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Currency Attacks with Information Correlation

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This study introduces information correlation between small traders and a large trader to study the issue of currency attacks. First, I find that in the strategic interaction between small traders and the large trader, they do not necessarily coordinate with each other. Strategic substitutes may be present under certain circumstances. Second, signals below a certain threshold are not destined to cause a currency attack. Third, information correlation creates different levels of desire for coordination. Comparative statics analysis provides fresh insights into how information structure and government policy affect the difficulty of undertaking currency attacks.

Key Words: Currency attack; Information correlation.
JEL Classification Numbers: F31, D82.

1. INTRODUCTION

Both small and large traders can be involved in currency attacks (Corsetti et al., 2004). Compared with several independently working small traders, a large trader is particularly large and often possesses an informational advantage. However, small traders can unite with each other and obtain a similar advantage to that of large traders. For example, in the well-known GameStop event of 2021, small traders united to defeat institutional traders from Wall Street. Although the GameStop event was not a currency attack, it showed that small traders, when united, can be as powerful as large traders. Similarly, for currency attacks, small traders can unite to obtain power, especially informational advantage, which large traders usually possess. This study considers two types of players: united small traders and a large trader.

In this study, I examine the strategic interaction between united small and a large traders on the issue of currency attacks. Morris and Shin (1998), who used global games as their modeling approach, conducted one of the most prominent second-generation currency attack studies; their

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findings emphasized the role of information in currency attacks. In this study, I adopt the same payoff structure as Morris and Shin (1998), but depart from them by employing the joint normal distribution to construct the core of the model, the information structure. In particular, I use the correlation coefficient in the information structure to measure the extent of information correlation between united small traders and the large trader. This modeling approach is more flexible than the global-games approach, which mechanically decomposes a signal additively with common shock and noise.

The literature on second-generation currency attacks examines the role of self-fulfilling expectations in currency attacks. Morris and Shin (1998) found that the role of self-fulfilling expectation was much stronger in the second-generation currency attack literature. In their model, currency attacks are completely initiated by expectation, which is supported by information. Morris and Shin (1998) adopted global games to model an information structure based on which expectations are formed. Morris and Shin (1998) emphasized the importance of information in initiating currency attacks.

An important feature of information is that it cannot be completely private, which means that privately held information by one entity may overlap with privately held information by another. This overlap is the information correlation referred to in this study. For example, traders individually study strategies for currency investments and keep their research results completely confidential. Because they study the same issue, unless some traders are highly unprofessional, their results must overlap. Hence, private information about currency investment strategies is expected to overlap and hence, correlate. This important information feature plays a significant role in forming expectations and hence, currency attack decisions. Therefore, it is necessary to explore the effect of information correlation on currency attack decisions.

Morris and Shin (1998) used global games to model the information structure, which provides a mechanical link between the players' private information. Initially, there is no private information about state, and the state information is common knowledge for all traders. Morris and Shin introduced noise for each trader into common knowledge so that their knowledge of state becomes private to some extent. Hence, common knowledge is linked to a trader's private information. However, such a link cannot reflect the information correlation among traders because it is flexible by nature rather than mechanically linked by common knowledge. The private information held by each trader, although correlated, is explored individually, which involves different intellectual processes and hence, contains considerable heterogeneity. Such heterogeneity determines the flexibility of the information correlation. Hence, an information structure featuring information correlation cannot be modeled simply by using global games. Therefore, to capture this flexible nature, I use statistical correlation, which is natural for describing the correlation among different objects in the world, to model information correlation.

However, I emphasize that the initial purpose of Morris and Shin (1998), like all studies applying global games, was not to model the link between players' private information. Rather, they applied global games to differentiate the private information held by players.

With this new information structure modeled by statistical correlation, unlike in Morris and Shin (1998), the game does not necessarily exhibit strategic complements. I find that with the new information structure, the pegged exchange rate switches strategic complementarity on or off. In addition, the pegged exchange rate affects the results of coordination and the difficulty of undertaking currency attacks, owing to changes in the information structure. Coordination occurs only when the pegged exchange rate is large enough. Strategic substitutes can also occur in a new information structure. When traders coordinate with each other, if the pegged exchange rate is below a threshold, then the change in information correlation causes a change in the quality of private information, so that a unique equilibrium emerges. However, if the pegged exchange rate is above a threshold, then the stimulus brought about by the large exchange rate makes traders prone to coordination under any extent of information correlation, causing multiple equilibria to arise. When considering how the precision of private information affects the difficulty of undertaking currency attacks, the pegged exchange rate again plays a critical role. When the pegged exchange rate is large enough, enhanced information precision is helpful for coordination; when the pegged exchange rate is not large enough, enhanced information precision is not helpful for coordination.

Suppose the pegged exchange rate is sufficiently large such that the game exhibits strategic complements, with the information structure featuring information correlation, and the quality of private information matters. When the information correlation is loose, there is considerable heterogeneity in each player's private information. When information correlation is tight, there is considerable homogeneity in the private information of each player. Therefore, loose information correlation provides room for strategic complementarity, which strengthens coordination between the two players. The motivation for coordination is due to not only uncertainty between players' private information but also the quality of private information; the more heterogeneity there is within the two players' private information, the more worthwhile the coordination is. Such coordination can be very strong, resulting in multiple equilibria.

By analyzing how information correlation affects the difficulty of undertaking currency attacks, I first find that such an impact is independent of the pegged exchange rate. Second, by analyzing the impact, I differentiate between several types of information structures that feature information correlation. Some types of information structures prevent currency attacks after information correlation is tightened; other types of information structure facilitate currency attacks. As time passes, it is natural that the private information of the traders becomes increasingly homogeneous; hence, the information correlation of the two players becomes increasingly tighter.

Related Literature This study is related to the second-generation currency attack literature, which usually refers to studies on currency attacks based on self-fulfilling expectations (Burnside et al., 2008). For a detailed description of the second-generation currency attack literature, refer to the survey of Burnside et al., 2008).

Among second-generation currency attack models, Morris and Shin (1998) are among the most prominent in emphasizing the role of information on currency attacks, applying global games as modeling and equilibrium refinement approach. Morris and Shin (1998) have become a standard for modeling currency attack activities using global games in textbooks, such as Veldkamp (2023), and have spawned a strand of related literature. Such studies as Sbracia and Zaghini (2001), Corsetti et al. (2004), Tarashev (2007), Morris and Yildiz (2019), and Duley and Gai (2023) all follow the methodology of Morris and Shin (1998), and their results are consistent. I use an information structure that differs from this strand of literature and provide fresh insights into incentives for currency attacks and relevant policy implications.

This study is a significant upgrade to Wang (2016), who considered how information correlation affects strategic interaction in a strategic complements game. Wang (2016) provides the technical preparation for this study; I employ the same information structure as Wang (2016) in the currency attack context of Morris and Shin (1998). Therefore, under the same payoff structure as Morris and Shin (1998), the results of this study can be compared in a straightforward way with those of Morris and Shin (1998) to measure the difference between the two information structures.

The remainder of this paper is organized as follows. Section 2 presents the proposed model. Section 3 solves the model. Section 4 analyzes the comparative statics of equilibria. Section 5 concludes.

2. MODEL SETUP

This study considers a countable set of small traders and a single large trader. The small traders are classified as N type. The proportion of type i traders among the population of small traders is $\beta_i \in (0, 1)$. Type i traders obtain signal ε_i, which follows a normal distribution $N(0, \sigma_i)$. The signals obtained by each type of small traders are independently and identically distributed (i.i.d.).

Corsetti et al. (2004) differentiated between small and large traders, principally in terms of the signal precision obtained by each type. In their view, a large trader, such as George Soros, should be more precise than small traders should. However, I adopt a different view of the signal precision obtained by each type of trader. As stated below, the signal distributions $f(\varepsilon)$ and $f(\varepsilon^*)$ are identical in equilibrium, and hence, the signal precision of small traders and large traders should be the same.

The signal obtained by the entire set of small traders, that is, ε, follows a normal distribution with mean 0 and variance σ^2, that is, $\varepsilon \sim N(0, \sigma)$. Because there are i types of small traders and the signals obtained by each type are i.i.d., the relationship between the signals of the entire set of small traders and the signals of each type of small trader is $\varepsilon = \sum_{i=1}^{N} \beta_i \varepsilon_i$. Hence, the variance in the signals obtained by the entire set of small traders can be expressed as $\sigma^2 = \sum_{i=1}^{N} \beta_i^2 \sigma_i^2$. Because $\beta_i \in (0, 1)$, where $i \in N$, $\sigma^2 < \sum_{i=1}^{N} \sigma_i^2$, which indicates that when the small traders unite, the signals they obtain become more precise than when they work independently. Such a force attracts the attention of the large trader; hence, strategic interaction between the set of small traders and the large trader emerges. The signal obtained by the large trader, ε^*, follows a normal distribution with mean 0 and variance σ^{*2}, that is, $\varepsilon^* \sim N(0, \sigma^*)$. As mentioned, the variance of the signals can reflect the precision of the signals obtained by the set of small traders and the large trader. The higher σ^2 is, the more precise are the signals obtained by the set of small traders; the higher σ^{*2} is, the more precise are the signals obtained by the large trader. In the following, for convenience, I designate the set of small traders as "small traders."

