A Large Speculator in Contagious Currency Crises: A Single "George Soros" Makes Countries More Vulnerable to Crises, but Mitigates Contagion

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Abstract

This paper studies the implications of the presence of a large speculator like George Soros during a contagious currency crisis. The model proposes a new contagion channel and shows how a currency crisis can spread from one country to another even when these countries are totally unrelated in terms of economic fundamentals. This model enables us to distinguish between whether a crisis is a coincidence or due to contagion when it happens in two countries. It finds that the *better* the economic fundamentals in the originating crisis country, the more severe the contagion under certain conditions. The large speculator is more aggressive in attacking the currency peg than he would be if his size were small. Furthermore, the mere presence of the large speculator makes other small speculators more aggressive in attacking the currency peg, which in turn makes countries more vulnerable to currency crises. But surprisingly, the presence of the large speculator *mitigates* contagion of crises across countries. The model presents policy implications as to financial disclosure and size regulation of speculators such as hedge funds, which recently have been hot topics among policy makers. First, financial disclosure by speculators eliminates contagion, but may make countries more vulnerable to crises. Second, regulating the size of speculators (e.g., prohibiting hedge funds from high-leverage and thereby limiting the amount of short-selling) makes countries less vulnerable to crises, but makes contagion more severe.

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"Has anyone noticed just how small a player the IMF really is? That $18 billion U.S. contribution to the IMF, which has finally been agreed upon after countless Adminstration appeals and conservative denunciations, is about the same as the short position that [George] Soros single-handedly took against the British pound in 1992 — and little more than half the position Soros' Quantum Fund, Julian Robertson's Tiger Fund, and a few others took against Hong Kong last August [in 1997]."

— Paul Krugman, Soros' Plea: Stop Me! [1]

1 Introduction

The names of recent financial crises, such as the Mexican *Tequila* crises in 1994, the Asian *Flu* in 1997, the Russian *Virus* in 1998, and the Brazilian *Sneeze* in 1999, suggest a common feature. Clearly the common feature is "contagion," where a financial crisis begins locally, in some region, country, or institution, and subsequently spreads elsewhere. The international transmission of financial shocks per se is not always a surprising phenomenon. What is quite surprising in recent contagion episodes, however, is that the financial crises in small economies like Thailand or Russia have devastating effects on economies of very different sizes and structures, thousands of miles apart, with few direct trade or financial links, and in very severe and unexpected ways.[2] Put another way, it is quite surprising that severe contagion of crises has happened across seemingly "unrelated" countries, originating from crises in small economies. Why did Australian and South African stock market indices fall by 14% in the turmoil over the Asian Flu?[3] Why did the Brazilian stock market fall by over 50% and the sovereign spreads of Brazil rise sharply during the Russian Virus?[4] While several contagion channels have been proposed in the literature, none seem able to entirely explain the extent of contagion. This paper provides a complement to the growing literature by proposing a new contagion channel.

Closely related to the issue of contagion, is the issue of "large" speculators. Large speculators, like George Soros or Julian Robertson, have not only been blamed for destabilizing the market unnecessarily during the turmoil of contagious currency crises, but also for triggering these contagious crises by themselves. For instance, during the turmoil of the Asian Flu, the then Malaysian prime minister, Mahathir Mohamad, accused George Soros and others of being "the anarchists, self-serving rogues and international brigandage".[5] There are two main reasons that these large speculators are often blamed. First, they are considered to be able to affect the

[1] Krugman (1998).

[2] As to the Russian Virus, Calvo, Izquierdo, and Talvi (2003) argue that "it was hard to even imagine, ex ante, that a crisis in a country that represents less than 1 percent of world output would have such devastating effect on the world capital market." (p.4)

[3] See Forbes (2003).

[4] See Forbes and Rigobon (2000).

[5] Financial Times, July 25, 1997.

whole market to some degree. As opposed to small traders, they can exercise a disproportionate influence on the likelihood and severity of a financial crisis by fermenting and orchestrating attacks against weakened currency pegs, as the opening quote of this paper suggests. Second, they are often registered in so-called tax havens, typically small islands in the Caribbean, Europe, and Asia Pacific. These "offshore" funds typically do not forward financial information about themselves to other tax and financial authorities, since the regulation on them in the tax havens is often less stringent than that of major industrialized countries. Therefore, they are often thought of as "monsters" whose true nature is unknown. Regardless of whether this is factually correct or not, it is quite important to investigate how such speculators can affect the market during contagious currency crises.

Both of the issue of contagion and that of large speculators have been arguably the most serious concerns for policy makers in international finance, following recent detrimental financial crises. Recent international policy issues have revolved around questions on how to stop, mitigate, or prevent contagion of financial crises when there are incredibly large speculators like George Soros who do not disclose financial information about themselves to policy makers. In order to answer these questions, it is important to clarify and pin down the possible channels through which a financial crisis spreads from one country to another and how the presence of large speculators influences contagious financial crises.

This paper attempts to answer these questions. As far as I know, this paper is the first to investigate both the issue of contagion across unrelated countries and that of a large speculator in a unified framework. By investigating both issues in the unified framework, it becomes clear that the presence of the large speculator, who typically does not disclose financial information about himself to the regulatory authorities or to the market, has important implications during contagious currency crises. By finding a new contagion channel, an important intuition comes to light. The large speculator's financial information about himself (i.e., his "type") is not public, instead it is his own private information. However, under some special situations such as financial crises, such information is revealed to the market to some degree under certain conditions. This revealed information about his "type" can change the optimal behavior of other speculators who did not know the information before the crisis, which in turn can cause contagion of crises across unrelated countries.

In fact, this is what happened around a hedge fund, called the Long Term Capital Management (LTCM), during the Russian Virus. LTCM is one of the most famous and infamous hedge funds[6] in history. On the one hand, it was famous because it was considered a "dream team". For example, it was made up of two Nobel prize winning economists, a couple of living legendary Wall Street traders, and a person who had been a vice chairman of the U.S. Federal Reserve and second in the Fed's hierarchy to the Fed chairman Alan Greenspan. On the other hand, it was infamous

[6] Hedge funds are typically organized as private investment vehicles for wealthy individuals and institutional investors. Often, if not always, hedge funds are offshore funds that register themselves in tax havens. Both hedge funds and offshore funds are mostly unregulated. Since they circumvent financial disclosure regulations, little is known about them.

because the world financial market was on the verge of annihilation and complete meltdown during the Russian Virus due to the near-bankruptcy of LTCM. This was because LTCM was unbelievably large. According to Dunbar (1999),

> "LTCM's derivatives positions amount to a total of \$1.25 trillion... How big is \$1.25 trillion? It is roughly the size of Italy's national debt, ... , the same as the entire annual budget of the US government." (pp.190-191)

Given the astronomic size of LTCM's position, the Fed thought that if LTCM went bankrupt, "markets would ... possibly cease to function" (William J. McDonough, the then President of Federal Reserve Bank of New York).[7] Thus, the Fed finally rescued LTCM. No doubt LTCM was one of the key players during the Russian Virus. It was also one of the reasons why the Russian Virus became so contagious. For example, before the Russian Virus, LTCM had been the "secrecy-obsessed" hedge fund. Nobody outside of LTCM knew much about LTCM. But during the Russian Virus, the situation changed. Lowenstein (2000) reported that

> "... the partners [of LTCM] noticed an ominous pattern: *their* trades were falling more than others'. There was a rally in junk bonds, for instance, but the specific issues that Long-Term owned stayed depressed. ... Wall Street traders were running from Long-Term's trades like rats from a sinking ship. ... all Wall Street knew about Long-Term's troubles. Rival firms began to sell in advance of what they feared would be an avalanche of liquidating by Long-Term. 'As people smelled trouble, they started getting out,' ... a trader at Salomon, remarked. 'Not to attack LTCM — to save themselves.'" (pp.163-164)

Here is an important point. Before the Russian Virus, traders in the market did not really know how LTCM was going to behave to earn profits or to avoid losses. Thus they were not quite sure whether or not they should immediately sell securities of which LTCM had positions, because they did not know how and when LTCM would dispose of the positions of those securities. But during the Russian Virus, they learned some new information. LTCM could not help but sell those securities in the near future to avoid further possible losses, meaning that prices would be deeply depressed due to liquidation by LTCM. Thus they rushed to sell those securities before prices fell due to LTCM's liquidation. Yet their selling behavior depressed the prices of those securities that seemed totally *unrelated* to Russia. This is one of the contributing factors that translated the Russian financial crisis into the contagious one, the Russian Virus.

The model in this paper does not intend to capture all aspects of the LTCM's story.[8] In fact, the model seems far distant from the LTCM's story. In Section 3, however, I will explain how the model can be applied to capture an important aspect of LTCM's interesting story: the financial crisis reveals the large player's "type" to

[7] See chapter 10 of Lowenstein (2000).

[8] For detailed description of the story, see Dunbar (1999) and Lowenstein (2000).

some degree under certain condition and thereby changes the optimal behavior of other players, which in turn can cause contagion of crises across unrelated countries.

The main findings of this paper are summarized as follows.

- First, this paper proposes a new contagion channel and shows why and how contagion of currency crises happens across countries even when these countries are totally unrelated in terms of economic fundamentals. Speculators attack countries whenever they think it is possible and profitable to attack, irrespective of whether or not these countries are related in terms of economic fundamentals. Thus the key to explaining contagious currency crises in the model lies in each speculator's private information and learning behavior about other speculators' types. Since the payoff of each speculator depends on other speculators' behavior determined by their types, each speculator's behavior depends on her belief about other speculators' types. If a currency crisis in one country reveals the speculators' types to some degree, it leads to an updating of each speculator's belief about other speculators' types and can therefore change her optimal behavior, which in turn can cause a currency crisis even in an unrelated country.

- Second, this paper shows a new implication about what kind of the currency crisis is contagious. The literature commonly implies that the *worse* the economic fundamentals in the originating crisis country, the more severe the contagion. Yet the literature has a gap. Why was the Argentine financial crises in 2002 *not* very contagious? This is a puzzle because the economic fundamentals of Argentina during and after the crisis were arguably much worse than those of Asian countries during the Asian Flu. Why was the Asian Flu so contagious while the Argentine financial crisis was not? This paper provides a potential answer to this question: the *better* the economic fundamentals in the originating crisis country, the more severe the contagion. This is because the better the economic fundamentals in the originating crisis country, the more information the crisis conveys about the types of speculators under certain conditions. When the economic fundamentals are really bad, the crisis will happen for sure because all the speculators will attack irrespective of their types. But when economic fundamentals are not so bad, the crisis will happen only if speculators are of certain types because not all types have an incentive to attack. Even if a financial crisis in country A is not contagious, another financial crisis in another country with better economic fundamentals than country A can be contagious.

- Third, this paper enables us to distinguish between whether a crisis is a coincidence or due to contagion when it happens in two countries. It becomes possible to distinguish between them, by clarifying under what conditions the crisis in country A in fact triggers the crisis in country B.

- Fourth, a single large speculator ("George Soros") makes other small speculators more aggressive in attacking the currency peg, which in turn makes countries more vulnerable to crises. This finding is essentially the same as Corsetti, Pesenti, and Roubini (2002) and Corsetti, Dasgupta, Morris, and Shin (2004). But these two papers are not concerned with the issue of contagion. This paper shows this finding leads to a surprising result in terms of contagion, which is explained next.

- Fifth, a single "George Soros" *mitigates* contagion, *because* he makes other small speculators more aggressive in attacking the currency peg. This seems paradoxical, but it actually makes sense. The source of contagion in my model uses Bayesian updating to portray each speculator's belief about other speculators' types. When other speculators' behavior differs greatly across different types, the change in each speculator's behavior due to Bayesian updating in belief about other speculators' types becomes quite large, which in turn makes the contagion more severe. Because one "George Soros" makes other small speculators more aggressive in attacking the currency peg, all the speculators become "more similar" in terms of their behavior even when their types are different. This means that Bayesian updating in each speculator's belief about other speculators' types does not matter much. Even when a speculator can sort out different types of speculators, it does not matter since speculators of different types behave in a similarly aggressive way due to the presence of a single "George Soros."

