises. Thus, our model implies that fundamentals are better predictors of economic outcomes when the Central Bank commits to a communication policy. This implication is common to models in which commitment allows the Central Bank to pick one of many equilibria of the game, effectively removing any multiplicity. In our framework, however, not all disclosure rules would eliminate multiplicity, even with commitment. Uniqueness arises with the additional step of the Central Bank choosing the specific disclosure rule that yields the lower bound for its payoff.

A Appendix

A.1 Derivation of θ_k

For $k \in [-\varepsilon, 1+\varepsilon]$, define θ_k as

$$\theta_k = \sup\{\theta : s(\theta, I_k) \geq a(\theta)\}. \tag{6}$$

θ_k is the largest value of θ at which that the Central Bank finds it optimal to abandon the peg when speculators' aggregate short sales are given by I_k. Since $s(\cdot, I_k)$ is decreasing and $a(\cdot)$ is increasing, the Central Bank abandons the peg if and only if $\theta \leq \theta_k$. Given that $a(\theta) = 0$ for $\theta \leq \underline{\theta}$, the set on the right hand side of (6) is never empty and θ_k is well defined. Moreover, we have that $\theta_k \geq \underline{\theta}$ for all k.

Define $\bar{k}$ as the unique value of k that solves

$$s(1, I_k) = G(k-1) = a(1),$$

that is, $\bar{k} = 1 + G^{-1}(a(1))$. If speculators follow the cutoff rule $I_{\bar{k}}$, the peg is abandoned for every realization of θ. Since $s(\theta, I_k)$ is increasing in k, we have that $\theta_k = 1$, for all $k \geq \bar{k}$. Then $k - \theta_k = k - 1$, which is strictly increasing in k.

Now suppose that speculators follow the cutoff rule I_k, with $k \leq \underline{\theta} - \varepsilon$. In this case, there are no attacks when $\theta > \underline{\theta}$, which implies that $\theta_k = \underline{\theta}$. We have that $k - \theta_k = k - \underline{\theta}$, which is strictly increasing in k.

Finally, if $k \in (\underline{\theta} - \varepsilon, \bar{k})$, then θ_k is the unique value of θ that solves

$$s(\theta, I_k) = G(k-\theta) = a(\theta). \tag{7}$$

Note that $\theta \leq \underline{\theta}$ cannot be a solution to the equation above, since the left hand side of (7) is strictly positive, while the right hand side equals 0. Thus, $\theta_k > \underline{\theta}$. For $\theta > \underline{\theta}$, we have that $a(\theta)$ is strictly increasing, thus θ_k is strictly increasing in k. In addition, $a(\theta) \in (0,1)$ implies that $\theta_k \in (k - \varepsilon, k + \varepsilon)$. In this case, $k - \theta_k = G^{-1}(a(\theta_k))$, and since θ_k is strictly increasing in k, then so is $k - \theta_k$.

Therefore θ_k is continuous in k, and that $k - \theta_k$ is strictly increasing in k, for all $k \in [-\varepsilon, 1+\varepsilon]$.

A.2 Proof of Lemma 1

Lemma 1. *Suppose that Assumption 1 is satisfied. When the aggregate strategy is given by I_k, the payoff from attacking the currency, $u_y(x, I_k)$, is decreasing in the private signal x.*

Proof: Suppose that the aggregate strategy is given by I_k. Let $\mathcal{I}(\theta)$ be an indicator function that equals 1 if the currency peg is abandoned when the state is θ. Since, by assumption, speculators follow a cutoff rule, $\mathcal{I}(\theta)$ is weakly decreasing in θ.[18] Define

$$U(\theta) = [f(\theta) - e^*]\mathcal{I}(\theta),$$

[18] $\mathcal{I}(\theta) = 1$, if $\theta \leq \theta_k$; and $\mathcal{I}(\theta) = 0$, if $\theta > \theta_k$.

