

## Optimal Transparency and Risk-Taking to Avoid Currency Crises

by

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This paper reconsiders a central bank's problem of determining rules for information dissemination and risk-taking behavior that minimize the probability of currency crises. In a global-games approach, we find that optimal transparency is adversely related to prior market beliefs. In countries with pessimistic prior beliefs about economic performance, the central bank should commit to disclosing information with maximal precision. In addition, it should increase the risk of economic performance. For good prior expectations, posterior information should be of lower precision, depending on the variance of fundamentals. Here, the central bank can reduce the crisis probability by reducing that variance. (JEL: D 82, F 31, G 33)

### 1 Introduction

Following the many economic crises of the last years, a large number of economists took the view of demanding the highest possible degree of transparency by the information-providing principal as appropriate to prevent future turmoil (KING [1999], GELOS AND WEI [2002]). In the case of fixed-exchange-rate crises, for instance, central banks were told that they should have provided speculators with precise information, so that the observed speculative attacks could have been prevented. One particularly obvious case of a disguised information policy leading to a severe attack on the fixed parity was the peso crisis in Mexico, 1994–1995 (EDWARDS [1997]). Similarly, firms facing liquidity crises were often told they would have been better off had they only disclosed sufficiently precise information about their business development to investors. *Transparency* in this respect refers to precise disclosures both about policy measures influencing business development and economic situation and about the principal's *ex-post* information about the fundamental state (BUIITER [1999], GERAATS [2000], CUKIERMAN [2002]).

Questions of optimal information disclosure and choice of operational risk become particularly important whenever the outcome of a principal's policy is threatened by coordinated behavior of opposing agents. In this paper, we question the

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current demand for full transparency and analyze the determinants for a principal's optimal combination of transparency and risk-taking in coordination instances such as currency crises. In this, we build on the global-games approach introduced to the analysis of currency crises by MORRIS AND SHIN [1998]. This approach rests on the distinction between private and public information. Private information is interpreted as either insider information or more generally as individual interpretation of commonly accessible information. Public information, in contrast, is information that is common knowledge to all market participants. Both types of information may be noisy in the sense that they are imprecise signals of the underlying economic fundamentals.

MORRIS AND SHIN [2003] and HELLWIG [2002] show that there is a unique equilibrium with a critical state below which currency crises occur with certainty, provided that private information is sufficiently precise relative to public information. Assuming that a central bank may have an incentive to influence the precision of information to reduce the probability of a devaluation, METZ [2002] shows that informativeness of private and public signals may have contrary effects on the critical state. PRATI AND SBRACIA [2002] extend her analysis to include the effects of information precision on the proportion of traders who attack.

However, there are two problems associated with these approaches: first, they assume that the state of the economy has a uniform distribution with unbounded support, so that finite changes in the critical state, strictly taken, have no impact on the probability of crises. Second, the conditions for the various effects of transparency on the threshold to a crisis regime given by METZ [2002] and PRATI AND SBRACIA [2002] are contingent on the equilibrium threshold itself. The authors fail to identify conditions based on exogenous parameters, and it is not entirely clear how exogenous parameters affect optimal transparency.

MORRIS AND SHIN [1999] assume that the prior distribution of states is normal. Here, shifts in the threshold go along with changes in the prior probability of a crisis. Since distributions are assumed to be common knowledge, the prior mean of the state is public information. Compared to the formerly mentioned models, there is a slight difference in interpretation: "precision of public information" is identical to the precision of the prior distribution of states and therefore cannot be chosen without affecting the fundamental risk in the economy. In the present paper, we use the model of MORRIS AND SHIN [1999] and analyze the effects of the precisions of private information and of the prior distribution of states on the probability of currency crises. Extending METZ [2002], we derive conditions on exogenous parameters required for positive (or negative) effects of the precisions of distributions on the probability of crises and show that the optimal degree of transparency may be an interior solution.

Similarly to our approach, ROCHET AND VIVES [2004] discuss the ambiguous role of transparency, depending on whether the principal's information dissemination leads to common or to private beliefs. However, the means by which a central bank can affect beliefs are not entirely clear: policy measures and strategic commitments that guide the long-run development of the economy are widely observable. They can

be verified, market participants' reactions to them can be observed, and hence they are likely to become common knowledge.<sup>1</sup> Public statements about the current state of the economy are, however, often disseminated through different types of media at slightly different times, and may thus induce short-run formation of different opinions about their meaning and relevance. Unless there exists a common updating procedure (AMATO AND SHIN [2003]), we believe that public statements about the current state of the economy induce private rather than public beliefs among the speculators about the chance of succeeding in an attack.<sup>2</sup>

Taking these arguments into account, we assume that the distributional parameters of the economic state, including the prior mean, are common knowledge, while the central bank's disclosures about posterior realizations of the state provide private information. In our model, risk-taking behavior of the principal refers to the accepted variability of the fundamental state around the *a-priori* expected value, also referred to as *market sentiment*. An optimistic market sentiment represents a high value commonly expected for the fundamental state of the economy; a pessimistic one, a low value. By choosing appropriate risk policy measures, central bank or government can decide whether the fundamental development of the economy may deviate strongly from the *a-priori* expected path or whether monetary and fiscal policy should be used in order to stabilize the economic development relative to the market sentiment. Information policy of the principal is conducted by disseminating signals on the realized fundamental state to agents. These signals are perceived and interpreted individually, so that information is private in the sense that *ex-post* beliefs can and almost certainly will differ among agents. Transparency is described by the degree of precision of this posterior private information.