If small traders' signals are less precise than those of a large trader, from the large trader's perspective, the small traders are not sufficiently qualified to care; it is less probable they will make the right decision. In this situation, strategic interaction between the small traders and the large trader does not occur.

However, it is also impossible for small traders' signals to be more precise than those of large traders. Large traders are considered large by virtue of their possessing substantial resources to acquire information for economic and financial decisions. Moreover, they are more professional in information analysis than small traders are. Therefore, even if the aggregation of small traders can make their signals more precise, this precision is unlikely to surpass that of the large trader.

Therefore, in equilibrium, the aggregation of small traders stops when the precision of small traders' signals reaches that of the large trader's signals, followed by strategic interaction between the small traders and the large trader.

The signal distributions of the aggregated small traders and the large trader can be further integrated into a joint normal distribution $f(\varepsilon, \varepsilon^*)$, where $(\varepsilon, \varepsilon^*) \sim N(0, 0, \sigma, \sigma^*, \rho)$. ρ, the statistical correlation coefficient, is used to model the information correlation between the two players. The value of ρ is expected to be between 0 and 1, which indicates that traders agree on the state value after acquiring the state information independently, although the agreement is not publicly known. The information structure for the aggregated small traders and the large trader are (ρ, σ) and (ρ, σ^*), respectively. The exchange rate in the absence of government intervention for small traders is a function of ε and ε^*, given by the function $h(\varepsilon, \varepsilon^*)$:

$$h(\varepsilon, \varepsilon^*) = \frac{1}{\sigma^* \sqrt{2\pi(1-\rho^2)} f(\varepsilon^* | \varepsilon)} = \exp\left[\frac{1}{2}\left(\frac{\frac{\varepsilon^*}{\sigma^*} - \frac{\rho\varepsilon}{\sigma}}{\sqrt{1-\rho^2}}\right)^2\right],$$

where $f(\varepsilon^*|\varepsilon)$ is the conditional probability of ε^* given ε. According to $h(\varepsilon, \varepsilon^*)$, whether a higher ε leads to a stronger economy (a higher value of $h(\varepsilon, \varepsilon^*)$) for small traders depends on the relative magnitude between ε and $\frac{\varepsilon^*}{\rho}$.

Similarly, the exchange rate for a large trader in the absence of government intervention is $h(\varepsilon^*, \varepsilon)$:

$$h(\varepsilon^*, \varepsilon) = \frac{1}{\sigma \sqrt{2\pi(1-\rho^2)} f(\varepsilon | \varepsilon^*)} = \exp\left[\frac{1}{2}\left(\frac{\frac{\varepsilon}{\sigma} - \frac{\rho\varepsilon^*}{\sigma^*}}{\sqrt{1-\rho^2}}\right)^2\right],$$

where $f(\varepsilon|\varepsilon^*)$ is the conditional probability of ε given ε^*. According to $h(\varepsilon^*, \varepsilon)$, whether a higher ε^* informs a stronger economy (a higher value of $h(\varepsilon^*, \varepsilon)$) for the large trader depends on the relative magnitude of ε^* and $\frac{\varepsilon}{\rho}$.

The government initially pegs the exchange rate at $\bar{e}$, where

$$\bar{e} \geq \max\{h(\varepsilon, \varepsilon^*), h(\varepsilon^*, \varepsilon)\} \text{ for all } (\varepsilon, \varepsilon^*).$$

Both small traders and the large trader take binary actions: attack the currency by short selling one unit of it, or otherwise not. If the trader short sells the currency and the government gives up the exchange rate peg, then the payoff in state $(\varepsilon, \varepsilon^*)$ by attacking the currency is the decrease in the exchange rate minus the transaction cost. Thus, the payoff of small traders is $\bar{e} - h(\varepsilon, \varepsilon^*) - t$, and that of the large trader is $\bar{e} - h(\varepsilon^*, \varepsilon) - t$. If the peg is defended by the government, then the trader pays the transaction cost, but no capital gains are generated. Therefore, the trader's payoff is $-t$. If the trader does not decide to attack the currency, then the payoff obtained is zero.

The government obtains a value $v > 0$ from defending the exchange rate at the pegged level but also incurs costs of doing so. The cost of peg defense depends on the signals, the proportion of small traders who choose to attack the currency, and the probability of the large trader deciding to attack the currency. The game is specified as symmetric and I focus on its symmetric equilibrium. It is hard to judge whether the game exhibits strategic substitutes or strategic complements yet. If the game exhibits strategic complements, then all equilibria would be symmetric. In the symmetric equilibrium, the proportion of small traders who decide to attack the currency equals the probability that a large trader decides to attack the currency. Based on this insight, I denote the cost of peg defense by $c(\alpha, \varepsilon, \varepsilon^*)$ if proportion α of small traders decides to attack the economy, or if the large trader attacks the currency with probability α given $(\varepsilon, \varepsilon^*)$. The government's payoff for giving up the peg is zero. The payoff of the exchange rate defense is

$$v - c(\alpha, \varepsilon, \varepsilon^*).$$

The function $c(\alpha, \varepsilon, \varepsilon^*)$ is specified as continuous and increasing in α but decreasing in ε and ε^*.

All traders have a signal on the fundamentals of the economy. Nature draws $(\varepsilon, \varepsilon^*)$ from distribution $f(\varepsilon, \varepsilon^*)$. Finally, the government learns the realized proportion of small traders who choose to attack the currency or the probability of a large trader attacking the currency, α; the government, small traders, and the large trader also learn about $(\varepsilon, \varepsilon^*)$.

This description of the model determines the payoffs for the game. The assumption in Morris and Shin (1998) also applies to this study's context:

Assumption (Morris and Shin (1998)): If a trader is indifferent between attacking and not attacking, they refrain from attacking. If the government is indifferent between defending the peg and abandoning it, the government chooses to abandon the peg.

The equilibrium of the game includes the government's strategies, the small traders' strategies, and the large trader's strategy. To solve the game, consider the marginal proportion of small traders required to cause the government to abandon the peg and the marginal probability of the large trader required to cause the government to abandon the peg, given $(\varepsilon, \varepsilon^*)$. Define $a(\varepsilon^*, \varepsilon)$ for small traders, which represents the abovementioned critical mass, or $a(\varepsilon, \varepsilon^*)$ for a large trader, which represents the abovementioned marginal probability, as the solution to α that solves $c(\alpha, \varepsilon, \varepsilon^*) = v$.

The government's optimal strategy is to give up the peg only if α is greater than or equal to $a(\varepsilon^*, \varepsilon)$ or $a(\varepsilon, \varepsilon^*)$, both of which should be equal in equilibrium, given the signals $(\varepsilon, \varepsilon^*)$.

Given the government's optimal strategy, I then characterize the payoffs of traders. Given ε, denote $A(\varepsilon^*)$ as an event in which the government gives up the peg if the large trader's signals are in the following area:

$$A(\varepsilon^*) = \left\{\varepsilon^* \middle| \int_{-\infty}^{+\infty} \pi(\varepsilon^*) f(\varepsilon^*|\varepsilon) d\varepsilon^* \geq a(\varepsilon^*, \varepsilon)\right\},$$

where $\pi(\varepsilon^*)$ denotes the proportion of small traders who attack a currency when the large trader's signal is ε^*. Assume $a(\varepsilon, \varepsilon^*) = \varepsilon^2 - \varepsilon^{*2}$. Denote $\min x^*$ and $\max x^*$ as the solutions to $\int_{-\infty}^{+\infty} \pi(\varepsilon^*) f(\varepsilon^*|\varepsilon) d\varepsilon^* = a(\varepsilon, \varepsilon^*)$ given ε.

Correspondingly, given ε^*, denote $A(\varepsilon)$ as an event in which the government gives up the peg if the small traders' signals are in the following area:

$$A(\varepsilon) = \left\{\varepsilon \middle| \int_{-\infty}^{+\infty} \pi(\varepsilon) f(\varepsilon|\varepsilon^*) d\varepsilon \geq a(\varepsilon, \varepsilon^*)\right\},$$

where $\pi(\varepsilon)$ is the probability of a large trader deciding to attack the currency when the signal value of small traders is ε. Assume that $a(\varepsilon^*, \varepsilon) = \varepsilon^{*2} - \varepsilon^2$. Denote $\min x$ and $\max x$ as the solutions of $\int_{-\infty}^{+\infty} \pi(\varepsilon) f(\varepsilon|\varepsilon^*) d\varepsilon = a(\varepsilon^*, \varepsilon)$ given ε^*.

Denote the $\min x^*$ and $\max x^*$ given ε equal to $\min x$ or $\max x$ by $-\bar{x}^*$ and $\bar{x}^*$, and the $\min x$ and $\max x$ given ε^* equal to $\min x^*$ or $\max x^*$ by $-\bar{x}$ and $\bar{x}$. The area of strategies in which the government certainly abandons the currency peg when small traders or a large trader attack the currency is $[-\bar{x}, \bar{x}] \times [-\bar{x}^*, \bar{x}^*]$.

The small traders' payoff from attacking the currency, given ε is

$$k(\varepsilon^*) = \begin{cases} \bar{e} - h(\varepsilon^*, \varepsilon) - t \qquad if \qquad \varepsilon^* \in A(\varepsilon^*) \\ -t \qquad if \qquad otherwise. \end{cases}$$

Similarly, the large trader's payoff from attacking the currency, given ε^* is

$$k(\varepsilon) = \begin{cases} \bar{e} - h(\varepsilon, \varepsilon^*) - t \qquad if \qquad \varepsilon \in A(\varepsilon) \\ -t \qquad if \qquad otherwise. \end{cases}$$

Before the game ends, the small traders do not observe ε^* and the large trader does not observe ε.