which is negative and increasing. Consider a public signal y and a pair of private signals x_1 and x_2, with $x_1 < x_2$. Then

$$\int_0^1 U(\theta)d\Phi(\theta|x_2, y) \geq \int_0^1 U(\theta)d\Phi(\theta|x_1, y),$$

where the inequality comes from Assumption 1 and the fact that U is increasing. Hence

$$\begin{aligned} u_y(x_1, I_k) &= -\int_0^1 U(\theta)d\Phi(\theta|x_1, y) - t \\ &\geq -\int_0^1 U(\theta)d\Phi(\theta|x_2, y) - t \\ &= u_y(x_2, I_k), \end{aligned}$$

which completes the proof. □

A.3 Proof of Lemma 2

Before proving Lemma 2, we need two auxiliary results.

Lemma A.1. *For a given public signal y, if $\pi(x, y) \geq \pi'(x, y)$ for all x, then $u_y(x, \pi) \geq u_y(x, \pi')$ for all x.*

Proof: Suppose that $\pi(x, y) \geq \pi'(x, y)$ for all x. Then

$$s(\theta, \pi) \geq s(\theta, \pi') \Rightarrow A(\pi) \cap y \supseteq A(\pi') \cap y \Rightarrow u_y(x, \pi) \geq u_y(x, \pi').$$

□

Lemma A.2. *The payoff function $u_{y_n}(k, I_k)$ is continuous in k, for all $k \in X_{y_n}$.*

Proof: From (5), the payoff function when $y = y_n$ is given by

$$u_{y_n}(k, I_k) = \int_{k-\varepsilon}^{\theta_k} [e^* - f(\theta)]\phi(\theta|k, y_n)d\theta - t,$$

Since $\phi(\cdot|k, y_n)$ and the limits of integration are continuous in k (because θ_k is continuous), $u_{y_n}(k, I_k)$ is continuous in k. □

Now we are ready to prove Lemma 2.

Lemma 2. *For a given public signal y,*

i. if $u_y(k, I_k) < 0$ for all $k \in X_y$, then, in any equilibrium, $\pi(x, y) = 0$ for all $x \in X_y$;

ii. if $u_y(k', I_{k'}) \geq 0$ for some $k' \in X_y$, then, in the worst equilibrium for the Central Bank, speculators use the cutoff rule I_k after observing y, where $k = \sup\{k' \in X_y : u_y(k', I_{k'}) \geq 0\}$.

Proof: i. Suppose that $u_y(k, I_k) < 0$ for all $k \in X_y$. Let π be a equilibrium strategy, and suppose by way of contradiction that there is $x \in X_y$ such that $\pi(x, y) > 0$. If this is true, then the set $\{x' \in X_y : \pi(x', y) > 0\}$ is non-empty and we can define $\bar{x}_y$ as

$$\bar{x}_y = \sup\{x' \in X_y : \pi(x', y) > 0\}.$$

Note that $\bar{x}_y \in X_y$ because X_y is right-closed. Also note that, if π is an equilibrium strategy, then for any x' such that $\pi(x', y) > 0$, it has to be true that $u_y(x', \pi) \geq 0$. By the continuity of u_y in the private signal, $u_y(\bar{x}_y, \pi) \geq 0$. From Lemma A.1,

$$u_y(\bar{x}_y, I_{\bar{x}_y}) \geq u_y(\bar{x}_y, \pi) \geq 0,$$

which contradicts the assumption that $u_y(k, I_k) < 0$ for all $k \in X_y$.

ii. If $u_y(k, I_k) > 0$, by continuity (Lemma A.2), it has to be true that k is the right bound of the interval X_y and, by the decreasing property of u_y in the private signal (Lemma 1), I_k is an equilibrium strategy. If $u_y(k, I_k) = 0$, then we know from Lemma 1 that I_k is an equilibrium strategy. Now it is left to show that any equilibrium strategy π features $\pi(x, y) = 0$ for $x > k$. Assume by way of contradiction that there is an equilibrium with $\pi(x, y) > 0$ for some $x > k$. Let $\bar{x}_y = \sup\{x' \in X_y : \pi(x', y) > 0\} \in X_y$. By Lemma A.1, $u_y(\bar{x}_y, I_{\bar{x}_y}) \geq u_y(\bar{x}_y, \pi) \geq 0$, which contradicts the assumption that k is the supremum of the set $\{k' \in X_y : u_y(k', I_{k'}) \geq 0\}$.

