The Role of (Non)transparency in a Currency Crisis Model

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Abstract: This paper examines the implications of transparency of fundamentals/policies which might be pivotal to the recent Asian currency crisis. In a recent paper, Morris and Shin (1998) argue that multiple equilibria in the standard currency attack models are only apparent and are due to an unrealistic assumption that all agents observe the same fundamentals. They show equilibrium uniqueness when agents observe fundamentals privately with small errors. The present paper extends their model and shows that, under a more general specification, noisy private observations in general are not sufficient to prevent multiplicity of equilibria. The conditions under which non-transparency decreases the incidence of speculative attacks are investigated.

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1. Introduction

There are two genres of models on currency crisis in the literature. The first generation models, a la Krugman (1979), explained currency crisis from the inconsistencies between the exchange rates and domestic macroeconomic fundamentals. The second generation models (see Obstfeld, 1986, 1994, 1996) viewed currency attacks as shifts between different equilibria generated from self-fulfilling speculative attacks. In a recent paper, Morris and Shin (1998a; MS, hereafter) suggest that the multiplicity of equilibria in the currency attack models is in fact apparent and is due to an unrealistic assumption that all agents observe the same signals without error. By replacing this assumption with a more realistic one in which agents privately observe fundamentals with small errors, Morris and Shin show that the multiplicity of equilibria in a standard second generation model is eliminated. This result has made self-fulfilling expectations and their required belief coordination less relevant.

Since MS demonstrate that lack of common knowledge of fundamentals, or non-transparency of fundamentals in their notion, may trigger speculative attacks as a unique equilibrium outcome even though everyone knows that the fundamentals are sound, their analysis urges governments to adopt transparent policy. Their analysis also lends new support to the recent debate on the currency crisis in East Asia. Researchers in the debate argued that it is the close and non-transparent relationships among Asian governments, financial institutions and large corporations that created serious moral hazards. Close government ties led to excessive guarantees. This, together with the lack of transparency in the supervisory role of the Asian financial institutions, led to over-investment in speculative and unproductive projects. These over-investments, compounded and self-reinforced, drove the East Asian economies into the currency crisis (see Chang and Velasco, 1998; and Krugman, 1998). The study of MS suggests that non-transparency alone, without the requirement of moral hazards, is sufficient to generate currency attacks as had witnessed in East Asia. The MS model, together with new research works on the recent East Asian currency turmoil, may have started a new generation of currency crisis models.

The notion of transparency that MS define is novel but may not be the only accepted notion of transparency. Transparency quite often means less noisy private signals, as market information is subjected to private perceptions of market agents who have differential information-processing ability and access to private information. The reader is referred to King (1999) for a throughout discussion. In this paper, nevertheless, we adopt MS's notion of transparency. In addition to the argument MS put forward for their notion, we adopt it also with the purpose to further clarify the policy suggestion advocated by MS, as well as the intimate relationship between common knowledge of fundamentals and multiple equilibria of currency crises.

The present paper enlarges the analytical framework of MS by including various "boundary conditions." We find that transparency alone in many cases cannot discourage currency attacks, contrary to MS's assertion. In fact, for some cases, currency attacks are even prevented by nontransparency. We also clarify that the MS's uniqueness result depends on the nature of the equilibrium at the boundaries, and it is the uniqueness of the boundary equilibrium that generates their results. If there are multiple equilibria at the boundaries, then the lack of common knowledge of the fundamentals will also lead to multiple rather than a single equilibrium as found by MS. In other words, private observational errors are generally not sufficient to eliminate multiplicity of equilibria. The ultimate equilibrium will still need to be determined by self-fulfilling expectations. It still leaves open the question how agents succeed in coordinating their belief.[1]

A closely related research, but of opposite purpose from ours, is a paper by Heinemann and Illing (1999), where they establish the MS uniqueness result using the solution concept of rationalizable equilibrium, instead of Nash equilibrium used in MS. Since the set of rationalizable equilibria is a superset of the set of Nash equilibria, MS's result is strengthened by Heinemann and Illing. Rationalizable equilibrium is not particularly useful for this paper precisely because the concept is more relaxing than Nash equilibrium. Multiple Nash equilibria imply multiple rationalizable equilibria, but not vice versa. Thus the result of multiple (Nash) equilibria that we obtain in this paper is stronger than a result of multiple rationalizable equilibria. Heinemann and Illing also investigate the role of transparency of fundamentals in triggering currency crises. They find that, within the MS framework, an increase in transparency of their notion, defined by them as a reduction in the dispersion of private signals, makes currency crises less likely.[2]

The rest of the paper is organized as follows. Section 2 of the paper presents model and the intuition why multiplicity of equilibria at the boundaries can drastically affect the results in the MS model. Taking the MS model as the norm, Section 3 examines the cases of a comparatively weaker and stronger economy. Section 4 presents a broader picture of the framework and a proposition on the conditions under which non-transparency decreases the incidence of speculative attacks. Section 5 concludes.

[1] In the literature, some attempts have been made to deal with this issue; see for example, Postlewaite and Vives (1987).

[2] Two other related papers are Morris and Shin (1998b) and Sbracia and Zaghini (1999). The first paper extends their earlier study to a continuous time framework and establishes a similar uniqueness outcome. The second paper studies two self-fulfilling crisis models to explore, respectively, the role of changes of speculators' beliefs and the role of public information.

2. The Model and A Demonstrating Example

We follow the MS model closely. The players of the game are the government of a country and a large number of speculators. All values to be introduced are measured in terms of a foreign currency. The country's overvalued currency is pegged at e^*. The exchange rate that otherwise prevails in a freely floating market is $f(\theta)$, where θ is the country's state of fundamentals, a larger θ distinguishes stronger fundamentals, and is distributed uniformly in $[0, 1]$ interval. $f(\theta)$ is a strictly increasing function of θ. The country's exchange rate is so overvalued that $e^* > f(\theta)$ for all θ. Once the fundamentals are determined and revealed, each speculator can choose whether or not to short sell one unit of the country's currency. The speculator's payoff is $e^* - f(\theta) - t$ for a successful attack, and is $-t$ otherwise, where t is the transaction cost of short sales. If he does not short sell, his payoff is zero, regardless of whether the currency unpegs. The country's benefit from successfully defending its currency is v, while the cost from defending is $c(\alpha, \theta)$ where α is the proportion of speculators who attack. The cost $c(\alpha, \theta)$ is assumed to be continuous, increasing in α and decreasing in θ.

We follow the tie-breaking rule in MS that whenever the government is indifferent between maintaining and abandoning the currency peg, it chooses to abandon, and that whenever the speculator is indifferent between attacking and not attacking, he refuses to attack.[3]

As in MS, we make the assumption that $v - c(1, 1) < 0$. In other words, if all speculators attack, it will be too costly for the country to defend even in the best state of the fundamentals. MS make the following two assumptions as well.

(A1) $v - c(0, 0) < 0$. There exist fundamentals which are so bad that the country

[3] This tie-breaking rule is made for simplicity. Nothing consequential will depend on it.

will unpeg its currency in the absence of any attack.

(A2) $e^* - f(1) - t < 0$. In the best state of the fundamentals, the gain from a successful attack is too small to offset the transaction cost.