- Sixth, if the regulatory authorities can have large speculators such as George Soros disclose their financial information, they can eliminate contagion but may make countries *more vulnerable* to crises. If small speculators know the exact type of Soros from the beginning due to financial disclosure, there is no room for Bayesian updating in belief about Soros' type. No Bayesian updating means no contagion in my model. But if small speculators initially know that Soros is truly the most aggressive type, they can become the most aggressive in attacking the currency peg, which in turn makes countries more vulnerable to crises.

- Seventh, if the regulatory authorities can limit the size of speculators by regulating the amount of short-selling, they can make countries less vulnerable to crises but may make contagion *more severe*. This is a mirror image of the finding that one large "George Soros" makes countries more vulnerable to crises, but mitigates contagion.

The remainder of the paper is organized as follows. Section 2 reviews the literature. Section 3 sets out the model and Section 4 concludes. All proofs are presented in the Appendix.

2 Related Literature

Why can a currency crisis spread from one country to another even when these countries appear to be unrelated in terms of economic fundamentals? Three possible contagion channels have been proposed to explain contagion of crises across seemingly unrelated countries that do not share correlated fundamental shocks, direct trade or financial linkage.[9]

The first possible channel is an indirect trade linkage through a third market.[10] Suppose a couple of countries compete in the third market. A devaluation in one country gives it a temporarily boost in its competitiveness, in the presence of nominal rigidities. Its trade competitors are then at a competitive disadvantage; those adversely affected by the devaluation are likely attacked next, thereby inciting contagion.

The second possible channel is an indirect financial linkage through a "common lender" and/or interbank market.[11] If a currency crisis occurs in a country, international investors and/or international banks would incur losses. Facing losses due to the crisis, they may pull out their money or call in their loans to re-balance their portfolio or meet the capital ratio requirement, not only from the originating crisis country but also from seemingly unrelated countries. As a result, their withdrawal may cause contagion. From the viewpoint of unrelated countries, they share international investors and/or international banks with the originating crisis country as the common lender. Moreover, if the common lender incurs huge losses or goes bankrupt due to the crisis, this negative effect can spread to other investors or banks through the interbank market, which in turn can amplify contagion.

The third possible channel argues that contagion can be explained as jumps between multiple equilibria.[12] However, it is often pointed out that multiple equilibria models of crises provide only a feeble explanation of contagion, as they are consistent with other outcomes, including the absence of contagion. Moreover, even if a crisis occurs in two countries, it may be a coincidence. In multiple equilibria models, it is not very clear whether or not the crisis in one country in fact triggers the crisis in the other.

This paper proposes a new contagion channel by *refining* multiple equilibria to explain how and why one particular equilibrium (e.g., "Crisis") is selected over another (e.g., "No Crisis") out of two possible equilibria. In so doing it becomes clear

[9]For contagion across related countries, see Chang and Majnoni (2002).

[10]See Gerlach and Smets (1995) and Corsetti, Pesenti, Roubini, and Tille (2000). For empirical evidence, see Glick and Rose (1999).

[11]For theoretical explanations of contagion due to portfolio re-balancing, see Calvo (1999) and Calvo and Mendoza (2000a, 2000b). For theoretical explanations of contagion due to the interbank market or other relations among banks, see Backus, Foresi, and Wu (1999), Aghion, Bolton, and Dewatripont (2000) Allen and Gale (2000), Dasgupta (2001), and Giannetti (2003). For empirical evidence for the common lender as the contagion channel, see Van Rijckeghem and Weder (2001). For empirical weakness of the common lender or the interbank market as the contagion channel, see Van Rijckeghem and Weder (2000) and Furfine (2002).

[12]See Furman and Stiglitz (1998), Krugman (1999) and Masson (1999a, 1999b).

whether or not the crisis in one country in fact triggers the crisis in the other. The key to explaining contagious currency crises in this paper lies in each speculator's private information and learning behavior about other speculators' types. Since the payoff of each speculator depends on other speculators' behavior determined by their types, each speculator's behavior depends on her belief about other speculators' types. If a currency crisis in one country reveals the speculators' types to some degree, it leads to an updating of each speculator's belief about other speculators' types and can therefore change her optimal behavior, which in turn can cause a currency crisis even in an unrelated country. The closest papers to this paper are Corsetti, Pesenti, and Roubini (2002) and Corsetti, Dasgupta, Morris, and Shin (2004). They show how to refine multiple equilibria and consider implications of the existence of a large speculator in a currency crisis. One of the important differences between their papers and this one is that this paper shows a new contagion channel and studies the implications of the presence of a large speculator in a *contagious* currency crisis whereas their papers are not concerned with the issue of contagion.

Notice that the contagion channels, including the one proposed in this paper, are not competing but complementary. They can work simultaneously and can amplify contagion. I do not intend to claim that the model in this paper offers a single explanation for contagion. Instead, this paper complements the growing literature by proposing the new contagion channel. Thus this paper intends to claim that contagion can become more severe than the literature would predict.

3 The Model

There are two countries, country A and country B. The government of each country pegs the currency at some level. The economy in each country is characterized by a state of underlying economic fundamentals, θ_j ($j = A, B$). A high value of θ_j refers to good fundamentals while a low value refers to bad fundamentals. I assume θ_j is randomly drawn from the real line, with each realization equally likely. Also, there is *no* linkage of economic fundamentals between country A and country B: θ_A and θ_B are *independent*. That is, there is no direct trade or financial linkage, no indirect trade linkage through a third market, or no indirect capital linkage through a common lender or an interbank market.

There are two groups of speculators, group 1 and group 2. Group 1 consists of a single large speculator, "George Soros."[13] Group 2 consists of a continuum of small speculators, so that an individual speculator's stake is negligible as a proportion of the whole. The distinguishing feature of the large speculator is that he has access to a sufficiently large line of credit in the domestic currency to take a short position up to the limit of λ: he can change speculative pressure by himself alone. On the other hand, each small speculator in group 2 cannot change speculative pressure by himself alone. Only group 2 as a whole can change speculative pressure. Because

[13] In Taketa (2003), group 1 consists of a continuum of small speculators, rather than a single Soros.

	Success	Failure
Attack	$D - t - \mu_1$	$-t - \mu_1$
Not Attack	0	0

Table 1: Payoff Matrix

Soros does not disclose financial information about himself (i.e., his "type"), his type is not public, instead it is his own private information.[14] There are two possible types with respect to aggressiveness: one type is the "bull Soros" with probability q while another type is the "chicken Soros" with probability $1 - q$. The size of group 1 is λ while that of group 2 is $1 - \lambda$, where $0 \leq \lambda \leq 1$.

Receiving the possibly *noisy* private signal about economic fundamentals, a speculator decides whether to short-sell the currency, i.e., attack the currency peg, or not. I envisage the short-selling as consisting of borrowing the domestic currency and selling it for dollars. If the attack is successful (i.e., the peg is abandoned), she gets a fixed payoff D (> 0). Attacking the currency, however, also leads to a cost $t + \mu_1$ (> 0). The cost t can be viewed largely as consisting of the interest rate differential between the domestic currency and dollars, plus the transaction cost. If a speculator refrains from attacking the currency, she is not exposed to any cost but she does not gain anything either. (See Table 1.) μ_1 captures an idiosyncratic difference of aggressiveness among speculators, as specified below. To make the model interesting, I assume that successful attack is profitable for any speculator.

Assumption 1 (Successful Attack Is Profitable) $D - t - \mu_1 > 0$.

I assume that the government defends the currency peg if the cost of this action is not too high. The cost of defending the peg depends on two factors: the proportion of speculators attacking the currency peg of country j, l_j, and the economic fundamentals of country j, θ_j. I assume the cost is increasing in l_j and decreasing in θ_j. The intuition behind this is as follows. If, for instance, speculative pressure is very high (i.e, l_j is so large), the government may need to increase interest rates quite sharply in order to defend the peg, which will be detrimental to the country. Thus the cost of defending is increasing in l_j. But if the economic fundamentals are good, the government may have plenty of foreign reserves to defend the peg so that it may not have to raise the interest rates. This means that the negative effect of defending the peg on the country will be relatively mild. Therefore, the cost of defending is decreasing in θ_j. More specifically, I assume the net cost of defending the peg is $l_j - \theta_j$.

Assumption 2 (Government's Optimization) *The government defends the peg if $l_j - \theta_j < 0$. It abandons the peg if $l_j - \theta_j \geq 0$.*

[14] Remember that large speculators, either hedge fund or offshore fund, typically do not forward financial information about themselves.

In what follows, a *Crisis* will occur if the government abandons the peg and *No Crisis* will occur if the government defends the peg.

Regarding speculators' preferences, the expected utility of attacking the currency of the country is the following.

$$U = \text{Prob}\left[\text{Attack is successful}\right] D - t - \mu_1$$

Since attacking the currency may fail depending on the government's action or other speculators' action (i.e., it will fail if $l_j - \theta_j < 0$), it is a riskier action than not-attacking. When Soros faces trouble such as a liquidity shortage for some reason (e.g., he needs more cash to meet the margin call), he cannot engage in risky behavior as aggressively as he can at other times. In this case, he is a "chicken," captured by the term $\mu_1(\geq 0)$, which is specified in more detail below.[15]

On the other hand, it is safe to refrain from attacking the currency in that the payoff is surely zero irrespective of the government's action or other speculators' action. Therefore, the utility of not attacking the currency is zero for every speculator.

As will be shown, it is critical that the *private* signal of economic fundamentals is *noisy* to speculators, to derive the unique equilibrium. The intuition behind the *noisy private* information is that the relevant information in deciding whether or not to attack is not always accurate. Sometimes the information may be faulty due to measurement error. Sometimes the government may announce the wrong information intentionally in an attempt to discourage speculators from attacking.[16] This in turn implies that there is some room for small discrepancies among speculators as to how the information is interpreted. In reality, each speculator commonly does not know exactly which information other speculators have or how they interpret the information. This means that the signal is *private* at least to some degree. The *noisy private* signal in the model captures the above idea. Let x_{ji} be the speculator i's private signal about economic fundamentals of country j ($j = A, B$). I assume the property of x_{ji} as follows.

Assumption 3 (Noisy Private Signal)
When the true state is θ_j, a speculator i observes a signal x_{ji} which is drawn uniformly from the interval $[\theta_j - \epsilon, \theta_j + \epsilon]$, for some small ϵ. Conditional on θ_j, the signals are identical and independent across individuals.

Notice that there is no difference, in terms of precision, between the Soros' private signal and small speculators' private signal. In the model, the only difference between one Soros and small speculators is their size: one Soros can affect the market

[15] Chamley (2003) shows that some uncertainty about other speculators plays a key role in explaining the currency crisis in a different context, but is not concerned with the issue of contagion.

[16] For example, the Bank of Korea announced that its international reserves were more than \$30 billion in face of the Thai Baht collapse in the 1997 Asian currency crisis. The announcement was intended to restore foreigners' confidence about the Korean economy. However, it turned out that the actual reserves the Bank of Korea could use in the crisis were considerably less than its announced official reserves. See **?**).

to some degree by himself alone while each small speculator cannot. In order to focus on the size effect as clearly as possible, I exclude the possibility that Soros has "better" information about economic fundamentals than the small speculators.

The timing of the game among governments and speculators is structured as follows.

- Period 1
  - Nature chooses each value of θ_A and θ_B *independently*, as well as the type of group 1 (Soros). Soros is chosen to be bull with probability q or chicken with probability $1-q$ $(0 < q < 1)$. The value of θ_j is known to the government of country j. The type of Soros is known to Soros himself, but it is not known to any speculator in group 2.
  - Each speculator receives a *private* signal $x_{Ai} = \theta_A + \epsilon_{Ai}$.
  - Each speculator decides individually whether or not to attack the currency of country A.
  - The government of country A abandons the peg if $l_A - \theta_A \geq 0$. It defends the peg if $l_A - \theta_A < 0$.
  - Both the aggregate outcome in country A and the value of θ_A are known to every speculators. If the attack is successful, those who attacked get $D - t - \mu_1$. If the attack is not successful, their payoff is $-t - \mu_1$. The payoff of those who did not attack is zero irrespective of the result of attack.
- Period 2
  - Each speculator receives a private signal $x_{Bi} = \theta_B + \epsilon_{Bi}$.
  - Each speculator decides individually whether or not to attack the currency of country B.
  - The government of country B abandons the peg if $l_B - \theta_B \geq 0$. It defends the peg if $l_B - \theta_B < 0$.
  - Both the aggregate outcome in country B and the value of θ_B are known to every speculators. If the attack is successful, those who attacked get $D - t - \mu_1$. If the attack is not successful, their payoff is $-t - \mu_1$. The payoff of those who did not attack is zero irrespective of the result of attack. (See Figure 1.)

