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SIGNALING VERSUS COMMITMENT STRENGTHENING: EXCHANGE RATE INSURANCE AGAINST CURRENCY ATTACKS

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Signaling versus Commitment Strengthening: Exchange Rate Insurance against Currency Attacks

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Abstract

Both empirical and theoretical studies suggest that currency attacks can occur even in a fixed exchange rate regime with sound fundamentals. Can mechanisms be designed to prevent such currency attacks? To address this question, we first need a theory of currency crisis. I argue that such a theory must contain two ingredients: the government's lack of commitment and its preferences being private information; and that a successful mechanism must handle both of the problems. With such a theory in mind, I evaluate the proposal that Chan and Chen (1999) and Merton Miller (1998) made during the Asian economic crisis to defend the Hong Kong dollar and Chinese RMB via the government sale of insurance against devaluation. I argue that the proposal will not perform as well as claimed. As the issuance of insurance makes devaluation more costly, the commitment to peg is strengthened. That the insurance scheme serves as a commitment device renders it an ineffective signaling device: in the game where the government's type is private information, a separating equilibrium does not, in general, exist where only the strong type adopts the insurance scheme. Despite this, I also find that it is never a negative signal: that is, it will never be the case that the weak type adopts the proposal while the strong type does not. Therefore, the potential problem of the Miller proposal can be fixed by giving the government one more dimension of choice. One remedy, for example, is to allow the government to also choose whether to sell the insurance or to give it out for free. The dimensionality critique that is identified above is valid for other unidimensional proposals. The recent path breaking work of Morris and Shin (1998) is employed to tackle the coordination problem among speculators.

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"If the Hong Kong Monetary Authority can provide insurance to the public against HK dollar's devaluation and make it clear to the public that the Authority will suffer a great loss in case HK dollar is devalued afterwards, then the public will be convinced of the Authority's determination ... I also gave a similar suggestion to the Chinese government." (p. 18)

"I told (Chinese vice) Primer Zhu: '...Issuing this type of insurance is a sure win. If you know your currency will not devalue and still sell devaluation insurance, in the U.S. you will be prosecuted for insider trading. 'I also told him: 'You even do not need to actually issue the guarantee. Merely declaring such an intention will have a very palatable effect.'" (p. 21)

– Merton Miller (1998b), in a speech delivered in Hong Kong, January 1998

1. Introduction

The Asian economic crisis taught us a great lesson about the fragility of fixed exchange rates under increasing financial openness. Its alternatives—ranging from floating rates to dollarization to regional common currencies—are not without risk. Hence, it is important to study how the fixed exchange rate can be further improved. Such research can enhance our understanding of both the strength and weakness of the fixed exchange rate. Needless to say, we will be concerned with fixed exchange regimes *that have sound fundamentals*; according to the first generation models, fixed exchange rates are not recommended for economies with poor fundamentals (see, Krugman 1979, Salant and Henderson 1978, and Flood and Garber 1984). While the literature has focused more on how a currency crisis arises and propagates, and whether and how the government can defend the parity *during* a crisis, our focus is different. Here I shall address the following question: can the government design mechanisms *ex ante* to avoid future crises? To my knowledge, relatively little work has been conducted on this important issue. (One exception is the work of Ozkan and Sutherland 1995. Related work includes that of Breuer 1999, Chu 2001, Garber and Spencer 1995, Lall 1997, and Taylor 1995.)

To address the question, we first need a theory on the causes of currency crises for regimes with sound fundamentals. Such a theory should contain two ingredients: a government's lack of commitment, and government preferences being private information. The first ingredient has been identified by Obstfeld (1994, 1996) and Ozkan and Sutherland (1995), among others. While the currency peg is sustainable in the absence of attacks, it is no longer so when the attack scale is large enough. Therefore, when the government is unable to precommit not to devalue, a successful coordinated attack can result. This idea is generally viewed to be central in the so-called second-generation models of currency crisis. The second ingredient is clearly a realistic assumption as well. Although it has not been emphasized as much as the commitment problem in the currency attack literature, it plays a key role in the new political economy literature (see, e.g., Vickers 1986, Drazen and Masson 1994, and Drazen 2000a, b).

Specifically, this paper is a theoretical study of an exchange rate insurance (ERI) proposal that Merton Miller (1998a, b), among others, made during the Asian economic crisis to rescue the Hong Kong dollar and the Chinese RMB. The reason that I choose to study Miller's proposal is threefold. Firstly, it is a fairly concrete proposal made by notable economists that has also been hotly debated. It is likely that a similar proposal will emerge when the next currency crises arise. Secondly, the Miller proposal is a member of a family of proposals that argues for more government involvement in the currency option market. A study of Miller's proposal will offer us insights into related proposals. Thirdly, a theoretical investigation will further our understanding of the tension between the two ingredients that are identified above.

Miller's proposal is as follows. Instead of reiterating the intent to maintain the peg, the government should "put its money where its mouth is." Specifically, the government was advised to sell insurance to holders of local currency against devaluation risk with the premium of the insurance to be determined via market forces. The amount of local dollars that are to be insured does not need to cover all of the money supply; in the case of Hong Kong, an amount of HK$ 50 billion would be good enough (this amounted to approximately 6% of the foreign reserves). The proposal assumes that the government's resolve to defend the currency is uncertain to the public. According to Chan and Chen (1999) and Miller, a strong (determined) government will be more ready to issue the insurance; therefore, such an instrument becomes a useful signaling device for the strong government to distinguish itself from a weak (undetermined) government. Chan and Chen (1999) also point out another merit: the insurance increases the government's commitment to the fixed rate, which reduces the likelihood of a self-fulfilling attack equilibrium in the fashion of Obstfeld.

The initial idea seems to have originated from a group of academic economists in Hong Kong (see Chan and Chen, 1999) and then been accepted, modified, and brought under a greater spotlight by Miller (1998a,b), who even tried to sell the same idea to China to boost the credibility of the RMB when he met the then Chinese Vice Premier Zhu Rongji in early 1998. It appears that he considered his proposal suitable for all fixed exchange regimes with relatively sound fundamentals. It was also reported that two other Nobel laureates - Gary Becker and Myron Scholes - also greatly supported the proposal for Hong Kong (Chan and Kwan, 1998, p. 130). Despite the proposal's wide reception in the media, there has been little consensus as to whether it would have worked for Hong Kong, or will work in general. There have been almost no theoretical investigations into it, and the objective here is to evaluate it via a formal model.

There are three main results of this paper. First, a pooling equilibrium exists, so that neither type of government chooses to issue the insurance. This equilibrium is supported by pessimistic beliefs that the public updates its belief that the issuance of ERI is a sign of a lack of determination. Such an equilibrium is more likely to be feasible when political constraints place an upper bound on the amount of insurance that will be issued. The second and more important result is that, even without political constraints, a separating equilibrium is unlikely to exist where only the strong type of government issues ERI. Every separating equilibrium in the game generally involves both types choosing positive but different levels of ERI. This poses a great difficulty when determining the usefulness of ERI as a signaling device.

The intuition of the second result is as follows. A standard signaling game usually presumes two conditions: (a) the Spence-Mirrlees single-crossing condition which states that given that government type is commonly known, the weaker the type, the greater the marginal disutility of using the signaling instrument will be; and (b) given that the type is commonly known, each type's utility is decreasing in the amount of signaling instrument chosen. While condition (a) presumably holds in our model, condition (b) need not hold. The reason for this is simple. Note that the issuance of ERI, which partially mitigates the time consistency problem, presumably benefits the government, at least when the amount of ERI is small enough, hence invoking condition (b).

One response to this second point might be to restrict attention to the scenario where when the type is commonly known the weak government cannot benefit from issuing ERI. In that case, in the game with asymmetric information, there will be a separating equilibrium in which only the strong type will issue ERI. However, that a weak government cannot benefit from issuing ERI when its type is commonly known is not a weak government's *defining characteristic*; we can easily envision a weak government that can benefit from such an action without violating its definition. Hence, the true message of the restriction is that whether Miller's proposal is useful is inconclusive; it sometimes works and sometimes does not.

The possibility that an instrument turns out to have a negative signaling effect has been pointed out in the currency attack literature. In his study of the use of high interest rate to defend against currency attacks, Drazen (2000a) establishes an equilibrium in which only the weak type of government uses high interest rates to defend. According to Drazen, this provides a rationale for why high interest rates do not always succeed in defending against currency attacks. The third result of the present paper is to show that ERI does not have such a negative signaling effect. That is, it will never be the case that an equilibrium exists where only the weak type adopts the insurance scheme. This result is quite significant in the sense that the deficiency of the original ERI proposal implied by our second result is curable.

The second result suggests a tension between the commitment problem and the asymmetric information problem, and to solve these two problems we, in general, require two instruments. In a more abstract sense, this confirms the conventional wisdom that the number of policy instruments should be no less than the number of problems. Yet, what are these two instruments? Is ERI per se one of them? Our third result gives an affirmative answer: ERI should be maintained, and what is really needed is to introduce one more dimension of choice. Suppose that the government is allowed to choose whether to sell the insurance (and receive the market price) or to give it out for free. In this scenario, we expect a separating equilibrium to exist in which only the strong type will issue ERI for free (political feasibility is another issue). In this equilibrium, the strong type can both credibly signal its type and strengthen its commitment.

It is well known that the multiple equilibrium issue in currency crisis models poses great difficulty in comparative static exercises.[1] To resolve this difficulty, I construct a framework based upon the recent path breaking work of Morris and Shin (1998). These authors argue that multiple equilibria in the second generation models are only apparent - they are merely an unintended result of the unrealistic assumption that agents observe fundamentals without errors. The novelty of my proposed model is that it allows characteristics of the government to be private information, and the government to make the optimal policy choice before future fundamentals are revealed. As far as I know, this study is the first along the line of Morris and Shin (1998) to investigate the optimal strategy on the part of the government.

The rest of this paper is organized as follows. Section 2 highlights the tension between the commitment problem and the signaling problem. Section 3 describes a framework that gives the properties of reduced form utility functions that are described in Section 2. Section 4 solves the speculators' attack decisions. Sections 5 and 6 study the optimal choice of ERI when the government's type is and is not commonly known. Section 7 discusses the role of some main assumptions. Section 8 concludes the paper.

[1] I suspect that this is the true reason why the issue of commitment strengthening in the second generational models a la Obstfeld (1994, 1996) has been so little studied.

2. Basic Intuition

A reduced form model is used to convey my main arguments. There are two types of government: strong and weak. Compared with a weak type, a strong type is always more determined to defend the currency peg. The type i government is allowed to make a policy choice D_i, which is publicly observable, $i = s$ (strong), w (weak). The set of feasible choices is denoted by Ω which, dependent on the context, equals either $[0,\infty]$ or $[0, \overline{D}]$, where $\overline{D}$ is a known upper bound. Although the policy choice that is used here is the amount of ERI that will be issued to the public, it can be any other policy choice that affects the government's incentive to devalue. Represent type i government's expected utility function by $W_i\,(\pi_s^u, D)$, $i = s, w,$ where D is the policy choice that the public observes and π_s^u is the public's updated belief, upon observing D, about the probability that the government is strong. For the moment we discuss the equilibrium outcome based on the properties of these reduced form utility functions. (The next few sections will be devoted to justifying these properties.) The following assumption is made.

A1 $W_i\,(\pi_s^u, D)$ is strictly concave in $D \in \Omega$, and hence, for every π_s^u, there exists a unique $D_i(\pi_s^u) \in \Omega$ that maximizes $W_i\,(\pi_s^u, D)$, $i = s, w$.

2.1 Tension between Signaling and Commitment Strengthening

Two candidate equilibria are of particular interest: a separating equilibrium in which the strong type chooses a $D_s > 0$, while the weak type chooses $D_w = 0$; and a semi-separating equilibrium in which the strong type chooses a $D_s > 0$, while the weak type mixes between $D_w = 0$ and $D_w = D_s > 0$ with strictly positive probabilities. The following proposition is easy to show (proof omitted).