Let $\underline{\theta}$ be the value of θ which solves $c(0, \theta) - v = 0$ and $\overline{\theta}$ be the value of θ which solves $e^* - f(\theta) - t = 0$. MS consider the generic case in which $0 < \underline{\theta} < \overline{\theta} < 1$. This tripartite classification has a quite interesting interpretation. For $\theta \leq \underline{\theta}$ (the unstable region), the fundamentals are so weak that the country will unpeg its currency in the absence of any speculative attack; for $\theta \geq \overline{\theta}$ (the stable region), the fundamentals are fairly strong and speculators' gain from a successful attack is too slim to cover the transaction cost; for $\underline{\theta} < \theta < \overline{\theta}$ (the ripe-for-attack region), the economy is ripe for speculative attack in the sense that speculators will benefit from attacking if and only if a sufficiently large proportion of speculators attack. In the standard model of currency attack where θ is commonly observed without errors, there will be multiple equilibria for this range of $\underline{\theta} < \theta < \overline{\theta}$. In MS, however, fundamentals are observed with errors: when θ is the true state, each speculator will observe an independent signal x drawn from a uniform distribution in $[\theta - \varepsilon, \theta + \varepsilon]$. Their contribution was to show that, for this range of $\underline{\theta} < \theta < \overline{\theta}$, the multiple equilibria reduce to a unique equilibrium: there exists a cutoff point θ^* such that the unique equilibrium outcome is to unpeg for $\theta \leq \theta^*$ and not to unpeg otherwise.

Whereas (A1) and (A2) represent plausible scenarios, there are other plausible scenarios that are not covered in MS. For instance, it is conceivable that $e^* - f(1) - t > 0$; that is, the cost-adjusted capital gains of a successful attack on an overvalued currency, even in the strongest state of the fundamentals, are positive to the speculators. This can happen because the transaction cost in the market for foreign exchange is typically very small or the existing peg rate is highly over-valued.

Another plausible scenario is that $v - c(0,0) > 0$. In other words, even under the weakest plausible macro fundamentals, the currency is sustainable in the absence of speculative attacks. There are plenty crisis economies in which the weakest *plausible* fundamentals right before a speculative attack may not be bad enough for the peg to be abandoned automatically. A pointer to recent East Asian crisis and the attack on the European Exchange Rate Mechanism in 1992 may be useful. Although there is evidence that the situation in the East Asian countries had deteriorated significantly two years prior to the crisis (see Corsetti, Pesenti and Roubini 1998), there is no evidence, even on hindsight, that either the crisis or the abandonment of currency pegs was necessary (see also Furman and Stiglitz 1998; and Radelet and Sachs 1998 for this documentation). Likewise in 1992, the crisis countries in Europe had weak but reasonable fundamentals (see, for example, Obstfeld, 1996). Their national governments, if fully committed, would be able to defend the rates.

The former scenario corresponds to the case where $\overline{\theta}$ does not exist (i.e., there is no $\overline{\theta}$ in $[0,1]$ such that $e^* - f(\overline{\theta}) - t = 0$), while the latter to the case where $\underline{\theta}$ does not exist (i.e., there is no $\underline{\theta}$ in $[0,1]$ such that $v - c(0,\underline{\theta}) = 0$), Taking this into consideration, we have the following typology.

- Case A: Both $\underline{\theta}$ and $\overline{\theta}$ exist. $[v - c(0,0) < 0;\ e^* - f(1) - t < 0.]$
- Case B: Only $\underline{\theta}$ exists. $[v - c(0,0) < 0;\ e^* - f(1) - t > 0.]$
- Case C: Only $\overline{\theta}$ exists. $[v - c(0,0) > 0;\ e^* - f(1) - t < 0.]$
- Case D: Neither $\underline{\theta}$ nor $\overline{\theta}$ exists. $[v - c(0,0) > 0;\ e^* - f(1) - t > 0.]$

It is useful to relate this typology to the classification in Obstfeld (1996). Assuming common knowledge of fundamentals, Obstfeld classifies economies into three categories: the very strong economies, the very weak economies, and large-middle-ground economies where self-fulfilling crises are possible but not inevitable. Note that in Obstfeld's classification each country is characterized by a unique state of fundamentals. To generalize to a non-common knowledge framework, however, one has to characterize a country by a distribution of possible states of fundamentals. That is, countries distinguish themselves by having different distribution functions of fundamentals. What MS study is a country of a particular type of distribution, one where the three regions co-exist, but countries of other distributions are ignored. A complete "tripartite" state space in this regard should be a set of distribution functions, rather than a set of states. With this interpretation, Cases A to D together constitute the large middle category economies that self-fulfilling crises are possible but not inevitable when realized fundamentals are common knowledge.

One may be tempting to claim that the insights from case A (MS's focus) may be applicable to other cases. Take Case D, for example, one may conjecture that there exists a threshold θ^* such that for $\theta \leq \theta^* (> \theta^*)$ the unique equilibrium outcome is to abandon (maintain) the peg. This conjecture, as we will show, is incorrect. The implication from Case A cannot be generalized. The following proposition is easy to prove.

Proposition 1. *Suppose $v - c(0,0) > 0$ and $e^* - f(1) - t > 0$, i.e., neither $\underline{\theta}$ nor $\overline{\theta}$ exists. Then for all $\theta \in [0,1]$ there exist two equilibria to the game: one in which all speculators attack and the government abandons the currency peg, and another in which no speculators attack and the government maintains the peg.*

The intuition is as follows. Note that when $v - c(0,0) > 0$ (i.e., $\underline{\theta}$ does not exist), the government's best response, even in the worst state of the fundamentals, is to maintain its currency peg if only a negligible proportion of speculators attack. Knowing this and that other speculators do not attack, it is each speculator's best strategy not to attack, regardless of the signal observed. This accounts for the no-attack equilibrium for each θ. Because of the assumption that $v - c(1,1) < 0$, the government's best response, even in the strongest state of the fundamentals, is to abandon the currency peg if a sufficiently large portion of speculators attack. Knowing this, that $e^* - f(1) - t > 0$ (i.e., $\overline{\theta}$ does not exist), and that other speculators all will attack, it is in each speculator's interest to attack as well. This accounts for the attack equilibrium for each θ.

The above scenario, where there are two equilibria at both the upper and lower boundaries, should be contrasted with the MS model. In the MS model, because of the existence of $\underline{\theta}$ and $\overline{\theta}$, upon seeing a signal sufficiently close to zero (one), speculators will certainly attack (not attack), regardless of others' actions. This leads to a unique attack equilibrium when θ equals zero and a unique no-attack equilibrium when θ equals one. With proper induction from the lower (upper) boundary equilibrium, speculators continue to maintain an attack (no attack) position when θ is not too far above zero (below one). That is, there exist some θ' and θ'' (where $0 < \theta' < \theta'' < 1$) such that there is a unique attack equilibrium for $\theta \leq \theta'$ and a unique no attack equilibrium for $\theta \geq \theta''$. Iterated induction of this fashion eventually gives rise to a critical value of signal below which speculators attack and above which speculators do not attack. However, multiple equilibria at both boundaries will destroy that. What would happen when there are two equilibria at one boundary while only one at the other boundary? The analysis of Cases B and C in Section 3 will examine this less obvious situation.

3. Analysis

3.1. Preliminaries

We first fill in some details of the game and introduce some useful notion. Define $H(x|\theta)$ as the cumulative function of signal x conditional on state θ, and $G(\theta|x)$ as the corresponding cumulative function of true state θ conditional on signal x. MS have specified $H(x|\theta)$ only for $\theta \in [\varepsilon, 1-\varepsilon]$ but not for other values of θ.[4] Instead of specifying the exact characterization of $H(x|\theta)$ for $\theta \notin [\varepsilon, 1-\varepsilon]$, we want to point out three properties that any candidate $H(x|\theta)$ should possess and imply.

(B1) $x \in [\theta-\varepsilon, \theta+\varepsilon]$ and $x \in [0,1]$.

(B2) $H(x|\theta)$ is continuous in x and θ except possibly for a jump at $x=1$, and decreasing in θ.

(B3) $G(\theta|x)$ is continuous in θ and x, decreasing in x, and for all x, $G(0|x)=0$.[5]

The first part of (B1) is made to be consistent with MS's assumption of $H(x|\theta)$ for $\theta \in [\varepsilon, 1-\varepsilon]$, while the second part of (B2) means the speculator can never observe a signal which he is certain to be impossible.[6] Both (B2) and (B3) are standard and, given (B1), are automatically satisfied for $\varepsilon < \theta < 1-\varepsilon$ and $2\varepsilon < x < 1-2\varepsilon$.