Our analysis results in a more strongly differentiated picture regarding optimal information policy than does earlier work on this subject. It is shown that the optimal degree of transparency depends both on the market sentiment and on the chosen degree of fundamental risk. This result contrasts with HEINEMANN AND ILLING [2002], who, in a model with uniform distributions, conclude that increasing transparency unambiguously decreases the danger of a crisis.<sup>3</sup> In our paper, however, a commitment to release information of maximum precision, *i.e.*, to create full transparency, is optimal only if the prior market belief with respect to the fundamental state of the economy is below some exogenously fixed threshold, *i.e.*, only for a sufficiently high degree of pessimism. For an optimistic market, we find that the optimal information policy is a commitment to provide information with a precision

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<sup>1</sup> It has been shown in experiments that higher-order beliefs are created by repetitions of a game when other players' actions are observed (NAGEL [1995]).

<sup>2</sup> BENASSY-QUERE, LARRIBEAU, AND MACDONALD [2003] provide empirical evidence for heterogeneous beliefs of traders on the foreign exchange market.

<sup>3</sup> A similar case is made by ROCHET AND VIVES [2004] for the influence of private information in liquidity crises of banks. Additionally, they analyze information disclosures by the central bank, which are interpreted as public information. They show that coordination failures are aggravated with increasing precision of public information if fundamentals are weak.

that depends on the variance of fundamentals and hence on the chosen fundamental risk. If the market expects a low variation of fundamentals, the probability of crises increases monotonically in the precision of private information. The optimal degree of transparency is then given by the minimum precision of information that is needed to avoid crises triggered by self-fulfilling beliefs.<sup>4</sup> If markets expect a sufficiently high variation of fundamentals due to high fundamental risk, or if the prior expected state is not sufficiently good given the economic uncertainty, then the optimal degree of transparency is an interior solution and rises with increasing variance of fundamentals. This last result contrasts with earlier findings by METZ [2002], who argued that optimal precision of private information is either minimal or infinite.

Concerning the optimal choice of fundamental risk, our model delivers the intuitive result that in the case of good prior expectations, avoiding risk locks in the good expectations and thus minimizes the probability of crises. Combined with low transparency, such risk policy may reduce the probability of a speculative attack to levels close to zero. In the case of bad prior expectations, however, the probability of speculative attacks can be lowered by increasing risk in economic performance. Together, high risk and high transparency reduce the prior probability of a currency crisis to levels close to  $1/2$ , which is the best that can be achieved for pessimistic prior expectations.

The remainder of the paper is structured as follows. Section 2 presents the game structure, which builds upon the model by MORRIS AND SHIN [1998], [1999]. We will briefly state the main results of earlier work on the role of information in currency crises and depict the shortcomings in these approaches that we wish to overcome in the present paper. Section 3 presents our modified model, which enriches the original currency-crisis game by an additional stage, in which the central bank chooses optimal parameters of the relevant distributions. Section 3.1 derives optimal rules for transparency. Section 3.2 shows how risk-taking behavior can change the probability of a crisis. Section 4 sums up the results and concludes.

## 2 *The Global-Games Approach to Currency Crises*

Throughout this paper we refer to a reduced-form currency-crisis model initially developed by MORRIS AND SHIN [1998], [1999].<sup>5</sup> In this model, it is assumed that the central bank has pegged the exchange rate to a fixed parity. There is a continuum of risk-neutral speculators, indexed by  $[0, 1]$ . Each speculator disposes of one unit of domestic currency that he may hold or sell. A speculator short-selling the currency faces transaction costs as well as costs stemming from the interest-rate differential

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<sup>4</sup> Such a result of “constructive ambiguity” is also derived by ANGELETOS AND PAVAN [2004]. In contrast to our work, they analyze aspects of optimal transparency in a model with varying degrees of strategic complementarities in agents’ behavior that accounts also for multiple equilibria.

<sup>5</sup> For correction of a faulty expression in MORRIS AND SHIN [1998] see HEINEMANN [2000].

between domestic and foreign currency. Both costs are comprised in a parameter  $t$ . If the attack is successful (*i.e.*, the fixed parity is abandoned and the domestic currency is devalued), selling yields a fixed revenue  $D > t$ . In situations of currency crises, transaction costs are rather low compared with potential gains from a devaluation, so that it seems reasonable to assume that  $t < D/2$ .<sup>6</sup>

The fundamental state of the economy is given as an index denoted by  $\theta$ . A high (low) value of  $\theta$  represents a good (bad) fundamental state. In accordance with usual second-generation currency-crisis models, we assume that in order to force the central bank to abandon the peg, the proportion of attacking speculators, denoted by  $l$ , must be large if  $\theta$  is high, whereas for bad fundamentals a small proportion of market participants is sufficient to enforce a devaluation. Normalizing  $\theta$ , we assume that the central bank abandons the peg if  $l \geq \theta$ .

Whenever a speculator knows that  $\theta < 0$ , it is a dominant strategy to attack, since the peg will be abandoned anyway. If an agent knows that  $\theta > 1$ , the dominant strategy is not to attack, because an attack can never be successful. With common knowledge of the fundamental state, there are two symmetric equilibria in pure strategies for all  $\theta \in [0, 1]$ . Either all agents attack and get a reward of  $D - t > 0$ , or no agent attacks, since any single attacker receives a negative payoff of  $-t$ . Within this interval of intermediate fundamental values, it is impossible to predict whether or not agents will coordinate on a speculative attack, thereby triggering a currency crisis.

Applying the global-games approach, originally developed by CARLSSON AND VAN DAMME [1993], MORRIS AND SHIN [1999] have shown that there is a unique equilibrium for all fundamental values if  $\theta$  is not common knowledge but agents receive sufficiently precise private information on  $\theta$ . In their model, the fundamental state is normally distributed around a mean of  $y$  with variance  $1/\alpha$ . The central bank exclusively knows the exact value of  $\theta$ . Speculators cannot observe the true fundamental value. Instead, they individually receive private signals  $x_i = \theta + \varepsilon_i$ , with  $x_i|\theta \sim \text{iid } N(\theta, 1/\beta)$ . While signals are private information, the common distribution of state and signals is common knowledge, including the prior mean  $y$  and precisions  $\alpha$  and  $\beta$ .