I specify μ_1 as follows.

Assumption 4

$$\mu_1 = \begin{cases} \mu \quad (> 0) & \textit{if Soros is chicken} \\ 0 & \textit{otherwise} \end{cases}$$

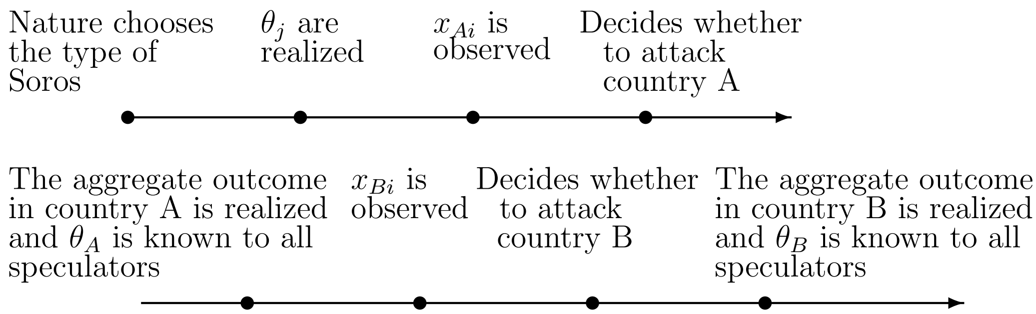

Figure 1: Timing of the Game

From Assumptions 2 and 4, the expected utility of attacking the currency can be rewritten as follows.

$$U = \begin{cases} \text{Prob}\,[l_j \geq \theta_j]\,D - t - \mu & \text{if Soros is chicken} \\ \text{Prob}\,[l_j \geq \theta_j]\,D - t & \text{otherwise} \end{cases}$$

In sum, the information structure of the model *in period 1* is the following. The government of country j knows the value of θ_j. Soros knows his own type, the type of speculators in group 2 ($\mu_1 = 0$ for any speculator in group 2), the government's optimization rule and his own private signal. Soros' type is private information. Each speculator in group 2 knows her own type, the *probability* that Soros is chicken (bull) q $(1-q)$, the government's optimization rule and her own private signal. In order to derive the model's equilibrium, it is crucial to correctly define which elements of the game are common knowledge in period 1. These are the payoff D, the cost t, the value of μ_1 (μ or 0), the distribution of noise and its parameter ϵ, the probability that Soros is chicken, the type of speculators in group 2 and the government's optimization rule. The value of θ_j is common knowledge if and only if $\epsilon = 0$. The intuition behind the assumption that Soros' type is private information is the following. Since information about the offshore funds is not typically open to the public, it is hard to figure out how much risk they can take. In other words, since some uncertainty exists about Soros' attitude for risk, the Soros' type is private information.

Before investigating the case $\epsilon > 0$, consider the case where there is no noise in the signal: $\epsilon = 0$. Two observations are worth noting.

- First, there are multiple equilibria if $\epsilon = 0$. To see this, suppose $\theta_A = 1$. In this case, Crisis is the equilibrium in country A if all the speculators coordinate an attack ($l_A - \theta_A = 1 - 1 = 0$), while No Crisis is the equilibrium in country A if no speculator attacks ($l_A - \theta_A = 0 - 1 = -1 < 0$).

- Second, *there is no significant difference, in terms of equilibrium selection, between the chicken Soros and the bull Soros.* If Soros's attack is successful, he earns *positive* profits irrespective of his type: the chicken Soros earns $D - t - \mu > 0$ and the bull Soros earns $D - t > 0$. Therefore, if every speculator in group 2 attacks the peg, it is optimal for Soros to attack *irrespective of his type*, as long as $\theta_A \leq 1$.

Both of these observations raise obstacles to the objective of this paper. The multiplicity of equilibria in the first observation is not well-suited for distinguishing between whether a crisis is a coincidence or due to contagion when it happens in two countries. Even worse, the second observation means that, as long as $D - t - \mu > 0$, multiple equilibria models cannot capture any implications about the fact that the large speculator does not disclose his type information. This is because the type difference does not matter at all for the equilibrium selection in multiple equilibria models. For the purpose of this paper, it must be determined which particular equilibrium, Crisis or No Crisis, will arise under what conditions.

Carlson and van Damme (1993) are the first to show that the multiplicity of equilibria is an artifact of the simplifying common knowledge assumption. This assumption is meant only to simplify the analysis in the literature but in fact delivers more than intended; under certain conditions, *non-common knowledge* can generate a unique equilibrium in these class of models. Morris and Shin (1998) apply it to derive the unique equilibrium in the multiple equilibria model of currency crises *à la* Obstfeld (1986, 1994).[17] I follow Morris and Shin's approach in this paper. One of the contributions of this paper is to show a new contagion channel whereas their papers are not concerned with contagion. In the new channel, it is critical that economic fundamentals are *not* common knowledge, there are two possible types of Soros, Soros' type is *not* common knowledge, and each type behaves differently in period 1 under certain circumstances. The different behaviors, which are contingent on type, may reveal their type to some degree and thereby allowing speculators in group 2 to update their beliefs about Soros' type. It in turn leads to a change in the behavior of the speculators in group 2 in period 2, resulting in contagion across unrelated countries.

Now assume $\epsilon > 0$. In this case, θ_j is no longer common knowledge because the signal about θ_j is *noisy* and *private*.[18] This is a much more realistic situation where each speculator does *not* know exactly what everyone else knows in deciding whether or not to attack, as opposed to in the situation where there is no noise in the signal.

Following Morris and Shin (1998) and Metz (2002), I concentrate on *the switching*

[17] As regards to other applications of non-common knowledge to obtain the unique equilibrium in various settings that have multiple equilibria under common knowledge, see an important series of works by Morris and Shin (1999, 2000, **?**, 2001, 2002, 2003a, 2003b). But non-common knowledge is not always a panacea to obtain the unique equilibrium. There can be multiple equilibria under certain conditions even when we assume non-common knowledge. See Chan and Chiu (2002). Metz (2002), and Morris and Shin (2003b).

[18] In different contexts, Caplin and Leahy (1994) and Abreu and Brunnermeier (2003) explore models to explain the timing of market crashes in which the private noisy signal plays the key role, yet are not concerned with contagion.

strategy equilibrium. The switching strategy equilibrium consists of the following values conditional on the choice of nature and the information structure: a unique value of the economic fundamentals $\tilde{\theta}_j$ up to which the government always abandons the peg, and a unique value of the private signal conditional on the type of speculators $\tilde{x}_{ji}(\mu_1)$, such that every speculator who receives signal lower than $\tilde{x}_{ji}(\mu_1)$ attacks the currency peg.

The general intuition behind this equilibrium is the following: conditional on the information structure, there is a unique switching fundamental value of $\tilde{\theta}_j$ below which the government always abandons the currency peg. The unique value $\tilde{\theta}_j$ generates a distribution of private signals, such that there is exactly one switching signal $\tilde{x}_{ji}(\mu_1)$, for each type respectively, below which the speculator always attacks the currency. The switching signal $\tilde{x}_{ji}(\mu_1)$ would make a speculator receiving it indifferent between attacking and not-attacking. If all speculators with signals smaller than $\tilde{x}_{ji}(\mu_1)$ decide to attack, the distribution of private signals, generated by $\tilde{\theta}_j$, would in turn generate a proportion $l_j = \tilde{\theta}_j$ of attackers that will be sufficient to force a devaluation of the currency peg.

Let $Y_A = I\{\tilde{\theta}_A \geq \theta_A\}$ where $I\{\bullet\}$ is the indicator function whose value is unity if the argument is true and zero otherwise. Thus $Y_A = 1$ if and only if the currency crisis happens in country A. Using $\tilde{\theta}_j$ and Y_A, I define contagion in this model as follows.

Definition 1 (Contagion)
There is contagion if and only if $\tilde{\theta}_B(Y_A = 1) > \tilde{\theta}_B(Y_A = 0)$.

Definition 1 can distinguish between whether a crisis is a coincidence or due to contagion when it happens in two countries. To see this, first pick any θ_B such that $\tilde{\theta}_B(Y_A = 0) < \theta_B < \tilde{\theta}_B(Y_A = 1)$. Given such θ_B, the currency crisis can happen in country B *if and only if the crisis happens in country A*. This is contagion. Next, pick any θ_B such that $\theta_B < \tilde{\theta}_B(Y_A = 0)$. In this case, the currency crisis happens in country B *irrespective of the occurrence of the crisis in country A*. Therefore, it is just a coincidence in the latter case if the crisis happens in both countries.

I derive the unique equilibrium in this two-period game by deriving the unique equilibrium in the one-shot game in each period separately. Next I show that the unique equilibrium for both periods is indeed the subgame-perfect equilibrium in the two-period game. This way is somewhat unusual and of course I can derive the subgame-perfect equilibrium in the two-period game by the usual backward induction. However, I believe this way is helpful to gain insights into how the model works.

3.1 Equilibrium in Country A

Suppose that each small speculator in group 2 follows the symmetric trigger strategy around a switching signal $\bar{x}_{A2}$ below which he attacks the currency peg of country A. Because there is a continuum of small speculators in group 2, conditional on θ_A, there is no aggregate uncertainty about the proportion of small speculators attacking the currency. Since $\text{Prob}\left[x_{A2} \leq \bar{x}_{A2} | \; \theta_A\right]$ is the proportion of small speculators observing a signal lower than $\bar{x}_{A2}$ and therefore attacking country A at θ_A, an attack by small speculators alone is sufficient to break the peg at θ_A if $(1-\lambda)\text{Prob}\left[x_{A2} \leq \bar{x}_{A2} | \; \theta_A\right] \geq \theta_A$. From this, we can define a critical value of economic fundamentals below which an attack by the small speculators alone is sufficient to break the peg. Let $\underline{\theta}_A$ be defined by:

$$\begin{aligned} \underline{\theta}_A &= (1-\lambda)\text{Prob}\left[x_{A2} \leq \bar{x}_{A2} | \; \underline{\theta}_A\right] \\ &= (1-\lambda)\frac{\bar{x}_{A2} - \underline{\theta}_A}{2\epsilon} \end{aligned} \tag{1}$$

Notice that the assumption that the noise distributes uniformly is exploited. When θ_A is below $\underline{\theta}_A$, the attack is successful irrespective of Soros' action.

Next, consider the additional speculative pressure due to Soros. If the small speculators follow the trigger strategy around $\bar{x}_{A2}$, the incidence of attack at θ_A attributable to the small speculators is $(1-\lambda)\text{Prob}\left[x_{A2} \leq \bar{x}_{A2} | \; \theta_A\right]$. If Soros also chooses to attack, then there is an additional λ to this incidence. Hence, when Soros participates in the attack, the peg is broken if $\lambda + (1-\lambda)\text{Prob}\left[x_{A2} \leq \bar{x}_{A2} | \; \theta_A\right] \geq \theta_A$. Thus, the critical value of economic fundamentals at which an attack is successful if and only if Soros participates in the attack is defined by:

$$\begin{aligned} \bar{\theta}_A &= \lambda + (1-\lambda)\text{Prob}\left[x_{A2} \leq \bar{x}_{A2} | \; \bar{\theta}_A\right] \\ &= \lambda + (1-\lambda)\frac{\bar{x}_{A2} - \bar{\theta}_A}{2\epsilon} \end{aligned} \tag{2}$$

As is evident from (1) and (2), $\bar{\theta}_A$ lies between $\underline{\theta}_A$ and 1. (See Figure 2.)