For a given profile of strategy of the speculators, denote by $\pi(x)$ the proportion of speculators who attack after observing the signal x. (In short, we will refer $\pi(x)$ as the

[4] MS define $H(x|\theta)$ for $\theta \in [\varepsilon, 1-\varepsilon]$ as follows. $H(x|\theta)$ is equal to 0 if $x \le \theta-\varepsilon$, to $1/2+(x-\theta)/2\varepsilon$ if $\theta-\varepsilon < x \le \theta+\varepsilon$, and to 1 otherwise.

[5] If $G(0|x) \neq 0$ for some x, then the signal x arises only for a finite number of possible states θ (one of which is 0). Such a possibility is clearly odd enough to be assumed away.

[6] The second part of (B1) is perhaps more controversial than other assumptions. If it is relaxed to be $x \in [-\varepsilon, 1+\varepsilon]$, then the results in Propositions 2 and 3 will be stated a bit differently. In particular, the strategy profile that all speculators attack regardless of the observed signals is denoted by $\overline{I}_{1+\varepsilon}$. However, multiple equilibria may still exist. In addition, numeric examples 1 to 3 are still valid; in each example, the critical state of fundamentals that can give rise to multiple equilibria is exactly the same. The reader is referred to the first paragraph subsequent to Example 2 for details.

strategy profile.) Given $\pi(x)$, the government defends if and only if $v - c(s(\theta,\pi),\theta) > 0$ where

$$s(\theta,\pi) \equiv \int_{x=0}^{x=1} \pi(x) dH(x|\theta) \tag{3.1}$$

is the proportion of speculators who attack given the true state θ. Define $a(\theta)$ as the minimum proportion of attacking speculators for a successful attack when the true state is θ, i.e., $a(\theta) \equiv \arg\min_{\alpha}\{v - c(\alpha,\theta) \leq 0\}$, and $A(\pi) \equiv \{\theta | s(\theta,\pi) \geq a(\theta)\}$ as the set of θ in which the government abandons the peg. Given the government's response, we can define $u(x,\pi)$ to be the speculator's payoff from short sales where x is his signal and π the strategy that all other speculators adopt. Formally,

$$u(x,\pi) \equiv \int_{A(\pi)} (e^* - f(\theta)) dG(\theta|x) - t. \tag{3.2}$$

The speculator will attack if and only if $u(x,\pi) > 0$.

We are particularly interested in the following type of strategy profile:

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

A closely related strategy profile is

$$\overline{I}_k(x) = \begin{cases} 1 & \text{if } \ x \leq k \\ 0 & \text{if } \ x > k. \end{cases}$$

Note that the difference between the two profiles is inconsequential, except possibly for $k = 1$ where for some θ there may be a non-negligible fraction of speculators who observe the signal $x = k = 1$.[7] We introduced the notion $\overline{I}_k(x)$ because we will make use of $\underline{I}_1(x)$, i.e., the strategy profile such that all speculators attack regardless of the signals observed. From the definition in (3.1) and assumption (B2), it is clear that $s(\theta, \underline{I}_k)$ and $s(\theta, \overline{I}_k)$ are continuous and decreasing in θ. The sets of fundamentals in which attacks following $\underline{I}_k$ and $\overline{I}_k$ are successful are $A(\underline{I}_k) = [0, \underline{\phi}(k)]$ and $A(\overline{I}_k) = [0, \overline{\phi}(k)]$, respectively, where

$$\begin{aligned} \underline{\phi}(k) &\equiv \max\left\{\theta | s(\theta, \underline{I}_k) \geq a(\theta)\right\} \\ \text{and} \quad \overline{\phi}(k) &\equiv \max\left\{\theta | s(\theta, \overline{I}_k) \geq a(\theta)\right\}. \end{aligned} \tag{3.3}$$

are the strongest states in which attacks are successful. The following Lemma is easy to obtain.

Lemma 1. *The following results hold for both case B and case C.*

1. *$u(k, \underline{I}_k)$ is continuous in $k \in (0,1)$.*

2. *$u(x, \underline{I}_k)$ are continuous in x for all $x \in [0,1]$ for all $k \in [0,1]$.*

3. *$u(x, \underline{I}_k)$ are decreasing in x for all $x \in [0,1]$ for all $k \in [0,1]$.*

The first result, the proof of which follows that of MS and hence is omitted here, locates the signal k with which the player is indifferent between attacking or not when $\underline{I}_k$ is followed by other speculators. The second result is a technical one. The third result, the proof of which is relegated to the Appendix, states that, once the critical signal k satisfying $u(k, \underline{I}_k) = 0$ is found, $\underline{I}_k$ will indeed be an equilibrium play: those

[7] Whenever there is an interior critical $k \in (0,1)$ that makes the speculator with such a signal indifferent between attacking and not attacking when $\underline{I}_k$ or $\overline{I}_k$ is adopted by others, our tie-breaking rule dictates that he not attack and hence $\overline{I}_k$ be ruled out as a candidate of equilibrium strategy profile.

speculators with signals $x < k$ gain from attacking and those with signals $x \geq k$ do not.

3.2. Results: Case B

In this subsection, we will focus on the case where $\underline{\theta}$ exists ($0 < \underline{\theta} < 1$), but $\overline{\theta}$ does not exist. Following MS, we assume that $\underline{\theta} > 2\varepsilon$ to simplify the exposition.[8] With the above preliminaries, we can come to the following proposition.

Proposition 2. ***(Case B)*** *Suppose $\underline{\theta}$ exists (and $> 2\varepsilon$), but $\overline{\theta}$ does not exist. Multiple equilibria at which the government abandons and maintains the currency peg, respectively, may arise under some states of fundamentals. Specifically, if there exists some $x \in (0,1)$ such that $u(x, \underline{I}_x) = 0$, define $\theta^* \equiv \underline{\phi}(x^*)$, where x^* is the smallest $x \in (0,1)$ satisfying $u(x, \underline{I}_x) = 0$. It must be true that $0 < \theta^* < 1$. For $\theta \leq \theta^*$ there is a unique equilibrium outcome in which the government abandons the peg. For $\theta > \theta^*$ there are multiple equilibrium outcomes: one in which the government maintains the peg, and the other the government abandons.*

Proof. See the Appendix.

The proposition is better understood with the help of Figure 1. Since $v - c(1,1) < 0$, it becomes common knowledge that if all speculators attack regardless of the signals observed, the government must abandon its currency peg at any θ. Since $\overline{\theta}$ does not exist, the speculators' net gain from a successful attack at any state of fundamentals is positive. Hence, $u(x, \overline{I}_1)$ must be positive for $x \leq 1$, as represented by the dashed line in Figure 1. This means that $\overline{I}_1$ is an equilibrium profile for every θ.

[8] In fact, the relaxation of $\underline{\theta} > 2\varepsilon$ makes multiple equilibria more likely to occur.

Figure 1

In Figure 1, $u(x, \underline{I}_x)$ cuts the horizontal axis at $x = x^*$. The downward sloping line AA' depicts $u(x, \underline{I}_{x^*})$(which equals $u(x, \overline{I}_{x^*})$), intersecting $u(x, \underline{I}_x)$ at the same horizontal intercept. It is clear that $\underline{I}_{x^*}$ itself is an equilibrium strategy, as speculators observing signals lower than x^* will gain from attacking ($u(x, \underline{I}_{x^*}) \geq 0$ for $x \leq x^*$) and speculators observing signals greater than x^* will lose from attacking ($u(x, \underline{I}_{x^*}) \leq 0$ for $x > x^*$). With the strategy profile $\underline{I}_{x^*}$, fundamentals that end up with the collapse of the peg are simply those $\theta \leq \theta^* \equiv \underline{\phi}(x^*) \equiv \max\{\theta | s(\theta, \underline{I}_{x^*}) \geq a(\theta)\}$. In these weaker states, the proportion of attacking speculators is too large for the government to defend, resulting in an attack equilibrium. In contrast, the peg is stable for stronger fundamentals, at which either no speculators attack (for $\theta \geq x^* + \varepsilon$) or the proportion of attacking speculator is small enough that the government can successfully defend (for $\theta \in (\theta^*, x^* + \varepsilon)$). This leads to a no-attack equilibrium.