In contrast, MORRIS AND SHIN [2003] and HELLWIG [2002] consider  $\theta$  to have an improper uniform distribution on  $(-\infty, +\infty)$ . In applying this model to the case of currency crises (METZ [2002]; PRATI AND SBRACIA [2002]), it is assumed that the central bank disseminates posterior private and public information, where the public information  $y|\theta \sim N(\theta, 1/\alpha)$ . The equilibrium analysis in this type of model is equivalent to MORRIS AND SHIN [1999].

Based on their noisy information about  $\theta$ , speculators simultaneously decide whether or not to attack the fixed parity. The central bank then observes the proportion  $l$  of attacking speculators and abandons the peg if  $l$  is higher than or equal to  $\theta$ .

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<sup>6</sup> A discussion of the modeling of cost and payoff parameters can be found in METZ [2003].

Since traders are uncertain about the information of other agents even in equilibrium, they hold probabilistic beliefs on the proportion of attacking agents and on the ultimate success of an attack. In equilibrium, each agent attacks if and only if his signal is below some critical level  $x^*$ , at which the agent is indifferent. There is an associated threshold state  $\theta^*$ , at which the proportion of attacking agents equals  $\theta^*$ . The currency is therefore devalued if and only if the actual fundamental state  $\theta$  is below  $\theta^*$ .

The critical values  $x^*$  and  $\theta^*$  are derived from indifference conditions. A speculator with signal  $x^*$  is indifferent between attacking and not attacking if

$$\begin{aligned} D \cdot \text{prob}(\theta \leq \theta^* | x^*) &= t \\ \Leftrightarrow D \cdot \Phi\left(\sqrt{\alpha + \beta}\left(\theta^* - \frac{\alpha}{\alpha + \beta}y - \frac{\beta}{\alpha + \beta}x^*\right)\right) &= t, \end{aligned}$$

while the central bank is indifferent between abandoning and keeping the peg at state  $\theta^*$  if

$$\begin{aligned} l = \text{prob}(x \leq x^* | \theta^*) &= \theta^* \\ \Leftrightarrow \Phi(\sqrt{\beta}(x^* - \theta^*)) &= \theta^*. \end{aligned}$$

As shown by MORRIS AND SHIN [1999], [2003], solving these equations for the critical fundamental state  $\theta^*$  yields

$$(1) \quad \theta^* = \Phi\left(\frac{\alpha}{\sqrt{\beta}}[\theta^* - y] - \sqrt{1 + \frac{\alpha}{\beta}}\Phi^{-1}\left(\frac{t}{D}\right)\right),$$

where  $\Phi(\cdot)$  is the cumulative density function of the standard normal distribution. The critical private signal  $x^*$  is

$$(2) \quad x^* = \frac{\alpha + \beta}{\beta}\theta^* - \frac{\alpha}{\beta}y - \frac{\sqrt{\alpha + \beta}}{\beta}\Phi^{-1}\left(\frac{t}{D}\right).$$

There is a unique solution to these equations for all  $y$  if and only if

$$(3) \quad \beta \geq \frac{\alpha^2}{2\pi}.$$

Thus, uniqueness of equilibrium requires the conditional variance of private signals,  $1/\beta$ , to be sufficiently small relative to the variance of the fundamental state  $1/\alpha$ . For  $\beta/\alpha \rightarrow \infty$ , the equilibrium threshold  $\theta^*$  converges to

$$(4) \quad \theta_0^* = 1 - t/D.$$

This limit point has the property that it is a best response to each agent believing that the proportion of attacking agents has a uniform distribution in  $[0, 1]$  (MORRIS AND SHIN [2003]).

Totally differentiating (1), METZ [2002] has shown that  $\theta^*$  rises with increasing precision of private information,  $\beta$ , if and only if

$$(5) \quad \theta^*(\alpha, \beta, y) < y + \frac{1}{\sqrt{\alpha + \beta}}\Phi^{-1}\left(\frac{t}{D}\right).$$

Moreover,  $\theta^*$  rises with increasing  $\alpha$  if and only if

$$(6) \quad \theta^*(\alpha, \beta, y) > y + \frac{1}{2\sqrt{\alpha + \beta}} \Phi^{-1}\left(\frac{t}{D}\right).$$

Hence, for sufficiently low prior means  $y$ , increasing precision of private signals ( $\beta$ ) and decreasing  $\alpha$  reduce the threshold level  $\theta^*$ . For sufficiently high values of  $y$ , the effects on  $\theta^*$  are reversed. Similar results are obtained by PRATI AND SBRACIA [2002] with regard to the effects of  $\alpha$  and  $\beta$  on  $x^*$ , *i.e.*, on the share of speculators who decide to attack the fixed parity, defined by (2).<sup>7</sup>

There are, however, two major shortcomings connected to these results. As can be seen from (5) and (6), the threshold values for the prior mean  $y$  are contingent on  $\theta^*$ , which itself is a function of  $\alpha$  and  $\beta$ . Thus, it cannot be concluded from these results that a central bank should commit to fully precise private information (*i.e.*, maximum  $\beta$ ) and minimum  $\alpha$  under bad prior fundamentals, or the reverse if prior fundamentals are good. In order to make inferences about an optimal policy device, one must derive conditions on exogenous parameters for which the threshold to crises rises or falls with increasing precision of either kind of distribution.