Proposition 1 *There exists a separating (semi-separating) equilibrium in which $D_s > 0$ is chosen with probability one and $D_w = 0$ with probability one (with positive probability) only if*

$$\text{for all } D \in \Omega, \min_{\pi_s^u} W_w(\pi_s^u, D) \leq W_w(0,0). \tag{1}$$

Equation (1) states that there is a profile of updated belief $\pi_s^u(D)$ such that the weak type of government finds it (at least weakly) optimal to choose $D_w = 0$ with the associated updated belief of $\pi_s^u(0) = 0$, instead of choosing any $D_w > 0$ with associated updated belief $\pi_s^u(D_w)$. To ensure the existence of the equilibrium we need also to consider the incentive compatibility constraint on the part of the strong type. Hence, (1) is only a necessary condition for the aforementioned separating or semi-separating equilibrium. Yet, this necessary condition is not automatically guaranteed. There are two possible scenarios according to the characteristics of the weak type's expected utility function.

A2a It is not in the weak type of government's interest to choose any positive D when its type is commonly known, i.e., $W_w\,(0, D)$ is non-increasing in D when $D = 0$.

A2b It is still in the weak type of government's interest to choose a positive D when its type is commonly known, i.e., $W_w\,(0, D)$ is increasing in D when $D = 0$.

The two scenarios correspond to Panels a and b in Figure 1. For Panel a, (1) is easy to satisfy. For instance, $\pi^u_s(D) = 0$ for $D \notin \{0, D_s\}$ is one such profile of updated belief because $W_w(0, D) < W_w(0, 0)$ for all $D > 0$. (In addition, $\pi^u_s(D_s)$, which follows the Bayes rule, must satisfy $W_w(\pi^u_s(D_s), D_s) \leq W_w(0,0)$). This type of equilibrium is well studied in the signaling literature: the strong type of government chooses a sufficiently large signal, while the weak type chooses no signal at all.

For Panel b, it is more difficult to find a belief profile to satisfy (1). Note that the profile that $\pi^u_s(D) = 0$ for $D \notin \{0, D_s\}$ will not work for this purpose. Given that its type is revealed, the weak type will prefer to choose a positive D. To prevent it from doing so, we need stringent beliefs. A necessary condition for (1) is that $W_w(\pi^u_s(D),D) < W_w(0,D)$ for all $D \in (0,D^*)$, where $D^* > 0$ is defined as the largest D such that $W_w(0,D) \geq W_w(0,0)$. (Refer to Figure 1.) That is, *for each* $D \in (0,D^*)$, *there exists a strictly positive* $\pi^u_s(D) > 0$ *such that the weak type's payoff is lower than the one resulting from the case where its type is completely revealed* ($\pi^u_s(D) = 0$). Although it is difficult to rule out, this condition is rare.

Policy that increases the cost of devaluation to the government presumably hardens the government's defense commitment. Insurance against devaluation from the current peg is one such policy, as compensation to insurees is incurred only upon devaluation of the peg. As long as the government gets enough premia from selling the insurance to compensate for the expected later loss in compensation, the weak government will have the incentive to choose a positive D. This argument holds for the weak type of government as well. Therefore, scenario b should be plausible and deserves our attention. This accords with Ozkan and Sutherland (1995), who argue that increasing the devaluation cost can increase the life expectancy of a fixed exchange rate.

The above analysis highlights a basic conflict when a policy instrument is used as both a signaling device and a commitment strengthening device. Somewhat paradoxically, being a successful commitment device makes it less likely to be a successful signaling device. A comparison with Spence's (1974) classic education signaling game is instructive. In that model, education is totally unproductive. Therefore, education will not be used in case the worker's type becomes public information. This ensures that in the game where the worker's type is private information, a separating equilibrium exists where the low-ability type will not choose any level of education. Once education is productive, its role as a signaling device is hampered.

2.2 Constraint on the Choice of D Leading to Pooling

The discussion above indicates that if A2a is the case, then a separating equilibrium exists in which only the strong type of government will choose a positive D. This is true only if a large enough D is in the feasible set Ω. However, when Ω is bounded to equal $[0, \overline{D}]$, the separating equilibrium that we desire may still be infeasible, and there will be a tendency towards pooling.

In what follows, assume that assumption A2b holds and the set of feasible D is bounded so that $D \in [0, \overline{D}]$. Although the government might consider a very large D to be beneficial, the electorate may not agree. Political consideration thus allows the government to choose at most a moderate level of D. (I do not think that few people will agree to a level that exceeds, say, 40% of the foreign reserves.) Therefore, the accountability to the electorate or legislature places an extra constraint on the types and levels of signaling devices that will be used. This important feature of public policy making distinguishes itself from other decision making problems.

Assume that this $\overline{D}$ is smaller than any of the optimal D_i (for arbitrarily given π_s^u), and that $W_i(\,.,.\,)$ have the following properties.[2]

A3 For $D \in [0, \overline{D}]$, $W_i\,(\pi_s^u, D)$ is strictly increasing in π_s^u, where $i = s, w$.

A4 For $D \in [0, \overline{D}]$, $W_i\,(0, D)$ is strictly increasing in D, where $i = s, w$.

A5 For $D \in [0, \overline{D}]$, $W_s\,(1, D)$ is strictly increasing in D.

The following propositions are immediate.

Proposition 2 *Assume A3 and A5. There exists a critical π_s^* such that a pooling equilibrium at $D = 0$ exists if and only if $\pi_s \geq \pi_s^*$. (Pooling at $D = 0$.)*

Proposition 3 *Assume A3 and A4. There always exists an equilibrium in which both types of government choose the same $D = \overline{D}$ with certainty. (Pooling at some $D > 0$.)*

Proposition 4 *Assume A3 and A4. There does not exist any separating (semi-separating) equilibrium in which the strong type chooses a positive D with probability one while the weak type chooses $D = 0$ with probability one (a strictly positive probability). (No separation at $D = 0$.)*

Proposition 5 *Assume A3 and A5. There does not exist a semi-separating equilibrium in which the weak type chooses $D_w = 0$ with probability one and the strong type mixes between some $D_s > 0$ and $D_s > 0$ with strictly positive probabilities. (No separation at any positive D.)*

Proposition 2 states that pooling equilibrium is feasible when the prior probability of the government being strong is high enough. It is supported with a pessimistic belief about the type of government that uses a positive D. This justifies the fact that not choosing a positive D can be an optimal strategy even for the strong type government. The simulation in Section 5 will demonstrate that when the government type is commonly known, the weaker the government the larger D will be. Proposition 3 states that pooling at the maximum $\overline{D}$ is also feasible. Such an equilibrium is supported if the public construes the government that does not choose the maximum $\overline{D}$ as the weak type. As being viewed as the weak type implies a lower welfare, each type will choose $\overline{D}$.[3] These two propositions as a whole demonstrate a strong tendency to yield pooling. Propositions 4 and 5 ruled out the most "natural" separating and semi-separating equilibria.

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2 When $\overline{D}$ is larger than any of these optimal D's, the result will be similar to the one discussed in the previous subsection. That is, it will appear as if there is no upper bound on D at all.

3 However, in general the strong type of government is likely to be better off when compared to the scenario in which ERI is not permited, while there is no guarantee that the weak type is strictly better off compared with the scenario where ERI is not permitted. The reason is as follows. Because of pooling, the two types receive the same premium out of selling insurance. (Risk neutral) insurees are rational and will pay a premium in accordance with the risk. Thus, the premium that the strong (weak) type of government receives is greater (smaller) than its expected payment of compensation.

3. Framework

3.1 One Type of Reactive Government

This section presents a more structured model that will give properties highlighted in the previous section. A model is first presented in the fashion of Morris and Shin (1998) with a large group of speculators and a passive government in which the type of the government is commonly known. Through this model we can review and clarify the commitment problem, the multiple equilibrium issue, and how the approach in Morris and Shin (1998) can help to select a unique equilibrium.[4]

The players of the game are the government of a country and a continuum of speculators, whose size is normalized to unity; all players are risk neutral. All values that are to be introduced are measured in terms of a foreign currency. The country currency is pegged at e^*. The exchange rate that otherwise prevails in a freely floating market is $m(\theta)$, where θ is the country's state of fundamentals[5] and is drawn from a cumulative distributive function $G(\theta)$ so that $0 < G(\theta) < 1$ for all $(\theta) \in (-\infty,+\infty)$. As a larger θ represents stronger fundamentals, $m(\theta)$ is a strictly increasing function of (θ). The country's exchange rate is overvalued as long as $e^* > m(\theta)$. For the study to be economically interesting, assume that the chance of overvaluation is quite high, i.e., $G(m^{-1}(e^*))$ is close to unity. For weaker fundamentals where $e^* > m(\theta)$, devaluation is possible. For simplicity, also assume that the government commits to no revaluation when $\theta > m^{-1}(e^*)$. In other words, we will study a scenario in which there is devaluation risk but not revaluation risk.

Once the fundamentals are determined and observed, each speculator can choose, independently and simultaneously, whether or not to short sell one unit of the country's currency. The speculator's payoff is $R(\theta) \equiv e^* - m(\theta) - t$ for a successful attack (i.e., when the currency is let float), and $- t$ otherwise, where t is the transaction cost of short sales. If the speculator does not short sell, his payoff is zero whether or not the currency is maintained. Upon an attack, the government can abandon the peg, which will result in a floating rate of $m(\theta)$. In this case, the government's utility is normalized to zero. Otherwise, it will maintain its currency peg, which gives it a utility that decreases with the scale of attack but increases with the fundamentals. Therefore, the government will defend as long as defending gives it a positive utility.

Define $\overline{\theta}$ such that $R(\overline{\theta}) = 0$; i.e., for $\theta \geq \overline{\theta}$, the fundamentals are so strong that speculators' gain from a successful attack is too slim to cover the transaction cost. Define $\underline{\theta}$ as the strongest θ such that for $\theta \leq \underline{\theta}$, the fundamentals are so weak that the country will unpeg its currency in the absence of any

[4] Note that there are two senses of multiple equilibria. After the update belief is formed, there may be multiple equilibria in the attack game. Given that there is no multiplicity in this attack game, there still may be multiple equilibria in the game where the government decides on *D*, as there are few restrictions on the out-of-equilibrium updated belief. Morris and Shin remove the first type of multiplicity, but not the second.

[5] The fundamentals that are considered include the business environment and exchange rates of other countries. This is motivated by the case where during the Asian financial crisis devaluation in other Asian countries made Hong Kong more likely to devalue its currency peg, even if the business environment inside Hong Kong had not experienced as much deterioration as had those of other Asian countries.

attack. Currency attacks that occur for this range of parameters have been explained by the first generational models (see, Krugman 1979, Salant and Henderson 1978, and Flood and Garber 1984). For the intermediate range where $\underline{\theta} < \theta < \overline{\theta}$, the economy is “ripe for attack”: the currency peg may be attacked and finally break down not because the fundamentals are so bad to make the fixed exchange rate unsustainable, but because the government is unable to commit to maintaining the peg. If it was able to do so, speculators would never be interested in attacking, and the peg would turn out to be viable. This lack of commitment problem is also known as the time (in)consistency problem, or credibility problem,[6] and is emphasized in the second generation currency crisis models of Obstfeld (1994, 1996). The commitment problem is an inherent problem in public decision making, and it is difficult to imagine an economy without such a problem.

When θ is commonly observed without errors, there will be multiple equilibria (or self-fulfilling prophecies) for this range of $\underline{\theta} < \theta < \overline{\theta}$. In this case, the time consistency problem and multiple equilibria occur under exactly the same conditions. However, this is not the case in general. Suppose that the fundamentals are observed with errors: given the true state θ, each speculator observes an independent signal x that is distributed according to a cumulative function $H(x|\theta)$. Provided that the signal is not very noisy, Morris and Shin (2000) show that for this range of $\underline{\theta} < \theta < \overline{\theta}$, the multiple equilibria reduce to a unique equilibrium: there is a cutoff point θ^* such that the unique equilibrium outcome is to unpeg for $\underline{\theta} \leq \theta^*$ and not to unpeg otherwise. Note that, for $\theta > \theta^*$, the time consistency problem still occurs, and this means speculators can gain if they can co-ordinate a large enough attack. Difficulty in co-ordination arises, however, because each speculator is uncertain of what other speculators have observed. For $\theta > \theta^*$, successful self-fulfilling attacks are infeasible, and for $\underline{\theta} \leq \theta^*$ the co-ordination *not* to attack is infeasible. Therefore, the commitment problem and multiple equilibria do not occur under exactly the same conditions, and cannot be referred to interchangeably.[7]

A remark about the Morris and Shin approach is in order. Whereas their uniqueness result seems to render irrelevant the role of multiple equilibria in the study of currency crises, we take it primarily as a powerful workhorse to conduct comparative statics in light of multiple equilibria. The issue of multiple equilibria still deserves further study.[8]

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6 In the literature, credibility can refer to either the commitment problem or the uncertainty arising from asymmetric information on the part of the policy maker. Because of this potential confusion, we will generally stick to the notion of commitment problem and avoid the notion of the credibility.