To summarize, for $\theta \leq \theta^*$, no matter whether $\underline{I}_{x^*}$ or $\overline{I}_1$ is coordinated, the unique equilibrium outcome is to abandon the peg. For $\theta > \theta^*$, depending on whether $\underline{I}_{x^*}$ or $\overline{I}_1$ is coordinated, the equilibrium outcome can be either to maintain or to abandon the peg. An additional comment is in order here. Although in Figure 1 the line $u(x, \underline{I}_x)$ is depicted to cut the horizontal axis, it is possible for $u(x, \underline{I}_x)$ to be completely above the horizontal axis for all $x \in (0, 1)$. In this case, the equilibrium is unique with strategy profile $\overline{I}_1$.

To illustrate that multiple equilibria do exist, we now provide some numeric examples. We adopt here an exact specification on $H(x|\theta)$ for $\theta \notin [\varepsilon, 1-\varepsilon]$. Specifically, for $\theta < \varepsilon, H(x|\theta)$ is equal to $(\varepsilon - \theta)/2\varepsilon$ if $x = 0$, to $1/2 + (x - \theta)/2\varepsilon$ if $0 < x \leq \theta + \varepsilon$, and to 1 otherwise. As for $\theta > 1-\varepsilon$, $H(x|\theta)$ is equal to 0 if $x \leq \theta-\varepsilon$, to $1/2+(x-\theta)/2\varepsilon$ if $\theta-\varepsilon < x < 1$, and to 1 if $x = 1$. That is, it prescribes a density function $h(x|\theta) = 1/2\varepsilon$ for $x \in [\theta-\varepsilon, \theta+\varepsilon] \cap [0,1]$, with a mass of remaining probability at the relevant boundary. The density function of θ conditional on signal x, $g(\theta|x)$, can easily be computed and is relegated to the Appendix. It can be easily checked that this specification satisfies the properties we pointed out before ((B1) to (B3)). We will later argue that the multiple equilibrium result in our paper has little to do with our specification of $H(x|\theta)$ at the two tails.

In Example 1, $a(1) = v/c_0 = 0.75$; that is, in the strongest state of fundamentals, the government will abandon the peg only if three fourths or more of speculators attack. A larger $a(1)$ makes the no attack equilibrium in the strongest states more likely.[9] However, $a(1)$ does not need to be as high as 0.75. In Example 2, $a(1) = 0.4$. But as the transaction cost t is increased from 0.3 to 0.4, self-fulfilling expectations can still make the no-attack equilibrium feasible.

Example 1. *Suppose $f(x) \equiv e^* - 1/(1+x)$, and $c(\alpha,\theta) \equiv (1-\theta+\alpha)c_0$. We can determine that $a(\theta) = 0$ if $\theta \leq 1 - v/c_0$ and $= v/c_0 - 1 + \theta$ otherwise. Suppose $\varepsilon = 0.05$, $v/c_0 = 0.75$, and $t = 0.3$. With this parameterization, $\overline{\theta}$ does not exist, but $\underline{\theta}$ exists and equals 0.25. There exists a unique $x = 0.735$ such that $u(x, \underline{I}_x) = 0$. We can also reckon that $\theta^* \equiv \underline{\phi}(x^*) = \underline{\phi}(x) = 0.737$.*

Example 2. *Use the same functional forms as in example 1, but with $\varepsilon = 0.05$, $v/c_0 = 0.4$, and $t = 0.4$. With this parameterization, $\overline{\theta}$ does not exist, but $\underline{\theta}$ exists and equals 0.6. One can demonstrate that $u(x, \underline{I}_x)$ cuts the horizontal-axis twice, first from above at $x = 0.844$ and then from below at $x = 0.971$. Hence one can reckon*

[9] A large $a(1)$ means that either the country is large with capable government or there are a small number of potential speculators (a small amount of hot money being circulated).

that $x^* = 0.844$ *and* $\theta^* = \underline{\phi}(x^*) = 0.868$.

Two points regarding the examples are worth noticing. First, the exact specification of $H(\theta|x)$ that we have used at the two ends is not crucial. Consider example 1, where $x^* = 0.735$ is more than 4ε below the state $\theta = 1-\varepsilon = 0.95$. Any specification of $H(\theta|x)$ for $\theta \in (1-\varepsilon, 1]$ satisfying (B1) to (B3)–our exact specification is one such– will not give rise to signals that are more than ε below the state $1-\varepsilon$, and hence has no effect on the value of $u(k, \underline{I}_k)$ at the proximity of $k = x^*$. Therefore, the result that $u(k, \underline{I}_k)$ first cuts the horizontal axis at $k = x^* = 0.735$ is invariant under alternative specifications of $H(\theta|x)$. A similar argument works for Example 2. Whereas a change in the specification of $H(\theta|x)$ for $\theta \in (1-\varepsilon, 1]$ will change the second cutting point, it will not affect the first cutting point $x^* = 0.844$ which is more than 3ε below the state $\theta = 1-\varepsilon$. Needless to say, the specification of $H(\theta|x)$ for $\theta \in [0, \varepsilon)$ has no effect on examples 2 and 3 as well.

The second point is that we can link the presence of multiple equilibria with the non-monotonicity of $u(k, \overline{I}_k)$. An important property in MS is the decreasingness of $u(k, \underline{I}_k)$ in k for all k. In the MS study (or our Case A), since $u(0, \underline{I}_0) < 0$ and $u(1, \underline{I}_1) > 1$, the decreasingness of $u(k, \underline{I}_k)$ is sufficient to give their unique equilibrium result. This property does not hold in our Case B (as well as Case C). Let us focus on the relevant function $u(k, \overline{I}_k)$ here. (Recall that $u(k, \overline{I}_k)$ and $u(k, \overline{I}_k)$ are identical for $k < 1$.) It can be shown that, using the same argument as in MS, $u(k, \overline{I}_k)$ is decreasing for $k \leq 1-\varepsilon$. However, it may not be decreasing for greater value of k. The non-decreasingness may take place either for $k \in [1-\varepsilon, 1)$ as demonstrated in Example 2, or right at $k = 1$,where the value of $u(k, \overline{I}_k)$ jumps up, as demonstrated in Example 1 and depicted in Figure 1. Note that the existence of multiple equilibria implies the existence of some $x^* < 1$ such that $u(x^*, \overline{I}_{x^*}) = 0$. This latter fact, in conjunction with $u(1,\overline{I}_1) > 0$, implies non-monotonicity of $u(k,\overline{I}_k)$. Thus non-monotonicity of $u(k,\overline{I}_k)$ is a necessary condition for multiple equilibria.[10] For general specifications of $H(x|\theta)$, the conditions under which non-monotonicity of $u(k,\overline{I}_k)$ arises are difficult to establish.[11]

3.3. Results: Case C

Here we examine the scenario in which $\overline{\theta}$ exists $(0 < \overline{\theta} < 1)$, but $\underline{\theta}$ does not exist. Following MS, we assume $\theta < 1 - 2\varepsilon$ to simplify exposition.[12] Since the analysis is largely asymmetric to case B, the proof of the following proposition will be omitted.