Although the notations do not make it explicit, both $\underline{\theta}_A$ and $\bar{\theta}_A$ are functions of the switching signal $\bar{x}_{A2}$. In turn, $\bar{x}_{A2}$ will depend on Soros' switching signal $\bar{x}_{A1}(\mu_1)$ which is conditional on Soros' type. The task is to solve these three switching signals ($\bar{x}_{A1}(\mu_1 = 0)$, $\bar{x}_{A1}(\mu_1 = \mu)$, and $\bar{x}_{A2}$) simultaneously from the respective optimization problems of the speculators.

To do this, first consider Soros' optimal switching strategy. Soros observes signal x_{A1} and assigns probability $\text{Prob}\left[\theta_A \leq \bar{\theta}_A | \; x_{A1}\right]$ to the event that $\theta_A \leq \bar{\theta}_A$. Therefore, his (gross) expected payoff to attacking conditional on x_{1A} is $\text{Prob}\left[\theta_A \leq \bar{\theta}_A | \; x_{A1}\right] D$. His optimal strategy is to attack if and only if $x_{A1} \leq \bar{x}_{A1}(\mu_1)$, where $\bar{x}_{A1}(\mu_1)$ is defined by:

$$\text{Prob}\left[\theta_A \leq \bar{\theta}_A | \; \bar{x}_{A1}(\mu_1)\right] D = t + \mu_1 \tag{3}$$

From (3) and the assumption that the noise is distributed uniformly, the two equations for the two possible values of μ_1 are as follows.

$$\frac{\bar{x}_{A1}(\mu_1 = 0) - \bar{\theta}_A}{2\epsilon} = 1 - \frac{t}{D} \tag{4}$$

$$\frac{\bar{x}_{A1}(\mu_1 = \mu) - \bar{\theta}_A}{2\epsilon} = 1 - \frac{t + \mu}{D} \tag{5}$$

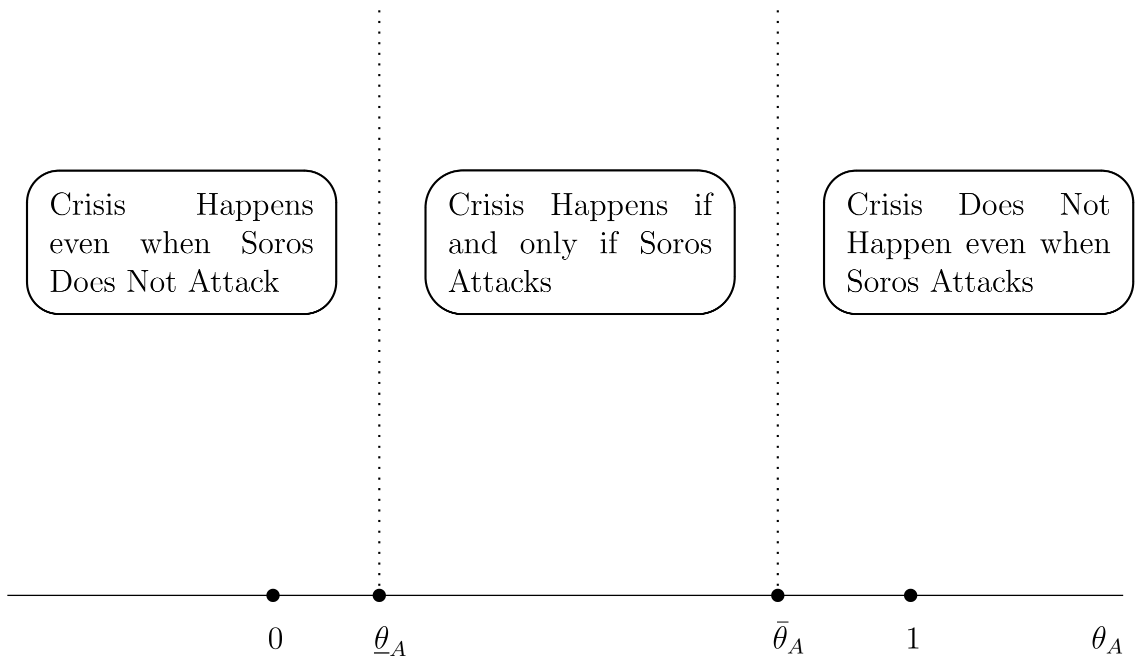

Figure 2: Soros and Switching Economic Fundamentals

Second, consider the small speculators' optimal switching strategy. For $\theta_A \leq \underline{\theta}_A$, the speculative attack by the small speculators is successful irrespective of Soros's action. For $\underline{\theta}_A \leq \theta_A \leq \bar{\theta}_A$, the peg breaks if and only if both Soros and the small speculators attack. For $\bar{\theta}_A \leq \theta_A$, the peg withstands the attacks, irrespective of the action of the small speculators and Soros. Note that the speculators in group 2 do not know Soros' type. Let p_h $(1-p_h)$ be his belief in period h $(h = 1, 2)$ that Soros' type is $\mu_1 = 0$ $(\mu_1 = \mu)$. It can be shown that the speculator observing x_{A2} assigns the probability that his attack is successful as follows.[19]

$$\begin{aligned}
p_1 \times & \text{Prob}\left[\text{Attack is successful when } \mu_1 = 0 |\ x_{A2}\right] \\
& \qquad + (1-p_1) \times \text{Prob}\left[\text{Attack is successful when } \mu_1 = \mu |\ x_{A2}\right] \\
&= 1 - \frac{x_{A2} - \underline{\theta}_A}{2\epsilon} + \frac{p_1}{4\epsilon^2}\left(\bar{x}_{A1}(\mu_1 = 0)\bar{\theta}_A - \frac{(\bar{\theta}_A)^2}{2} - \bar{x}_{A1}(\mu_1 = 0)\underline{\theta}_A + \frac{(\underline{\theta}_A)^2}{2}\right) \\
&\quad + \frac{1-p_1}{4\epsilon^2}\left(\bar{x}_{A1}(\mu_1 = \mu)\bar{\theta}_A - \frac{(\bar{\theta}_A)^2}{2} - \bar{x}_{A1}(\mu_1 = \mu)\underline{\theta}_A + \frac{(\underline{\theta}_A)^2}{2}\right) \qquad (6)
\end{aligned}$$

Because the expected payoff to attacking country A net of costs must be zero con-

[19]See the appendix.

ditional on the switching signal $\bar{x}_{A2}$, the following must hold from (6).

$$1-\frac{\bar{x}_{A2}-\underline{\theta}_A}{2\epsilon}+\frac{p_1}{4\epsilon^2}\left(\bar{x}_{A1}(\mu_1=0)\bar{\theta}_A-\frac{(\bar{\theta}_A)^2}{2}-\bar{x}_{A1}(\mu_1=0)\underline{\theta}_A+\frac{(\underline{\theta}_A)^2}{2}\right)$$
$$+\frac{1-p_1}{4\epsilon^2}\left(\bar{x}_{A1}(\mu_1=\mu)\bar{\theta}_A-\frac{(\bar{\theta}_A)^2}{2}-\bar{x}_{A1}(\mu_1=\mu)\underline{\theta}_A+\frac{(\underline{\theta}_A)^2}{2}\right)=\frac{t}{D} \quad (7)$$

There are five equations, (1), (2), (4), (5), and (7) and there are five unknowns, $\underline{\theta}_A$, $\bar{\theta}_A$, $\bar{x}_{A1}(\mu_1=0)$, $\bar{x}_{A1}(\mu_1=\mu)$, and $\bar{x}_{A2}$. Solving these five equations for five unknowns, the following can be obtained. (See Figure 2 and Figure 3.)

$$\underline{\theta}_A = \frac{1-\lambda}{2\epsilon+(1-\lambda)}\left[(4\epsilon+1)(1-\frac{t}{D})-\frac{\mu}{D}\lambda(1-p_1)+\frac{1}{2}\frac{\lambda}{2\epsilon+(1-\lambda)}\right] \quad (8)$$

$$\bar{\theta}_A = \frac{1-\lambda}{2\epsilon+(1-\lambda)}\left[(4\epsilon+1)(1-\frac{t}{D})-\frac{\mu}{D}\lambda(1-p_1)+\frac{1}{2}\frac{\lambda}{2\epsilon+(1-\lambda)}\right]$$
$$+\frac{2\epsilon\lambda}{2\epsilon+(1-\lambda)} \quad (9)$$

$$\bar{x}_{A1}(\mu_1=0) = \frac{1-\lambda}{2\epsilon+(1-\lambda)}\left[(4\epsilon+1)(1-\frac{t}{D})-\frac{\mu}{D}\lambda(1-p_1)+\frac{1}{2}\frac{\lambda}{2\epsilon+(1-\lambda)}\right]$$
$$+\frac{2\epsilon\lambda}{2\epsilon+(1-\lambda)}+2\epsilon(1-\frac{t}{D}) \quad (10)$$

$$\bar{x}_{A1}(\mu_1=\mu) = \frac{1-\lambda}{2\epsilon+(1-\lambda)}\left[(4\epsilon+1)(1-\frac{t}{D})-\frac{\mu}{D}\lambda(1-p_1)+\frac{1}{2}\frac{\lambda}{2\epsilon+(1-\lambda)}\right]$$
$$+\frac{2\epsilon\lambda}{2\epsilon+(1-\lambda)}+2\epsilon(1-\frac{t+\mu}{D}) \quad (11)$$

$$\bar{x}_{A2} = (4\epsilon+1)(1-\frac{t}{D})-\frac{\mu}{D}\lambda(1-p_1)+\frac{1}{2}\frac{\lambda}{2\epsilon+(1-\lambda)} \quad (12)$$

Clearly all five values are functions of p_1, the belief of the small speculators in group 2 about Soros' type. As it turns out, the following lemma is particulary important in considering contagion.

Lemma 1 (Dependence of Switching Variables on Group 2's Belief)
All the switching values, $\underline{\theta}_A$, $\bar{\theta}_A$, $\bar{x}_{A1}(\mu_1=0)$, $\bar{x}_{A1}(\mu_1=\mu)$, *and* $\bar{x}_{A2}$ *are increasing in* p_1.

The intuition behind Lemma 1 is simple. Because of the strategic interaction between Soros and the small speculators, the optimal behavior of the small speculators depends on the aggressiveness of Soros. In particular, it is optimal for the small speculator to be more aggressive in attacking the peg when Soros is more aggressive.