A.4 Proof of Proposition 4

We first need the following lemma.

Lemma A.3. *Suppose that $y = y_n$ and that speculators follow I_k, for $k \in X_{y_n}$. The payoff function $u_{y_n}(x, I_k)$ is continuous in both m_{n-1} and m_n. Furthermore, it is decreasing in m_{n-1} for $k < m_{n-1} + \varepsilon$, and constant otherwise; it is also decreasing in m_n for $k > m_n - \varepsilon$, and constant otherwise.*

Proof: We want to show that u_{y_n} is decreasing in both m_{n-1} and m_n. Fix m_{n-1} and consider a change from m_n to $m'_n > m_n$. Recall that, when agents are using a cutoff strategy, $(e^* - f(\theta))\,\mathcal{I}(\theta)$ is a decreasing function of θ, where $\mathcal{I}(\cdot)$ is the indicator function that equals 1 if the peg is abandoned. For $x > m_n - \varepsilon$, we have

$$
\begin{aligned}
& u_{[m_{n-1},m'_n]}(x, I_k) + t \\
& = E\left[(e^* - f(\theta))\,\mathcal{I}(\theta)|x, \theta \in [m_{n-1}, m'_n]\right] \\
& = E\left[(e^* - f(\theta))\,\mathcal{I}(\theta)|x, \theta \in [m_{n-1}, m_n]\right] \mathbb{P}(\theta \in [m_{n-1}, m_n]|x, \theta \in [m_{n-1}, m'_n]) \\
& + E\left[(e^* - f(\theta))\,\mathcal{I}(\theta)|x, \theta \in [m_n, m'_n]\right] \quad \mathbb{P}(\theta \in [m_n, m'_n]|x, \theta \in [m_{n-1}, m'_n]) \\
& < E\left[(e^* - f(\theta))\,\mathcal{I}(\theta)|x, \theta \in [m_{n-1}, m_n]\right] \mathbb{P}(\theta \in [m_{n-1}, m_n]|x, \theta \in [m_{n-1}, m'_n]) \\
& + E\left[(e^* - f(\theta))\,\mathcal{I}(\theta)|x, \theta \in [m_{n-1}, m_n]\right] \mathbb{P}(\theta \in [m_n, m'_n]|x, \theta \in [m_{n-1}, m'_n]) \\
& = E\left[(e^* - f(\theta))\,\mathcal{I}(\theta)|x, \theta \in [m_{n-1}, m_n]\right] \\
& = u_{[m_{n-1},m_n]}(x, I_k) + t,
\end{aligned}
$$

that is, $u_{y_n}(x, I_k)$ is decreasing in m_n. For $x \leq m_n - \varepsilon$, we have

$$
\mathbb{P}(\theta \in [m_n, m'_n]|x, \theta \in [m_{n-1}, m'_n]) = 0,
$$

therefore $u_{y_n}(x, I_k)$ is constant in m_n. Analogous reasoning shows that $u_{y_n}(x, I_k)$ is decreasing in m_{n-1}, for $x < m_{n-1} + \varepsilon$, and constant otherwise. Regarding continuity, note that the payoff function is given by

$$
u_{y_n}(x, I_k) = \int_{\max\{x-\varepsilon, m_{n-1}\}}^{\min\{x+\varepsilon, m_n\}} [e^* - f(\theta)]\,\mathcal{I}(\theta) \frac{g\,(x-\theta)}{G\,(x - m_{n-1}) - G\,(x - m_n)} d\theta - t,
$$

which is continuous in both m_{n-1} and m_n. $\square$

Now the proof of Proposition 4.