Proposition 3. ***(Case C)*** *Suppose $\overline{\theta}$ exists (and $< 1-2\varepsilon$) but $\underline{\theta}$ does not. Multiple equilibria at which the government abandons and maintains the currency peg, respectively, may arise under some states of fundamentals. Specifically, if there exists some $x \in (0,1)$ such that $u(x,\underline{I}_x) = 0$, define $\theta^* \equiv \underline{\phi}(x^*)$ where x^* is the largest $x \in (0,1)$ satisfying $u(x,\underline{I}_x) = 0$. Note that it must be that $0 < \theta^* < 1$. For $\theta > \theta^*$ there is a unique equilibrium outcome in which the government maintains the peg. For $\theta \leq \theta^*$ there are multiple equilibrium outcomes: one in which the government maintains the peg, and the other the government abandons.*

The proposition is better understood with the help of Figure 2. Since $v - c(0,0) > 0$, if no speculators attack, regardless of the signals observed, the government must maintain its currency peg at any θ. As this itself is common knowledge, and as each speculator on his own cannot lead to a successful attack at any θ, it in turn means that

[10] Clearly non-monotonicity of $u(k,\overline{I}_k)$ is not a sufficient condition for multiple equilibria; without being monotone, $u(k,\overline{I}_k)$ could be positive for all k and never cuts the horizontal axis.

[11] For the specification of $H(\theta|x)$ used in Examples 1 and 2, $u(k,\overline{I}_k)$ will have a jump (an increase) at $k = 1$ if and only if $a(1) > 0.5$. But Example 2 (in which $u(k,\overline{I}_k)$ does not have a jump at $k = 1$) illustrates that this jump is not necessary for multiple equilibria.

[12] If $\overline{\theta} \geq 1 - 2\varepsilon$, multiple equilibria are more likely to occur.

no speculator will have unilateral incentive to deviate from $\underline{I}_0$. Hence $u(x, \underline{I}_0) < 0$ for all x, as depicted in Figure 2. This means that $\underline{I}_0$ is an equilibrium profile for every θ.

Figure 2

In Figure 2, $u(x, \underline{I}_x)$ cuts the horizontal axis at $x = x^*$. The downward sloping line AA' depicts $u(x, \underline{I}_{x^*})(= u(x, \overline{I}_{x^*}))$, which intersects $u(x, \underline{I}_x)$ at the same horizontal intercept. It is clear that $\underline{I}_{x^*}$ is an equilibrium strategy, as speculators observing signals lower than x^* will gain from attacking $(u(x, \underline{I}_{x^*}) \geq 0$ for $x \leq x^*)$ and speculators observing signals greater than x^* will lose from attacking $(u(x, \underline{I}_{x^*}) \leq 0$ for $x > x^*)$. With strategy profile $\underline{I}_{x^*}$, fundamentals that end up with the collapse of the peg are those $\theta \leq \underline{\phi}(k) \equiv \max\{\theta | s(\theta, \underline{I}_{x^*}) \geq a(\theta)\}$. The peg can be maintained for the remaining stronger fundamentals.

To summarize, for $\theta \leq \underline{\phi}(x^*)$, depending on whether $\underline{I}_0$ or $\underline{I}_{x^*}$ is coordinated, the equilibrium outcome can be either to maintain or to abandon the peg. For $\theta > \underline{\phi}(x^*)$, the unique equilibrium outcome is to maintain the peg. An additional comment is in order here. Although the line $u(x, \underline{I}_x)$ is depicted to cut the horizontal axis, it is possible that $u(x, \underline{I}_x)$ is everywhere below the horizontal axis for all $x \in (0, 1)$. In this case, the equilibrium is unique with strategy profile $\underline{I}_0$.

Examples with multiple equilibria can easily be constructed. The same specification of $H(x|\theta)$ for $\theta \notin [\varepsilon, 1 - \varepsilon]$ as in examples 1 and 2 is used in the following example 3. Also choose $a(0) = 0.20$; that is, in the weakest state of the fundamentals, the government will abandon the currency peg when one fifth or more of speculators attack. Both equilibria, to abandon and to maintain the peg, are present when $\theta \le \theta^* = 0.256$. But for $\theta > 0.256$, there is a unique equilibrium of maintaining the peg. One can expect that, other things being equal, an increase in $a(0)$ will make multiple equilibria less likely.

Example 3. *Suppose $f(x) \equiv e^* - 1/(1+x)$, and $c(\alpha, \theta) \equiv (1 - \theta + 2\alpha)c_0$. We can compute that $a(\theta) = v/2c_0 - (1-\theta)/2$. Suppose $\varepsilon = 0.05, v/c_0 = 1.4$, and $t = 0.55$. With this parameterization, we know that $\overline{\theta}$ exists and equals = 0.818 while $\underline{\theta}$ does not exist. In addition, there exists a unique $x = 0.239$ such that $u(x, \underline{I}_x) = 0$. One can compute that $\theta^* \equiv \underline{\phi}(x^*) = 0.256$.*

The multiple equilibrium result in this example also has nothing to do with the exact specification of $H(x|\theta)$ used at the two ends. As now θ^* is about 4ε above the state $\theta = \varepsilon = 0.05$, the distribution of $H(x|\theta)$ at the two ends cannot influence the value of $u(k, \underline{I}_k)$ at the proximity of $k = x^*$. Similar to Case B, the presence of multiple equilibria here can be linked to the non-monotonicity of $u(k, \overline{I}_k)$. In Example 3, the non-monotonicity occurs at $k = 0$, where $u(0, \underline{I}_0) < \lim_{x \downarrow 0} u(x, \underline{I}_x)$, as depicted in Figure 2.

4. A Parsimonious Classification and the Value of (Non)transparency

A parsimonious classification of scenarios can be constructed in the (e^*, t) space of Figure 3, in which the parameters of the MS model belong to one of the partitions in the (e^*, t) space. Note that $\overline{\theta}$ exists if and only if $e^* - f(1) - t \le 0$, and that $\underline{\theta}$ exists if and only if $v - c(0,0) \le 0$. In MS, v and $c(s, \theta)$ are written independent of e^*. But in general, it is reasonable to write the net benefit of defending the peg as $v - c = w(e^*, s, \theta)$, with the property that $\partial w / \partial e^* < 0$. That is, the larger is the over-valuation, the smaller will be the benefit for defending the exchange rate, ceteris paribus. Therefore, there should be an $\widehat{e}$ such that $\underline{\theta}$ exists if and only if $e^* \geq \widehat{e}$. We will now be able to partition the space of (e^*, t) into different regions, as depicted in Figure 3. Note that if such an $\widehat{e}$ does not exist, regions C and D will simply vanish, while regions A and B will expand leftward.

Figure 3

An examination of Figure 3 quickly reveals that Region A is what MS study. Region B and Region C in Figure 3 depict an economy comparatively weaker and stronger than the one in the MS model, respectively. Region B, or Case B studied above, is where the cost of speculation is very low. Region C, or Case C above, is where the net benefit for the government to maintain the peg is always positive in the absence of attacks—this is possible if the exchange rate is just mildly overvalued. Region D is a region of vigorous contest as the stakes for speculation and for defending the peg are both high.

The following proposition summarizes the key insights from previous discussions and from Figure 3.

Proposition 4. *When the economic fundamentals are strong, i.e.,* $\theta > \theta^*$, *(weak, i.e.,* $\theta \leq \theta^*$*), the lack of common knowledge (the presence of common knowledge) of the fundamentals among market agents will not increase — and in most cases will decrease — the incidence of speculative attacks.*

A careful examination of the MS model and Case C reveals that when the economic fundamentals are strong, the lack of common knowledge of the fundamentals leads speculators towards the single no-attack equilibrium for the MS model and Case B, whereas common knowledge of the fundamentals leads to two equilibria, an attack and a no-attack equilibrium, in the ripe-for-attack region. Thus, the incidence of speculative attacks will be reduced if fundamentals are non-transparent. In the stable region of the MS model and of Case C, it does not matter whether or not the fundamentals are transparent, as there is only one no-attack equilibrium in either case. However, when economic fundamentals are weak in the ripe-for-attack region in the MS model and in Case B, the lack of common knowledge of the fundamentals lead to a single attack equilibrium while common knowledge of the fundamentals leads to two equilibria, an attack and a no-attack equilibrium. The incidence of speculative attacks will be reduced if fundamentals are transparent. Transparency will have no impact in the unstable region of the MS model and of Case B, because there is only a single attack equilibrium. As for Case A and Case D, transparency of fundamentals makes no impact on the incidence of speculative attacks for all the values of θ.