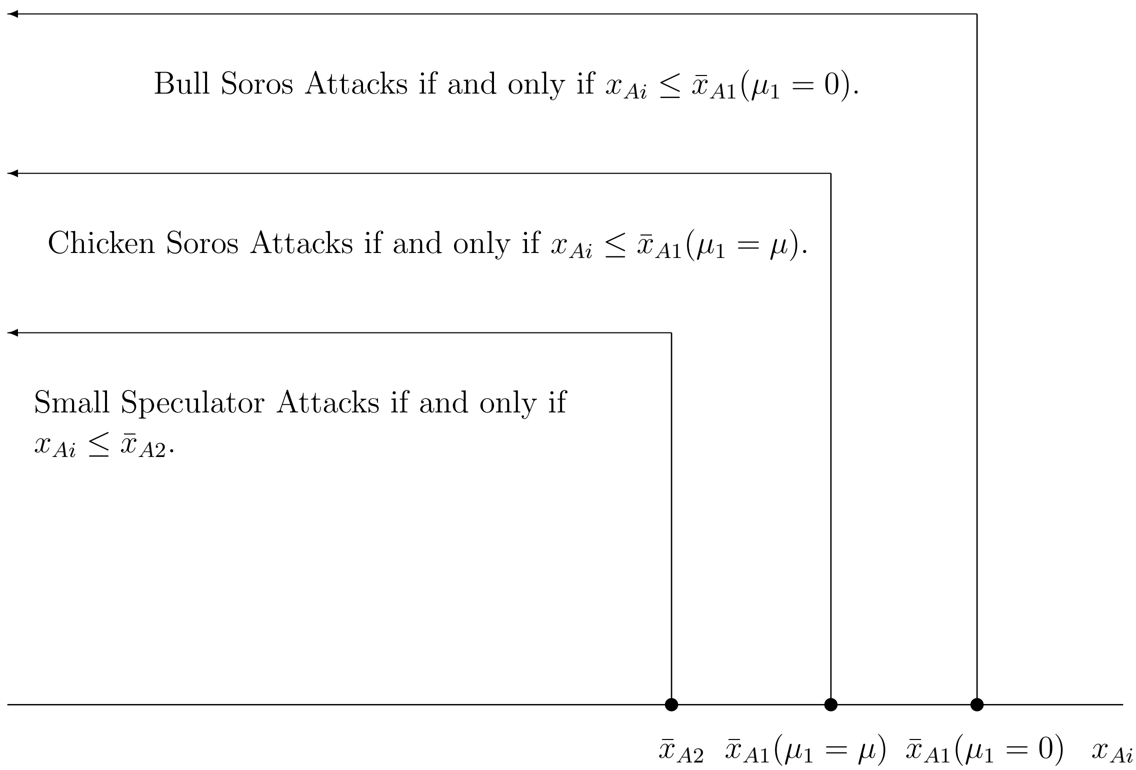

Figure 3: Switching Signals and Speculators' Decision

As shown in Corollary 1 below, Soros is more aggressive in attacking the currency when $\mu_1 = 0$ than when $\mu_1 = \mu$. Therefore, the small speculators are more aggressive when they assign the larger probability p_1 to the event that Soros is more aggressive in attacking the currency peg. That is why $\bar{x}_{A2}$ is increasing in p_1. In turn, when the small speculators are more aggressive, Soros becomes more aggressive than otherwise because of the strategic interaction between Soros and the small speculators. It implies that both $\bar{x}_{A1}(\mu_1 = 0)$ and $\bar{x}_{A1}(\mu_1 = \mu)$ are increasing in p_1. When both the small speculators and Soros become more aggressive, country A is more vulnerable to the currency crisis. That is why $\underline{\theta}_A$ and $\bar{\theta}_A$ are increasing in p_1.

In the rational expectation equilibrium, $p_1 = q$. Using this, the equilibrium in country A can be described as follows.

Proposition 1 (Unique Equilibrium in Country A)
The unique switching strategy equilibrium in country A consists of the switching private signals $\bar{x}_{A1}(\mu_1 = 0; p_1 = q)$, $\bar{x}_{A1}(\mu_1 = \mu; p_1 = q)$, and $\bar{x}_{A2}(p_1 = q)$ and the switching economic fundamentals $\underline{\theta}_A(p_1 = q)$ and $\bar{\theta}_A(p_1 = q)$.

(i) Suppose $\mu_1 = 0$. Soros attacks the currency peg if and only if he observes the private signal less than or equal to $\bar{x}_{A1}(\mu_1 = 0; p_1 = q)$.

(ii) *Suppose* $\mu_1 = \mu$. *Soros attacks the currency peg if and only if he observes the private signal less than or equal to* $\bar{x}_{A1}(\mu_1 = \mu; p_1 = q)$.

(iii) *Each speculator in group 2 attacks the currency peg if and only if he observes the private signal less than or equal to* $\bar{x}_{A2}(p_1 = q)$.

(iv) *The government of country A always abandons the currency peg when economic fundamentals are less than or equal to* $\underline{\theta}_A(p_1 = q)$, *irrespective of Soros' action.*

(v) *The government of country A abandons the currency peg when economic fundamentals are less than or equal to* $\bar{\theta}_A(p_1 = q)$, *if and only if both small speculators and Soros attack.*

From Proposition 1, the following corollary holds. In addition to Lemma 1, this corollary will turn out to be quite important in considering contagion. (See Figure 3.)

Corollary 1 (Difference of Aggressiveness)
Soros is more likely to attack when $\mu_1 = 0$ *than when* $\mu_1 = \mu$: $\bar{x}_{A1}(\mu_1 = 0) > \bar{x}_{A1}(\mu_1 = \mu)$.

This corollary is simply because Soros' cost of attacking is smaller when $\mu_1 = 0$ than when $\mu_1 = \mu$. Thus Soros becomes more aggressive when $\mu_1 = 0$ than when $\mu_1 = \mu$. This is quite reasonable, but is something that could not be captured by the multiple equilibria models.[20]

The model has considered the "one-Soros" case where group 1 consists of a single Soros. In order to study how a large Soros makes a difference, consider the "no-Soros case" where group 1 consists of a continuum of small speculators, instead of a single Soros. In the no-Soros case, all the speculators in group 1 are bull with probability q while they are chicken with probability $1 - q$.

Definition 2 (One-Soros Case)
The one-Soros case is the case where group 1 consists of a single large Soros and he is bull (chicken) with probability q $(1 - q)$.

Definition 3 (No-Soros Case)
The no-Soros case is the case where group 1 consists of a continuum of small speculators and all of them are bull (chicken) with probability q $(1 - q)$.

Thus the only set-up difference between the one-Soros case and the no-Soros case is whether group 1 consists of a single large speculator or a continuum of small speculators. It is the same for both cases that all the speculators in group 1 are bull (chicken) with probability q $(1 - q)$ and its type is private information.

[20]Remember there is no difference, in terms of the equilibrium behavior, between the chicken Soros and the bull Soros within the multiple equilibria models. See the second observation of the case where there is no noise in the signal: $\epsilon = 0$.

The equilibrium differences between the one-Soros case and the no-Soros case can be clarified by comparing the switching private signals and the switching economic fundamentals of the one-Soros case with their counterparts in the no-Soros case. Denote their counterparts by double-bar: let $\bar{\bar{x}}$ be the switching private signals of the no-Soros case, $\underline{\underline{\theta}}$ be the switching economic fundamentals of the no-Soros case below which speculative attacks by group 2 alone is enough to break the peg, and $\bar{\bar{\theta}}$ be the switching economic fundamentals of the no-Soros case below which speculative attacks are successful if and only if both group 1 and group 2 participate in the attack.[21] The difference between the one-Soros case and the no-Soros case can be summarized as follows.

Proposition 2 (Soros Makes Country A More Vulnerable to Crisis)

(i) Group 1 is more aggressive in attacking the currency in the one-Soros case than in the no-Soros case: $\bar{\bar{x}}_{A1}(\mu_1 = 0; p_1 = q) < \bar{x}_{A1}(\mu_1 = 0; p_1 = q)$ *and* $\bar{\bar{x}}_{A1}(\mu_1 = \mu; p_1 = q) < \bar{x}_{A1}(\mu_1 = \mu; p_1 = q)$.

(ii) The small speculators in group 2 are more aggressive in attacking the currency in the one-Soros case than they would be in the no-Soros case: $\bar{\bar{x}}_{A2}(p_1 = q) < \bar{x}_{A2}(p_1 = q)$.

(iii) Country A is more vulnerable to the crisis in the one-Soros case than it would be in the no-Soros case: $\underline{\underline{\theta}}_A(p_1 = q) < \underline{\theta}_A(p_1 = q)$ *and* $\bar{\bar{\theta}}_A(\mu_1 = \mu; p_1 = q) < \bar{\bar{\theta}}_A(\mu_1 = 0; p_1 = q) < \bar{\theta}_A(p_1 = q)$.

The intuition of Proposition 2 is that once Soros chooses to attack, he can affect the market more disproportionately than he could if he were small. Knowing this, Soros becomes more aggressive in attacking the peg than he would if he were small. Because of the strategic interaction among Soros and the small speculators, the small speculators become more aggressive in attacking when Soros is more aggressive. In turn, Soros is even more aggressive when the small speculators are more aggressive. As a result, both Soros and the small speculator become more and more aggressive, which means that country A becomes more vulnerable to the currency crisis. In particular, if the economic fundamentals of country A, θ_A, satisfy $\underline{\underline{\theta}}_A(p_1 = q) < \theta_A < \underline{\theta}_A(p_1 = q)$, the currency crisis is inevitable in the one-Soros case even when Soros does not attack. On the other hand, the currency crisis never happens for such θ_A in the no-Soros case if the speculators in group 1 do not attack. This leads to the following corollary.

Corollary 2 (Soros Cannot Be "Innocent")
The mere existence of Soros, even when he does not do anything ex post, makes country A more vulnerable to the crisis.

[21] For a detailed explanation of the no-Soros case, see Taketa (2003).

Proposition 2 is essentially the same finding as that of Corsetti, Pesenti, and Roubini (2002) and Corsetti, Dasgupta, Morris, and Shin (2004). But these two papers are not concerned with the issue of contagion. This paper shows this finding leads to a surprising result in terms of contagion, which is explained next.

3.2 Equilibrium in Country B and Contagion

In this subsection, I show the equilibrium in country B and how contagion can happen under certain conditions. Contagion happens due to group 2's Bayesian updating about Soros' type.

In period 2, Soros and the small speculators observe what has happened in country A and the economic fundamentals θ_A. What has happened in country A reveals information about Soros' type to some degree under certain circumstances, if speculators follow the strategy described in Proposition 1. The strategy in Proposition 1 is the Nash equilibrium in the one-shot game. First, I analyze the switching strategy equilibrium in country B *assuming* speculators follow the strategy described in Proposition 1 and then summarize the results in Proposition 3. Next, I will prove that Proposition 1 and Proposition 3 describe the subgame perfect equilibrium in the two-stage game.

Thus by observing what has happened in country A, the small speculators sometimes, if not always, update their belief about Soros' type. Their Bayesian updating can be summarized as follows.

Lemma 2 (Bayesian Updating about the Type of Soros)

(i) For any $\theta_A \notin \left[\underline{\theta}_A, \bar{\theta}_A\right]$, no Bayesian updating occurs: $p_2 = p_1 = q$.

(ii) For any $\theta_A \in \left[\underline{\theta}_A, \bar{\theta}_A\right]$, Bayesian updating occurs.

(a) If the currency crisis has happened in country A, $p_2 > p_1 = q$.

(b) If the currency crisis has not happened in country A, $p_2 < p_1 = q$.

For any $\theta_A \leq \underline{\theta}_A$, the currency crisis happens in country A with probability one, irrespective of Soros' type. Therefore, what has happened in country A when $\theta_A \leq \underline{\theta}_A$, provides no information about Soros' type. For any $\theta_A \geq \bar{\theta}_A$, the currency crisis will never happen in country A, irrespective of Soros' type. Therefore, what has happened in country A when $\theta_A \geq \bar{\theta}_A$ provides no information about Soros' type either. That is why no Bayesian updating occurs for any $\theta_A \notin \left[\underline{\theta}_A, \bar{\theta}_A\right]$. However, for any $\theta_A \in \left[\underline{\theta}_A, \bar{\theta}_A\right]$, the currency crisis happens in country A *only if Soros attacks*. Soros attacks country A if and only if he observes the private signal smaller than or equal to the switching signal conditional on his type. Corollary 1 shows that Soros is more likely to attack when $\mu_1 = 0$ than when $\mu_1 = \mu$. Therefore, the occurrence of the crisis in country A tells the small speculators that Soros attacking the peg is more likely to be "bull" ($\mu_1 = 0$). In other words, whether or not the crisis happens in country A for any $\theta_A \in \left[\underline{\theta}_A, \bar{\theta}_A\right]$ does provide some information about Soros' type. That is why Bayesian updating occurs for any $\theta_A \in \left[\underline{\theta}_A, \bar{\theta}_A\right]$.

Let p_2^{C} be the updated belief of group 2 about the Soros' type when the crisis has happened in country A for any $\theta_A \in \left[\underline{\theta}_A, \bar{\theta}_A\right]$, and p_2^{NC} be the updated belief of group 2 about Soros' type when the crisis has not happened in country A for any $\theta_A \in \left[\underline{\theta}_A, \bar{\theta}_A\right]$.

Proposition 3 (Unique Equilibrium in Country B)

(i) For any $\theta_A \notin \left[\underline{\theta}_A, \bar{\theta}_A\right]$, the unique switching strategy equilibrium in country B replicates the one in country A exactly: every speculator and the government follow the exactly same switching strategy as in Proposition 1.

(ii) If the currency crisis has happened for any $\theta_A \in \left[\underline{\theta}_A, \bar{\theta}_A\right]$, the unique switching strategy equilibrium in country B is as follows.