Proposition 4. *For any partition $Y = \{y_n\}_{n=0}^{N}$, there exists $Y' = \{y'_n\}_{n=0}^{N'}$ with $N' = 2$, such that $V(Y') \geq V(Y)$.*

Proof: Given Proposition 3, the only non trivial result left to show is that, for any $Y = \{[0, m_1], (m_1, m_2], (m_2, 1]\}$, with $m_1 < \overline{\theta} < m_2$, there is a $Y' = \{[0, m'], (m', 1]\}$ such that $V(Y') \geq V(Y)$. Under Y, the peg is abandoned on y_1, it is not attacked on y_3, and there are two alternative cases for the fate of the peg on y_2:

- *Case 1: the peg is not attacked for all θ in y_2.*

  We know from Proposition 3 that $u_{(m_1,m_2]}(k, I_k) < 0$ for all $k \in X_{(m_1,m_2]}$. Since $m_2 > \overline{\theta}$, we also know that $u_{(m_2,1]}(k, I_k) < 0$ for all $k \in X_{(m_2,1]}$. Consider the alternative partition $Y' = \{[0, m_1], (m_1, 1]\}$. The peg is still abandoned if $\theta \leq m_1$. Moreover, from Lemma A.3 in Appendix A.4,

  $$u_{(m_1,1]}(k, I_k) \leq u_{(m_1,m_2]}(k, I_k) < 0, \quad \text{for all } k \in (m_1 - \varepsilon, m_2 + \varepsilon],$$

  and

  $$u_{(m_1,1]}(k, I_k) = u_{(m_2,1]}(k, I_k) < 0, \quad \text{for all } k \in (m_2 + \varepsilon, 1 + \varepsilon].$$

  These inequalities imply that $u_{(m_1,1]}(k, I_k) < 0$ for $k \in X_{(m_1,1]}$. From Proposition 3, under the new partition Y' the peg is still not attacked if $\theta > m_1$. Thus, $V(Y') = V(Y)$.

- *Case 2: the peg is attacked for some θ in y_2.*

  From Proposition 3, speculators follow a cutoff rule I_{k_2} after observing y_2, where $k_2 = \sup\{k' \in X_{y_2} : u_{y_2}(k', I_{k'}) = 0\}$. Given the speculators' strategy, there exists $\theta_{k_2} \in (m_1, m_2]$ such that the peg is abandoned if and only if $\theta \leq \theta_{k_2}$. Consider partition $Y' = \{[0, \theta_{k_2}], (\theta_{k_2}, 1]\}$. From Lemma A.3 ,

  $$u_{(\theta_{k_2},1]}(k, I_k) \leq u_{(m_1,m_2]}(k, I_k) < 0, \quad \text{for all } k \in (k_2, m_2 + \varepsilon],$$

  and

  $$u_{(\theta_{k_2},1]}(k, I_k) = u_{(m_2,1]}(k, I_k) < 0, \quad \text{for all } k \in (m_2 + \varepsilon, 1 + \varepsilon],$$

  which imply that I_k cannot be an equilibrium strategy if $k > k_2$. From Lemma

2, the Central Bank maintains the peg if $\theta > \theta_{k_2}$. By changing the partition from Y to Y', the Central Bank no longer has to pay a cost to defend the peg on $(\theta_{k_2}, \theta_{k_2} + \varepsilon) \cap y_2$. Thus $V(Y') \geq V(Y)$, with strict inequality if $\theta_{k_2} < m_2$ (i.e., if the peg was originally defended for some θ in $(m_1, m_2]$). □

A.5 Proof of Proposition 5

Before proving Proposition 5 we need the results in Lemmas A.4 and A.5 below.