Therefore, for small traders, the expected payoff from attacking the currency conditional on ε is

$$u = \int_{-\infty}^{x^*} [\bar{e} - h(\varepsilon^*, \varepsilon)] f(\varepsilon^*|\varepsilon) d\varepsilon^* - t.$$

For the large trader, the expected payoff from attacking the currency conditional on ε^* is

$$u^* = \int_{-\infty}^{x} [\bar{e} - h(\varepsilon, \varepsilon^*)] f(\varepsilon|\varepsilon^*) d\varepsilon - t.$$

Because the traders can guarantee a payoff of zero by refraining from attacking the currency, their decisions depend on whether u and u^* are positive or negative. Therefore, if the government adheres to its equilibrium strategy, $\pi(.)$ is the equilibrium of the first period of the game if, for the small traders, $\pi(\varepsilon^*) = 1$ whenever $u > 0$ (while $\pi(\varepsilon^*) = 0$ whenever $u \leq 0$) and for the large trader, $\pi(\varepsilon) = 1$ whenever $u^* > 0$ (while $\pi(\varepsilon) = 0$ whenever $u^* \leq 0$).

3. SOLVING THE MODEL

In this section, based on the model established in the previous section, the best response functions and equilibria are obtained. In equilibrium, given the large trader's strategy x^*, the small traders' strategy x must satisfy

$$u = \int_{-\infty}^{x^*} [\bar{e} - h(\varepsilon^*, x)] f(\varepsilon^*|x) d\varepsilon^* - t = 0.$$

By reformulating the above equation, I obtain

$$\bar{e}\left[\Phi\left(\frac{\frac{x^*}{\sigma^*} - \rho\frac{x}{\sigma}}{\sqrt{1-\rho^2}}\right) - \Phi\left(\frac{\frac{x^*}{\sigma^*} + \rho\frac{x}{\sigma}}{\sqrt{1-\rho^2}}\right)\right] = \frac{2x^*}{\sigma^*\sqrt{2\pi(1-\rho^2)}} + t. \tag{1}$$

Similarly, in equilibrium, given the small traders' strategy x, the large trader's strategy x^* should satisfy

$$u^* = \int_{-\infty}^{x} [\bar{e} - h(\varepsilon, x^*)] f(\varepsilon|x^*) d\varepsilon - t = 0.$$

By reformulating the above equation, I obtain

$$\bar{e}\left[\Phi\left(\frac{\frac{x}{\sigma} - \rho\frac{x^*}{\sigma^*}}{\sqrt{1-\rho^2}}\right) - \Phi\left(\frac{\frac{x}{\sigma} + \rho\frac{x^*}{\sigma^*}}{\sqrt{1-\rho^2}}\right)\right] = \frac{2x}{\sigma\sqrt{2\pi(1-\rho^2)}} + t. \tag{2}$$

Because the set of small traders and the large trader are symmetric, the best response functions $x(x^*)$ and $x^*(x)$ are also expected to be symmetric. Thus, the following subsection focuses on the strategy of a single player (small traders). However, from (1) (and (2)), it is difficult to obtain an analytical solution for $x(x^*)$ (and $x^*(x)$). Therefore, I directly analyze the properties of the best response function(s).

3.1. The Game Exhibits Strategic Complements Conditionally

According to the implicit function theorem, the slope of the best response function $x(x^*)$ is

$$\frac{\partial x}{\partial x^*}=\frac{\frac{1}{\sigma^*\sqrt{1-\rho^2}}\left[\Phi\left(\frac{\frac{x}{\sigma}-\rho\frac{x^*}{\sigma^*}}{\sqrt{1-\rho^2}}\right)+\Phi\left(\frac{\frac{x}{\sigma}+\rho\frac{x^*}{\sigma^*}}{\sqrt{1-\rho^2}}\right)\right]-\frac{2}{\bar{e}\sigma^*\sqrt{2\pi(1-\rho^2)}}}{\frac{\rho}{\sigma}\frac{1}{\sqrt{1-\rho^2}}\left[\Phi\left(\frac{\frac{x}{\sigma}-\rho\frac{x^*}{\sigma^*}}{\sqrt{1-\rho^2}}\right)-\Phi\left(\frac{\frac{x}{\sigma}+\rho\frac{x^*}{\sigma^*}}{\sqrt{1-\rho^2}}\right)\right]}$$

Therefore, small traders exhibit strategic complements if and only if

$$\left[\Phi\left(\frac{\frac{x}{\sigma}-\rho\frac{x^*}{\sigma^*}}{\sqrt{1-\rho^2}}\right)-\Phi\left(\frac{\frac{x}{\sigma}+\rho\frac{x^*}{\sigma^*}}{\sqrt{1-\rho^2}}\right)\right]\left[\Phi\left(\frac{\frac{x}{\sigma}-\rho\frac{x^*}{\sigma^*}}{\sqrt{1-\rho^2}}\right)+\Phi\left(\frac{\frac{x}{\sigma}+\rho\frac{x^*}{\sigma^*}}{\sqrt{1-\rho^2}}\right)-\frac{1}{\bar{e}}\sqrt{\frac{2}{\pi}}\right]>0,$$

where $(x,x^*)\in[-\bar{x},\bar{x}]\times[-\bar{x}^*,\bar{x}^*]$.

For strategic-complements games, the signs of the strategies are expected to be the same in equilibrium. Therefore, to obtain the conditions that guarantee the game's strategic complements, I focus on strategies in which $xx^*>0$. In fact, $\Phi\left(\frac{\frac{x}{\sigma}-\rho\frac{x^*}{\sigma^*}}{\sqrt{1-\rho^2}}\right)>\Phi\left(\frac{\frac{x}{\sigma}+\rho\frac{x^*}{\sigma^*}}{\sqrt{1-\rho^2}}\right)$ can be reformulated to $-x^*x<x^*x$, which holds when x^* and x have the same sign. Therefore, an additional condition to ensure that the game exhibits strategic complements is

$$\Phi\left(\frac{\frac{x}{\sigma}-\rho\frac{x^*}{\sigma^*}}{\sqrt{1-\rho^2}}\right)+\Phi\left(\frac{\frac{x}{\sigma}+\rho\frac{x^*}{\sigma^*}}{\sqrt{1-\rho^2}}\right)-\frac{1}{\bar{e}}\sqrt{\frac{2}{\pi}}>0,$$

which can be reformulated as

$$\bar{e}>\frac{\sqrt{\frac{2}{\pi}}}{\Phi\left(\frac{\frac{x}{\sigma}-\rho\frac{x^*}{\sigma^*}}{\sqrt{1-\rho^2}}\right)+\Phi\left(\frac{\frac{x}{\sigma}+\rho\frac{x^*}{\sigma^*}}{\sqrt{1-\rho^2}}\right)}.$$

Therefore, for $(x,x^*)\in[-\bar{x},\bar{x}]\times[-\bar{x}^*,\bar{x}^*]$, if $xx^*>0$ and

$$\bar{e}>\frac{\sqrt{\frac{2}{\pi}}}{\Phi\left(\frac{\frac{x}{\sigma}-\rho\frac{x^*}{\sigma^*}}{\sqrt{1-\rho^2}}\right)+\Phi\left(\frac{\frac{x}{\sigma}+\rho\frac{x^*}{\sigma^*}}{\sqrt{1-\rho^2}}\right)},$$

plus symmetry of the game, then the game exhibits strategic complements. In the remainder of this paper, I adopt a stronger condition to ensure that the game exhibits strategic complements:

Proposition 1. *Given that* $(x, x^*) \in [-\bar{x}, \bar{x}] \times [-\bar{x}^*, \bar{x}^*]$ *and* $xx^* > 0$, *if*

$$\bar{e} > \max_{(x,x^*)\in[-\bar{x},\bar{x}]\times[-\bar{x}^*,\bar{x}^*]} \frac{\sqrt{\frac{2}{\pi}}}{\Phi\left(\frac{\frac{x}{\sigma}-\rho\frac{x^*}{\sigma^*}}{\sqrt{1-\rho^2}}\right)+\Phi\left(\frac{\frac{x}{\sigma}+\rho\frac{x^*}{\sigma^*}}{\sqrt{1-\rho^2}}\right)},$$

then the game exhibits strategic complements.

Therefore, when the pegged interest rate is large enough, the small traders and large trader coordinate with each other to attack the currency. Intuitively, when the pegged interest rate is very high, the profit obtained by attacking the currency is greater and sufficient for both the small traders and the large trader to share. Therefore, to improve the likelihood of a successful attack, the small traders and large trader are willing to coordinate with each other.

Morris and Shin's (1998) game exhibited only strategic complements. However, strategic complements also occur in my model, albeit conditionally.

3.2. Large Signal or Small Signal Leads to Attack

Given that the game exhibits strategic complements because it is symmetric, its equilibria are also expected to be symmetric. Denote the equilibria by (r, r), which are the solutions to the following equation reformulated from (1):

$$F(r) = \frac{2}{\bar{e}\sigma\sqrt{2\pi(1-\rho^2)}}r + \frac{t}{\bar{e}},$$

where $F(r) = \Phi\big(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\big) - \Phi\big(-\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\big)$. $\frac{\partial F(r)}{\partial r} > 0$ for $r \in \mathbb{R}$, that $\frac{\partial^2 F(r)}{\partial r^2} > 0$ can be proven for $r < 0$ and that $\frac{\partial^2 F(r)}{\partial r^2} < 0$ for $r > 0$. These properties aid analysis of the conditions that ensure the uniqueness/multiplicity of the game's equilibria.