7 Prati and Sbracia (2001) present empirical results that are supportive of the Morris-Shin approach.

8 As a matter of fact, researchers have constructed models that exhibit multiple equilibria in the Morris and Shin framework. The parameter space that allows for mulitple equilibria, however, is much narrower relative to that of Obslfeld. See Chan and Chiu 2002, Sbracia and Zaghini 2001, and Heinemann and Illing 1999 for details.

3.2 Two Types of Proactive Government

This subsection introduces a variant model that allows both private information about the government preferences and pre-emptive actions by the government to avoid a currency crisis. The game consists of the following three stages.

At the beginning of stage 1, the exchange rate has already been pegged at e^*. The government can be either strong (s) or weak (w). (The exact utility representation will be discussed shortly.) While the government knows its own type, the public holds a belief π_s ($\pi_w \equiv 1- \pi_s$) as the likelihood that the incumbent government is strong (weak). The fundamentals are sound and there is no immediate risk of currency crisis or devaluation. The state of future fundamentals is a random variable distributed according to a given cumulative distribution function $G(\theta)$. The government cares about bad fundamentals and currency attacks that may occur in the future. While it cannot change $G(\theta)$, it can affect the likelihood of a currency attack by making speculators less aggressive and making itself more determined. To do so, each type i issues an amount of ERI, D_i, $i = s, w$, against a devaluation of its domestic currency.[9] In the absence of insurance, upon a devaluation to m, the holder of one unit of domestic currency will experience a loss that amounts to $e^*- m$ of foreign currency. In the case of no devaluation, no loss is incurred. Assume that the insurance contract takes the following form: for each unit of domestic currency that is insured, the government is obligated to repay an amount of foreign currency, $\gamma(e^* - m)$, upon devaluation, and repay nothing otherwise.[10] The Chan-Chen-Miller proposals assume a complete insurance, i.e., $\gamma = 1$. However, we can generalize it to allow for incomplete insurance. The insurance contracts are sold via the market. Let $P(D_i)$ be the total premium that type i government collects. Presumably, the choice of D_i leads the public to come up with updated beliefs, which follow Bayes rule whenever applicable, about the probability of the government being strong, $\pi_s^u(D_i)$.[11]

In stage 2, the state of fundamentals, θ, is revealed. While the government observes the true value of θ, the speculators each observe only an iid signal x that is distributed according to a cumulative function $H(x|\theta)$. Upon observing the iid signals, all speculators simultaneously and independently decide whether to short sell one unit of local currency. We assume that neither the number of potential speculators nor the transaction cost is affected by the government's choice of D_i, $i = s, w$.

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9 Merton Miller proposed a value of D that was equal to HK$50 billion, i.e., about 22% of Hong Kong's M1, or 6% of foreign reserves at the time.

10 The interest rate of the foreign currency is normalized to zero, while that of the domestic currency is endogenously determined; the interest rate differential thus represents the risk premium that is associated with the domestic currency's devaluation probability.

11 We assume that the government will make institutional arrangements to ensure proper delivery of obligation. One method is to earmark enough foreign reserves and have them stored via a third party, such as an international organization. Another is to follow Chan and Chen (1999), where the instrument takes the form of domestic currency put options: basically, the government loans out an amount of foreign currency of $D \times e^*$ to authorized institutions, which are allowed to repay the loans in foreign currency or in a corresponding amount of domestic currency at the rate (e^*) that was fixed when the contracts were signed. In this case, the concern about lack of commitment on the part of the government clearly does not exist, as money has already been in the borrowers' hands. Note that this proposal is analytically identical to the full insurance proposal in which $\gamma = 1$ (with a difference of a multiplying factor that is dependent on the interest rate differential).

In stage 3, upon seeing the magnitude of attack, the type i government can choose either to keep the peg or to float, $i = s, w$. (The payoff to each speculator under each possible outcome has been described in the previous subsection and is not repeated here.) In the latter case, the type i government's welfare will be $-D_i \gamma R(\theta)$, which is the loss of foreign reserves upon devaluation thanks to insurance reimbursement. In the former case, its welfare will be $v_i - c_i(\alpha, \theta, D_i)$. The term v_i is the utility that is gained from having the exchange rate regime unchanged, and $c_i(\alpha, \theta, D_i)$ is the cost of maintaining the exchange rate where $\alpha \in [0,1]$ is the extent of attack (the proportion of speculators who have attacked). I assume that $c(\alpha, \theta, D)$ is decreasing in θ but increasing in α and D. More elaboration on $\partial c/\partial D$ is in order. The repayment upon devaluation clearly plays an important role in the government's devaluation decision. However, that is already captured elsewhere. Thus, it does not appear to me that D would enter $v - c$ (.) directly. Nonetheless, I maintain the argument D in the expression c (.) in order not to miss something that the reader may find important.

Note that I also assume that $v_s \geq v_w$ and $v_s(\alpha, \theta, D)\ c_w(\alpha, \theta, D)$ for all α, θ and D, and that one of the inequalities must be strict. This means that given the same θ and D, the maximum scale of attack that the strong type of government is able and willing to stand against is always greater than that of the weak type. This justifies the notion of strong and weak types that we use. Assuming a unity discount factor and a zero interest rate (for foreign currency), type i government's objective in stage 1 is to choose a D to maximize its expected overall utility

$$W_i(\pi_s^u D) = P(D) + \int_{A_i(D)} (-D\gamma R(\theta))dG(\theta) + \int_{(-\infty,+\infty)\setminus A_i(D)} (\upsilon_i - c_i(\alpha(D), \theta, D))dG(\theta) \qquad (2)$$

where $A_i(D)$ is the set of fundamentals in which the peg is foreseen to be abandoned and $\alpha(D)$ is the scale of the attacks that are anticipated.

Finally, we have two assumptions about the tripartite classification of the space of θ. For each D, define $\underline{\theta}_i(D)$ as the θ that satisfies $v_i - c_i(0, \theta, D) = -D\gamma R(\theta)$. Recall that $\overline{\theta}$ has been defined such that $R(\overline{\theta}) = t$. Assume:

B1 For all D, a finite $\underline{\theta}_i(D)$ exists and $G(\underline{\theta}_i(D)) > 0$, $i = s, w$.

This states that the event of devaluation in the absence of attacks is still positive regardless of the size of D. Put another way, for all D, we can imagine very bad fundamentals under which, even in the absence of any attacks, the government may prefer devaluation rather than keeping the peg. An alternative assumption that serves the same purpose is that however independent the government is, political constraints still impose an upper bound to the choice of D. Consequently, even with the optimally chosen amount of ERI, the possibility of devaluation cannot be ruled out completely.

B2 A finite $\overline{\theta}$ exists and $G(\overline{\theta}) < 1$.

It states that, for both types of government, attacking is not always beneficial. For $\overline{\theta} < \theta < m^{-1}(e^*)$, devaluation is possible upon a large enough attack, but the capital gain is too small to offset the transaction cost. For $\theta > \overline{\theta}$, devaluation is simply impossible and attacks can never be successful. The purpose of this assumption is to rule out the possibility that, back in stage 1, it is foreseen with certainty that the currency will be devaluated later.

I follow the tie-breaking rules that the government will give up the currency peg if it is indifferent between defending and abandoning the peg, and that each speculator will not attack if he is indifferent between attacking and not attacking. A time line of the game is depicted in Figure 2.

4. The Attack Game

I analyze the game by backward induction. Consider the government's decision at stage 3. Given D_i and upon observing α and θ, type i government's optimal strategy is to defend (i.e., maintain) the peg as long as defending gives a utility greater than that from not defending. That is, there is a minimum scale of attack

$$a_i(\theta, D_i) \equiv \{\alpha \mid v_i - c_i(\alpha, \theta, D) \geq -D_i\gamma R(\theta)\} \tag{3}$$

such that type i government will defend the peg as long as $\alpha < a_i(\theta,D_i)$.

A few remarks on $a_i(\theta,D_i)$ are in order. First, $a_i(\theta,D_i)$ is continuous in θ and D_i. Second, according to B1, for all D, there is a $\underline{\theta}_i(D)$ such that $G(\underline{\theta}_i(D)) > 0$ and for all $\theta \leq \underline{\theta}_i(D)$, $a_i(\theta,D_i) = 0$. Hence, ERI cannot completely rule out devaluation; even in the presence of ERI, the abandonment of the peg in the absence of attack will still occur with a strict positive probability. Third, for stronger fundamentals where $\theta > \underline{\theta}_i(D)$, it takes a positive attack size for the peg to be abandoned. I assume that $a_i(\theta,D_i)$ is increasing in θ (which must be true when D is small enough).[12] Fourth, as depicted in Figure 4, $a_s(\theta,D)$ always lies on the left hand side of $a_w(\theta,D)$. That is, it takes a greater attack scale for the strong type government to give up its peg. A pair of representative $a_i(\theta,D)$ as functions of θ are depicted in Figure 3.

12 This assumption is part of the sufficient condition for the equilibrium uniqueness in the attack game. In some simulation studies which will be reported later, this condition does not hold. However, I have checked that the equilibrium uniqueness is not invoked in any of those exercises.

We now solve the speculators' attack decisions in stage 2, when they know the size of D and the updated beliefs π_s^u, and correctly foresee the future government reactions that are captured by $a_i(\theta,D_i)$, $i = s, w$. Define a cutoff strategy k as the strategy that prescribes an attack if the speculator's observed signal is strictly less than k and no attack otherwise. If all speculators play the same cutoff strategy k, the government will actually see an attack scale $s(k,\theta)$, which equals $H(k|\theta)$, where θ is the true state. The government will abandon the currency peg if $s(k, \theta) \geq a_i(\theta, D)$. As $s(k, \theta)$ is decreasing in θ and $a_i(\theta,D_i)$ is increasing in θ,[13] the type i government will abandon the currency peg upon an attack if and only if

$$\theta \leq \phi_i(k,D) \equiv \arg\max_{\theta}\{s(k,\theta) - a_i(\theta,D) \geq 0\}. \tag{4}$$

A representative $s(k, \theta)$ as a function of θ is depicted in Figure 3.

4.1 Unique Equilibrium in the Attack Game

Denote by $u_k(i,x)$ as the utility that a speculator is expected to gain from attacking when he has a signal x, the government is of type i, and all other speculators adopt the cutoff strategy k. (To simplify the notation, I ignore π_s^u and D as arguments in $u_k(.)$.) Due to the negligible size of this speculator, the government will still abandon the peg under states $\theta \leq \phi_i(k,D)$. Therefore,

$$u_k(i,x) \equiv \int_{-\infty}^{\phi_i(k,D)} R(\theta)dF(\theta|x) - t \tag{5}$$

where $F(\theta|x)$ is the cumulative distribution function of θ given signal x.

In reality, the speculator does not know the government's type. The expected utility that will be gained from attacking, $E_i u_k(i,x)$, is a weighted average of the expected utility when the type is otherwise known, i.e.,

$$E_i u_k(i,x) = \pi_s^u u_k(s,x) + (1-\pi_s^u)u_k(w,x). \tag{6}$$

It can be shown that $E_i u_k(i,x)$ is strictly decreasing in x; i.e., other things being equal, a speculator is expected to gain less from attacking when the observed signal becomes stronger. If the speculator's signal is just equal to k, then the expected utility becomes

$$E_i u_k(i,k) = \pi_s^u u_k(s,k) + (1-\pi_s^u)u_k(w,k). \tag{7}$$

[13] Even if $a(\theta,D)$ is downward sloping, as long as $s(k,\theta)$ cuts $a(\theta, D)$ from above, which must be true for sufficiently precise signals, the definition of $\phi(k,D)$ below still holds true.