Lemma A.4. *Consider the game following the disclosure of $y = y_L$. If $m \leq \theta_{k^*}$, the equilibrium is unique and the peg is always abandoned. If, in addition, $m \leq \overline{\theta}$, then speculators coordinate on attacking the currency peg .*

Proof: Let $u(\cdot)$ denote the payoff function when there is no public signal, or, equivalently, when there is a single public signal $y_1 = [0, 1]$ ($u(\cdot) \equiv u_{[0,1]}(\cdot)$). Then

$$u(k, I_k) = \int_{k-\varepsilon}^{\theta_k} [e^* - f(\theta)]\phi(\theta|k, [0, 1])d\theta - t.$$

Note that the payoff function is continuous in k. If we can prove that $u(k, I_k)$ is strictly decreasing in k, then the proof of existence and uniqueness of equilibrium in the game without a public signal is analogous to the one in Morris and Shin (1998). For $k \in (\varepsilon, 1 - \varepsilon)$, we have that

$$u(k, I_k) = \int_{k-\varepsilon}^{\theta_k} [e^* - f(\theta)]g(k - \theta)\, d\theta - t = \int_{k-\theta_k}^{\varepsilon} [e^* - f(k - \tilde{\varepsilon})]g(\tilde{\varepsilon})d\tilde{\varepsilon} - t.$$

Since $k - \theta_k$ is increasing and $f(\cdot)$ is strictly decreasing, we have that $u(k, I_k)$ is strictly decreasing in k. Thus, as in Morris and Shin (1998), speculators follow a cutoff strategy I_{k^*}, such that $u(k^*, I_{k^*}) = 0$, with $k^* \in (\varepsilon, 1 - \varepsilon)$, and the peg is abandoned for $\theta \leq \theta_{k^*}$. Since $u(k, I_k) > 0$ for $k \leq \varepsilon$, and $u(k, I_k) < 0$ for $k \geq 1 - \varepsilon$, it follows that $u(k, I_k) > 0$ for $k < k^*$, and that $u(k, I_k) < 0$ for $k > k^*$.

Now we turn to the game with a public signal. Consider an equilibrium strategy profile π. Let $\pi(x, y_L)$ denote the probability that a speculator attacks the currency given a private signal x and a public signal $y = y_L$. Define $\underline{x}$ as [19]

$$\underline{x} = \inf\{x \in X_{y_L} : \pi(x, y) < 1\}.$$

Then, from Lemma A.1,

$$u_{y_L}(\underline{x}, I_{\underline{x}}) \leq u_{y_L}(\underline{x}, \pi) \leq 0, \tag{8}$$

where the last inequality comes from the fact that $u_y(x, \pi) \leq 0$ if $\pi(x, y) < 1$, and from the continuity of $u_y(x, \pi)$ in x.

From Lemma A.3, we have that

$$u_{y_L}(k, I_k) \geq u(k, I_k) > 0, \quad \text{for } k < k^*.$$

Hence, (8) implies that $\underline{x} \geq k^*$, and that $\pi(x, y_L) = 1$ for every $x < k^*$. This means that, in equilibrium, the peg is abandoned for all $\theta \in y_L = [0, m] \subseteq [0, \theta_{k^*}]$.

After observing $y = y_L$, speculators know that peg is always abandoned in equilibrium. Thus, a speculator who receives a private signal x attacks the currency if and only if

$$\mathbb{E}[e^* - f(\theta) - t | x, y_L] \geq 0,$$

and it follows that the equilibrium is unique. If $m \leq \overline{\theta}$, attacking is always profitable when $y = y_L$, thus speculators coordinate on attacking the currency peg regardless of their private signals. □

Lemma A.5. $\underline{m} < \overline{\theta}$.

Proof: We need to find $m < \overline{\theta}$ such that $u_{(m,1]}(k, I_k) < 0$ for all k. Consider the partition $Y^{\overline{\theta}}$ and let $\bar{k}$ solve $\theta_{\bar{k}} = \overline{\theta}$.[20] First we prove that there is a bound $\delta < 0$ such that $u_{(\overline{\theta},1]}(k, I_k) \leq \delta$ for all $k \in X_{(\overline{\theta},1]}$. Then we use continuity of $u_{(m,1]}(k, I_k)$ in m to show that there is an m below $\overline{\theta}$ that belongs to M.