Before analyzing the number of equilibria, it is necessary to consider whether a large or small signal leads to an attack on the currency that causes the government to abandon the peg. A large signal can make the payoff for players greater than zero, whereas a small signal can achieve the same outcome under different conditions. I find that the pegged interest rate $\bar{e}$ plays a critical role in determining whether traders attack the currency in a way that causes the government to abandon the peg:

Proposition 2. *Given that the game exhibits strategic complements, in equilibrium, for* $\bar{e} > (<) \frac{\sqrt{\frac{2}{\pi}}}{\phi\left(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\right)(1-\rho)+\phi\left(-\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\right)(1+\rho)}$, *then if* ε *or*

$\varepsilon^* > (<) r$, where $(r, r) \in [-\bar{x}, \bar{x}] \times [-\bar{x}^*, \bar{x}^*]$, small traders or a large trader attack the currency and the government abandons the peg.

Therefore, given that the game exhibits strategic complements, if the pegged exchange rate is large enough, then a large value of ε or ε^* induces the small traders or large trader to attack the currency, causing the government to abandon the peg. if the pegged exchange rate is small, then a small value of ε or ε^* induces the small traders or large trader to attack the currency, causing the government to abandon the peg. These signals reflect the fundamentals of the economy. When the pegged exchange rate is very large, the economy's fundamentals are relatively weak; a weak economy usually needs to artificially depreciate its currency to spur its economy. Hence, the greater the value of the signal, the weaker the fundamentals of the economy. Therefore, a higher signal value indicates a weaker economy and hence, motivates traders to attack the currency.

When the pegged exchange rate is small, the fundamentals of the economy are relatively healthy: a healthy economy does not need to depreciate its currency much to spur its economy. Hence, the greater the value of the signal, the stronger the fundamentals of the economy. Therefore, a small signal value indicates a weaker economy and hence, motivates traders to attack the currency.

Regardless of whether a small or large signal value induces traders to attack the currency, the analysis is independent of the number of equilibria. This feature indicates that when multiple equilibria exist, it is possible that for some equilibria, a small signal value induces traders to attack the currency, whereas for the remaining equilibria, a large signal value induces traders to attack the currency.

According to Morris and Shin (1998), in equilibrium, when the signal is below a certain threshold, then traders attack the currency. However, in my model, the occurrence of the same phenomenon depends on the value of the pegged exchange rate.

3.3. Uniqueness and Multiplicity of Equilibria

In this subsection, I analyze the game equilibria. As I show, whether the game exhibits a unique equilibrium or multiple equilibria depends on the pegged exchange rate and information structure (mainly referring to the information correlation coefficient ρ). Unlike Morris and Shin (1998), whose global game shows that introduced informational uncertainty can refine equilibria, my model reveals that informational uncertainty can generate equilibria that make the game more complex.

The number of equilibria obtained is

PROPOSITION 3. *Given that the symmetric game exhibits strategic complements, assume $\bar{x}$ and $\bar{x}^*$ are large enough for the support $[-\bar{x}, \bar{x}] \times [-\bar{x}^*, \bar{x}^*]$ to be large enough to include all equilibria (r, r) that solves the following equation:*

$$F(r) = \frac{2}{\bar{e}\sigma\sqrt{2\pi(1-\rho^2)}} r + \frac{t}{\bar{e}}.$$

1) If

$$\begin{cases} \bar{e} \leq \frac{t}{F\left\{\max F'^{-1}\left[\frac{F(\bar{x})-F(-\bar{x})}{2\bar{x}}\right]\right\} - \frac{F(\bar{x})-F(-\bar{x})}{2\bar{x}} \max F'^{-1}\left[\frac{F(\bar{x})-F(-\bar{x})}{2\bar{x}}\right]} \\ \rho^2 > 1 - \frac{\bar{x}}{\bar{e}\sigma\pi[F(\bar{x})-F(-\bar{x})]}, \end{cases}$$

then the game has a unique equilibrium (r, r), where $r < 0$.

2) If

$$\begin{cases} \bar{e} = \frac{t}{F\left\{\max F'^{-1}\left[\frac{F(\bar{x})-F(-\bar{x})}{2\bar{x}}\right]\right\} - \frac{F(\bar{x})-F(-\bar{x})}{2\bar{x}} \max F'^{-1}\left[\frac{F(\bar{x})-F(-\bar{x})}{2\bar{x}}\right]} \\ \rho^2 = 1 - \frac{\bar{x}}{\bar{e}\sigma\pi[F(\bar{x})-F(-\bar{x})]}, \end{cases}$$

then the game contains two equilibria: (r_1, r_1) and (r_2, r_2), where $r_1 < 0$ and $r_2 > 0$.

3) If

$$\begin{cases} \bar{e} \leq \frac{t}{F\left\{\max F'^{-1}\left[\frac{F(\bar{x})-F(-\bar{x})}{2\bar{x}}\right]\right\} - \frac{F(\bar{x})-F(-\bar{x})}{2\bar{x}} \max F'^{-1}\left[\frac{F(\bar{x})-F(-\bar{x})}{2\bar{x}}\right]} \\ \rho^2 < 1 - \frac{\bar{x}}{\bar{e}\sigma\pi[F(\bar{x})-F(-\bar{x})]}, \end{cases}$$

or if

$$\bar{e} > \frac{t}{F\{\max F'^{-1}[\frac{F(\bar{x})-F(-\bar{x})}{2\bar{x}}]\} - \frac{F(\bar{x})-F(-\bar{x})}{2\bar{x}} \max F'^{-1}[\frac{F(\bar{x})-F(-\bar{x})}{2\bar{x}}]},$$

then the game contains three equilibria (r_a, r_a), (r_b, r_b), and (r_c, r_c). Assuming $r_a < r_b < r_c$, then $r_a < 0$ and $r_c > 0$. r_b could be either positive or negative.

By adjusting the value of $\bar{x}$ and $\bar{x}^*$, the equilibria can be further refined. If the values of $\bar{x}$ and $\bar{x}^*$ are too small, then it is possible that no equilibrium exists. The values of $\bar{x}$ and $\bar{x}^*$ that do not allow the existence of equilibrium depend on the exact parameter specifications.

Proposition 3 indicates that if the pegged exchange rate is very large, then multiple equilibria arise. Intuitively, a large value of pegged exchange rate motivates traders to attack the currency more actively and their coordination can be heightened so that multiple equilibria arise. The coexistence of a negative r and a positive r shows that in some equilibrium, it is easier to attack the currency in a manner that causes the government to give up the peg while for the remaining equilibria, it is less likely for currency attacks to occur. However, if the pegged exchange rate is not very large, then the motivation to attack is not very strong. In this situation, the number of equilibria depends on the information correlation between the signals that both players obtain.

Specifically, in the situation in which the pegged exchange rate is not very large, if the information correlation between the two players is very large, that is, $\rho^2 > 1 - \frac{\bar{x}^*}{\bar{e}\sigma\pi[F(\bar{x}^*)-F(-\bar{x}^*)]}$, then the game contains a unique equilibrium. If the information correlation between the two players satisfies $\rho^2 = 1 - \frac{\bar{x}^*}{\bar{e}\sigma\pi[F(\bar{x}^*)-F(-\bar{x}^*)]}$, then the game contains two equilibria: one indicates it is easier for the attack to occur and the other that it is less likely for the attack to occur. If the information correlation between the two players is loose, that is, $\rho^2 < 1 - \frac{\bar{x}^*}{\bar{e}\sigma\pi[F(\bar{x}^*)-F(-\bar{x}^*)]}$, then the game contains three equilibria: some indicate that it is easier for the attack to occur and the remainder that the attack is less likely to occur. Note that $1 - \frac{\bar{x}^*}{\bar{e}\sigma\pi[F(\bar{x}^*)-F(-\bar{x}^*)]}$ can be negative. In this situation, for all $\rho \in [0,1]$, the game contains only a unique equilibrium. No matter what specific situation happens, it is certain that when the pegged exchange rate is not very large, if the information correlation is tight, a unique equilibrium will emerge. This indicates that the information correlation between the two players can reduce their eagerness to coordinate with each other: the small pegged exchange rate already reduces the motivation for both players to coordinate. Both players want to coordinate with each other to acquire information they do not have about the economic fundamentals from the other player. However, when information correlation is tight, then the information each player obtains becomes more homogeneous; hence, they are less motivated to coordinate with each other and therefore, only a unique equilibrium exists. When $1 - \frac{\bar{x}^*}{\bar{e}\sigma\pi[F(\bar{x}^*)-F(-\bar{x}^*)]} > 0$ and the information correlation becomes loose, there is much heterogeneity in each player's private information and hence, it becomes more valuable for them to coordinate with each other so that the other player's private information can be better acquired. Therefore, in this case, multiple equilibria arise.[1]