Clearly, any k^* that satisfies $E_i u_{k*}(i,k^*)=0$ constitutes an equilibrium. To see this, suppose all other speculators indeed use this cutoff strategy k^*. Then the speculator will be indifferent about whether or not to attack if his signal is exactly k^*, and will find it strictly beneficial to attack (not to attack) if the signal is less (greater) than k^*. (This is due to the earlier claim that $E_i u_k(i,x)$ is strictly decreasing in x.) As this argument applies to each speculator, playing k^* by all speculators becomes an equilibrium.

Provided that the signal is sufficiently precise, according to Morris and Shin (1998, 2000), the function $u_k(i,k), i = s, w$, is strictly downward sloping in k, which implies that their linear combination $E_i u_k(i,x)$ is also strictly downward sloping in k. Hence, the solution k^* to $E_i u_k(i,k) = 0$ is unique, and hence the equilibrium. B1 and B2 imply that $u_k(i,k)$ is positive for sufficiently small k and negative for sufficiently large k. The intermediate value theorem then guarantees the existence of k^*, as well as the equilibrium. Note that while the cutoff strategy k^* clearly constitutes a unique equilibrium among the class of symmetric equilibria, my claim is in fact stronger. It is unique among the class of all equilibria (asymmetric equilibria included).[14] Despite the main concern of this paper being the feasibility of the ERI, the extension of the uniqueness result in MS to an environment where there is incomplete information on the part of government is by itself a useful contribution.

Proposition 6 *Provided that signals are precise enough, given D and π_s^u there exists a unique equilibrium in which all speculators adopt cutoff strategy $k^*(\pi_s^u,D)$ and the type i government abandons the peg if and only if $\theta \le \theta_i^*(D) = \phi_i(k^*(\pi_s^u,D),D)$, $i = s, w$. The values $k^*(\pi_s^u,D)$ and $\theta_i^*(\pi_s^u,D)$, $i = s, w$, are solved by equating (7) to zero together with (4).*

Three points are worth further discussion. First, other things being equal, the earlier comparison between $a_s(\theta,D)$ and $a_w(\theta,D)$ tells us that it requires a larger attack for the strong type of government to abandon its peg. This must also be true in equilibrium when the speculators' actions are optimally chosen. Given D and π_s^u, we can partition space of θ into three categories. For sufficiently weak fundamentals $(\theta \le \theta_s^*)$, the government will certainly abandon the peg; for moderate fundamentals $(\theta_s^* \le \theta \le \theta_w^*)$, it will do so only if it is weak; for sufficiently strong fundamentals $(\theta \le \theta_w^*)$, the government will not devalue at all. This justifies the notation of being strong and weak. (To simplify the notation, I omit the arguments in these $\theta_j^*(.)$.)

Second, the prescribed strategy for the speculators is optimal only in the expected value sense; it may turn out to be unprofitable ex post. For instance, when a speculator's signal is less than k^*, the prescribed attack will fail if the true state is greater than θ_w^*; likewise, when the signal is greater than k^*, the prescribed action not to attack misses an opportunity to profit if the true state turns out to be lower than θ_s^*.

[14] Morris and Shin (1998, and 2000) show that in the game in which government type i is commonly known, the equilibrium uniqueness (among all possible types of equilibria) is guaranteed if $u_k(i,k)$ is decreasing in k. Exactly the same proof will show that for the game in which the government type is private information, the sufficient condition for equilibrium uniqueness is $E_i u_k(i,k)$ being decreasing in k. That condition is satisfied here.

Third, the proposition suggests a competing explanation for episodes such as the EMS crisis, and attacks on economies with relatively sound fundamentals in general, on which models in the fashion of Obstfeld (1994, 1996) were proposed to explain. First, note that $a_i\ (\theta,0),\ i = s,\ w$, are independent of the update belief π_s^u. However, an increase in π_s^u will make the speculators less aggressive, which will result in a shift of both the $s(k,\theta)$ and $\phi_i\ (k,D)$ to the left. In other words, the attack scale given the same θ is variable, and this variability is more distinguished when θ is neither too small nor very large. Therefore, without resorting to the notion of multiple equilibria or self-fulfilling prophecies, this variability can be completely explained by the public's expectations about the government type.

In empirical work, the public's beliefs about the government type (or in general, the government's private information that is related to devaluation likelihood) can be proxied by some measure of interest rate differentials. While both my theory and the self-fulfilling multiple equilibrium models (such as that of Obstfeld) interpret these differentials as indicative of the public's beliefs about future devaluation, they place different restrictions and allow for different predictability on these differentials. The self-fulfilling models maintain that this belief is self-fulfilling, and hence faces few restrictions. A detailed event study of a currency crisis (or non-crisis) will not enable us to tie down the dynamics of beliefs. My theory, however, maintains that the belief comes from an updating process following the Bayes rule.[15] An event study, when detailed enough, should enable us to tie it down. That is, with more information hindsight, starting with the belief at time zero (using the interest rate differential as a proxy), taking into account events that happened at time one, we can account for the belief at time two. We think that this sort of event studies is greatly needed.

4.2 The Effect of D and Updated Belief π_s^u on Speculators' Behavior

Having studied speculators' equilibrium behavior given D and π_s^u, we now study, while still fixing π_s^u, how a change in D affects speculators' attack decisions. An increase in D will affect the speculators' equilibrium behavior because the government defense decision is expected to alter accordingly. Given the same attack scale α and the same state θ, an increase in D increases not only the government's cost of defense ($c_i(\alpha,\theta,D)$) but also its cost of devaluation ($D\gamma R(\theta)$). Therefore, it affects the value of $a_i\ (\theta,D)$ for each $\theta,\ i = s,\ w$; given θ, for one unit increase in D, the minimum scale that type i government can endure is increased by $\partial a_i\ (\theta,D)/\partial D=(\gamma R(\theta) - c_3)\ /c_i$. If the increase in devaluation cost is greater than the increase in defense cost - a case which we assume to be normal - then an increase in D makes the government more determined in its defense. This is the motivation behind Panel b in Figure 1, where the weak type of government's expected utility is increasing in D, when its type is publicly known both with and without the ERI. If on the contrary the increase in the devaluation cost is smaller than that in the defense cost, the pattern as depicted in Panel a will result.

[15] For events that are out of the equilibrium path, the corresponding beliefs cannot be updated via Bayes' rule, and hence can be quite arbitrary. However, this does not matter much in our discussion, as by definition, those events will not occur in practice; the beliefs in an event study should always be updated by Bayes rule.

The speculators' equilibrium strategy will be affected accordingly. For the case in which $a_i(\theta,D)$ is increasing in D, the unique equilibrium prescribes speculators to adopt a less aggressive cutoff strategy (i.e., a weaker cutoff signal) when D is increased. To see this, first note that given the same cutoff strategy k, $s(k,\theta)=H(\theta|k)$ will remain unchanged, which will result in a smaller critical state $\phi_i(k,D+\triangle D) < \phi_i(k,D)$, where $i = s, w$. While initially a speculator with signal k is barely able to break even by attacking, after an increase in D he is expected to make a loss if attacking. Therefore, speculators will be more conservative in their attack decisions, i.e., they will adopt cutoff strategies with lower cutoff signals. Mathematically, an increase in D shifts $E_iu_k(i,k)$ as a function of k to the left, which leads to a new, smaller k^* that satisfies $E_iu_{k*}(i,k^*)=0$.

Likewise, we can study, given D, how π_s^u affects speculators' attack decisions. It is straightforward to see that, regardless of the sign of $\partial a_i/\partial D$, an increase in π_s^u always makes speculators less aggressive, which results in a lower cutoff state k^*. The results in this subsection are summarized in the following proposition.

Proposition 7

1. If $\partial a_i/\partial D > 0(i.e., \gamma R(\theta) > \partial c_i/\partial D)$, then $\partial k^*(\pi_s^u,D)/\partial D < 0$ and $\partial\theta^*/\partial D < 0$.
2. $\partial k^*(\pi_s^u,D)/\partial\pi_s^u < 0$ and $\partial\theta^*/\partial\pi_s^u < 0$.

Note that as the likelihood of devaluation decreases, the interest rate differential of domestic currency in excess of that of the foreign currency will go down. This is exactly what we usually expect from such a commitment device.

5. The Optimal Choice of D when the Government's Type Is Commonly Known

After studying the problems in stages 2 and 3, we now are ready to study the problem in stage 1, in which the government chooses an optimal D. In this section, I will study a simpler problem where the government's choice of D in which the government's type is commonly known, while the game with two types of government is relegated to the next section. The government knows, for any given D that all speculators in stage 2 will adopt a cutoff strategy $k^*(D)$ and the government itself in stage 3 will abandon the peg if and only if $\theta \le \theta^*(D)= \phi(k^*(D),D)$. Therefore, the government's objective can be written as follows:

$$\max_D W(D) = \int_{\theta^*(D)}^{\infty}()dG(\theta) + \int_{-\infty}^{\theta^*(D)} (-D\gamma R(\theta))dG(\theta) + P(D), \tag{8}$$

where $W(D)$ is the government's expected utility as a function of D, $P(D)$ is the premium that the government raises from issuing insurance of an amount D against its devaluation. (As the government type is known, I omit the subscript that indicates the type of the government in all notations.) Assuming risk neutrality, the amount that the insured are willing to pay as premium is just equal to the expected repayment, i.e., $P(D) = -\int_{\infty}^{\theta^*(D)} D\gamma R(\theta)dG(\theta)$. Hence, (8) is simplified to

$$W(D) = \int_{\theta^*(D)}^{\infty} (v - c(s(k^*(D),\theta),\theta,D))dG(\theta). \tag{9}$$

Differentiating $W(D)$ with respect to D, we have

$$\frac{dW(D)}{dD} = -(v - c(s(k^*(D),\theta^*(D),),\theta^*(D),D))g(\theta)\frac{d\theta^*(D)}{dD}$$
$$+\int_{\theta^*(D)}^{\infty}\left(-\frac{dc(s(k^*(D),\theta),\theta,D)}{dD}\right)dG(\theta).$$

Substituting $v\text{-}c(.)=-\gamma DR(\theta^*)$ in the first term of RHS, we have

$$\frac{dW(D)}{dD} = \gamma DR(\theta^*)g(\theta)\frac{d\theta^*(D)}{dD} + \int_{\theta^*(D)}^{\infty}\left(-\frac{dc(s(k^*(D),\theta),\theta,D)}{dD}\right)dG(\theta). \tag{10}$$

Focusing on the case in which an increase in D leads to less aggressive attacks, the above equation states that the consequence of increasing D involves both a cost and a benefit. Note that in the critical state, the government is indifferent between keeping the peg and abandoning it, i.e., $v\text{-}c(.)=-\gamma DR(\theta^*) < 0$. In this critical state, the government is in fact receiving a loss. Thus, a reduction in $\theta^*(D)$ that arises from an increase in D enlarges this loss. Hence, the first term of the RHS of the equation is negative, representing the cost. The second term on the RHS — the reduction in $c(.)$ for every $\theta > \theta^*(D)$ — is the benefit from an increase in D. If there is a downward shifting of the $c(s(k^*(D),\theta),\theta,D)$ as a function of θ, and if this gain is large enough to offset the first term on the RHS, then $dW(D)/dD > 0$. (Refer to Figure 4.) With a greater D, the speculators are less aggressive, hence the interest rate premium is lower, and the government derives greater net benefits from keeping the peg (recalling that such net benefits are defined as $v\text{-}c(.)$).