Furthermore, we believe the interpretation of optimal public information to be misleading. In the setup where the prior distribution of  $\theta$  is uniform and  $y$  represents *ex-post* information, changes in the threshold are irrelevant at the time when the central bank commits to the rules of information dissemination, because these rules induce finite changes of the threshold and zero changes in the prior probability of crises. In the setup where  $y$  gives the mean of the prior distribution and  $1/\alpha$  gives its variance, referring to this distribution as public information would imply that the central bank can determine the economic development through its posterior public information. We think it is more reasonable to interpret the central bank's choice of  $\alpha$  as a measure of risk policy and to view  $y$  as the market belief about the fundamental state of the economy. Hence, the market in our model is able to correctly perceive the average development of the economic fundamental state, but the central bank, by choosing either a stabilizing monetary policy (high  $\alpha$ ) or a destabilizing one (low  $\alpha$ ), can decide on the variability of fundamentals.

### 3 Optimizing Information and Risk Policy

In the following, we analyze a modification of the basic crisis model by MORRIS AND SHIN [1999] as delineated above. In our model, the central bank in an additional first stage of the game commits to an optimal information and risk policy in order

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<sup>7</sup> Precision of private information has two effects on traders' behavior: It affects the critical value  $x^*$  and the proportion of traders who get signals below  $x^*$  and attack in a given state  $\theta$ . Imprecise private information induces coordination failure among traders and may lead some of them to attack in states where attacks will not be successful.

to minimize the prior probability of a currency crisis, which is given by

$$(7) \quad \text{prob}(\theta < \theta^*) = \Phi(\sqrt{\alpha}(\theta^* - y)).$$

To be precise, we analyze a game with the following structure: At stage 1, the government can decide on the precision of private information,  $\beta$ , and influence the economic risk, measured by  $1/\alpha$ . Its goal is to minimize the prior probability of a successful speculative attack. The chosen precision  $\beta$  of private information binds the central bank to provide certain kinds of information to agents at stage 2. While selecting optimal values of  $\alpha$  and  $\beta$ , the government in any case wants to avoid instabilities arising from multiple equilibria. This restricts its choice to parameters for which the uniqueness condition (3) holds.<sup>8</sup>

At stage 2 of the game, speculators get posterior private information and decide on either attacking or not. At stage 3, the central bank keeps the peg or devalues, depending on the proportion of attacking speculators. Stages 2 and 3 are the Morris–Shin game as described above. Our *addendum* is the endogenous choice of the fundamentals' variance  $1/\alpha$  and of the precision of private information,  $\beta$ , in a first stage of the game.

The government's choice of  $\beta$  is a commitment to supply private agents with well-specified kinds of information at stage 2. The limit  $\beta \rightarrow \infty$  may be viewed as full economic transparency. The higher  $\beta$ , the more reliable are private signals and the better can private agents infer the actual fundamental state as observed by the central bank. The government's influence on  $\alpha$  may be interpreted as fiscal and monetary policy, affecting the real economy, and leading to more or less risk for economic development. While information policy is freely chosen by the authorities, their influence on  $\alpha$  may admittedly be thought to be limited. Therefore, we first derive the optimal precision of private information for a given distribution of fundamentals, *i.e.*, for exogenous  $\alpha$ . In a second step, we analyze under which conditions authorities have an incentive to increase or decrease economic risk.

Note that the prior mean of the fundamental state,  $y$ , is treated as an exogenous variable, although the central bank has strong incentives to raise the prior mean whenever it is able to. However, with rational expectations traders correctly infer all policy measures taken at the first stage, so that the market sentiment will not be biased and can reasonably be assumed to coincide with the prior mean of the fundamentals' distribution. Thus, an endogenous choice of  $y$  would not alter our results.

A similar argument holds for the way information disclosure is modeled. Even if committed to provide accurate information in all states, authorities may want to bias posterior information towards good fundamentals in order to avoid an attack. With rational expectations, however, any possible way and incentive to provide one-sided information within the bands that commitments allow are anticipated by

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<sup>8</sup> We therefore limit our analysis to the case of a unique equilibrium in order to avoid potential comparisons with an intractable definition of crisis probability in sunspot equilibria.



private agents, who correct their posterior beliefs for any such information bias.<sup>9</sup> Therefore, information policy in our model is executed by choosing the precision of private information,  $\beta$ , only.

### 3.1 Optimal Transparency

We start analyzing the game by solving for the precision of private information,  $\beta$ , that minimizes the probability of a currency crisis for any given distribution of fundamentals characterized by  $y$  and  $\alpha$ . Since  $\beta$  enters the probability of crises (7) only through  $\theta^*$ , the government's task is simply to minimize  $\theta^*(\alpha, \beta, y)$  subject to (1) and (3). Recall that the limit point of the equilibrium threshold for infinitely precise private information is given by  $\theta_0^* = 1 - t/D$ . The government can always approach this default point by choosing a sufficiently large precision of private information,  $\beta$ , and hence, with optimal transparency,  $\theta^*$  cannot exceed  $\theta_0^*$ . In the following, we distinguish between prior market beliefs being good (*i.e.*,  $y > \theta_0^*$ ) and bad (*i.e.*,  $y < \theta_0^*$ ). As stated before, we assume that  $D > 2t$ , so that speculators would want to attack whenever the posterior probability of an attack being successful is at least  $1/2$ . For deriving the results with respect to  $\beta$ 's influence on the crisis probability, we furthermore have to keep in mind that  $\theta^*$  rises in  $\beta$  if and only if the inequality (5) holds.

*Case 1:  $y > \theta_0^*$ .* As  $\theta^*$  approaches the critical threshold value  $\theta_0^*$  for increasingly precise private information,  $\beta \rightarrow \infty$ , the inequality (5) holds for large values of  $\beta$ . Reducing  $\beta$  from high levels therefore lowers the threshold  $\theta^*$ , but also reduces the right hand side of (5). If there is some  $\tilde{\beta} > \beta^{\min} = \alpha^2/(2\pi)$  at which (5) holds with equality, a further reduction in  $\beta$  will increase the threshold  $\theta^*$  while the right hand side will continue to fall. Hence, there is at most one solution to (5) as equality. As indicated by Figure 1, the optimal precision of private information is then given by  $\tilde{\beta}$ .