Note that whether $1 - \frac{\bar{x}^*}{\bar{e}\sigma\pi[F(\bar{x}^*)-F(-\bar{x}^*)]} > 0$ depends on the value of $\bar{x}^*$. At the beginning of Proposition 3, the value of $\bar{x}$ and $\bar{x}^*$ is sufficiently

[1]Symmetrically, like Propositions 1 and 2, a list of conditions exists to differentiate unique equilibrium and multiple equilibria expressed based on the large player's strategy, but because both players are identical, the conditions are exactly the same and hence, I do not write them to save space.

large for the support $[-\bar{x}, \bar{x}] \times [-\bar{x}^*, \bar{x}^*]$ to contain all generically produced equilibria that solve $F(r) = \frac{2}{\bar{e}\sigma\sqrt{2\pi(1-\rho^2)}}r + \frac{t}{\bar{e}}$. Therefore, Proposition 3 (1)—(3) all express the generically produced equilibria. However, the value of $\bar{x}$ and $\bar{x}^*$ can be reduced so that the equilibria can be crowded out of the set in which the government abandons the peg if traders attack the currency. Inductively, because the equilibria are either positive or negative, if the value of $\bar{x}$ and $\bar{x}^*$ continues decreasing and moving closer to 0, then in the end, no equilibrium exists within the support $[-\bar{x}, \bar{x}] \times [-\bar{x}^*, \bar{x}^*]$ and hence, the game contains no equilibrium. In Morris and Shin (1998), their game always contains a unique equilibrium, and moreover, equilibrium of the game always exists, whereas in my model, equilibrium exists conditionally because of adjusting the support $[-\bar{x}, \bar{x}] \times [-\bar{x}^*, \bar{x}^*]$.

4. THE COMPARATIVE STATICS OF EQUILIBRIA

In this section, I study how the equilibria respond to changes in the information structure (ρ, σ), the pegged exchange rate $\bar{e}$, and t. I show that the pegged exchange rate again plays a critical role in determining how the equilibria respond to changes in these variables.

4.1. The Comparative Statics of Equilibria with respect to ρ

For the comparative statics of equilibria with respect to ρ, I obtain the following results:

LEMMA 1. *For equilibrium (r, r), given that* $\phi\big(\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\big)(1+\rho) < \phi\big(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\big)(1-\rho)$, *for* $\bar{e} \gtrless \frac{\sqrt{\frac{2}{\pi}}}{\phi\big(-\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\big)(1+\rho)+\phi\big(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\big)(1-\rho)}$, *then* $\frac{\partial r}{\partial \rho} \gtrless 0$.

Given that $\phi\big(\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\big)(1+\rho) > \phi\big(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\big)(1-\rho)$, *for*

$$\bar{e} < \min\left\{\frac{\rho\sqrt{\frac{2}{\pi}}}{\phi\Big(\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\Big)(1+\rho) - \phi\Big(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\Big)(1-\rho)}, \frac{\sqrt{\frac{2}{\pi}}}{\phi\Big(-\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\Big)(1+\rho) + \phi\Big(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\Big)(1-\rho)}\right\},$$

or

$$\bar{e} > \max\left\{\frac{\rho\sqrt{\frac{2}{\pi}}}{\phi\Big(\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\Big)(1+\rho) - \phi\Big(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\Big)(1-\rho)}, \frac{\sqrt{\frac{2}{\pi}}}{\phi\Big(-\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\Big)(1+\rho) + \phi\Big(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\Big)(1-\rho)}\right\},$$

then $\frac{\partial r}{\partial \rho} < 0$.

$$\min\left\{\frac{\rho\sqrt{\frac{2}{\pi}}}{\phi\Big(\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\Big)(1+\rho) - \phi(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r)(1-\rho)}, \frac{\sqrt{\frac{2}{\pi}}}{\phi\Big(-\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\Big)(1+\rho) + \phi\Big(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\Big)(1-\rho)}\right\} < \bar{e}$$

$$< \max\left\{\frac{\rho\sqrt{\frac{2}{\pi}}}{\phi\left(\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\right)(1+\rho)-\phi\left(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\right)(1-\rho)}, \frac{\sqrt{\frac{2}{\pi}}}{\phi\left(-\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\right)(1+\rho)+\phi\left(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\right)(1-\rho)}\right\},$$

then $\frac{\partial r}{\partial \rho} > 0$.

Lemma 1 shows how information structure determines the impact of ρ on equilibrium threshold r. At equilibrium (r, r), if the information structure ρ and σ satisfy $\phi\big(\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\big)(1+\rho) < \phi\big(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\big)(1-\rho)$, then tightened information correlation makes it more difficult for traders to attack the currency and hence, it is less likely for the government to give up the peg: for $\bar{e} > (<) \frac{\sqrt{\frac{2}{\pi}}}{\phi\left(-\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\right)(1+\rho)+\phi\left(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\right)(1-\rho)}$, when the signal ε or ε^* is greater (smaller) than r, then traders attack the currency. Increasing the information correlation given the existing information structure increases the threshold for an attack.

However, if the information structure ρ and σ satisfy $\phi\big(\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\big)(1+\rho) > \phi\big(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\big)(1-\rho)$, then a tightened information correlation can make it either easier or more difficult for traders to attack the currency, which depends on the relative magnitude between $\frac{\rho\sqrt{\frac{2}{\pi}}}{\phi\left(\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\right)(1+\rho)-\phi\left(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\right)(1-\rho)}$ and $\frac{\sqrt{\frac{2}{\pi}}}{\phi\left(-\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\right)(1+\rho)+\phi\left(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\right)(1-\rho)}$. In fact, the relative magnitude between $\frac{\rho\sqrt{\frac{2}{\pi}}}{\phi\left(\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\right)(1+\rho)-\phi\left(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\right)(1-\rho)}$ and $\frac{\sqrt{\frac{2}{\pi}}}{\phi\left(-\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\right)(1+\rho)+\phi\left(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\right)(1-\rho)}$ essentially reflects a kind of relationship on information structure. If $\frac{\sqrt{\frac{2}{\pi}}}{\phi\left(-\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\right)(1+\rho)+\phi\left(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\right)(1-\rho)} > \frac{\rho\sqrt{\frac{2}{\pi}}}{\phi\left(\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\right)(1+\rho)-\phi\left(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\right)(1-\rho)}$, then again, tightened information correlation between the two players would make it more difficult for traders to attack the currency. On the contrary, if $\frac{\sqrt{\frac{2}{\pi}}}{\phi\left(-\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\right)(1+\rho)+\phi\left(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\right)(1-\rho)} < \frac{\rho\sqrt{\frac{2}{\pi}}}{\phi\left(\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\right)(1+\rho)-\phi\left(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\right)(1-\rho)}$, then tightened information correlation between the two players would make it easier for traders to attack the currency: less coordination lowers the threshold for traders to attack the currency, making it more likely for the government to give up the peg. As time passes, the mutual understanding between the small traders and large trader deepens, thereby tightening the information correlation between the two players. Therefore, at equilibrium

(r, r), with tightened information correlation, the information structure

$$\phi\Big(\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\Big)(1+\rho) < \phi\Big(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\Big)(1-\rho),$$

or

$$\begin{cases} \phi\big(\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\big)(1+\rho) > \phi\big(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\big)(1-\rho) \\ \frac{\sqrt{\frac{2}{\pi}}}{\phi\big(-\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\big)(1+\rho)+\phi\big(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\big)(1-\rho)} > \frac{\rho\sqrt{\frac{2}{\pi}}}{\phi\big(\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\big)(1+\rho)-\phi\big(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\big)(1-\rho)} \end{cases}$$

can prevent a currency attack and hence, prevent abandonment of the peg, whereas the information structure

$$\begin{cases} \phi\big(\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\big)(1+\rho) > \phi\big(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\big)(1-\rho) \\ \frac{\sqrt{\frac{2}{\pi}}}{\phi\big(-\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\big)(1+\rho)+\phi\big(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\big)(1-\rho)} < \frac{\rho\sqrt{\frac{2}{\pi}}}{\phi\big(\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\big)(1+\rho)-\phi\big(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\big)(1-\rho)} \end{cases}$$

facilitates currency attacks.

4.2. The Comparative Statics of Equilibria with respect to σ

From the comparative statics of equilibria with respect to σ, I obtain the following results:

LEMMA 2. *Given equilibrium (r, r), suppose that*

$$\frac{1}{\phi\Big(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\Big)(1-\rho)+\phi\Big(-\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\Big)(1+\rho)} < \frac{\frac{r}{\sqrt{1-\rho^2}}}{\phi\Big(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\Big)+\phi\Big(-\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\Big)}.$$

For

$$\frac{\sqrt{\frac{2}{\pi}}}{\phi\Big(-\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\Big)(1+\rho)+\phi\Big(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\Big)(1-\rho)} < \bar{e} < \frac{\frac{r}{\sqrt{1-\rho^2}}\sqrt{\frac{2}{\pi}}}{\phi\Big(-\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\Big)+\phi\Big(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\Big)},$$

then $\frac{\partial r}{\partial \sigma} < 0$. *For* $\bar{e} < \frac{\sqrt{\frac{2}{\pi}}}{\phi\big(-\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\big)(1+\rho)+\phi\big(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\big)(1-\rho)}$ *or* $\bar{e} > \frac{\frac{r}{\sqrt{1-\rho^2}}\sqrt{\frac{2}{\pi}}}{\phi\big(-\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\big)+\phi\big(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\big)}$, *then* $\frac{\partial r}{\partial \sigma} > 0$.