Let $\delta = u_{(\overline{\theta},1]}(\bar{k}, I_{1+\varepsilon})$. Note that $\delta < 0$ because of the definition of $\overline{\theta}$. We claim that $u_{(\overline{\theta},1]}(k, I_k) \leq \delta$ for all $k \in (\overline{\theta} - \varepsilon, 1 + \varepsilon]$. To see this, let $k \leq \bar{k}$. If speculators follow I_k, then the threshold for the Central Bank to abandon the peg is $\theta_k \leq \overline{\theta}$, which means

[19] If $\pi(x, y) = 1$ for all $x \in X_{y_L}$, then define $\underline{x} = \sup X_{y_L}$.

[20] $a(\overline{\theta}) = s(\overline{\theta}, I_{\bar{k}})$, that is, if speculators follow the cutoff rule $I_{\bar{k}}$, the Central Bank is indifferent between defending the currency and abandoning the peg at $\theta = \overline{\theta}$.

that the Central Bank does not abandon the peg on $(\overline{\theta}, 1]$. Hence $u_{(\overline{\theta},1]}(k, I_k) = -t < \delta$ for any $k \leq \bar{k}$. For $k > \bar{k}$

$$u_{(\overline{\theta},1]}(k, I_k) \leq u_{(\overline{\theta},1]}(k, I_{1+\varepsilon}) \leq u_{(\overline{\theta},1]}(\bar{k}, I_{1+\varepsilon}) = \delta,$$

where the first inequality comes from Lemma A.1, and the second inequality comes from Lemma 1.Therefore, $u_{(\overline{\theta},1]}(k, I_k) \leq \delta$ for all $k \in X_{(\overline{\theta},1]}$, as claimed.

Define l_m^1 and l_m^2 as

$$l_m^1 = \lim_{k \downarrow \bar{k}} u_{(m,1]}(k, I_{1+\varepsilon}),$$

and

$$l_m^2 = \lim_{k \downarrow \overline{\theta} - \varepsilon} u_{(m,1]}(k, I_{\bar{k}}).$$

Since $u_{(\overline{\theta},1]}(k, I_{1+\varepsilon}) \leq \delta$ for all $k > \bar{k}$, we have that $l_{\overline{\theta}}^1 \leq \delta$. Since $u_{(\overline{\theta},1]}(k, I_{\bar{k}}) \leq \delta$ for $k \in (\overline{\theta} - \varepsilon, \bar{k}]$, we have that $l_{\overline{\theta}}^2 \leq \delta$. From Lemmas A.1 and 1, $l_m^1 \geq u_{(m,1]}(k, I_k)$ for $k > \bar{k}$, and $l_m^2 \geq u_{(m,1]}(k, I_k)$ for $k \in (\overline{\theta} - \varepsilon, \bar{k}]$. Then $l_m \equiv \max\{l_m^1, l_m^2\} \geq u_{(m,1]}(k, I_k)$ for $k > \overline{\theta} - \varepsilon$. From Lemma A.3, l_m^1 and l_m^2 are continuous in m, and so is l_m. Hence, there exists $m' < \overline{\theta}$ such that $l_{m'} < l_{\overline{\theta}} - \delta/2 \leq \delta/2 < 0$. This implies that $u_{(m',1]}(k, I_k) \leq \delta/2$ for $k > \overline{\theta} - \varepsilon$. In this case, either $u_{(m',1]}(k, I_k) < 0$ for all $k \in (m' - \varepsilon, \overline{\theta} - \varepsilon]$, or there exists $k' = \sup\{k \in (m' - \varepsilon, \overline{\theta} - \varepsilon] : u_{(m',1]}(k, I_k) \geq 0\}$. From Lemma 2, either there is no attack on $(m', 1]$, thus $m' \in M$, or, in the worst equilibrium for the Central Bank, speculators follow $I_{k'}$ after observing $(m', 1]$. In the latter case, the Central Bank abandons the peg for $\theta \leq \theta_{k'} \in (m', \overline{\theta})$. Consider partition $Y^{\theta_{k'}}$. From Lemma A.3, $u_{(\theta_{k'},1]}(k, I_k) < 0$ for all $k \in X_{(\theta_{k'},1]}$, and, from Lemma 2, there is no attack on y_H. This means that $\theta_{k'} \in M$. Thus, either $\overline{\theta} > m' \in M$ or $\overline{\theta} > \theta_{k'} \in M$, which implies that $\underline{m} < \overline{\theta}$. □

Now we present the proof of Proposition 5

Proposition 5. *For every partition Y, $V(Y) \leq \overline{V}$, where*

$$\overline{V} = \lim_{m \downarrow \underline{m}} V(Y^m),$$

and thus the Central Bank can achieve a payoff arbitrarily close to $\overline{V}$.