Inserting (5) as equality into (1),  $\tilde{\beta}$  is implicitly defined by

$$(8) \quad y + \frac{\Phi^{-1}(t/D)}{\sqrt{\alpha + \tilde{\beta}}} = \Phi\left(-\sqrt{\frac{\tilde{\beta}}{\alpha + \tilde{\beta}}} \Phi^{-1}(t/D)\right).$$

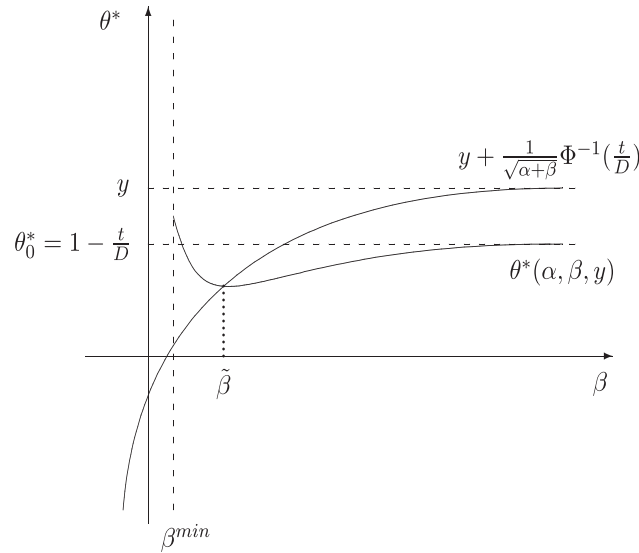
For  $\alpha \rightarrow 0$ , the left hand side of (8) approaches  $y + \Phi^{-1}(t/D)/\sqrt{\tilde{\beta}}$  while the right hand side approaches  $1 - t/D < y$ . Since  $\Phi^{-1}(t/D) < 0$ , there is a solution to (8) for sufficiently small  $\alpha$ .

Total differentiation of (8) delivers

$$(9) \quad \frac{d\tilde{\beta}}{d\alpha} = \frac{\sqrt{\tilde{\beta}} + \tilde{\beta}\phi(\cdot)}{\alpha\phi(\cdot) - \sqrt{\tilde{\beta}}},$$

<sup>9</sup> CHELI AND DELLA POSTA [2001] analyze the effect of biased information if the public cannot detect the bias.

Figure 1  
The Critical State as a Function of Precision of Private Information in the Case of Good Prior Expectations,  $y > \theta_0^*$



where

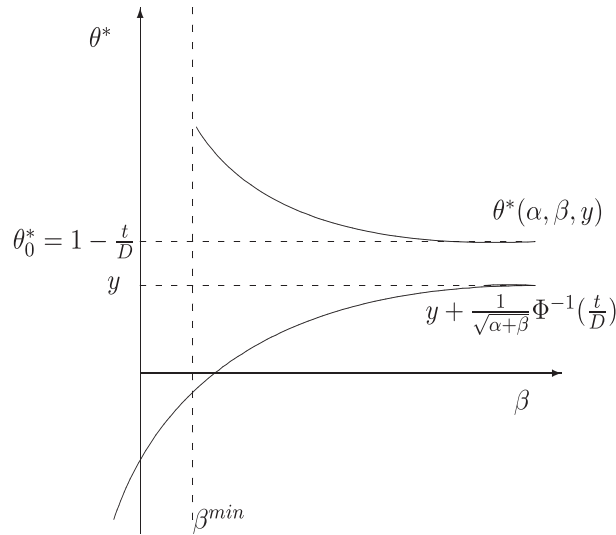
$$\phi(\cdot) = \phi\left(-\sqrt{\tilde{\beta}/(\alpha + \tilde{\beta})} \Phi^{-1}(t/D)\right)$$

represents the noncumulative density of the standard normal distribution at the argument from (8). The maximum value of the standard normal density is given by  $1/\sqrt{2\pi}$ . Since  $\tilde{\beta} > \beta^{\min} = \alpha^2/(2\pi)$ , the denominator of (9) is negative. The interior solution  $\tilde{\beta}$  decreases in  $\alpha$ . As  $\beta^{\min}$  is increasing in  $\alpha$  from zero to infinity, there must be a unique  $\tilde{\alpha}$  such that  $\tilde{\beta}(\tilde{\alpha}) = \beta^{\min}(\tilde{\alpha}) = \tilde{\alpha}^2/(2\pi)$ . For  $\alpha \geq \tilde{\alpha}$ , the optimal precision of private information is then  $\beta^{\min}$ , since any smaller variance of private signals leads to multiple equilibria. For  $\alpha < \tilde{\alpha}$ , however, the optimal precision value is at  $\tilde{\beta}(\alpha)$ .

Case 2:  $y < \theta_0^*$ . For  $\beta \rightarrow \infty$ , the inequality (5) is violated in this case. Thus, reducing  $\beta$  raises the threshold  $\theta^*$  and lowers the right hand side of (5). Therefore,  $\theta^*$  unambiguously rises with decreasing precision of private information. In this case, the best information policy is to choose the highest possible value of  $\beta$ , i.e.,  $\beta^*(\alpha) \rightarrow \infty$ . This can also be seen from Figure 2.