Suppose that $\frac{1}{\phi\left(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\right)(1-\rho)+\phi\left(-\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\right)(1+\rho)} > \frac{\frac{r}{\sqrt{1-\rho^2}}}{\phi\left(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\right)+\phi\left(-\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\right)}$. *For*

$$\frac{\frac{r}{\sqrt{1-\rho^2}}\sqrt{\frac{2}{\pi}}}{\phi\left(-\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\right)+\phi\left(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\right)} < \bar{e} < \frac{\sqrt{\frac{2}{\pi}}}{\phi\left(-\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\right)(1+\rho)+\phi\left(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\right)(1-\rho)},$$

then $\frac{\partial r}{\partial \sigma} < 0$. *For* $\bar{e} < \frac{\frac{r}{\sqrt{1-\rho^2}}\sqrt{\frac{2}{\pi}}}{\phi\left(-\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\right)+\phi\left(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\right)}$ *or* $\bar{e} > \frac{\sqrt{\frac{2}{\pi}}}{\phi\left(-\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\right)(1+\rho)+\phi\left(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\right)(1-\rho)}$, *then* $\frac{\partial r}{\partial \sigma} > 0$.

Lemma 2 considers a situation in which the precision of both players' private information changes simultaneously. Again, the asymmetric information structure between the two players cannot support strategic interaction between them. As time passes, the information structure between the two players must be identical; hence, strategic interaction between them must occur. Lemma 2 shows that when considering the impact of information precision on the equilibrium threshold, only the pegged interest rate ultimately matters. At equilibrium (r, r), for $\bar{e} < \frac{\frac{r}{\sqrt{1-\rho^2}}\sqrt{\frac{2}{\pi}}}{\phi\left(-\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\right)+\phi\left(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\right)}$, more precise private information makes currency attacks more difficult; on the contrary, for $\bar{e} > \frac{\frac{r}{\sqrt{1-\rho^2}}\sqrt{\frac{2}{\pi}}}{\phi\left(-\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\right)+\phi\left(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\right)}$, more precise private information makes currency attack easier. Note that the threshold $\frac{\frac{r}{\sqrt{1-\rho^2}}\sqrt{\frac{2}{\pi}}}{\phi\left(-\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\right)+\phi\left(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\right)}$ is determined by the information structure. Therefore, even though it does not play the ultimate role, the information structure here still has some impact on the sensitivity result about information precision. For $\bar{e} > \frac{\frac{r}{\sqrt{1-\rho^2}}\sqrt{\frac{2}{\pi}}}{\phi\left(-\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\right)+\phi\left(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\right)}$, a high peg already makes it attractive for traders to attack the currency. More precise private information would help them better coordinate with each other to attack the currency. On the contrary, for $\bar{e} < \frac{\frac{r}{\sqrt{1-\rho^2}}\sqrt{\frac{2}{\pi}}}{\phi\left(-\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\right)+\phi\left(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\right)}$, the low peg makes it unattractive for traders to attack the currency. More precise private information from both players would strengthen their perception that it is not worthwhile to attack the currency. Therefore, in this situation, a low peg makes currency attacks more difficult, making it less likely for the government to give up the peg once the private information of both players becomes more precise.

4.3. The Comparative Statics of Equilibria with respect to $\bar{e}$ and t

From the comparative statics of equilibria with respect to $\bar{e}$ and t, I obtain the following results:

LEMMA 3. *For equilibrium* (r, r), *if* $\bar{e} \gtrless \frac{\sqrt{\frac{2}{\pi}}}{\phi\left(-\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\right)(1+\rho)+\phi\left(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\right)(1-\rho)}$, *then* $\frac{\partial r}{\partial \bar{e}} \lesseqgtr 0$ *and* $\frac{\partial r}{\partial t} \gtrless 0$.

Lemma 3 shows that increasing the pegged exchange rate always makes attacking the currency easier, and hence, the government is more likely to give up the peg, while increasing the transaction cost always makes attacking the currency more difficult, and hence, the government is less likely to give up the peg. The intuition is straightforward. Regardless of the information structure, the more the currency depreciates, the more profit traders obtain when attacking the currency. On the contrary, the transaction cost squeezes profit when attacking the currency, discouraging traders from attacking the currency. Therefore, the higher the transaction cost, the less motivated traders are to attack the currency, making it less likely for the government to give up the peg.

5. CONCLUSION

This study adopts an information structure different from that of Morris and Shin (1998) to study currency attack problems. Morris and Shin (1998) used global games to model the information structure, but I apply an information structure to make the private information of small traders and a large trader statistically correlated. Under my information structure, I reveal a series of results that differ from those of Morris and Shin (1998); for example, players are not destined to coordinate in strategic interaction, and informational uncertainty does not necessarily help refine equilibria but generates equilibria.

Future research on currency attacks could introduce a more generalized distribution with statistical correlation. Additionally, information acquisition could be studied in the context of currency attacks, and rational inattention could be used to model the information acquisition process.

APPENDIX A

A.1. PROOF OF PROPOSITION 2

Define $G(r) = F(r) - \frac{1}{\bar{e}}\big[\frac{2}{\sigma\sqrt{2\pi(1-\rho^2)}}r + t\big] = \Phi\big(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\big) - \Phi\big(-\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\big)$. If r represents the equilibrium threshold where $r \in [-\bar{x}, \bar{x}] \times [-\bar{x}^*, \bar{x}^*]$, then $G(r) = 0$. Here, I temporarily replace r in $G(r)$ with s. If signal s equals r, which is the equilibrium threshold, then $G(s) = 0$.

I obtain

$$\frac{\partial G(s)}{\partial s} = \phi\bigg(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}s\bigg)\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}} + \phi\bigg(-\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}s\bigg)\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}} - \frac{1}{\bar{e}}\frac{2}{\bar{e}\sqrt{2\pi(1-\rho^2)}}.$$

By reformulating this equation, find that $\frac{\partial G(s)}{\partial s} > 0$ if and only if

$$\bar{e} > \frac{\sqrt{\frac{2}{\pi}}}{\phi\big(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}s\big)(1-\rho) + \phi\big(-\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}s\big)(1+\rho)}.$$

Therefore, given signal s, if the pegged exchange rate

$$\bar{e} > \frac{\sqrt{\frac{2}{\pi}}}{\phi\big(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}s\big)(1-\rho) + \phi\big(-\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}s\big)(1+\rho)},$$

then such signal leads to $\frac{\partial G(s)}{\partial s} > 0$, which equivalently leads to $s > r$, where r is the equilibrium threshold, and hence, the currency attack happens. Conversely, if the pegged exchange rate $\bar{e} < \frac{\sqrt{\frac{2}{\pi}}}{\phi\big(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}s\big)(1-\rho)+\phi\big(-\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}s\big)(1+\rho)}$, then such signal leads to $\frac{\partial G(s)}{\partial s} < 0$, which equivalently leads to $s < r$ and hence, a currency attack happens.

Then, I replace the notation s with r. Therefore, condition

$$\bar{e} > \frac{\sqrt{\frac{2}{\pi}}}{\phi\big(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\big)(1-\rho) + \phi\big(-\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\big)(1+\rho)}$$

indicates that for equilibrium (r, r), supposing an exchange rate

$$\bar{e} > \frac{\sqrt{\frac{2}{\pi}}}{\phi\big(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\big)(1-\rho) + \phi\big(-\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\big)(1+\rho)},$$

the equilibrium possesses the property that only when the signal surpasses the threshold r will a currency attack occur; otherwise, it does not happen. Similarly, condition

$$\bar{e} < \frac{\sqrt{\frac{2}{\pi}}}{\phi\left(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\right)(1-\rho) + \phi\left(-\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\right)(1+\rho)}$$

indicates that for equilibrium (r, r), supposing an exchange rate

$$\bar{e} < \frac{\sqrt{\frac{2}{\pi}}}{\phi\left(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\right)(1-\rho) + \phi\left(-\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\right)(1+\rho)},$$

the equilibrium possesses the property that only when the signal falls below the threshold r will the currency attack occur; otherwise, it does not happen. Therefore, Proposition 2 is proven.

A.2. PROOF OF COMPARATIVE STATICS RESULTS IN SECTION 4

This proof also requires use of the function $G(r)$ defined in the last section: $G(r) = F(r) - \frac{1}{\bar{e}}\left[\frac{2}{\sigma\sqrt{2\pi(1-\rho^2)}}r + t\right] = \Phi\left(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\right) - \Phi\left(-\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\right)$. Here, I use the implicit function theorem to prove the comparative statics results listed in Section 4.