(a) Suppose $\mu_1 = 0$. Soros attacks the currency peg if and only if he observes the private signal less than or equal to $\bar{x}_{B1}(\mu_1 = 0; p_2 = p_2^C)$.

(b) Suppose $\mu_1 = \mu$. Soros attacks the currency peg if and only if he observes the private signal less than or equal to $\bar{x}_{B1}(\mu_1 = \mu; p_2 = p_2^C)$.

(c) Each speculator in group 2 attacks the currency peg if and only if he observes the private signal less than or equal to $\bar{x}_{B2}(p_2 = p_2^C)$.

(d) The government of country B always abandons the currency peg when economic fundamentals are less than or equal to $\underline{\theta}_B(p_2 = p_2^C)$, irrespective of Soros' action.

(e) The government of country B abandons the currency peg when economic fundamentals are less than or equal to $\bar{\theta}_B(p_2 = p_2^C)$, if and only if the small speculators and Soros attack.

(iii) If the currency crisis has not happened for any $\theta_A \in \left[\underline{\theta}_A, \bar{\theta}_A\right]$, the unique switching strategy equilibrium in country B is as follows.

(a) Suppose $\mu_1 = 0$. Soros attacks the currency peg if and only if he observes the private signal less than or equal to $\bar{x}_{B1}(\mu_1 = 0; p_2 = p_2^{NC})$.

(b) Suppose $\mu_1 = \mu$. Soros attacks the currency peg if and only if he observes the private signal less than or equal to $\bar{x}_{B1}(\mu_1 = \mu; p_2 = p_2^{NC})$.

(c) Each speculator in group 2 attacks the currency peg if and only if he observes the private signal less than or equal to $\bar{x}_{B2}(p_2 = p_2^{NC})$.

(d) The government of country B always abandons the currency peg when economic fundamentals are less than or equal to $\underline{\theta}_B(p_2 = p_2^{NC})$, irrespective of Soros' action.

(e) The government of country B abandons the currency peg when economic fundamentals are less than or equal to $\bar{\theta}_B(p_2 = p_2^{NC})$, if and only if the small speculators and Soros attack.

So far I have investigated the equilibrium in the *one-shot game*. In particular, I have derived Proposition 3 *assuming* that Proposition 1 holds both in the *one-shot game* and in the *two-period game*. But it is not obvious whether Proposition 1 holds in the two-period game or not. In other words, it may *not* be the case that the sequence of Proposition 1 and Proposition 3 is the *sub-game* perfect equilibrium. Here I prove that this is indeed the case.

First, notice that the chicken Soros may have an incentive to mimic the bull Soros in period 1, in order to deceive the small speculators, thereby making the small speculators more aggressive in period 2. In this case, Proposition 1 does not hold in the two-period game, because the chicken Soros does not use $\bar{x}_{A1}(\mu_1 = \mu)$, but rather he uses $\bar{x}_{A1}(\mu_1 = 0)$ to mimic the bull Soros in order to deceive the small speculators. Second, note that neither the bull Soros nor the small speculator has an incentive to mimic anyone else. The bull Soros does not have any incentive to mimic the chicken Soros because mimicking makes the small speculators less aggressive. The small speculators cannot mimic Soros because they are not large. Therefore, it is necessary and sufficient to prove that the chicken Soros does not have an incentive to mimic the bull Soros in period 1 under certain conditions, in order to show that the sequence of Proposition 1 and Proposition 3 is the sub-game perfect equilibrium. I show that as long as ϵ is sufficiently small, the chicken Soros has no incentive to mimic the bull Soros.

Now use the backward induction. Consider first an additional benefit that the chicken Soros enjoys in period 2 by deceiving and then consider the cost of deceiving that the chicken Soros has to pay in period 1. The chicken Soros has an incentive to mimic the bull Soros if and only if the benefit exceeds the cost. I show that the cost outweighs the benefit as long as ϵ is sufficiently small.

Assume the chicken Soros succeeds in deceiving and the small speculators update their belief such that Soros is more likely to be bull. The benefit of deceiving depends on to what extent the small speculators become more aggressive in period 2. The larger the Bayesian updating is, the larger the change in the small speculators' behavior. In other words, if the Bayesian updating is not large, the benefit is relatively small because the small speculators' behavior does not change very much. Remember that there is *no* difference in aggressiveness between the bull Soros and the chicken Soros when $\epsilon = 0$. Intuitively, the aggressiveness difference is small when ϵ is close to zero. Thus the Bayesian updating is small because it is hard to sort out similar different types when the aggressiveness difference is small. Therefore, the benefit is small when ϵ is close to zero.

Next, consider the cost of deceiving for the chicken Soros. In order to deceive, the chicken Soros has to mimic the bull Soros in period 1. That is, the chicken Soros must behave *as if* $\mu = 0$. But he has to pay μ (> 0) in fact. Thus μ can be thought of as the deceiving cost.

In mimicking the bull Soros, the benefit must be enough for the chicken Soros to compensate the cost. Remember, however, that the benefit is small when ϵ is close to zero. So given the cost μ, one can choose sufficiently small ϵ such that the cost outweighs the benefit. Therefore, the chicken Soros does not have any incentive to mimic the bull Soros when ϵ is sufficiently small.

Proposition 4 (Sub-Game Perfect Equilibrium)
The unique sub-game perfect switching strategy equilibrium consists of switching private signal strategy and the switching economic fundamentals strategy as follows.

(i) In period 1, every speculator and the government follows the switching strategy in Proposition 1.

(ii) In period 2, every speculator and the government follows the switching strategy in Proposition 3.

It is worth noting that the switching strategy equilibrium in country B depends on what has happened in country A, even though these countries are totally unrelated in terms of the economic fundamentals (i.e., there is no direct trade or financial linkage, no indirect trade linkage through a third market, or no indirect capital linkage through a common lender or an interbank market). Under a certain range of economic fundamentals of country A, whether or not the crisis happens in country A reveals Soros' type to some degree, thereby the small speculators update their belief of Soros' type. The optimal behavior of the small speculators depends on their belief about Soros' type, so that Bayesian updating of their belief leads to the change in their optimal behavior. When their optimal behavior changes, the Soros' optimal behavior also changes because of the strategic interaction between the small speculators and Soros. Therefore, whether or not the crisis happens in country A changes the optimal behavior of both the small speculators and Soros under certain circumstances. It is this fact that leads to contagion from country A to country B,despite the fact that the economic fundamentals are totally unrelated between country A and country B. Proposition 5 describes the conditions under which contagion occurs and how the optimal behavior of Soros and that of the small speculators change.

Proposition 5 (Contagion across Unrelated Countries)

(i) For any $\theta_A \notin \left[\underline{\theta}_A, \bar{\theta}_A\right]$, contagion does not happen.

(ii) For any $\theta_A \in \left[\underline{\theta}_A, \bar{\theta}_A\right]$, contagion happens.

(a) Suppose $\mu_1 = 0$. Soros is more likely to attack the currency peg when the crisis has happened in country A than otherwise: $\bar{x}_{B1}(\mu_1 = 0; p_2 = p_2^{NC}) < \bar{x}_{B1}(\mu_1 = 0; p_2 = p_2^{C})$.

(b) Suppose $\mu_1 = \mu$. Soros is more likely to attack the currency peg when the crisis has happened in country A than otherwise: $\bar{x}_{B1}(\mu_1 = \mu; p_2 = p_2^{NC}) < \bar{x}_{B1}(\mu_1 = \mu; p_2 = p_2^{C})$.

(c) Each speculator in group 2 is more likely to attack the currency peg when the crisis has happened in country A than otherwise: $\bar{x}_{B2}(p_2 = p_2^{NC}) < \bar{x}_{B2}(p_2 = p_2^{C})$.

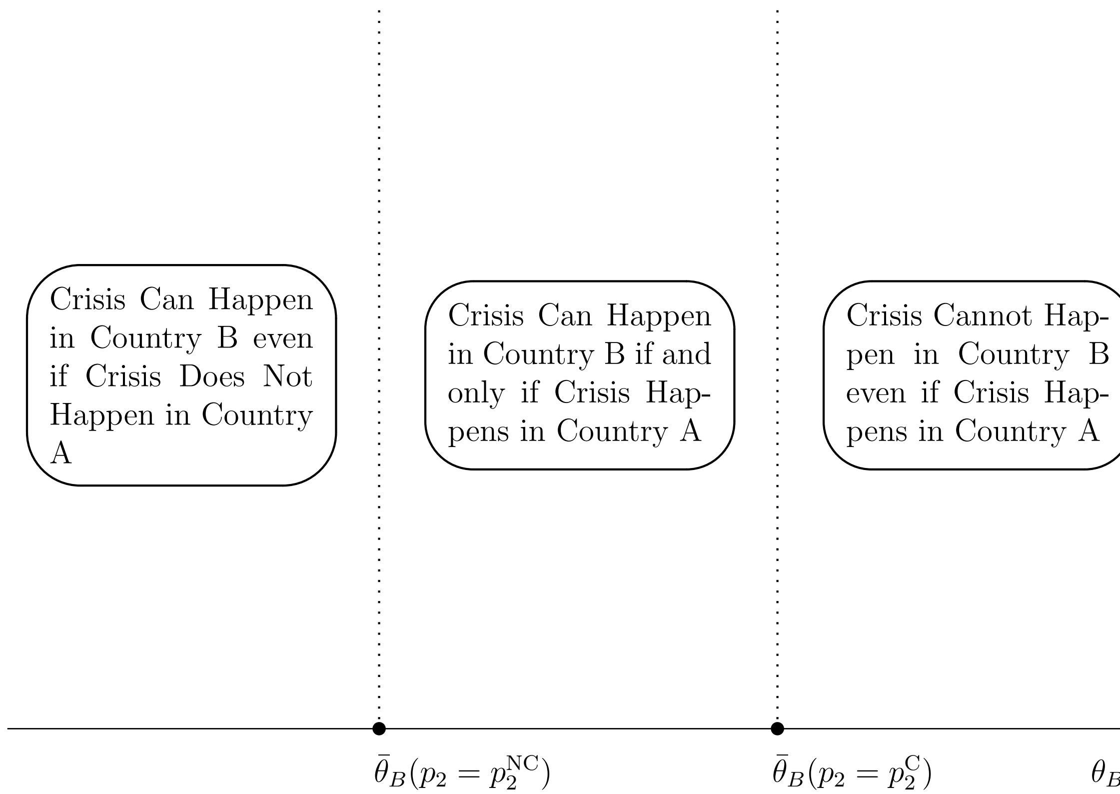

Figure 4: Contagion Can Happen when $\bar{\theta}_B(p_2 = p_2^{\mathrm{NC}}) < \theta_B < \bar{\theta}_B(p_2 = p_2^{\mathrm{C}})$

(d) *The government of country B is more likely to abandon the peg when the crisis has happened in country A:* $\underline{\theta}_B(p_2 = p_2^{NC}) < \underline{\theta}_B(p_2 = p_2^{C})$ *and* $\bar{\theta}_B(p_2 = p_2^{NC}) < \bar{\theta}_B(p_2 = p_2^{C})$.

Proposition 5 states that when $\bar{\theta}_B(p_2 = p_2^{\mathrm{NC}}) < \theta_B < \bar{\theta}_B(p_2 = p_2^{\mathrm{C}})$, contagion can happen: Crisis can happen in country B if and only if Crisis happens in country A. On the one hand, if Crisis did not happen in country A for any $\theta_A \in \left[\underline{\theta}_A, \bar{\theta}_A\right]$, Soros did not attack, which in turn implies that Soros is more likely to be chicken. So the small speculators become less aggressive. In this case, the switching economic fundamentals is $\bar{\theta}_B(p_2 = p_2^{\mathrm{NC}})$. Thus Crisis cannot happen in country B if $\bar{\theta}_B(p_2 = p_2^{\mathrm{NC}}) < \theta_B$. On the other hand, if Crisis happened in country A for any $\theta_A \in \left[\underline{\theta}_A, \bar{\theta}_A\right]$, Soros attacked, which in turn implies that Soros is more likely to be bull. So the small speculators become more aggressive. In this case, the switching economic fundamentals is $\bar{\theta}_B(p_2 = p_2^{\mathrm{C}})$. Thus Crisis can happen in country B if $\theta_B < \bar{\theta}_B(p_2 = p_2^{\mathrm{C}})$. In fact, Crisis happens if Soros attacks. (See Definition 1 and Figure 4.)