The results are summed up in the following proposition:

Figure 2  
The Critical State as a Function of Precision of Private Information in the Case of Bad  
Prior Expectations,  $y < \theta_0^*$



PROPOSITION 1 Assume  $t < D/2$ . The precision of information that minimizes the probability of a currency crisis for given variance of fundamentals  $1/\alpha$  is

$$\beta^*(\alpha) \begin{cases} = \frac{\alpha^2}{2\pi} & \text{if } y > 1 - t/D \text{ and } \alpha \geq \tilde{\alpha}, \\ = \tilde{\beta}(\alpha) & \text{if } y > 1 - t/D \text{ and } \alpha < \tilde{\alpha}, \\ \rightarrow \infty & \text{if } y < 1 - t/D, \end{cases}$$

where  $\tilde{\beta}(\alpha)$  is a decreasing function, implicitly defined by (8), and  $\tilde{\alpha}$  is defined by  $\tilde{\beta}(\tilde{\alpha}) = \tilde{\alpha}^2 / (2\pi)$ .

The intuition behind this result is that for a pessimistic market sentiment,  $y < \theta_0^*$ , the prior incentive to attack is rather high. Agents attack the currency if they do not get any posterior information that leads them to reconsider this action. So, even if the state turns out to be better than  $\theta_0^*$ , agents would not detect this without getting appropriate information. The more precise private information is, the larger is the set of states at which agents realize that an attack is not promising. The bad prior mean can be outweighed by good posterior information if private signals are reliable. Therefore, with a bad prior mean, private information should be as precise as possible:  $\beta \rightarrow \infty$ . This leads agents to abstain from an attack for all states above  $\theta_0^*$ , while for lower states an attack is inevitable no matter how precise private information is.

If the prior mean of fundamentals is better than  $\theta_0^*$ , the prior incentive to attack may be rather low. However, given that fundamentals have a normal distribution, there is always some probability for the state turning out to be far worse than the prior mean. In those cases, high precision of private information allows traders to realize that the state is bad and leads them to attack. Since posterior beliefs are a weighted sum of prior expectations  $y$  and private information  $x_i$ , a lower precision of private information reduces its weight and leads traders to abstain from an attack even at some bad states below  $\theta_0^*$ . Thus, it may be advantageous to withhold information in order to avoid attacks in case of bad outcomes.

In the case of an optimistic market sentiment, the optimal precision of private information depends on the variance of fundamentals. If this variance is small ( $\alpha \geq \tilde{\alpha}$ ), the prior probability of bad states is small and minimal private information is sufficient to keep most agents from attacking. If, however, the variance of fundamentals is large ( $\alpha < \tilde{\alpha}$ ), there is a rather large probability that state  $\theta$  will turn out to be so bad that a small proportion of attacking agents is sufficient for devaluation. But with low  $\beta$ , private signals are greatly dispersed and a small fraction of agents get very bad signals and attack. In this case, too little private information induces a high risk of an attack triggered by those agents who happen to get bad signals. Hence, for small  $\alpha$  there is an interior optimum for the precision of private information. This has not been detected by METZ [2002].

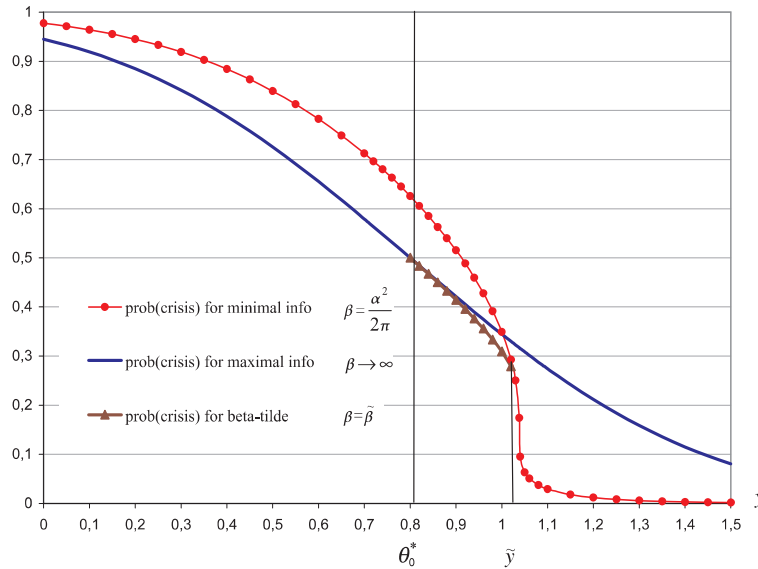
Figure 3 shows how the probability of a crisis depends on market sentiments for different information policies. If the prior mean  $y$  is below  $\theta_0^* = 0.8$  (in this example), the probability of an attack is minimal for  $\beta \rightarrow \infty$ . For higher means up to  $\tilde{y} = 1.03$ , optimal transparency is determined by the interior solution  $\tilde{\beta}$  and for  $y > \tilde{y}$  by the minimal transparency required for a unique equilibrium. Choosing the optimal degree of transparency can lead to a respectable decrease in the probability of a crisis. As can be seen from Figure 3, this is particularly apparent for good market sentiments.

The critical value for the prior mean at which optimal information policy switches between interior solution and minimal precision,  $\tilde{y}$ , is a decreasing function of  $\alpha$ , given by  $\tilde{\alpha}(\tilde{y}) = \alpha$ , and converges to  $\theta_0^*$  for  $\alpha \rightarrow \infty$ . Thus, another interpretation of our result is a tripartition of the space of market sentiments. For intermediate prior expectations the optimal degree of transparency is an interior solution.

### 3.2 Risk-Taking Behavior

As indicated above, authorities might also be interested in influencing the fundamentals distribution in order to reduce the probability of a currency crisis. In this section, we ask whether authorities might want to increase or decrease economic risk as measured by the variance of fundamentals. Assuming that authorities can adjust transparency to the optimal precision of private information as indicated by Proposition 1, we analyze how changes in  $\alpha$  influence the probability of a crisis. Economic risk has two effects on the probability of crises: it moves the threshold to crises, and it affects the probability of the state being below this threshold.