Suppose the government can observe clearly the fundamentals of the economy and has the means to control this public information. The preceding discussion suggests that, strategically, the government should not (should) publicly announce this information when the fundamentals are strong (weak). As a consequence, speculators cannot infer any additional information from the no announcement strategy of the government because they can observe only their own private signals of the fundamentals and are uncertain of the beliefs held by others.

A remark is in order here. As mentioned in the introduction, there are alternative definitions of transparency. Policy implications of transparency of course vary with the exact meaning of transparency. Heinemann and Illing show that, in an MS framework, an increase in transparency in their definition–a reduction in the dispersion of the private signals market participants receive–will shift the critical θ^* to the left, making currency attacks less likely. Although their result is obtained in a framework in which both $\underline{\theta}$ and $\overline{\theta}$ exist, it can be shown that such a reduction in dispersion of the private signals, i.e., a reduction in ε, will have a similar result in our Cases B and C.

5. Concluding Remarks

The present paper has shown that under a broader variety of boundary conditions, noisy private observations on the fundamentals do not completely eliminate multiple equilibria. In particular, we have included into the MS-framework certain "sound" economies where defending the peg is still viable at their worst possible fundamentals and certain "shaky" economies where attacking the peg at their best possible fundamentals can be beneficial. We have shown that in these extended scenarios, an equilibrium with a successful attack and one without attack co-exist under some certain conditions. In other words, their claim that multiple equilibria occur in self-fulfilling crises models is apparent holds true only under the scenario they study. It is premature to greet the research by MS—while valuable in clarifying the foundations of multiple equilibria— as a conclusive proof that multiple equilibria and self-fulfilling crisis is inherently weak.

Our study suggests that self-fulfilling expectations are generally unavoidable in analyzing currency crises. Another advantage of the self-fulfilling expectation paradigm is that it gives more flexibility in explaining field events than paradigms based on market fundamentals. It remains an empirical question whether speculative crises occurred in reasonably viable economies are attributable to MS's unique equilibrium mechanism or to the more general mechanism of self-fulfilling attacks.

The present paper also finds that, in general, the lack of common knowledge of the fundamentals among agents will generate less incidence of speculative attacks than perfect common knowledge when the economic fundamentals are strong, while the opposite is true when economic fundamentals are weak. Hence the claim on the superiority of transparent policy in alleviating the incidence of currency attacks has to be qualified in a more general framework.[13] This result raises doubts on the contention that the non-transparency of the financial sectors alone can explain the East Asian currency crisis, as most East Asian economies seem to have had viable fundamentals. Nonetheless, our result should not be overemphasized as the concept of transparency is so imprecise (so non-transparent!) that different researchers and policy makers have different interpretations. We hope that future research work can clarify the different meanings of transparency and their potentially different roles in triggering currency crises.

The crucial assumption in this paper that leads to different results from MS is that, in each of the economies studied, not all of the stable, unstable, and ripe-for-attack regions are feasible. We have justified these new cases by alluding to some stylized facts in recent crises, as well as the Obstfeld's classification of economies. Moreover, the co-existence of three regions in an economy is not an indispensable feature of a standard second generation model. The insight of self-fulfilling crises as a consequence of the time-inconsistency problem in the model does not depend on such an assumption. In fact, under common knowledge of fundamentals, all of Cases A to D exhibit the same insight that the second generation models intended to make (see Obstfeld, 1986, 1996; and Jeanne, 1997). Consequently, while study Case A alone under the assumption of common knowledge is a reasonable research agenda, it may

[13] The fact that non-transparency could avoid attack is noteworthy. It could provide insights why bank regulations in some advanced countries permit a certain degree of unobservability.

be misleading and restrictive otherwise.

Appendix:

A. LEMMA A.

The following Lemma, which is proved in MS, is needed to prove Propositions 2 and 3.

Lemma A1. (Morris and Shin) If $\pi(x) \geq \pi'(x)$ for all x (or $\pi \geq \pi'$, in short), then $u(x, \pi) \geq u(x, \pi')$ for all x.

B. PROOF OF LEMMA 1

Proof. *Continuity and Decreasingness of $u(x, \underline{I}_k)$ in x for all x.*

Writing $e^* - f(\theta)$ as $R(\theta)$, noting that $R(\theta)$ is strictly decreasing in θ, and making use of integration by part, we have

$$\begin{aligned} u(x, \underline{I}_k) &= \int_{[0,\underline{\phi}(k)]} R(\theta) dG(\theta|x) - t \\ &= R(\theta)G(\theta|x)|_{\theta=0}^{\theta=\underline{\phi}(k)} - \int_{\theta=0}^{\theta=\underline{\phi}(k)} G(\theta|x) dR(\theta) - t \\ &= R(\underline{\phi}(k))G(\underline{\phi}(k)|x) - R(0)G(0|x) \qquad \text{(A1)} \\ &\quad + \int_{R(\underline{\phi}(k))}^{R(0)} G(R^{-1}(y)|x) dy - t \end{aligned}$$

Continuity of $u(x, \underline{I}_k)$ follows immediately from the continuity of $G(.|x)$ in x. Using that $G(0|x) = 0$ for all x, differentiation of (A1) with respect to x gives

$$\begin{aligned} \frac{du(x, \underline{I}_k)}{dx} &= R(\underline{\phi}(k)) \underbrace{\frac{dG(\underline{\phi}(k)|x)}{dx}}_{\leq 0} + \int_{R(\underline{\phi}(k))}^{R(0)} \underbrace{\frac{dG(R^{-1}(y)|x)}{dx}}_{\leq 0} dy \\ &\leq 0. \end{aligned}$$

■

C. PROOF OF PROPOSITION 2.

Proof. We first show that if there is some $x \in (0,1)$ such that $u(x, \underline{I}_x) = 0$, the smallest one x^* such that $u(x^*, \underline{I}_{x^*}) = 0$ must also exist. Note that $u(x, \underline{I}_x)$ is continuous in x for $x \in (0,1)$. Such x^* does not exist only if $\inf\{x | u(x, \underline{I}_x) = 0\} = 0$. This is impossible for the following reason. Consider any $x < \varepsilon$. Taking into account of Lemma A and the fact that $\underline{\theta} > 2\varepsilon$, we have $u(x, \underline{I}_x) = u(x, \underline{I}_0) > 0$. This contradicts $\inf\{x | u(x^*, \underline{I}_{x^*}) = 0\} = 0$.

We next show that $\theta^* = \underline{\phi}(x^*) < 1$. Assume the contrary. Then $\underline{\phi}(x^*) = 1$ and $A(\underline{I}_{x^*}) = [0,1]$. We have

$$u(x^*, \underline{I}_{x^*}) = \int_{[0,1]} (e^* - f(\theta)) dG(\theta | x^*) - t > e^* - f(1) - t > 0.$$

This is contradictory to the assumption that $u(x^*, \underline{I}_{x^*}) = 0$. Hence $\theta^* < 1$.