Proposition 5 gives an explanation as to what kind of currency crisis is contagious. That is, it shows that not all currency crises are contagious. Moreover, it explains why a currency crisis is contagious and another is not contagious. This point is clarified in Corollary 3.

Corollary 3 (No Contagion When Economic Fundamentals Are Very Poor) *For any $\theta_A \leq \underline{\theta}_A$, the currency crisis in country A happens with probability one, but it is not contagious.*

Corollary 3 states that if the crisis happens in both country A and country B for any $\theta_A \leq \underline{\theta}_A$, it is just a coincidence. This is because in this case the Bayesian updating does not happen, which means no contagion. That is, the crisis in country B is *not* triggered by the crisis in country A. In sum, the model can distinguish between just a coincidence and contagion when the crisis happens in both countries.

Corollary 3 sharply contrasts with the literature. The common implication in the literature is that the *worse* the economic fundamentals in the originating crisis country (country A) are, the more contagious the crisis is. This is because the literature has been exploring the transmission mechanism through which *the negative effect of bad economic fundamentals* of the originating crisis country would spread directly or indirectly. If countries are related in terms of economic fundamentals such as direct financial or trade linkage, the negative effect of the crisis would hit them directly through the direct linkage. Similarly, if there is some indirect trade linkage across countries through a third market, the negative effect of the crisis would hit them because they are at a severe competitive disadvantage. If there is some indirect capital linkage through a common lender or the interbank market, the negative effect of the crisis would hit the common lender or the interbank market first and then would be transmitted to countries through capital linkage indirectly. In each case, the worse the economic fundamentals of country A, the larger the negative effect of the originating crisis. The larger the negative effect of the originating crisis, the greater the impact on the other countries. This is the logic behind the common implication above.

However, why was the Argentine financial crisis in 2002 *not* very contagious? This is a puzzle, because the economic fundamentals of Argentina during and after the crisis were arguably much worse than those of the Asian countries during the Asian Flu. According to the common implication of the literature, the Argentine financial crisis should have been contagious if the Asian Flu was contagious. But the Argentine financial crisis was not very contagious while the Asian Flu was contagious. Corollary 3 gives a possible answer to this puzzle: the *better* the economic fundamentals of the originating crisis country (country A), the more contagious the crisis. If the currency crisis happens where economic fundamentals are very poor (e.g., in Argentina in 2002), nobody is surprised by the crisis, so that no Bayesian updating happens, and no contagion occurs. However, if the currency crisis happens where economic fundamentals are considered to be good (e.g., in Asia in 1997), it is a big surprise and the crisis could even spread to unrelated counties sometimes. In sum, Corollary 3 shows that if there is no surprise, there is no contagion. Hausmann and Velasco (2003) argue that

> "Argentina's was not a crisis that caught people surprise. Instead, it was a protracted affair that, as it was marched inexorably towards a catastrophic demise, attracted the attention of some of the best minds

> in Washington, Wall Street and Buenos Aires for months on end. During this long agony, many well-trained economists proposed various diagnostics and innovative policy initiatives; the country's much-maligned politicians and parties supported austerity policies (such as cutting nominal public sector wages) that would be very hard to swallow in most democratic societies; and, until late in the game, the international community provided ample financial support. Yet the catastrophe proved impossible to avoid." (p.59)

Corollary 3 of this paper adds "Bayesian updating by speculators" to the argument of Hausmann and Velasco (2003) and thereby gives a potential answer to the puzzle: because the Argentine financial crisis did not surprise the market (i.e., it caused no Bayesian updating in the market), it was not very contagious.

Corollary 3 implies that even if country B could get rid of the contagion of the crisis originating in country A, it does not necessarily mean that it will not be vulnerable to a contagion of a crisis that happens in another country with better economic fundamentals than country A. This seems counterintuitive, but it is in fact reasonable. Again, if the currency crisis happens in the country whose economic fundamentals are good, everybody will be surprised, which can make the crisis more contagious. Therefore, even if the Argentine financial crisis was not very contagious, a future financial crisis in some country with better economic fundamentals than Argentina might be contagious.

Notice that contagion can happen even when group 1 consists of the small speculators, rather than the single large speculator.[22] The contagion channel is the Bayesian updating of group 2, so that contagion happens as long as the currency crisis in country A reveals the type of group 1 to some degree, irrespective of whether group 1 consists of one Soros or the small speculators. However, contagion in the one-Soros case is not necessarily identical to that in the no-Soros case. In the next subsection, I explain the difference.

3.3 Severity of Contagion

In this subsection, I consider the severity of contagion and how Soros' presence affects it. As far as I know, this paper is the first to study the severity of contagion theoretically.

First of all, a definition of severity of contagion is needed. Thus I propose the following two definitions.

Definition 4 (Relative Severity of Contagion)
Contagion is more severe in relative terms, when $\tilde{\theta}_B(Y_A = 1) - \tilde{\theta}_B(Y_A = 0)$ *is larger.*

Definition 5 (Absolute Severity of Contagion)
Contagion is more severe in absolute terms, when $\tilde{\theta}_B(Y_A = 1)$ *is larger.*

[22] See Taketa (2003).

The relative severity of contagion looks at an *additional increase* in the switching value of the economic fundamentals below which the crisis happens in country B, due to the occurrence of the crisis in country A. The larger the additional increase is, the more likely it is that country B will suffer from contagion. Therefore, the additional increase is thought of as a criterion for the severity of contagion. The absolute severity of contagion looks at the *size* of the switching value of the economic fundamentals below which the crisis happens in country B, after the crisis happens in country A. The larger the size is, the more likely country B suffers from contagion. Therefore, the size is also thought of as another criterion for the severity of contagion. According to these two criteria, the model shows that Soros mitigates contagion, as opposed to common intuition. (See Figure 5.)

Proposition 6 (Soros Mitigates Contagion)

(i) Contagion is more severe in relative terms in the no-Soros case than in the one-Soros case.

(ii) Contagion is more severe in absolute terms in the no-Soros case than in the one-Soros case, provided that Soros is not too large.

Proposition 6 seems strange, but is actually plausible. To see the intuition, first note that the speculators as a whole, in groups 1 and 2, affect the market, but their behavior is conditional on their types. Thus what happens in country A provides information about group 1's type. It is important to note that $\bar{\theta}_A$ *is unique as long as* $\bar{x}_{A2}$ *is unique, as evident from (2).* Put another way, $\bar{\theta}_A$ when nature chooses $\mu_1 = 0$ is the same as $\bar{\theta}_A$ when nature chooses $\mu_1 = \mu$. This is the distinguishing feature of the one-Soros case. On the other hand, in the no-Soros case, there are *two* counterparts of $\bar{\theta}_A$. To see this, note that group 1 does not consists of a single large speculator, but rather many small speculators in the no-Soros case. Thus, a counterpart of $\bar{\theta}_A$ in the no-Soros case, $\bar{\bar{\theta}}_A$, is defined by

$$\begin{aligned}\bar{\bar{\theta}}_A(\mu_1) &= \lambda \text{Prob}\left[x_{A1} \leq \bar{\bar{x}}_{A1}(\mu_1) |\ \bar{\bar{\theta}}_A(\mu_1)\right] + (1-\lambda)\text{Prob}\left[x_{A2} \leq \bar{\bar{x}}_{A2} |\ \bar{\bar{\theta}}_A(\mu_1)\right] \\ &= \lambda \frac{\bar{\bar{x}}_{A1}(\mu_1) - \bar{\bar{\theta}}_A(\mu_1)}{2\epsilon} + (1-\lambda)\frac{\bar{\bar{x}}_{A2} - \bar{\bar{\theta}}_A(\mu_1)}{2\epsilon} \qquad (13)\end{aligned}$$

where $\bar{\bar{x}}_{A1}(\mu_1)$ is the switching signal *conditional on the type of group 1* ($\mu_1 = \mu$ or 0) and $\bar{\bar{x}}_{A2}$ is the switching signal of group 2 in the no-Soros case respectively. Clearly, $\bar{\bar{\theta}}_A$ takes a different value when the switching signal of group 1 takes a different value conditional on the type of group 1: $\bar{\bar{\theta}}_A(\mu_1 = 0)$ and $\bar{\bar{\theta}}_A(\mu_1 = \mu)$. Therefore, there are *two* values of $\bar{\bar{\theta}}_A$, depending on the type of group 1 in the no-Soros case, as opposed to the one-Soros case. Thus in the no-Soros case, group 1 as a whole would affect the market proportionately to its type, as can be seen in (13). However, if it consists of the single large speculator Soros (i.e., the one-Soros case), it would affect the market *disproportionately* to its type, as can be seen in (2). Therefore, *what happens in country A provides more information about group 1's type in the*

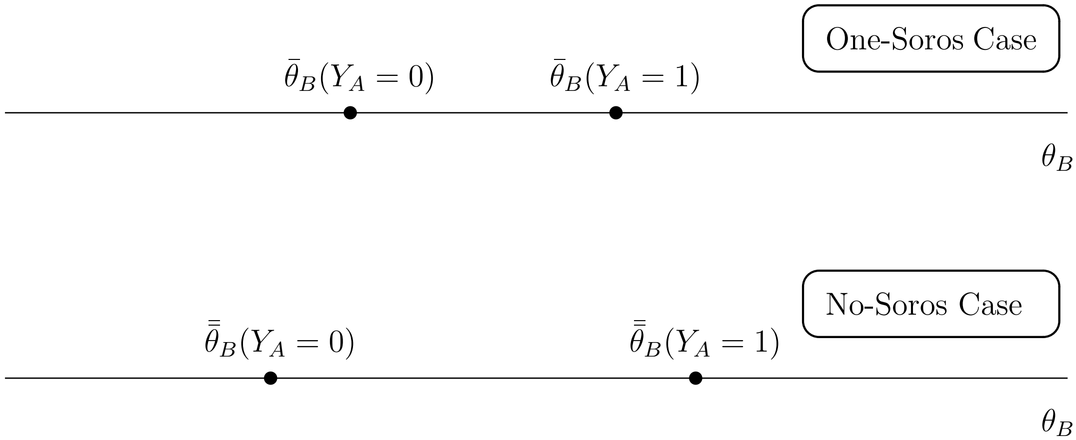

Figure 5: Severity of Contagion

no-Soros case than in the one-Soros case. Remember that the contagion channel in the model is the Bayesian updating by group 2 about group 1's type. The more drastic the Bayesian updating is, the larger $p_2 - p_1$ is. In turn, the larger $p_2 - p_1$ is, the more severe the contagion is. Due to events in country A, more information is available about group 1's type in the no-Soros case than in the one-Soros case. In other words, $p_2 - p_1$ is larger in the no-Soros case than in the one-Soros case. It is this fact that leads to Proposition 6.

3.4 Policy Implications

Recently two important policy issues have primarily concerned international financial policy makers: financial disclosure and size regulation of hedge funds. These policy issues correspond to two distinguishing features of hedge funds: they are not required to report their financial information and they are highly leveraged. However, these features have rarely been investigated. Thus in this subsection, I consider the implications of financial disclosure and size regulation.

Proposition 7 (Financial Disclosure) *Financial disclosure of the type of Soros eliminates contagion, but may make countries more vulnerable to crises.*

The intuition behind Proposition 7 is the following. Notice that the contagion channel in this paper is the small speculators' Bayesian updating about the type of Soros. If financial disclosure reveals Soros' type completely in period 1, no Bayesian updating occurs in period 2 because the small speculators already know Soros' type in period 1. Therefore no contagion happens. However, if financial disclosure reveals that Soros is bull, the small speculators do not need to worry about the possibility that Soros is chicken. Thus they become the most aggressive, which makes countries more vulnerable to crises.

Proposition 8 (Size Regulation) *Regulating the size of speculators makes countries less vulnerable to crises, but makes contagion more severe.*

Proposition 8 is a direct result of Proposition 2 and Proposition 6. Due to the mere presence of Soros, the small speculators become more aggressive, which makes countries more vulnerable to crises. Therefore, if the size of Soros is regulated such that group 1 consists of the small speculators like group 2 (i.e., the no-Soros case), both groups 1 and 2 are less aggressive, which makes countries less vulnerable to crises. However, because Soros mitigates contagion, contagion becomes more severe if there is no Soros.