For the particular case in which $D = 0$, the first term on the RHS of the above equation vanishes, and we have

$$\frac{dW(D)}{dD}\Big|_{D=0} = \int_{\theta^*(D)}^{\infty}\left(-\frac{dc(s(k^*(D),\theta),\theta,D)}{dD}\right)dG(\theta)\Big|_{D=0}$$

Thus, as long as $dc/dD\,|_{D=0} < 0$ for all $\theta > \theta^{*}(0)$, a marginal increase in D starting from $D = 0$ must be beneficial to the government. Note that the derivative dc/dD consists of two terms:

$$\frac{dc}{dD} = \underbrace{\frac{\partial c}{\partial s}}_{+}\underbrace{\frac{\partial s}{\partial k}}_{+}\underbrace{\frac{\partial k^{*}}{\partial D}}_{-} + \underbrace{\frac{\partial c}{\partial D}}_{-}, \tag{11}$$

where the second term corresponds to the effect that arises directly from an increase in D, while the first term represents the indirect effect that arises from the reduction in speculators' aggressiveness that results from the government's changed determination. The two effects are countervailing: the direct effect is positive while the indirect effect is negative. When the first term on the RHS is strong enough to offset the second term, $dW(D)/dD|_{D=0}$ must be positive. This is the likely case. First, we are considering an economy with abundant foreign reserves. The cost of earmarking an extra dollar of foreign reserves for the purpose of ERI should be negligible. (Note that this cost is also something that Chan-Chen and Miller disavow.) This should be so because we are discussing states where the economy is not threatened by currency crises $(\theta^{*} > \theta)$. We have the following proposition.

Proposition 8 *If* $\frac{\partial c}{\partial D}\Big|_{D=0} = 0$ *and* $\frac{\partial k}{\partial D} < 0$, *then* $\frac{dW(D)}{dD}\Big|_{D=0} > 0$.

This suggests that when the government's preferences are commonly known, it is always beneficial to adopt the ERI scheme. Its purpose, however, is not to signal the government's type - there is no role of signaling in a model where the government does not have private information. Rather, the scheme strengthens the government's commitment to the peg, hence mitigating the time consistency problem.

Is it possible that for strong type $dW(D)/dD|_{D=0} > 0$, while for the weak type $dW(D)/dD|_{D=0} < 0$ (in this case, we come back to a scenario that is depicted in Panel a of Figure 1). However, while this is possible, it is not always the case. Recall that the two types do not differ in the amount of foreign reserves, and that the definitive distinction between a strong and a weak government is that $v_s - c_s(\alpha,\theta, D) > v_w - c_w(\alpha, \theta, D)$, or in a more reduced form, $a_s(D) > a_w(D)$. This defining characteristic is perfectly compatible with the fact that $dW(D)/dD|_{D>0} > 0$ for both types. Therefore, the assumption that the two types have different signs for the $dW(D)/dD|_{D=0}$ is unwarranted, and may lead, in the signaling game to be considered in the next section, to peculiar results that do not carry over to the more general case. Hereafter, I will focus on the case that $dW(D)/dD|_{D>0} > 0$ for both types. This brings us back to scenario A2b (depicted in Panel b of Figure 1), and also supports our assumptions of A4 (for the weak type only) and A5, as specified in section 2. (If, otherwise, $dW(D)/dD|_{D>0} < 0$ for both types, we have scenario A2a.)

5.1 Simulation

This section will use specific functional forms to illustrate how the optimal choice of D varies with the parameters of the government, given that the government type is commonly known.

The following specification is adopted in the simulation. $G(\theta)$ is normal with mean $\tilde{\theta}$ and variance v^2, while $H(x|\theta)$ is also normal with mean θ and variance σ^2. As a consequence, the posterior distribution $F(\theta|x)$ has mean $\mu = (\sigma^2\tilde{\theta}+v^2x)/(\sigma^2+v^2)$ and variance $\rho^2=\sigma^2v^2/(\sigma^2+v^2)$. $R(\theta) = 0.5- (1/\pi)\arctan\theta$. Therefore, $R(\theta)$ is decreasing in θ, $R(-\infty) = 1$, and $R(\infty) = 0$. The defense cost $c(\alpha, \theta, D)=ba^2+d/(1- R(\theta))$ where $b > 0$ and $d > 0$. A greater b indicates a greater marginal cost of defense with respect to α. The coefficient d, in contrast, indicates the disutility of keeping the peg when the state is unfavorable. Note that in our specification, the defense cost is independent of D, i.e., $\partial c(\alpha, \theta, D)/\partial D=0$ for all D. It is easy to reckon that

$$a(\theta,D)=\sqrt{\frac{\upsilon-d/(1-R(\theta))+DR(\theta)}{b}} \tag{12}$$

Note that this critical $a(\theta, D)$ value is increasing in θ so long as $D < d$, and is decreasing in θ otherwise. I have carefully checked that for greater values of D, the non-monotonicity does not render the equilibrium uniqueness inapplicable.

Figure 5 reports the simulation results that the optimal D is decreasing in v, and increasing in b and d. In these exercises, $\tilde{\theta} = 0$, $v^2 = 4$, $\mu = 0$, and $\sigma^2 = 0.05$. Even though for all v and b the government gains from ERI, the weak government (low v, large b, and large d) needs ERI to a larger extent than does the strong government. The same pattern prevails for other parameters that were tried. While far from being conclusive, the above simulation suggests the possibility that a weak government may have a greater incentive to issue ERI than a strong government. The general insight is that a strong government is more capable of containing the time inconsistency problem, and further commitment strengthening is not particularly useful. Note that in the specification, I assume that D does not enter $c(\alpha, \theta, D)$. If D enters $c(\alpha, \theta, D)$, then the optimal choice of D will be reduced. Nevertheless, there is no reason to believe that the ranking of optimal D between strong and weak types would be reversed.

The sober reader may wonder why Indonesia would have been willing to commit to a larger D than Hong Kong. We should be very careful in interpreting the results, and in mapping them to the real world. In my model, a weak government and a strong government differ not in their foreign reserves but in their trade-off between keeping the peg and other macroeconomic aspects of the economy. It makes perfect sense to discuss the signaling by a more determined Hong Kong government that wishes to separate itself from a less determined Hong Kong government (whether the government is determined is uncertain to the public). It makes little sense, however, to discuss the signaling by Hong Kong to separate itself from Indonesia, as the two economies already have observable differences. Therefore, the aforementioned question is irrelevant; the simulation does not imply that Indonesia would have chosen a greater D than Hong Kong.

6. The Optimal Choice of *D* when the Government's Type Is Private Information

We now are ready to study the general game where D is chosen and the government's type is private information. In stage 1, foreseeing the other type's choice of D, the speculators strategy $k^*(D)$, and the defense strategy $a_i(a,D)$, the type i government needs to determine its D, while taking into consideration its effect on the update belief π_s^u. The type i government's welfare is

$$W_i\left(\pi_s^u, D\right)=\int_{\theta_i^*}^{\infty}\left(\upsilon_i - c_i\left(\alpha,\theta,D\right)\right)dG(\theta)+\left(p\left(D\right)-\int_{-\infty}^{\theta_i^*}\gamma DR\left(\theta\right)dG\left(\theta\right)\right), \tag{13}$$

where $i = s, w$, and

$$p\left(D\right)=\gamma D\sum_{j=s,w}\pi_j^u\int_{-\infty}^{\theta_j^*(D)}R\left(\theta\right)dG\left(\theta\right) \tag{14}$$

is the revenue raised from insurance selling.

A few observations are in order here. First, given the cutoff state θ_j^* unchanged, $j = s, w$, the average premium of the currency option, $p(D)/D$, is decreasing in the probability of the government being strong. The intuition is that a strong government is less likely to devaluate and therefore the per unit premium from issuing insurance is lower. Second, given the beliefs π_s^u, the premium is increasing in the cutoff state θ_j^*, $j = s, w$. The intuition is that, keeping the beliefs about the government unchanged, an increase in the cutoff devaluation point θ_j^* makes devaluation more likely, which increases the option value of the ERI.

Third, it should be noted that for the strong type,

$$p\left(D\right)-\int_{-\infty}^{\theta_j^*}\gamma DR(\theta)dG\left(\theta\right)=\gamma D\left(1-\pi_s^u\right)\int_{\theta_s^*}^{\theta_w^*}R(\theta)dG\left(\theta\right)\geq 0$$

for all π_s^u where equality holds only when $\pi_s^u = 1$,while

$$p\left(D\right)-\int_{-\infty}^{\theta_j^*}\gamma DR(\theta)dG\left(\theta\right)=-\gamma D\left(1-\pi_s^u\right)\int_{\theta_s^*}^{\theta_w^*}R(\theta)dG\left(\theta\right)\leq 0$$

for all π_s^u where equality holds only when $\pi_s^u = 0$. The two inequalities state that for the strong (weak) type government, the premium received is greater (less) than its expected insurance repayment.

Fourth, by differentiating (13) (after (14) is plugged into) with respect to π_s^u, we find that

$$\frac{dW_i\left(\pi_s^u, D\right)}{d\pi_s^u}\Big|_{D=0}=-\frac{d\theta_i^*}{d\pi_s^u}\overbrace{\left(\upsilon_i - c_i\left(\alpha,\theta_i^*,D\right)\right)}^{=0}g\left(\theta\right)-\int_{\theta_i^*}^{\infty}\overbrace{\frac{\partial c_i\left(\alpha,\theta,D\right)}{\partial\alpha}}^{+ve}\overbrace{\frac{d\alpha}{d\pi_s^u}}^{-ve}dG\left(\theta\right)>0 \tag{15}$$

for $i = s, w$.

The expression $v_i - c_i\,(\alpha,\ \theta_i^*,\ D)$ on the RHS is zero because at this cutoff θ_i^* the government is indifferent between defending (which gives the above payoff) and abandoning the peg (which gives zero payoff). The sign of the derivative $d\ \alpha/d\pi_s^u$ comes from Proposition 2. Equation (15) implies that, without the ERI, an increase in π_s^u is beneficial to the government, whatever type it is. Because of continuity, we expect the above comparative statics also hold for small positive D. This thus implies a property that is specified in A3, in section 2.

The fifth observation is that the marginal incentive of the strong type of government to issue ERI is greater. Keeping π_s^u constant and differentiating (13) with respect to D, we have, for a strong government,

$$\frac{dW_S\left(\pi_s^u, D\right)}{dD} = -\frac{d\theta_s^*}{dD}\left(\upsilon_w - c_w()\right)g\left(\theta\right)_{\theta_i^*} - \int_{\theta_s^*}^{\infty}\frac{dc_w}{dD}dG\left(\theta\right)$$

$$+\left(1-\pi_s^u\right)\int_{\theta_s^*}^{\theta_w^*}\gamma R\left(\theta\right)dG\left(\theta\right) + \gamma\left(1-\pi_s^u\right)D\frac{d\int_{\theta_s^*}^{\theta_w^*}R\left(\theta\right)dG\left(\theta\right)}{dD}$$

where the first term on the RHS equals $\dfrac{d\theta_i^*}{dD}DR\left(\theta_i^*\right)g\left(\theta\right)$. Consider a marginal increase from $D = 0$,

$$\frac{dW_s\left(\pi_s^u, D\right)}{dD}\Big|_{D=0} = -\int_{\theta_s^*}^{\infty}\frac{dc_s}{dD}dG\left(\theta\right) + \left(1-\pi_s^u\right)\int_{\theta_s^*}^{\theta_w^*}\gamma R\left(\theta\right)dG\left(\theta\right),$$

which is positive as long as $dc_s\ /dD < 0\ for\ \theta > \theta_s^*$ (which I have argued is the normal case). This suggests that even if the weak government is going to pool, it still (marginally) pays for the strong government to issue ERI. The intuition is that the revenue from selling ERI net of insurance payment is increasing in D when D increases from zero. Other things being equal, the second term on the RHS of (.) is largest when π_s^u, which suggests that it is likely that $W_s\ (0,D)$ is increasing in π_s^u, which is part of A4 stipulated in Section 2.

Likewise, we can calculate the weak government's marginal incentive to issue ERI. Keeping π_s^u constant and differentiating (13) with respect to D, we have

$$\frac{dW_s\left(\pi_s^u, D\right)}{dD}\Big|_{D=0} = -\int_{\theta_w^*}^{\infty}\frac{dc_w}{dD}dG\left(\theta\right) - \pi_s^u\int_{\theta_s^*}^{\theta_w^*}\gamma R\left(\theta\right)dG\left(\theta\right),$$

which may not be positive even if $dc_w\ /dD < 0\ for\ \theta > \theta_w^*$. Hence, I am less confident that the weak type will benefit from an increase in D when both types increase and use the same D. The intuition is that the revenue from option selling net of expected capital loss from devaluation is decreasing in D when D increases from zero.