Proof: Consider a partition Y. From Proposition 4, we can assume that $Y = Y^m =$

$\{[0, m], (m, 1]\}$. The proof consists of five steps:

i. if $m > \underline{m}$, then $m \in M$;

ii. for all $m < \underline{m}$, there exists $m' \in M$ such that $V(Y^{m'}) > V(Y^m)$;

iii. if $m > \theta_{k^*}$, then $V(Y^{\theta^*}) > V(Y^m)$;

iv. if $m \in (\underline{m}, \theta_{k^*})$, then $V(Y^m)$ is strictly decreasing in m;

v. $V(Y^{\underline{m}}) \leq \lim_{m \downarrow \underline{m}} V(Y^m)$.

When all the claims above are true, we have that $\overline{V}$ is well defined, no partition can yield a payoff higher than $\overline{V}$, and the Central Bank can achieve a payoff arbitrarily close to $\overline{V}$ by setting m arbitrarily close to $\underline{m}$. The proofs are presented below.

i. If $m > \underline{m}$, there exists $m' \in M$ such that $m' < m$. From Lemma 2, $m' \in M$ implies that $u_{(m',1]}(k, I_k) < 0$ for all $k \in X_{(m',1]}$. From Lemma A.3, $m' < m$ implies that $u_{(m,1]}(k, I_k) < u_{(m',1]}(k, I_k) < 0$ for all $k \in X_{(m,1]}$. Using Lemma 2 again, we conclude that $m \in M$.

ii. Let $m < \underline{m}$. From Lemma A.5, we know that $\underline{m} < \overline{\theta}$. Then, with partition Y^m, in the worst equilibrium for the Central Bank the peg is abandoned when $\theta \in [0, m]$. From Lemma 3, speculators follow a cutoff strategy I_{k_H} after observing y_H, where $k_H = \sup\{k \in X_{y_H} : u_{y_H}(k, I_k) \geq 0\}$. Given the speculators' strategy, there exists $\theta_{k_H} > m$ such that the peg is abandoned if and only if $\theta \leq \theta_{k_H}$. Following the arguments in the proof Proposition 4 (Case 3), $\theta_{k_H} \in M$ and partition $Y^{\theta_{k_H}} = \{[0, \theta_{k_H}], (\theta_{k_H}, 1]\}$ is preferred to Y^m.

iii. See discussion at the beginning of section 4.5.

iv. Let $m \in (\underline{m}, \theta_{k^*})$. From Lemma A.4, $m < \theta_{k^*}$ implies that the peg is abandoned on $[0, m]$; from part i, $m > \underline{m}$ implies that $m \in M$, therefore there are no attacks on $(m, 1]$. We then have that

$$V(Y^m) = \int_m^1 (v - c(0, \theta))\, d\theta,$$

which is strictly decreasing in m, and

$$\lim_{m \downarrow \underline{m}} V(Y^m) = \int_{\underline{m}}^{1} (v - c(0, \theta))\, d\theta.$$

v. If $\underline{m} \in M$, then $V(Y^{\underline{m}}) = \lim_{m \downarrow \underline{m}} V(Y^m)$. If $m \notin M$, then Lemma 2 implies that there exists $\theta_k > \underline{m}$ such that the peg is abandoned if and only if $\theta \leq \theta_k$. In this case, $V(Y^{\underline{m}}) \leq \int_{\theta_k}^{1} (v - c(0, \theta))\, d\theta < \int_{\underline{m}}^{1} (v - c(0, \theta))\, d\theta$.

□

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