We can now show that there are multiple equilibrium outcomes for $\theta > \theta^*$. It is straightforward to verify that both $\overline{I}_1$ and $\underline{I}_{x^*}$ are equilibrium strategy profiles. When speculators coordinate to $\overline{I}_1$, the government will abandon the currency peg for all θ, and in particular for $\theta > \theta^* = \underline{\phi}(x^*)$. This accounts for the collapse of currency peg as an equilibrium outcome for $\theta > \theta^*$. Strategy profile $\underline{I}_{x^*}$ is also an optimal strategy profile for the following result. Because of Result 3 of Lemma 1, we have $u(x, \underline{I}_{x^*}) \geq u(x^*, \underline{I}_{x^*})$ for $x < x^*$ and $u(x, \underline{I}_{x^*}) \leq u(x^*, \underline{I}_{x^*})$ for $x \geq x^*$. Given $\underline{I}_{x^*}$ is used, $\theta^* \equiv \underline{\phi}(x^*)$ is the greatest state at which attack will be successful. Therefore, for $\theta > \theta^*$, maintaining the peg is an equilibrium outcome as well.

It is straightforward to see that, for $\theta \leq \theta^*$, abandonment of the peg is an equilibrium outcome (which is supported by both $\underline{I}_{x^*}$ and $\overline{I}_1$). What remains to show is the uniqueness of this equilibrium outcome. Suppose the contrary. Then there must exist an *equilibrium* strategy profile π such that $s(\theta, \pi) \leq a(\theta)$ for some $\theta < \theta^*$.

Define $\underline{x} = \inf\{x|\pi(x) < 1\}$. Clearly, to have the said property, $\underline{x}$ must exist and be strictly less than x^*. If $\underline{x} = 0$, some speculators with signals sufficiently close to zero are prescribed not to attack. This cannot constitute an equilibrium, as the speculator with signal less than ε knows that the true state $\theta < 2\varepsilon < \underline{\theta}$ and finds it in his strict interest to attack. Hence $0 < \underline{x} < x^*$. Consider a sequence $\{x_i\} \subseteq \{x|\pi(x) < 1\}$ that are convergent to $\underline{x}$. Since for all such x_i, $u(x_i, \pi) \leq 0$, Lemma A implies that for all $x_i, u(x_i, \underline{I}_{\underline{x}}) \leq 0$. Because of the continuity of $u(x, \underline{I}_{\underline{x}})$ in x for $x \in (0, 1)$ (Result 2 of Lemma 1), we have $u(\underline{x}, \underline{I}_{\underline{x}}) \leq 0$. The assumption $\underline{\theta} > 2\varepsilon$ implies $u(x, \underline{I}_x)$ must be strictly positive for x sufficiently close to zero. Result 1 of Lemma 1 (continuity of $u(x, \underline{I}_x)$) implies that there must exist some $x' \leq \underline{x} < x^*$ such that $u(x', \underline{I}_{x'}) = 0$. This contradicts the fact that x^* is the smallest x that makes $u(x, \underline{I}_x) = 0$. This completes the whole proof. ■

D. A CHARACTERIZATION OF $g(\theta|x)$ AND $u(x, \underline{I}_k)$ FOR EXAMPLES 1 TO 3.

For $x = 0$,

$$g(\theta|x) = \begin{cases} \frac{2}{\varepsilon} - \frac{2\theta}{\varepsilon^2} & \text{if} \quad \theta \leq \varepsilon \\ 0 & \text{otherwise} \end{cases}$$

For $0 < x \leq \varepsilon$,

$$g(\theta|x) = \begin{cases} \frac{1}{x+\varepsilon} & \text{if} \quad \theta \leq x + \varepsilon \\ 0 & \text{otherwise} \end{cases}$$

For $\varepsilon < x < 1 - \varepsilon$,

$$g(\theta|x) = \begin{cases} \frac{1}{2\varepsilon} & \text{if} \quad x - \varepsilon \leq \theta \leq x + \varepsilon \\ 0 & \text{otherwise} \end{cases}$$

For $x \geq 1 - \varepsilon$,

$$g(\theta|x) = \begin{cases} \frac{1}{1-x+\varepsilon} & \text{if} \quad \theta \geq x - \varepsilon \\ 0 & \text{otherwise} \end{cases}$$

For $x = 1$,

$$g(\theta|x) = \begin{cases} \frac{2}{\varepsilon} - \frac{2(1-\theta)}{\varepsilon^2} & \text{if} \quad \theta \geq 1 - \varepsilon \\ 0 & \text{otherwise.} \end{cases}$$

In general,

$$u(x, \underline{I}_k) = \int_{[0,\underline{\phi}(k)] \cap [x-\varepsilon, x+\varepsilon]} (e^* - f(\theta)) g(\theta|x) d\theta - t.$$

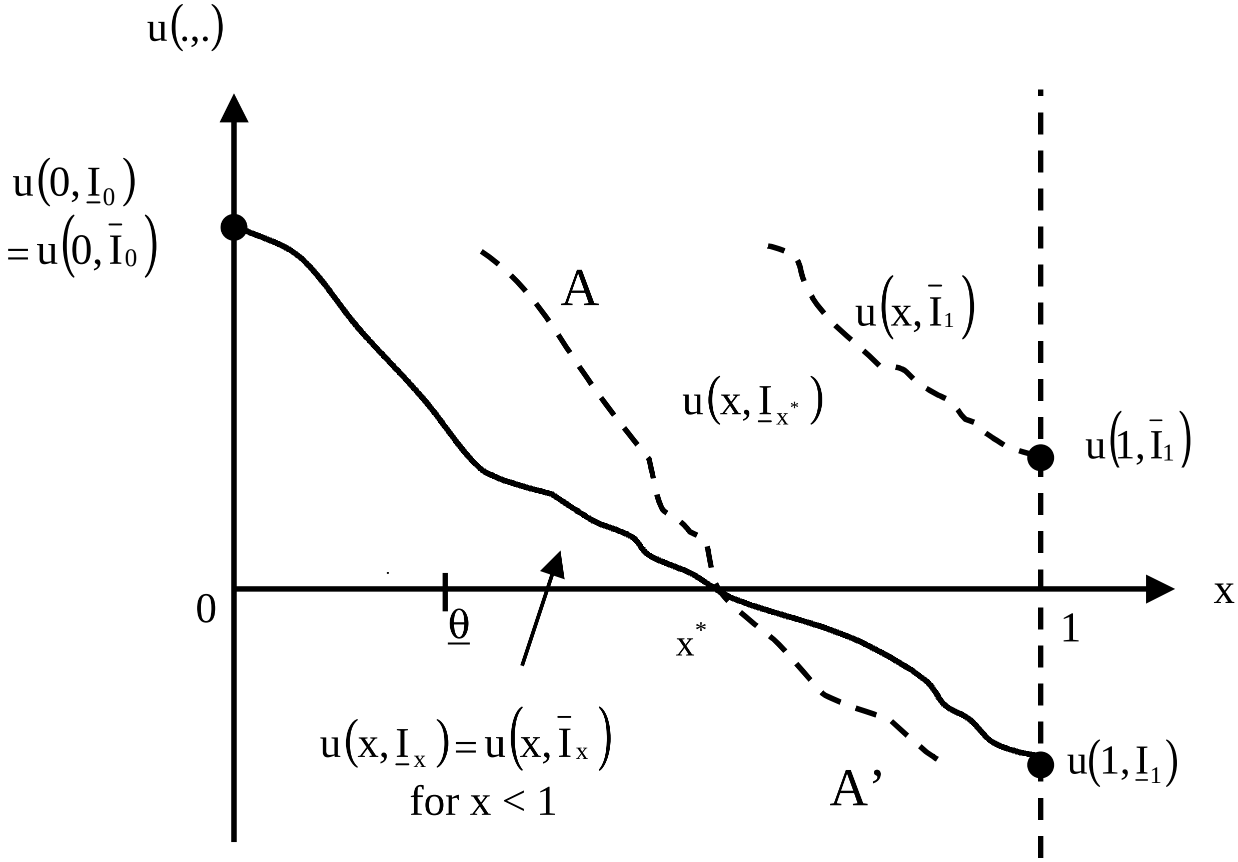


Figure 1: A diagramatic analysis of Case B:
$\underline{I}_{x*}$ and $\bar{I}_1$ are equilibrium strategies