This result seems to suggest that

$$\frac{dW_s\left(\pi_s^u, D\right)}{dD} > \frac{dW_w\left(\pi_s^u, D\right)}{dD} \quad \forall D \quad \forall \pi_s^u,$$

which means that given that the belief is unchanged, the marginal cost of using D is greater for the weaker type of government than the strong type.

Finally, let me state the result about the impossibility that adopting ERI is a negative signal. It is a *reversely separating equilibrium* (RSE) when the weak type of government chooses a positive D_w with certainty while the strong type chooses $D_s = 0$ with certainty. It is a *reversely semi-separating equilibrium* (RSSE) if (1) the weak type chooses a positive Dw with a probability strictly positive but less than one and the strong type chooses $D_s = 0$ with probability one, or if (2) the weak type chooses $D_w = 0$ with probability zero and the strong type chooses $D_s = 0$ with a probability strictly positive but less than one. The two cases are RSSE1 and RSSE2. Complete separation occurs at a positive D for RSSE1 and at $D = 0$ for RSSE2. Interpreting a zero D as the status quo, an RSE or RSSE corresponds to the scenario in which it is the weak type that initiates the separation or semi-separation.

These RSE and RSSE are plausible if the commitment effect of the weak type is far greater than that of the strong type. In that case, the weak type does not mimic the strong type because, to the weak type, the gain that arises from the strengthened commitment more than offsets the loss that arises from having the weak type revealed. Moreover, the weak type does not mimic the strong type because, to it, the gain that arises from having the strong type revealed more than offsets the gain from strengthened commitment. However, it turns out that such a possibility is non-existent.

Proposition 9 *Suppose $\Omega = [0, \overline{D}]$. If A5 holds, then there does not exist any RSE, or RSSE2. If the term $W_s(1,D)$ in A5 is replaced by $W_s(\pi_s^u, D)$ where π_s^u is any updated belief, then there does not exist any RSSE1.*

7. Discussion

I have argued that there is no guarantee that a separating (or semi-separating) equilibrium exists where the weak type of government chooses $D = 0$. In other words, if a separating equilibrium ever exists, it probably prescribes both types to choose positive, though different Ds. This greatly limits the usefulness of ERI as a signaling device. Suppose that the model builder finds a separating equilibrium in which the weak type chooses a low but positive D and the strong a large D. Suppose also that now the government chooses an amount of insurance coverage that is equal to 19.19% of its foreign reserves. Should the public consider this quantity as low or high? Game theory and economics in general are not good at making quantitative suggestions of this type.

Note that this result arises from the fact that even the weak type of government can benefit from issuing ERI when its type is commonly known. Under this scenario, the premium that is raised from issuing ERI is equal to the expected insurance repayment. Therefore, that the weak type has a greater chance of devaluation (and hence a greater insurance repayment) does not prevent it from benefiting from the ERI. Moreover, an increase in D leads to a smaller probability of devaluation, which presumably benefits the weak type as well.

Two assumptions are worth further elaboration. First, I have assumed that the speculators are atomistic. Building on Morris and Shin (1998), Corsetti et al. (2000) assume that there are two types of speculators: a large player with market power and small atomistic players, and study a game in which these players need to move simultaneously and another game in which they are allowed to move in two stages. They still find a unique equilibrium. We can likewise model the speculators as Corsetti et al. do, and obtain a unique equilibrium in this study. In this case, the same comparative statics will prevail, and hence this assumption is justified.

7.1 Will ERI "Fuel" Speculation?

The second assumption is that both the transaction cost t and the maximum scale of attack are independent of D. In general, the ERI affects the speculators through two separate channels. I have focused exclusively on the channel where the speculators change their behavior as a response to the government's tougher reaction to currency attacks. In principle, another channel exists where the insurance per se directly affects the speculators' incentive. For instance, by holding insurance policies, speculators will be more aggressive in attacking because they also gain from receiving compensation from devaluation. Similarly, those who are not speculating in the absence of ERI scheme, upon holding ERI, will want to see the peg unpegged; therefore, the ERI proposal affects the number and composition of potential speculators. This concern is not serious when speculators are atomistic because they will have to compete with genuine insurees over whom they have no cost advantage. It deserves more thought, however, if some speculators have market power. In this case, they are able to win ERI over genuine insurees as they can now internalize the potential benefit from holding ERI. To eliminate this possibility, the government should make special institutional arrangements such as amortization and the non-transferability of ERI.

The possibility that issuing ERI may fuel speculation (via the aforementioned second channel) was raised as a point of objection to the proposal in its debate in Hong Kong. Advocates of the proposal argued that this objection was pointless: speculators will not purchase the insurance in the first place because compared with other instruments, purchasing it is a dominated speculating instrument. This lends support to my analytical focus on the first channel, through which I have shown that ERI is not a very good signaling device. Ironically, if the scheme really fuels speculation and if this effect is large enough, then it will become a good signaling device. The reason is that in this case using the signal is costly for each type when the type is commonly known, and assuming the Spence-Mirrlees condition, we have a standard signaling game in which a separating equilibrium exists such that only the strong type issues a sufficiently large amount of ERI. Therefore, instead of designing implementation details that prevent ERI from fueling speculation, advocates of ERI should design implementation details that encourage such fueling. The success of signaling is based on a no-pain-no-gain principle.

7.2 Should ERI Be Given Out for Free?

This study has pointed out the tension between the ERI as a commitment device versus its role as a signaling device. The problem arises, in a more abstract sense, because we have only one instrument (ERI) while there are two targets. Thus, a proper remedy to the ERI scheme is to give one more dimension of choice. One alternative is to also allow the government to choose whether to sell ERI or to give it out for free. The problem with this is that there is still some restriction on the signaling cost incurred: the up front loss is equal to the premium that the government otherwise receives from selling the insurance. A more flexible alternative thus is to allow the government to choose an amount of money to "burn" – to spend on whatever purpose that does not directly benefit the government – independent of the amount of ERI to be sold. Of course, whether the policy makers or the public will accept such money burning is another issue.

8. Concluding Remarks

This paper has been concerned with the design of mechanisms to deter future currency crises for fixed exchange rate regimes with sound fundamentals. To address this issue, one first needs to have a theory of why currency crises may arise in such economies. I have pointed out that such a theory must contain two ingredients: the government's lack of commitment and its preferences being private information, and I have maintained that any proposal that addresses the issue should simultaneously deal with both ingredients.

In the currency crisis literature, this asymmetric information assumption is not as popular as the lack of commitment assumption. This makes sense because a framework with only the commitment problem helps to single out that a lack of commitment by itself can lead to currency crises. To this end, such a framework is very fruitful and clearly simple. However, to address the real world policy issue of deterring crisis, an emphasis on the commitment problem alone is potentially misleading. Therefore, the assumption of the government's preferences being private information is not only realistic, but also essential for the mechanism design problem.

Despite the tension between signaling and commitment strengthening, I have argued that ERI can still be a useful component of a complete package to deal with the two problems. That the sale of ERI is never a negative signal suggests so. I was initially concerned with the possibility of ERI being a negative signal, for the following reasons. First, a priori there is no reason to assume away such a possibility. Second, the simulation that the weak type of government has a greater optimal level of ERI when government preferences are commonly known is also consistent with such a possibility. Third, recent work on the role of high interest rates in defending a parity suggests such a possibility.

The last section has suggested two remedies to complete the ERI proposal. For either case, the government will incur direct loss at the outset. However, in a world where policy makers and bureaucrats suffer from moral hazards and adverse selection problems, it would be difficult to have these proposals endorsed. Therefore, to have a signaling mechanism adopted and yield good results, a good proposal is not enough, and we need "clean" policy makers and bureaucrats as well as a public that is endowed with the economic knowledge that successful signaling must entail ex ante costs. This difficulty cannot be overlooked. If the sale of ERI via the market price has difficulty to get approval from the public, a proposal where ex ante cost is incurred will be more difficult to be accepted. The extra restriction placed by political consideration is one feature that distinguishes the problem at hand from other signaling problems.

The Chan-Chen-Miller proposal belongs to a small family of proposals that argue for more government involvement in currency option and futures markets. Taylor (1995) suggests that governments buy local currency put options. By buying such options, the government can exercise them in case of devaluation. The foreign reserves that are gained can then be used to stabilize the exchange rate to prevent further devaluation. Chu (2001) proposes that the government issue catastrophe bonds: coupons are paid until a crisis driven devaluation (the catastrophe) has occurred. This is equivalent to government *purchases* of insurance against devaluation, which not only gives funds to the government upon devaluation, but also encourages the public to defend the currency upon attacks. Devaluation implies forfeitures of coupon payment from the government. While both proposals have their points, whether the benefits will more than offset the costs that arise from reduced defense determination is uncertain. More importantly, whichever is the case, the dimensionality problem that has been identified is also relevant to these proposals. As long as there is only one policy choice, it will not resolve the twin problem of lack of commitment and asymmetric information. In this regard, this study is relevant to all proposals to deter future currency crises.[16]

A final remark about multiple equilibria is in order. While the multiplicity of equilibria is usually thought to play an important role in currency crises, some authors choose to downplay its role in their models. For instance, Drazen (e.g., 2000a) rightly points out that a model of an optimizing government does not automatically imply multiple equilibria. His argument is based on models in which each trader's payoff is assumed in a way that eliminates payoff complementarity: each trader's payoff will be independent of others' actions. Using this modeling approach, one can greatly simplify the strategic interaction among speculators so as to allow a tractable analysis of the government behavior.[17]

Despite the enormous benefit of the simplification, I also highly value the role of payoff complementarity and am wary of the possible loss of important insights when it is removed. This motivated me to choose the Morris and Shin framework, in which equilibrium uniqueness emerges without compromising the strategic interaction among speculators. The lack of study of the design of defense mechanisms is deeply rooted; until the work of Morris and Shin there had been no obvious way to study the effect of policy change in the presence of multiple equilibria. Building this study on Morris and Shin seems to me as a very natural one, as policy analysis is now feasible without compromising speculators' payoff complementarity.

The Asian economic crisis has taught us a great lesson about the fragility of fixed exchange rates under increasing financial openness. I hope that this study is of use to the design of more robust mechanisms to defend against currency attacks.

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[16] See also Breuer (1999), Lall (1997), Garber and Spencer (1995). They are concerned with the exchange rate defense *during* a crisis.

[17] This clearly follows the tradition of Kydland and Prescott (1977) and Barro and Gordon (1983). Both papers ignore the interaction among the public so as to focus on the interaction between the government and a representative agent from the public.