By taking the derivatives with respect to r, ρ, σ, $\bar{e}$, and t, I obtain the following results:

$$\frac{\partial G(r)}{\partial r} = \phi\left(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\right)\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}} + \phi\left(-\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\right)\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}} - \frac{2}{\bar{e}\sqrt{2\pi(1-\rho^2)}};$$

$$\begin{aligned}\frac{\partial G(r)}{\partial \rho} = &-\phi\left(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\right)\frac{r}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}\frac{1}{(1+\rho)^2} \\ &+\phi\left(\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\right)\frac{r}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}\frac{1}{(1-\rho)^2} - \frac{2r}{\bar{e}\sigma\sqrt{2\pi}}\frac{\rho}{(1-\rho^2)^{\frac{3}{2}}};\end{aligned}$$

$$\frac{\partial G(r)}{\partial \sigma} = -\frac{1}{\sigma^2}\phi\left(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\right) - \frac{1}{\sigma^2}\phi\left(-\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\right) + \frac{2r}{\bar{e}\sqrt{2\pi(1-\rho^2)}}\frac{1}{\sigma^2};$$

$$\frac{\partial G(r)}{\partial \bar{e}} = \frac{1}{\bar{e}^2}\left[\frac{2}{\sigma\sqrt{2\pi(1-\rho^2)}}r + t\right];$$

$$\frac{\partial G(r)}{\partial t} = -\frac{1}{\bar{e}}.$$

It is proven that $\frac{\partial G(r)}{\partial r} > 0$ if and only if

$$\bar{e} > \frac{\sqrt{\frac{2}{\pi}}}{\phi\big(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\big)(1-\rho) + \phi\big(-\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\big)(1+\rho)}.$$

It can be proven that if $\phi\big(\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\big)(1+\rho) < \phi\big(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\big)(1-\rho)$, then $\frac{\partial G(r)}{\partial \rho} < 0$. If $\phi\big(\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\big)(1+\rho) > \phi\big(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\big)(1-\rho)$, then $\frac{\partial G(r)}{\partial \rho} > 0$ if and only if

$$\bar{e} > \frac{\rho\sqrt{\frac{2}{\pi}}}{\phi\big(\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\big)(1+\rho) - \phi\big(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}\big)(1-\rho)}.$$

I can also prove that $\frac{\partial G(r)}{\partial \sigma} > 0$ if and only if

$$\bar{e} < \frac{\sqrt{\frac{2}{\pi}}\frac{r}{\sqrt{1-\rho^2}}}{\phi\big(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\big) + \phi\big(-\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\big)}.$$

According to implicit function theorem, $\frac{\partial r}{\partial \rho} = -\frac{\frac{\partial G(r)}{\partial \rho}}{\frac{\partial G(r)}{\partial r}}$. Therefore, for equilibrium (r, r), given that $\phi\big(\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\big)(1+\rho) < \phi\big(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\big)(1-\rho)$, for $\bar{e} \gtrless \frac{\sqrt{\frac{2}{\pi}}}{\phi\big(-\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\big)(1+\rho)+\phi\big(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\big)(1-\rho)}$, then $\frac{\partial r}{\partial \rho} \gtrless 0$.

Given that $\phi\big(\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\big)(1+\rho) > \phi\big(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\big)(1-\rho)$, for

$$\bar{e} < \min\left\{\frac{\rho\sqrt{\frac{2}{\pi}}}{\phi(\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r)(1+\rho) - \phi(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r)(1-\rho)}, \frac{\sqrt{\frac{2}{\pi}}}{\phi(-\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r)(1+\rho) + \phi(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r)(1-\rho)}\right\}$$

or

$$\bar{e} > \max\left\{\frac{\rho\sqrt{\frac{2}{\pi}}}{\phi(\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r)(1+\rho) - \phi(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r)(1-\rho)}, \frac{\sqrt{\frac{2}{\pi}}}{\phi(-\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r)(1+\rho) + \phi(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r)(1-\rho)}\right\},$$

then $\frac{\partial r}{\partial \rho} < 0$. For

$$\min\left\{\frac{\rho\sqrt{\frac{2}{\pi}}}{\phi(\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r)(1+\rho) - \phi(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r)(1-\rho)}, \frac{\sqrt{\frac{2}{\pi}}}{\phi(-\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r)(1+\rho) + \phi(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r)(1-\rho)}\right\} < \bar{e}$$

$$< \max\left\{\frac{\rho\sqrt{\frac{2}{\pi}}}{\phi(\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r)(1+\rho)-\phi(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r)(1-\rho)},\frac{\sqrt{\frac{2}{\pi}}}{\phi(-\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r)(1+\rho)+\phi(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r)(1-\rho)}\right\},$$

then $\frac{\partial r}{\partial \rho} > 0$. Lemma 1 is proven.

Once more, according to implicit function theorem, $\frac{\partial r}{\partial \sigma} = -\frac{\frac{\partial G(r)}{\partial \sigma}}{\frac{\partial G(r)}{\partial r}}$. Therefore, for equilibrium (r,r), suppose that $\frac{1}{\phi(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r)(1-\rho)+\phi\left(-\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\right)(1+\rho)} < \frac{\frac{r}{\sqrt{1-\rho^2}}}{\phi\left(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\right)+\phi\left(-\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\right)}$. For

$$\frac{\sqrt{\frac{2}{\pi}}}{\phi\big(-\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\big)(1+\rho)+\phi\big(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\big)(1-\rho)} < \bar{e} < \frac{\frac{r}{\sqrt{1-\rho^2}}\sqrt{\frac{2}{\pi}}}{\phi\big(-\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\big)+\phi\big(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\big)},$$

then $\frac{\partial r}{\partial \sigma} < 0$. For $\bar{e} < \frac{\sqrt{\frac{2}{\pi}}}{\phi\left(-\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\right)(1+\rho)+\phi\left(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\right)(1-\rho)}$ or $\bar{e} > \frac{\frac{r}{\sqrt{1-\rho^2}}\sqrt{\frac{2}{\pi}}}{\phi\left(-\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\right)+\phi\left(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\right)}$, then $\frac{\partial r}{\partial \sigma} > 0$.

Suppose that $\frac{1}{\phi\left(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\right)(1-\rho)+\phi\left(-\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\right)(1+\rho)} > \frac{\frac{r}{\sqrt{1-\rho^2}}}{\phi\left(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\right)+\phi\left(-\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\right)}$. For

$$\frac{\frac{r}{\sqrt{1-\rho^2}}\sqrt{\frac{2}{\pi}}}{\phi\big(-\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\big)+\phi\big(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\big)} < \bar{e} < \frac{\sqrt{\frac{2}{\pi}}}{\phi\big(-\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\big)(1+\rho)+\phi\big(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\big)(1-\rho)},$$

then $\frac{\partial r}{\partial \sigma} < 0$. For $\bar{e} < \frac{\frac{r}{\sqrt{1-\rho^2}}\sqrt{\frac{2}{\pi}}}{\phi\left(-\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\right)+\phi\left(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\right)}$ or $\bar{e} > \frac{\sqrt{\frac{2}{\pi}}}{\phi\left(-\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\right)(1+\rho)+\phi\left(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\right)(1-\rho)}$, then $\frac{\partial r}{\partial \sigma} > 0$. Lemma 2 is proven.

Finally, according to the implicit function theorem, $\frac{\partial r}{\partial \bar{e}} = -\frac{\frac{\partial G(r)}{\partial \bar{e}}}{\frac{\partial G(r)}{\partial r}}$ and $\frac{\partial r}{\partial t} = -\frac{\frac{\partial G(r)}{\partial t}}{\frac{\partial G(r)}{\partial r}}$. Therefore, for equilibrium (r,r), if $\bar{e} \gtrless \frac{\sqrt{\frac{2}{\pi}}}{\phi\left(-\frac{1}{\sigma}\sqrt{\frac{1+\rho}{1-\rho}}r\right)(1+\rho)+\phi\left(\frac{1}{\sigma}\sqrt{\frac{1-\rho}{1+\rho}}r\right)(1-\rho)}$, then $\frac{\partial r}{\partial \bar{e}} \lessgtr 0$ and $\frac{\partial r}{\partial t} \gtrless 0$. Lemma 3 is proven.

A.3. PROOF OF PROPOSITION 3

In the following proof, I assume that $\bar{x}$ and $\bar{x}^*$ are sufficiently large to contain all generically produced equilibria. That means the support $[-\bar{x},\bar{x}]\times[-\bar{x}^*,\bar{x}^*]$ is large enough to contain all solutions of $F(r) = \frac{2}{\bar{e}\sigma\sqrt{2\pi(1-\rho^2)}}r + \frac{t}{\bar{e}}$.

Therefore, in Figures C.1—C.4, I do not denote $-\bar{x}$ and $\bar{x}$ on the coordinate.