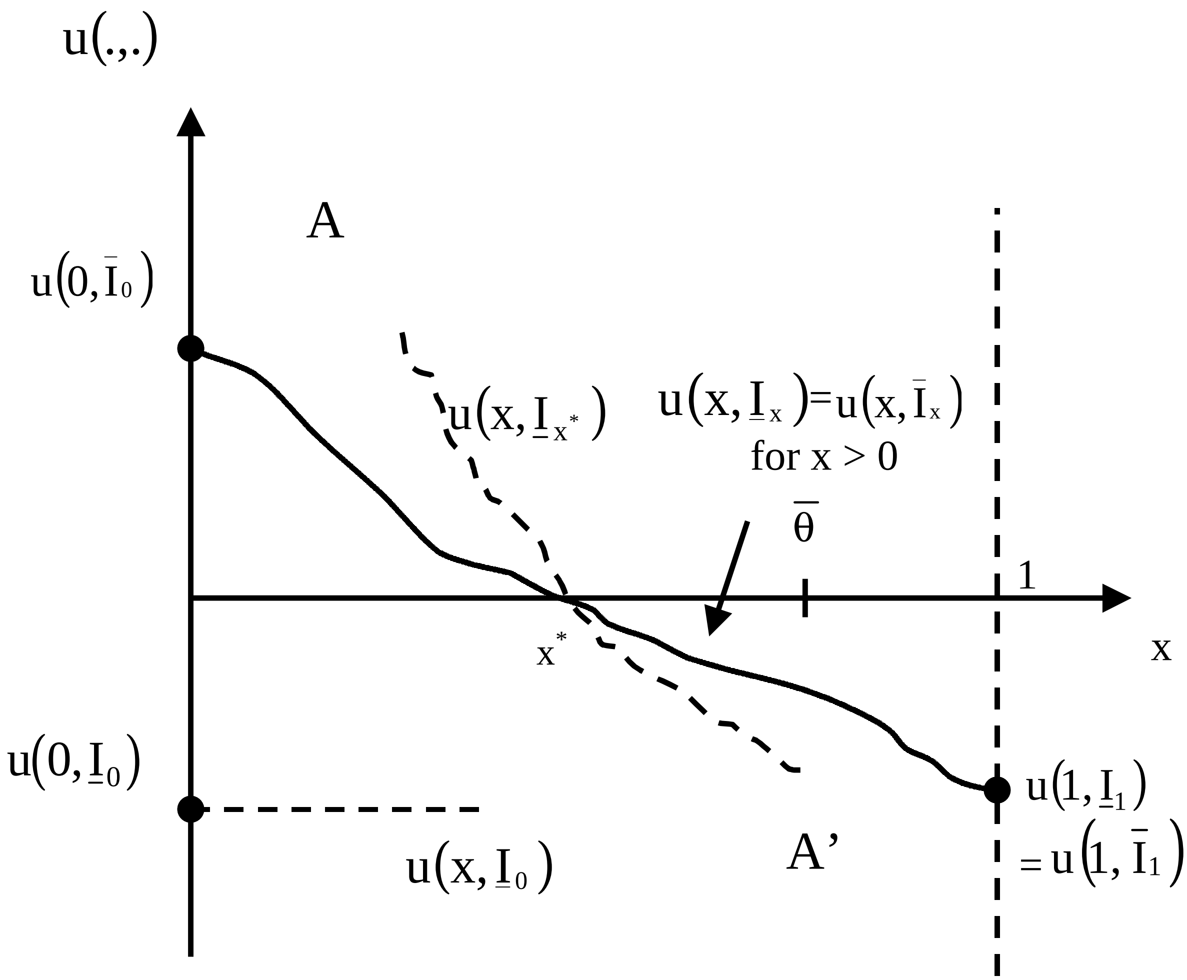
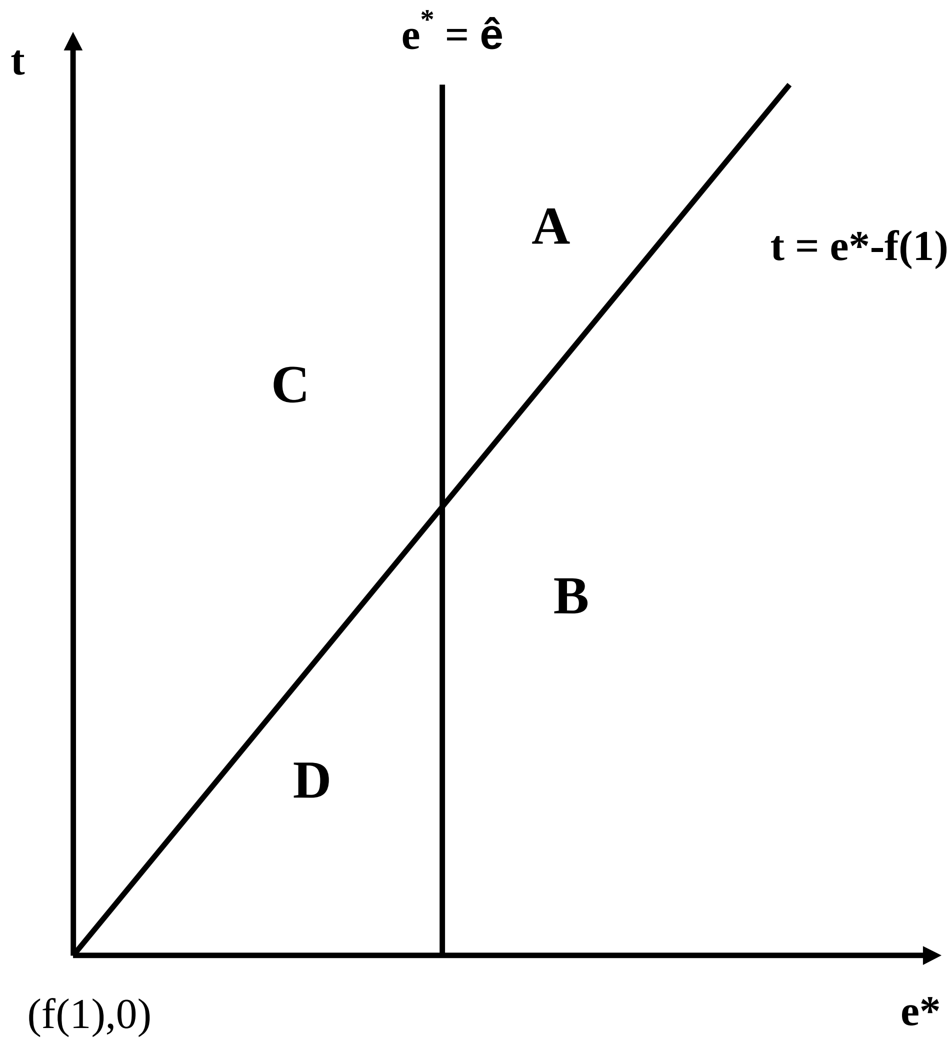


Figure 2: A diagramatic analysis of Case C:
$\underline{I}_0$ and $\underline{I}_{x*}$ are equilibrium strategies



Region A: Both $\bar{\theta}$ and $\underline{\theta}$ exist. (MS's Theorem 1)
Region B: Only $\underline{\theta}$ exists. (Proposition 2)
Region C: Only $\bar{\theta}$ exists. (Proposition 3)
Region D: Neither $\bar{\theta}$ nor $\underline{\theta}$ exists. (Proposition 1)

Figure 3: A typology of scenarios studied

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