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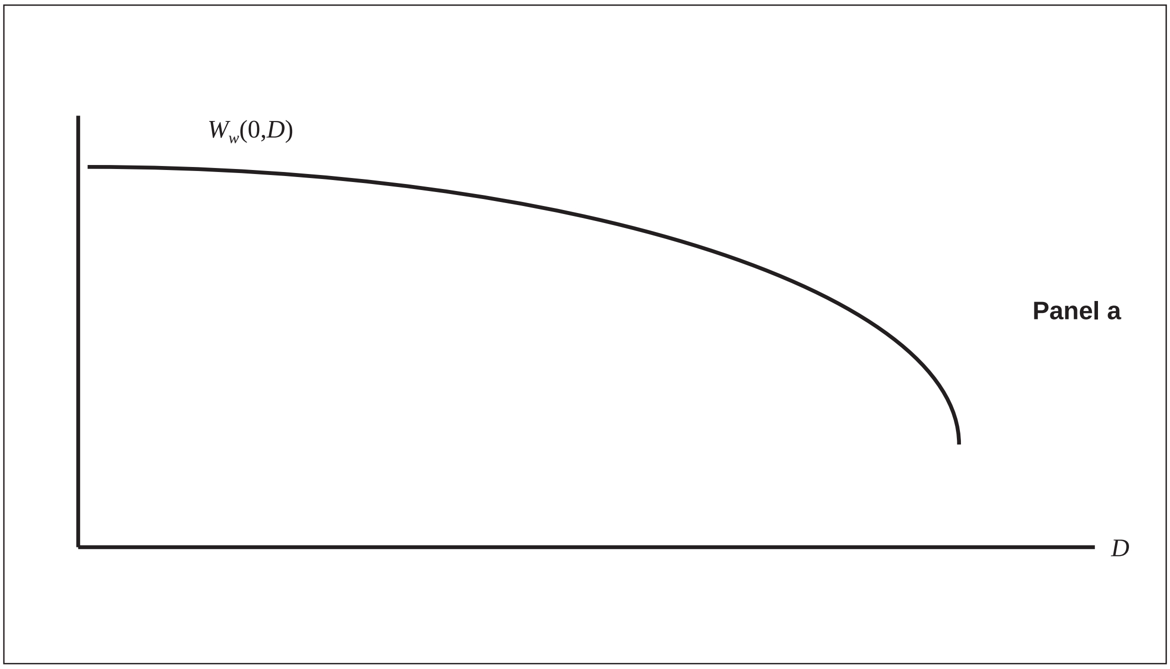
Figure 1



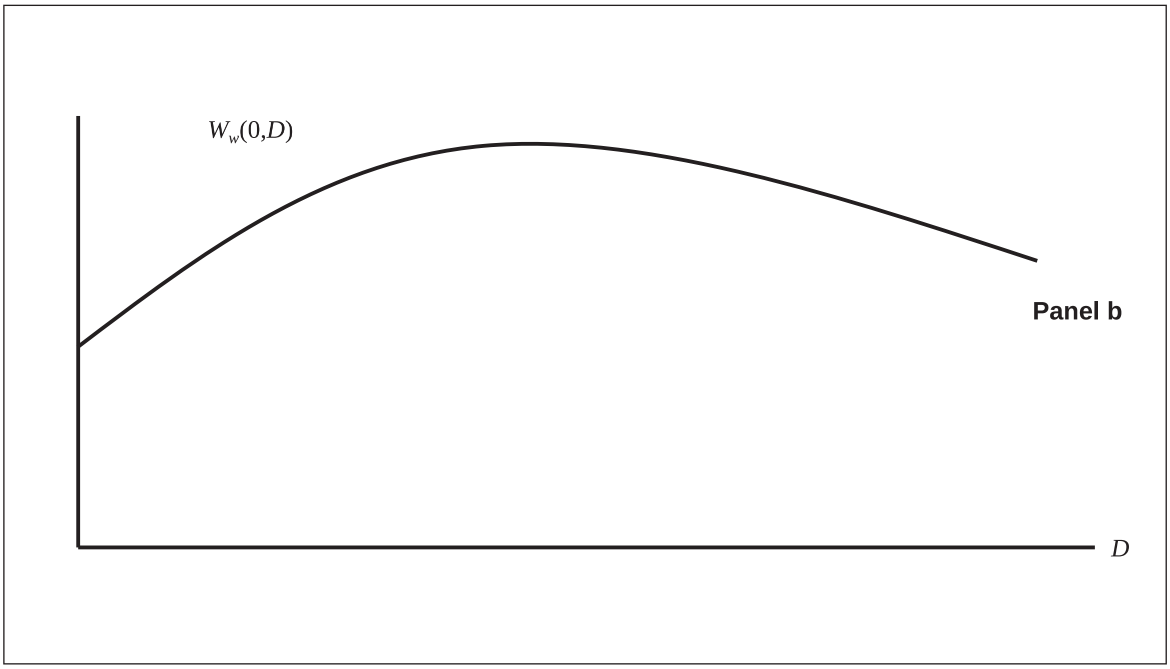


Figure 2: Time Line of the Game

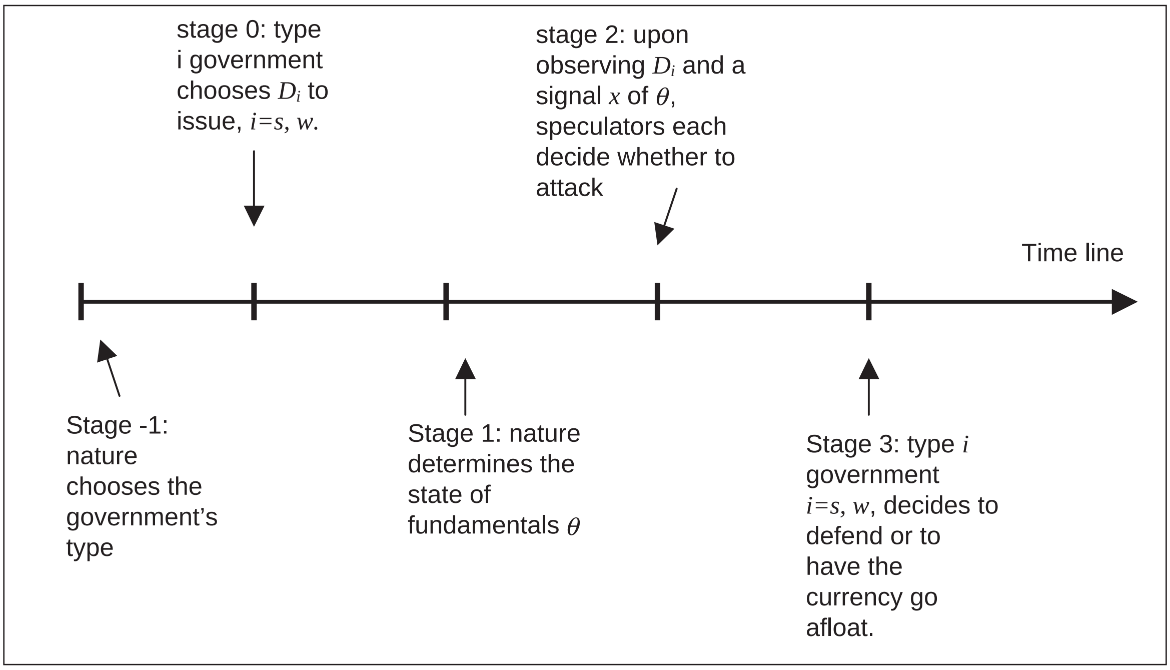
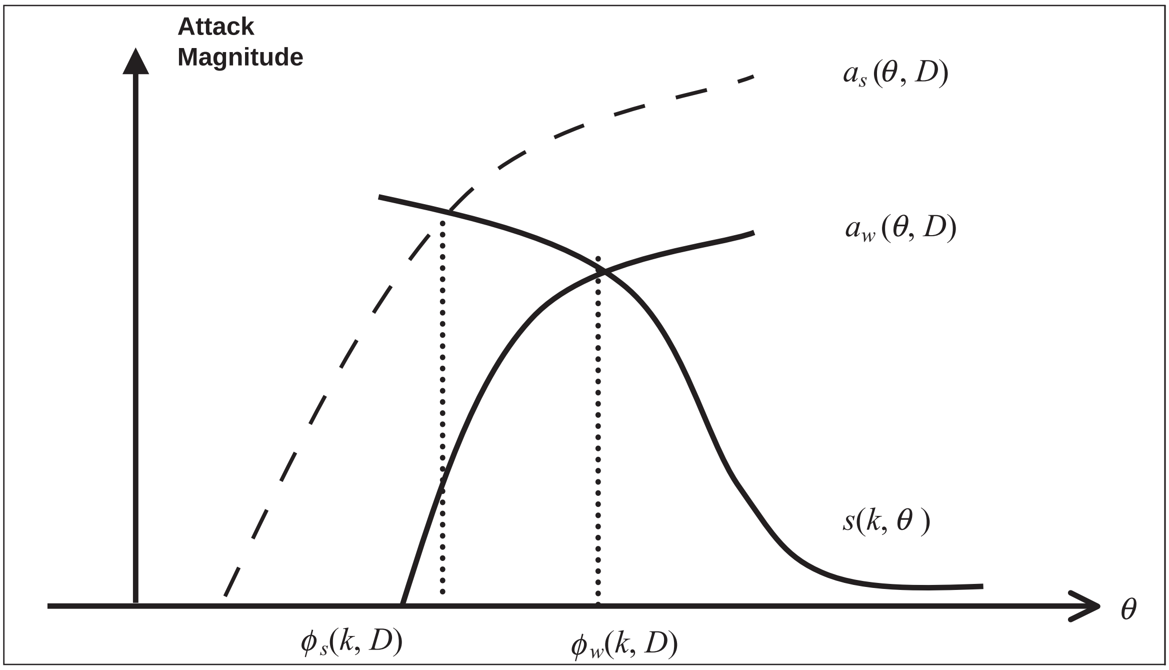


Figure 3



Given D and cutoff strategy k, the peg will be abandoned for $\theta \leq \phi_i(k, D)$ when the governement is of type i.

Figure 4: Strong Type Government's Welfare Change

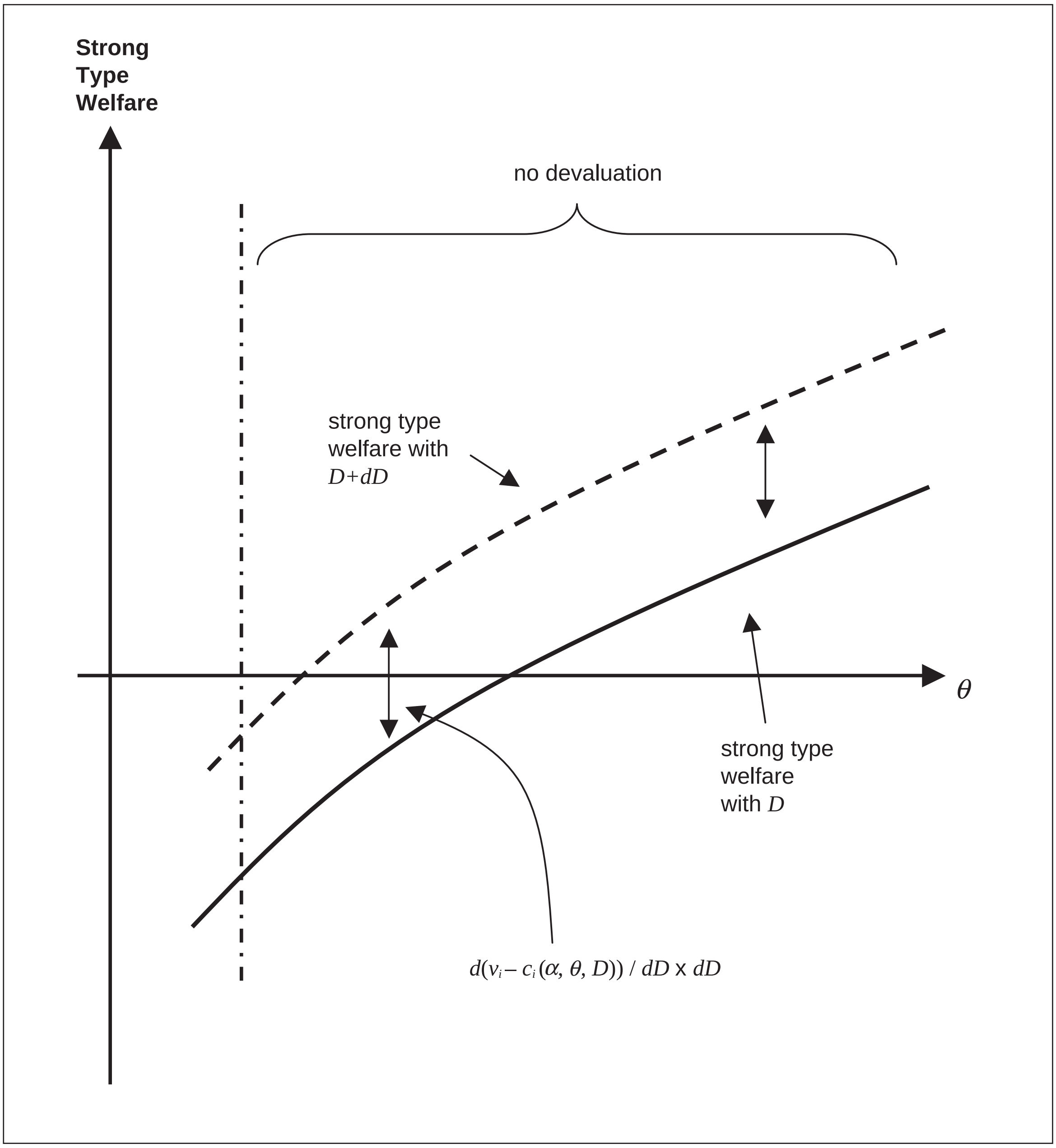
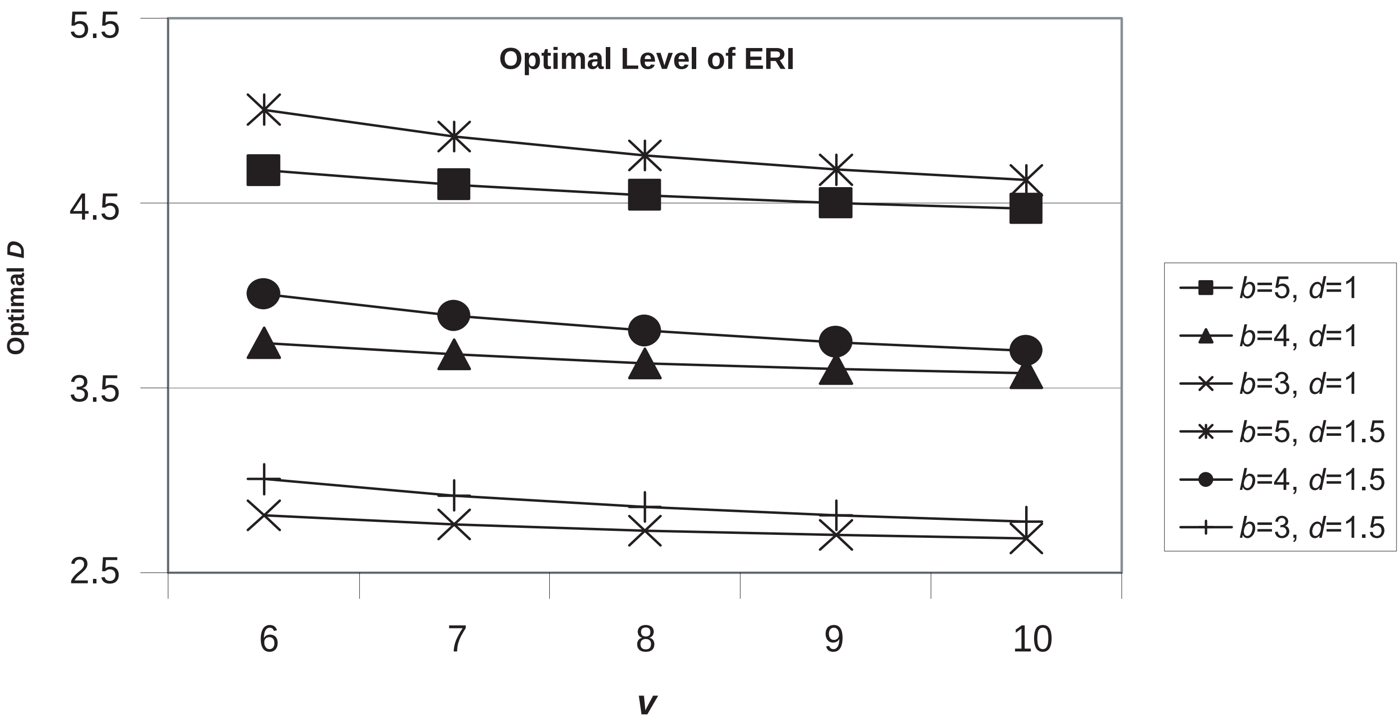