The curves in all four figures represent function $F(r)$. The black lines in all four figures represent line $y = \frac{2}{\bar{e}\sigma\sqrt{2\pi(1-\rho^2)}}r + \frac{t}{\bar{e}}$ at the initial position. The black line is tangential to $F(r)$ at point A, and they intersect at point B. This line is parallel to the line that links points ($\bar{x}$, $F(\bar{x})$) and (-$\bar{x}$, $F(-\bar{x})$). The black line denotes $y = kr + l$. Therefore, the slope of the black line is $k = \frac{F(\bar{x})-F(-\bar{x})}{2\bar{x}}$. On the curve $F(r)$, where $\frac{\partial^2 F(r)}{\partial r^2} > 0$ for $r < 0$ and $\frac{\partial^2 F(r)}{\partial r^2} < 0$ for $r > 0$, there are two points with the same slope as the black line. These two points must satisfy

$$F'(r) = \frac{F(\bar{x}) - F(-\bar{x})}{2\bar{x}}.$$

By solving the above equation, I obtain two points, denoted by

$$r = \min F'^{-1}\left[\frac{F(\bar{x}) - F(-\bar{x})}{2\bar{x}}\right]$$

or

$$r = \max F'^{-1}\left[\frac{F(\bar{x}) - F(-\bar{x})}{2\bar{x}}\right],$$

where $\min F'^{-1}\left[\frac{F(\bar{x})-F(-\bar{x})}{2\bar{x}}\right] < \max F'^{-1}\left[\frac{F(\bar{x})-F(-\bar{x})}{2\bar{x}}\right]$. Therefore, point A in the four figures is $\left(\max F'^{-1}\left[\frac{F(\bar{x})-F(-\bar{x})}{2\bar{x}}\right], F\left\{\max F'^{-1}\left[\frac{F(\bar{x})-F(-\bar{x})}{2\bar{x}}\right]\right\}\right)$. In addition, the intercept of the black line $l = F\{\max F'^{-1}\left[\frac{F(\bar{x})-F(-\bar{x})}{2\bar{x}}\right]\} - \frac{F(\bar{x})-F(-\bar{x})}{2\bar{x}} \max F'^{-1}\left[\frac{F(\bar{x})-F(-\bar{x})}{2\bar{x}}\right] > 0$. The black line represents the case described in Proposition 3 (2), where, if

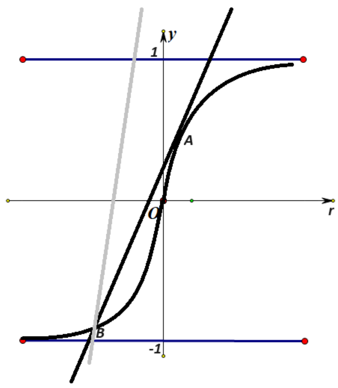
$$\begin{cases} \bar{e} = \dfrac{t}{F\left\{\max F'^{-1}\left[\frac{F(\bar{x})-F(-\bar{x})}{2\bar{x}}\right]\right\} - \frac{F(\bar{x})-F(-\bar{x})}{2\bar{x}} \max F'^{-1}\left[\frac{F(\bar{x})-F(-\bar{x})}{2\bar{x}}\right]} \\ \rho^2 = 1 - \dfrac{\bar{x}}{\bar{e}\sigma\pi\left[F(\bar{x})-F(-\bar{x})\right]}, \end{cases}$$

then the game contains two equilibria, (r_1, r_1) (indicating B) and (r_2, r_2) (indicating A), where $r_1 < 0$ and $r_2 > 0$.

In Figure 1, I counterclockwise rotate the black line around point B to the position represented by the gray line. In this case, only a unique equilibrium exists generically, represented by point B; it features a higher intercept and steeper slope than the tangent line. Therefore, I obtain Proposition 3 (1), where, if

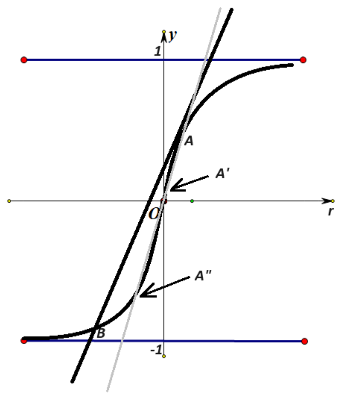
$$\begin{cases} \bar{e} \leq \dfrac{t}{F\left\{\max F'^{-1}\left[\frac{F(\bar{x})-F(-\bar{x})}{2\bar{x}}\right]\right\} - \frac{F(\bar{x})-F(-\bar{x})}{2\bar{x}} \max F'^{-1}\left[\frac{F(\bar{x})-F(-\bar{x})}{2\bar{x}}\right]} \\ \rho^2 > 1 - \frac{\bar{x}}{\bar{e}\sigma\pi[F(\bar{x})-F(-\bar{x})]}, \end{cases}$$

FIG. 1. Rotate the black line counterclockwise around point B to the position represented by the gray line. The black line has one tangent point and an intersection point with $F(r)$. The gray line has a unique intersection point with $F(r)$. The black line or gray line indicates $y = \frac{2}{\bar{e}\sigma\sqrt{2\pi(1-\rho^2)}}r + \frac{t}{\bar{e}}$.



then the game has a unique equilibrium (r, r), where $r < 0$.

FIG. 2. Rotate the black line counterclockwise around point A to the position represented by the gray line. The black line has one tangent point and an intersection point with $F(r)$. The gray line has three intersection points with $F(r)$. The black line or gray line indicates $y = \frac{2}{\bar{e}\sigma\sqrt{2\pi(1-\rho^2)}}r + \frac{t}{\bar{e}}$.

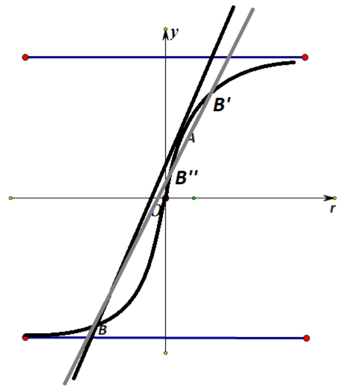


In Figure 2, I counterclockwise rotate the black line around point A to the position represented by the gray line. In this case, there are three equilibria, which are represented by A, A', and A''. It is certain that the value r of A is positive and that of A'' is negative, but that of A' is uncertain. The new position of the line, indicated by the gray line, features a lower intercept but a steeper slope. Therefore, I obtain the first part of Proposition 3 (3), where, if

$$\begin{cases} \bar{e} \leq \frac{t}{F\left\{\max F'^{-1}\left[\frac{F(\bar{x})-F(-\bar{x})}{2\bar{x}}\right]\right\}-\frac{F(\bar{x})-F(-\bar{x})}{2\bar{x}}\max F'^{-1}\left[\frac{F(\bar{x})-F(-\bar{x})}{2\bar{x}}\right]} \\ \rho^2 < 1-\frac{\bar{x}}{\bar{e}\sigma\pi[F(\bar{x})-F(-\bar{x})]}, \end{cases}$$

then the game contains three equilibria (r_a, r_a), (r_b, r_b), and (r_c, r_c). Assuming $r_a < r_b < r_c$, then $r_a < 0$ and $r_c > 0$. r_b could be either positive or negative.

FIG. 3. Rotate the black line clockwise around point B to the position represented by the gray line. The black line has one tangent point and an intersection point with $F(r)$. The gray line has three intersection points with $F(r)$. The black line or gray line indicates $y = \frac{2}{\bar{e}\sigma\sqrt{2\pi(1-\rho^2)}}r + \frac{t}{\bar{e}}$.



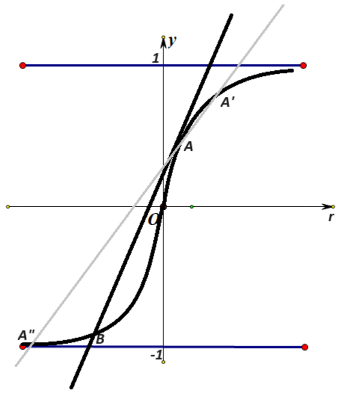
In Figure 3, I clockwise rotate the black line around point B to the position represented by the gray line. In this case, there are three equilibria, which are represented by B, B', and B''. It is certain that the value r of B is negative and that of B' is positive. The new position of the line, indicated by the gray line, features a lower intercept and flatter slope than the black line. Therefore, I obtain that, if

$$\begin{cases} \bar{e} > \frac{t}{F\left\{\max F'^{-1}\left[\frac{F(\bar{x})-F(-\bar{x})}{2\bar{x}}\right]\right\}-\frac{F(\bar{x})-F(-\bar{x})}{2\bar{x}}\max F'^{-1}\left[\frac{F(\bar{x})-F(-\bar{x})}{2\bar{x}}\right]} \\ \rho^2 > 1-\frac{\bar{x}}{\bar{e}\sigma\pi[F(\bar{x})-F(-\bar{x})]}, \end{cases}$$

then the game contains three equilibria (r_a, r_a), (r_b, r_b), and (r_c, r_c). Assuming $r_a < r_b < r_c$, then $r_a < 0$ and $r_c > 0$. r_b could be either positive or negative.

In Figure 4, I clockwise rotate the black line around point A to the position represented by the gray line. In this case, there are three equilibria,

FIG. 4. Rotate the black line clockwise around point A to the position represented by the gray line. The black line has one tangent point and an intersection point with $F(r)$. The gray line has three intersection points with $F(r)$. The black line or gray line indicates $y = \frac{2}{\bar{e}\sigma\sqrt{2\pi(1-\rho^2)}} r + \frac{t}{\bar{e}}$.



which are represented by A, A', and A''. It is certain that the value r of A'' is negative and that of A' is positive. The new position of the line, indicated by the gray line, features a higher intercept and steeper slope than those of the black line. Therefore, I obtain that, if

$$\begin{cases} \bar{e} > \dfrac{t}{F\left\{\max F'^{-1}\left[\frac{F(\bar{x})-F(-\bar{x})}{2\bar{x}}\right]\right\} - \frac{F(\bar{x})-F(-\bar{x})}{2\bar{x}} \max F'^{-1}\left[\frac{F(\bar{x})-F(-\bar{x})}{2\bar{x}}\right]} \\ \rho^2 < 1 - \frac{\bar{x}}{\bar{e}\sigma\pi[F(\bar{x})-F(-\bar{x})]}, \end{cases}$$

then the game contains three equilibria (r_a, r_a), (r_b, r_b), and (r_c, r_c). Assuming $r_a < r_b < r_c$, then $r_a < 0$ and $r_c > 0$. r_b could be either positive or negative.

Together, Proofs (3) and (4) form the second part of Proposition 3.

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