Figure 3  
Probability of a Crisis as a Function of the Prior Mean for Various Degrees of Transparency



Note: In this example, parameters are  $t/D = 0.2$  and  $\alpha = 4 \Leftrightarrow \text{var}(\theta) = 0.25$ .

These two effects show up in the derivative of (7) with respect to  $\alpha$ ,

$$(10) \quad \frac{d\text{prob}(\theta < \theta^*(\cdot))}{d\alpha} = \phi(\sqrt{\alpha}[\theta^* - y]) \left( \frac{1}{2\sqrt{\alpha}}[\theta^* - y] + \sqrt{\alpha} \frac{d\theta^*}{d\alpha} \right).$$

This derivative depends not only on the influence of  $\alpha$  on the threshold  $\theta^*$ , but also on whether  $\theta^*$  is higher or lower than  $y$ .

Case 1:  $y > \theta_0^*$ . In this case, with optimistic prior market beliefs, the optimal precision of private information is either the minimum value  $\beta^{\min}(\alpha) = \alpha^2/(2\pi)$  for  $\alpha \geq \tilde{\alpha}$ , or the interior solution  $\tilde{\beta}(\alpha)$  for  $\alpha < \tilde{\alpha}$ . Inserting  $\beta^{\min}(\alpha)$  in (1) delivers

$$(11) \quad \theta^*(\alpha, \beta^{\min}(\alpha), y) = \Phi\left(\sqrt{2\pi}(\theta^* - y) - \sqrt{1 + 2\pi/\alpha} \Phi^{-1}(t/D)\right).$$

For  $\alpha \rightarrow 0$ , this equilibrium threshold converges to  $\Phi(+\infty) = 1$ . Total differentiation of (11) yields

$$(12) \quad \frac{d\theta^*(\alpha, \beta^{\min}(\alpha), y)}{d\alpha} = \frac{\phi(\cdot) \pi \sqrt{\alpha}}{\alpha^2 \sqrt{\alpha + 2\pi} [1 - \sqrt{2\pi} \phi(\cdot)]} \Phi^{-1}(t/D).$$

Since  $\Phi^{-1}(t/D) < 0$  due to the assumption of low transaction costs, we find that  $\theta^*(\alpha, \beta^{\min}(\alpha), y)$  is decreasing in  $\alpha$ .

Plugging the second possible value for optimal information precision,  $\tilde{\beta}(\alpha)$ , into (1) instead, and using the implicit-function theorem, we find that

$$(13) \quad \frac{d\theta^*(\alpha, \tilde{\beta}(\alpha), y)}{d\alpha} = \frac{\partial\theta^*(\alpha, \beta, y)}{\partial\alpha} \Big|_{\beta=\tilde{\beta}(\alpha)} = \frac{\phi(\cdot)}{\sqrt{\tilde{\beta} - \alpha\phi(\cdot)}} \cdot \frac{\Phi^{-1}(t/D)}{2\sqrt{\alpha + \tilde{\beta}}},$$

which is negative for  $\tilde{\beta} > \beta^{\min}$ , *i.e.*, for  $\tilde{\beta}$  being the optimal precision of private information. Thus, both solutions show that increasing  $\alpha$  reduces  $\theta^*$ . Since the government can always approach the limit threshold  $\theta_0^*$  by high precision of private information,  $\theta^*(\alpha, \tilde{\beta}(\alpha), y)$  can never exceed  $\theta_0^*$ , and therefore  $\theta^* \leq \theta_0^* < y$ . Hence, (10) implies that the probability of a speculative attack decreases with rising  $\alpha$ . With optimistic market sentiments and optimal information policy, both effects go into the same direction: reduced risk lowers the threshold to crises and reduces the probability of the state being lower than this threshold. Optimal government policy is therefore given by minimizing economic risks and choosing the highest possible value of  $\alpha$ , *i.e.*,  $\alpha \rightarrow \infty$ .

*Case 2:  $y < \theta_0^*$ .* In this case, with a pessimistic market sentiment, Proposition 1 shows that it is optimal to choose the highest precision of information,  $\beta^*(\alpha) \rightarrow \infty$ . This leads the equilibrium threshold  $\theta^*$  to converge to the limit threshold  $\theta_0^* = 1 - t/D$ , which is independent of  $\alpha$ . Thus, the effect of risk-taking behavior on the threshold vanishes. Since  $y < \theta^* = \theta_0^*$  in this case,  $d\text{prob}(\theta < \theta^*(\cdot))/d\alpha > 0$ . Higher economic risk increases the chance for realizations above the threshold and thereby reduces the probability of crises. The optimal risk policy for the central bank prescribes choosing the lowest possible value of  $\alpha$ , *i.e.*,  $\alpha \rightarrow 0$ , so that the fundamental variance is maximized.

We summarize these results in Proposition 2 and Corollary 1.

**PROPOSITION 2** *Assume  $t < D/2$ . With optimal transparency  $\beta = \beta^*(\alpha)$ , the probability of a successful speculative attack monotonically increases in  $\alpha$  if  $y < \theta_0^* = 1 - t/D$ . It decreases in  $\alpha$  if  $y > \theta_0^*$ .*

**COROLLARY 1** *Assume  $t < D/2$ . The optimal risk-taking behavior and associated optimal precision of private information that minimize the probability of a crisis are*

$$\alpha^* \begin{cases} \rightarrow \infty & \text{if } y > 1 - t/D, \\ \rightarrow 0 & \text{if } y < 1 - t/D, \end{cases}$$

*and, since  $\beta^{\min}(\alpha) \rightarrow \infty$  for  $\alpha \rightarrow \infty$ ,  $\beta^*(\alpha^*) \rightarrow \infty$  for all  $y$ .*

The intuition behind these results is as follows: In the case of a pessimistic market sentiment,  $y < \theta_0^*$ , speculators have a high prior incentive to attack, so that the currency peg is very vulnerable. By increasing risk (reducing  $\alpha$ ) the government gambles for resurrection. Increasing the variance of fundamentals raises the probability of the fundamental state being better than  $\theta_0^*$  up to  $1/2$ . High precision of private information ensures that traders become aware of good outcomes whenever they occur, so that they abstain from an attack. In case of bad states, agents cannot

be kept from attacking, no matter how precise private information is. Maximal risk-taking and a commitment to provide private information as precise as possible may reduce the probability of devaluation to 1/2, which is the best that can be achieved in this case.