Figure 5: Optimal Level of ERI when Government Type Is Commonly Known



Appendix

A. Proof of Proposition 2

The updated beliefs are: $\pi_s^u(0) = \pi_s^u$ and $\pi_s^u(D) = 0$ for $D > 0$. The value of π_s^* is solved in the following way. Refer to Figure A1. Define q_s such that

$$W_s(q_s, 0) = W_s(0, \overline{D})$$

and q_w such that

$$W_w(q_w, 0) = W_w(0, \overline{D})$$

Then since $W_i(\pi_s^u, 0), i = s, w$ is increasing in π_s^u (assumption A3), we have $W_i(\pi_s^u, 0) \geq W_i(0, \overline{D})$ for $\pi_s^u \geq q_i$, where, $i = s, w$. Defining $\pi_s^* = \max\{q_s, q_w\}$, we have $W_i(\pi_s^u, 0) \geq W_i(0, \overline{D}), i = s, w$ for $\pi_s \geq \pi_s^*$. Therefore, pooling at $D = 0$ can be supported as an equilibrium.

B. Proof of Proposition 3

The equilibrium is supported by the following updated beliefs: $\pi_s^u(\overline{D}) = \pi_s$ and $\pi_s^u(D) = 0$ for all $D \neq \overline{D}$. Clearly, according to A3 and A4, we have for each type i, $W_i(\pi_s, \overline{D}) > W_i(0, \overline{D}) > W_i(0, D \neq \overline{D})$, $i = s, w$. Basically, in this equilibrium, the public construes the government that does not choose the maximum as the weak type. As being viewed as the weak type implies a lower welfare, each type will choose.

C. Proof of Proposition 4

Given that $\pi_s^u(D) = 0$ for all D, according to A3, the weak type still finds it beneficial to choose a positive D. Therefore, knowing that $\pi_s^u(0) = 0$ will be assigned, choosing $D = 0$ will never be optimal for the weak type even if it is thought to be a weak type with certainty upon choosing any $D \neq 0$. According to Proposition 1, to make $D_w = 0$ optimal, we in fact require a much more stringent condition:

$$\forall D > (0, \overline{D}), \min_{\pi_s^u} W_w(\pi_s^u, D) \leq W_w(0,0).$$

i.e., there always exists a belief profile $\pi_s^u(D)$ such that the weak type's welfare under that deviated D will be made smaller than under $D = 0$. This is ruled by assumptions A3 and A4, which imply that $\forall D > 0, \min_{\pi_s^u} W_w(\pi_s^u, D) = W_w(0, D) > W_w(0,0)$.

D. Proof of Proposition 5

For such an equilibrium, the strong type is prescribed to choose some positive D_s with a positive probability in addition to choosing $D = 0$ with probability $0 < p <1$. Given such actions by the strong and weak type, the updated beliefs are such that $\pi_s^u(D_s) = 1$, $\pi_s^u(0) = \pi_s p /(\pi_s p + (1-\pi_s)) < 1$. Therefore, to choose D_s, the strong type will receive a welfare of $W_s(1, D_s)$. To choose $D = 0$, it will receive a payoff of $W_s(\pi_s^u(0),0)$. But according to A5 and A4, respectively, we have $W_s(1, D_s) > W_s(1,0) > W_s(\pi_s^u(0),0)$. Hence, it is impossible for the strong type to find it optimal to mix between $D_s > 0$ and $D = 0$.

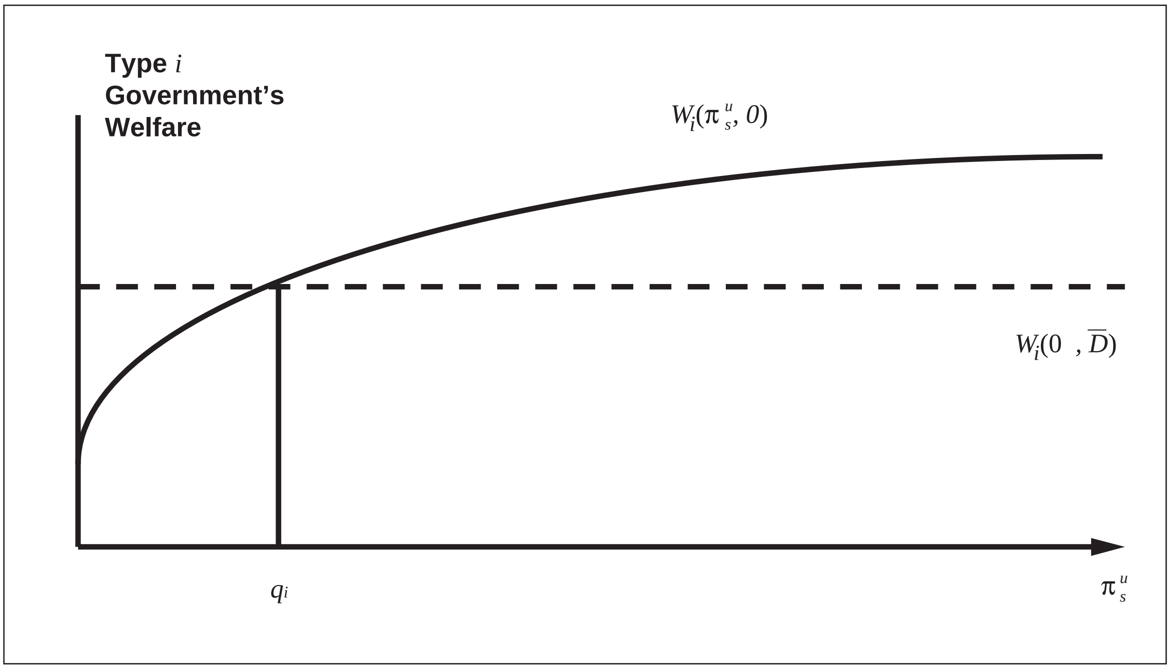
E. Proof of Proposition 9

Suppose not. Without loss of generality, let the positive D that is prescribed to be chosen in the equilibrium be D'. In other words, in the RSE, the strong type is prescribed to choose $D = 0$ with certainty, while the weak type $D = D'$ with certainty. In the RSSE1, the strong type is prescribed to choose $D = 0$ with certainty, while the weak type is prescribed to choose $D = 0$ with probability $0 < p <1$ and $D = D'$ with probability $1 - p$. In the RSSE2, the strong type is prescribed to randomize between $D = 0$ and $\underline{D} = D'$ with probabilities p and $1 - p$ where $0 < p <1$, while the weak type is prescribed to choose $\overline{D}$ with certainty. Consider any of the above three equilibria, we have $\pi_s^u(D') < \underline{\pi}_s^u(0)$. Given $D = 0$, let the strategy used by speculators be denoted by $k(\pi_s^u(0),0)$. Given $D = \overline{D}$, let the strategy used by speculators be denoted by $k(\pi_s^u(D'), D')$. For the weak type's strategy to be optimal, we have $W_w(\pi_s^u(D'), D') \geq W_w(\pi_s^u(0),0)$. This implies $k(\pi_s^u(0),0) < k(\pi_s^u(D'), D')$. Note that $k(.,.)$ has the following two properties: (i) $k(\pi_s^u(0), D)$ is continuous and decreasing in D and (ii) $k(\pi_s^u, D)$ is decreasing in π_s^u. These, along with the earlier result that $k(\pi_s^u(0),0) < k(\pi_s^u(D'),D')$, imply that there exists some $0 < D^* < D'$ such that $k(\pi_s^u(0), D) = k(\pi_s^u(D'), D')$ (intermediate value theorem). Now let us compare the strong type's welfare $W_s(\pi_s^u(0), D^*)$ and $W_s(\pi_s^u(D'), D')$. The strong type faces the same strategy by speculators and hence will have exactly the same devaluation decision. Therefore, the two welfares differ only in the revenue raised ex ante. Clearly, the revenue raised is larger in the case of $W_s(\pi_s^u(D'), D')$ as a result of $\pi_s^u(D') < \pi_s^u(0)$ and $D^* < D'$ Therefore, $W_s(\pi_s^u(0), D^*) < W_s(\pi_s^u(D'), D')$. If

$$W_w(\pi_s^u(0), D) \text{ is increasing in } D \tag{16}$$

we have $W_s(\pi_s^u(0), D^*) > W_s(\pi_s^u(0), 0)$. Hence, we have $W_s(\pi_s^u =0, D') > W_s(\pi_s^u(0), 0)$, a contradiction to the claim that playing $D = 0$ is the strong type's optimal strategy. Note that for RSE and RSSE2 (16) is guaranteed by A5, while for RSSE1 (16) is guaranteed by a stronger version of A5, as suggested by the statement of this proposition.

Figure A1



When D is small enough, there is a belief $q_i < 1$ such that type i government is indifferent between choosing D=0 (hence getting $W_i((\pi_s^u,0))$ and choosing $D=\overline{D}$ (hence getting $W_i(0,\overline{D})$)