By reducing risk the government locks in prior expectations. For large  $\alpha$  the distribution of fundamentals is concentrated around  $y$ . If prior expectations are good ( $y > \theta_0^*$ ), then low risk (high  $\alpha$ ) may reduce the probability of outcomes below  $\theta_0^*$  almost to zero. With a low probability of bad states, agents have a low prior incentive to attack except for those cases where their private information hints at an extremely bad outcome. For any finite  $\alpha$ , the optimal precision of information is finite. It may be either  $\beta^{\min}(\alpha)$  or the interior solution  $\tilde{\beta}(\alpha)$ . Low precision of private information prevents agents from reacting to bad news. For  $\alpha \rightarrow \infty$ , the precision of private information must increase to meet  $\beta^{\min}$  and thereby also converge to infinity.<sup>10</sup> If the precision of information stays below  $\beta^{\min}$ , speculative attacks could be triggered by self-fulfilling beliefs. With optimal risk, full transparency is also required for good prior expectations.

In our view, however, there are economic uncertainties that a central bank cannot eliminate. This puts limits on  $\alpha$  and makes the case for a finite degree of transparency. Hence, a central bank trying to prevent a currency crisis must be very careful in selecting the optimal strategy. If the fixed parity is threatened by a crisis due to high payoffs from a potentially successful attack, it is of utmost importance for the authorities to bear in mind the common prior belief of the market about the economy's fundamental state and its distribution.

If market sentiments are favorable for maintaining the currency peg, the central bank should avoid risky engagements that increase the variance of final outcomes. Depending on the relation between remaining risk and prior expectations, the optimal information policy requires a finite degree of precision. Information must be precise enough to relate actions to fundamentals and avoid sunspot equilibria. On the other hand, it should not be too precise, in order to prevent traders from easily detecting bad results. Since in an optimistic market the optimal combination of risk and information policy may reduce the crisis probability to almost zero, the necessity of selecting the appropriate level of information precision is obvious.

#### 4 Conclusion

Analyzing the optimal policy for a principal threatened by inefficient coordination of a continuum of agents, we find that quite contrary to current claims, full transparency is not necessarily suited to preventing economic crises. Rather, the optimal combination of information and risk policy is very sensitive both to the degree of fundamental risk and to the common belief of the market concerning the fundamental state underlying the crisis situation. Hence, when deciding on the optimal policy to reduce the probability of a financial crisis, the principal has to be very careful

<sup>10</sup> We are grateful to an anonymous referee for pointing this out.

to correctly assess the market sentiment with regard to relevant fundamentals. An incorrect perception of the market's belief might even lead to policy measures being chosen that, instead of minimizing the danger of a crisis, make turmoil almost inevitable.

For the interpretation of our results it may be advantageous to think of market sentiments as varying from country to country. In countries where markets are optimistic and attribute a low prior probability to the event of a currency crisis, the central bank should commit to disseminate information of limited precision. As the simulation documented by Figure 3 shows, optimal choice of information precision is of utmost importance in this case, since selecting the right degree of precision can decrease the probability of a crisis by a respectable amount. In order to absolutely minimize the danger of a crisis, this information policy should be accompanied by a commitment to an active stabilization policy minimizing the expected variation of outcomes. In doing so, the probability of a crisis can be reduced to a level close to zero.

For countries where pessimistic markets expect a crisis with high probability *a priori*, the optimal policy design calls for taking high risks in combination with a strong commitment to keep markets informed even in case of negative realizations. We did not take account of other costs of increased uncertainty that would limit the optimal degree of risk. Irrespective of such limits, though, for bad priors the optimal precision of information is always infinite.

In intermediate cases, the first best solution may be to avoid risk and choose full transparency. But, to the extent that economic risks can never be completely eliminated, the second best solution may call for a design where information is provided with an intermediate degree of transparency.

If market sentiments are overly optimistic in the sense that the prior expected state is better than the mean of the fundamentals' distribution, the central bank may want to reduce perceived risk to lock in good priors. Then, optimal information policy requires a low precision of information even if the prior mean is bad. This reduces the likelihood of agents becoming aware of their bias. Precise private information always helps to correct biased beliefs. For overly pessimistic markets, transparency is more likely to keep agents from attacking.

In our analysis, we derived rules to minimize the prior probability of crises, which might not necessarily be efficient. A devaluation may have positive effects on the economy according to the analysis of second-generation models (see OBSTFELD [1994], [1996] among others). Also, our model completely neglects a supposedly positive influence of transparency on the prior expected payoff of traders who suffer from coordination failure in the case of unreliable information.<sup>11</sup>

The main results of our model call into question the undifferentiated demands for high transparency. Rather, the rules of information dissemination must be conditioned on the expected long-run development of a country. In general, strict rules for

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<sup>11</sup> For an analysis of welfare effects of information policy, see also CHUI, GAI, AND HALDANE [2002] and MORRIS AND SHIN [2002].



timely and accurate information dissemination are better suited for avoiding crises if prior expectations attribute a higher probability to such events.

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