3.5 An Application of the Model to the LTCM Story

Although the model seems far distant from the LTCM story, in this subsection I explain how the model of this paper can be applied to capture one aspect of the LTCM story, if not all of the aspects. Before the crisis, no trader outside LTCM knew the "type" of LTCM. But the crisis in some country revealed the type of LTCM to some degree under certain conditions and led to Bayesian-updating of other traders, which in turn made contagion across unrelated countries more severe. I do not claim that this "Bayesian updating by speculators" is the only one reason why the Russian financial crisis became contagious or the single factor that triggered contagion. Another contagion channel might have triggered contagion first and then several contagion channels could work simultaneously, thereby making contagion more severe. I claim, however, that this "Bayesian updating about a player's type by other players" may be one of the contributing factors that made contagion more severe in the Russian Virus.

3.5.1 Creditors Game

To apply the model to the LTCM case, just rename the speculators in the model as foreign creditors (i.e., traders). Soros in the model is now "LTCM". Foreign creditors have invested both in a firm in country A and in another firm in country B and have financed a project in each firm. Observing the private signal, a creditor decides whether or not she liquidates her position. If she decides to liquidate, her payoff is $t + \mu_1$ with certainty. Liquidating is a safe choice, which corresponds to refraining from attacking the peg in the model. If she decides not to liquidate (i.e., roll over), her payoff depends on two factors - the economic fundamentals, θ_j, and the degree of disruption caused to the project by the early liquidation by creditors. The latter is measured by the proportion of creditors who liquidate, l_j. The project yields the payoff D (i.e., roll over is successful) if $\theta_j \geq l_j$. I call this "No Crisis". If $\theta_j < l_j$, the payoff of rolling-over is zero (i.e., roll over fails). That is, if a sufficient proportion of creditors refuse to roll over relative to the economic fundamentals ($\theta_j < l_j$), the project is liquidated entirely and yields nothing.[23] I call this "Crisis". Roll over is a risky choice in that the payoff is uncertain, which corresponds to attacking the peg in the model. Notice the similarity of the payoff structure between the speculators game and the creditors game (see Table 1 and Table 2). Indeed, all

[23]This formulation is similar to Diamond and Dybvig (1983).

	Success	Failure
Roll Over	D	0
Do Not Roll Over	$t+\mu_1$	$t+\mu_1$

Table 2: Payoff Matrix

the reasoning of the speculators game applies to the creditors game: the switching strategy equilibrium arises and contagion happens due to Bayesian updating about the type of group 1, LTCM. For any $\theta_A \in \left[\underline{\theta}_A, \bar{\theta}_A\right]$, Crisis happens in the firm in country A *only if LTCM chooses not to roll over.*[24] LTCM choosing not to roll over is more likely when LTCM is in trouble (due to the Russian financial crisis, for instance) than otherwise. Observing this, traders in group 2 assign larger probability to the event that LTCM would not roll over in country B because it is in trouble (i.e., Bayesian updating occurs). Through the Bayesian updating, Crisis in one country can trigger Crisis in another country even when the economic fundamentals are totally unrelated between the two countries.

3.5.2 The Relationship Between the Speculators Game and the Creditors Game

In the speculators game, contagion happens when Soros turns out to be more aggressive than expected. In the creditors game, contagion happens when LTCM turns out to be less aggressive than expected. Are they mutually exclusive? The answer is no. Here I explain why these two games are not exclusive but complementary.

In the speculators game, each speculator has "his money with him," as opposed to the creditor game where his money is already invested in countries. The decision is whether or not to use "readily available money" for short-selling. Short-selling is a risky choice and each speculator becomes more aggressive towards short-selling when Soros turns out to be more aggressive than expected, which causes contagion. In the creditors game, each creditor has already invested his money in countries. The decision is whether or not to pull out "his money from countries" in order to avoid possible losses. Rolling over (i.e., refraining from pulling out money) is a risky choice and each creditor becomes less aggressive toward rolling over when LTCM turns out to be less aggressive than expected, which causes contagion. These two games are related as follows. On the one hand, the more speculators attack a country, the more likely depreciation is in the country. When depreciation is more likely to happen in the country, creditors have a greater incentive to pull their money out of the country because they are afraid of depreciation. It means the more aggressive speculators are, the less aggressive creditors are. On the other hand, when many creditors becomes less aggressive and pull their money out of the country, foreign reserves of the country decrease. The smaller the foreign reserves, the more vulnerable the

[24]Notice that country A does not have to be Russia.

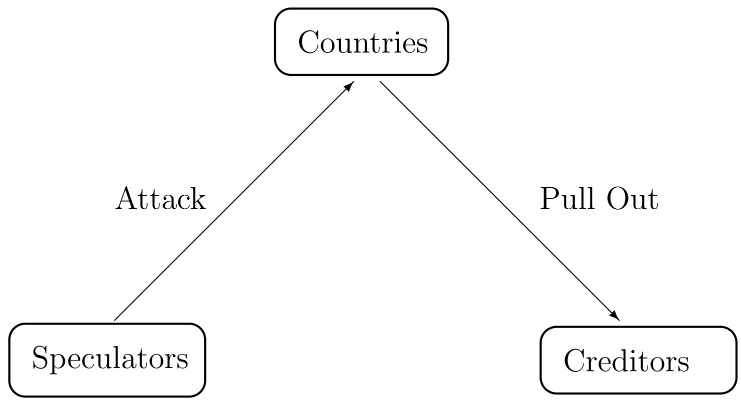

Figure 6: Complementarity between Speculators and Creditors

country becomes to the crisis. As a result, speculators become more aggressive. This implies that the less aggressive creditors are, the more aggressive speculators are. In the creditors game, contagion happens when creditors become less aggressive. In the speculators game, contagion happens when speculators become more aggressive. Because speculators tend to become more aggressive when creditors become less aggressive and vice versa, these two games can interact and contagion can become more severe. In this sense, these two games are not exclusive but complementary. (See Figure 6.)

3.6 Possible Research Extension

Soros' attitude for risk, which is captured by μ_1, is assumed to be his private information in the model. This is the source of contagion. I do not believe that this assumption is strange. Since neither hedge funds nor offshore funds are required to report their data by financial authorities, it is hard for outsiders to know how much risk they are willing to take. Thus their attitude for risk is considered to be their private information. Yet it is unclear where the difference of μ_1, 0 or μ, originates. In this subsection I consider a possible extension of the model that explains the differences.

Hedge funds have a distinguishing feature that is relevant to their attitude for risk. Hedge fund managers (i.e., speculators in the model) have a unique payoff structure, which is called "a high water mark." The high water mark is the highest point of value that a hedge fund has reached. Because the income of a hedge fund manager is performance based, the high water mark means if the manager loses money over one time period he has to get back to the high water mark before getting a performance fee on new gains. For instance, suppose an investor enters a hedge fund with \$1,000,000 at the beginning of year 1, and in that year the fund increases it by 10%, that is, the value of the investment increases to \$1,100,000 gross of fees. The investor pays a fixed fee as well as an incentive fee, say 20% of the gain

\$100,000 = \$1,100,000 - \$1,000,000, to the manager. Assume that after year 2 the investment value drops to \$1,000,000. Then the investor needs to pay only the fixed fee. He does not need to pay the incentive fee. Now suppose that after year 3 the investment value increases to \$1,100,000 gross of fees. Without the high water mark, the investor has to pay the fixed fee as well as the incentive fee (i.e, 20% of \$100,000 = \$1,100,000 - \$1,000,000). With the high water mark, however, the investor does not need to pay the incentive fee. The high water mark, which is the highest point of value that the hedge fund has reached, is \$1,100,000. The investor needs to pay the incentive fee only if the investment value exceeds the high water mark, \$1,100,000.

The high water mark is, therefore, relevant to the hedge funds manager's attitude for risk. For example, consider the hedge manager's viewpoint at the beginning of year 3 in the above example. He lost \$100,000 in year 2. Thus without the high water mark, he can receive the incentive fee as long as he attains some positive gains. With the high water mark, however, he needs to attain more than a \$100,000 increase of the investment value in order to receive the incentive fee. Thus with the high water mark he may have an incentive to take *more* risk than he would without the high water mark.

In the literature of contagion, however, this risk attitude has not been taken into account.[25] The literature considers only the wealth effect. For example, if a trader incurs losses (i.e., his speculative attack fails), then he cannot incur more risk due to the wealth effect so that he becomes less aggressive.[26] Yet the high water mark suggests the opposite could be true. With the high water mark, if the trader incurs losses, he may become more aggressive in order to receive the incentive fee. Therefore, even if speculative attacks to country A fail, it may increase speculative pressures on country B. In my model, μ_1 is exogenous so that it is not affected by what has happened in country A. The high water mark yields some hint as to how to endogenize μ_1 which may depend on what has happened in country A. This is an interesting extension for future research.

4 Conclusion

Both the presence of the large speculator and contagion of currency crises are the most serious concerns among international financial policy makers. The model in this paper extends the model of Taketa (2003) where there is no large speculator (the "no-Soros" case) to the "one-Soros" case where there is a large speculator. The model endogenously derives a unique threshold value of economic fundamentals of a country below which a currency crisis occurs in the country, as opposed to the multiple equilibria model. It shows that the threshold value depends on events in another *unrelated* country: the threshold value of one country (country B) can

[25] Goetzmann, Ingersoll, and Ross (2003) show how to price the high water mark in performance fees, using the option-like property of the high water mark. However they are not concerned with the issue of contagious currency crises.

[26] See Goldstein and Pauzner (2001) and Kodres and Pritsker (2002).

increase when a currency crisis occurs in another country (country A), even when those counties do not have related economic fundamentals. This means the currency crisis can be contagious even when those counties do not have related economic fundamentals. The large speculator is more aggressive in attacking the currency peg than he would be if his size were small. Moreover, the mere presence of the large speculator makes other small speculators more aggressive in attacking the currency peg, which in turn makes countries more vulnerable to a currency crisis. But surprisingly, the presence of the large speculator *mitigates* contagion of crises across countries. The meaning of this is twofold. First, the *increase* in the threshold value of country B, below which the currency crisis occurs, due to the occurrence of the currency crisis in another unrelated country (country A) is *smaller* in the one-Soros case than in the no-Soros case. Thus contagion is *less* severe in the one-Soros case in *relative* terms than in the no-Soros case. Second, the threshold value of country B when the currency crisis occurs in country A *itself* is smaller in the one-Soros case than in the no-Soros case, provided that Soros is not too large. Therefore, contagion is *less* severe in the one-Soros case in *absolute* terms than in the no-Soros case. The model presents policy implications for financial disclosure and size regulation of speculators such as hedge funds, which have recently been the subject of hot debate among policy makers. Two main conclusions are derived. First, financial disclosure of speculators eliminates contagion, but may make countries more vulnerable to crises. Second, regulating the size of speculators (e.g., prohibiting hedge funds from high-leverage) makes countries less vulnerable to crises, but makes contagion more severe.

A Appendix

A.1 Derivation of equation (6)

$$
\begin{aligned}
&p_1 \times \text{Prob}\left[\text{Attack is successful when } \mu_1 = 0\right] \\
&\qquad\qquad + (1-p_1) \times \text{Prob}\left[\text{Attack is successful when } \mu_1 = \mu\right] \\
&= p_1 \times \Big\{ \text{Prob}\big[\theta_A \le \underline{\theta}_A \big|\, x_{A2}\big] \\
&\qquad\qquad + \text{Prob}\big[\underline{\theta}_A \le \theta_A \le \bar{\theta}_A \text{ and Soros attacks when } \mu_1 = 0 \big|\, x_{A2}\big] \Big\} \\
&\quad + (1-p_1) \times \Big\{ \text{Prob}\big[\theta_A \le \underline{\theta}_A \big|\, x_{A2}\big] \\
&\qquad\qquad + \text{Prob}\big[\underline{\theta}_A \le \theta_A \le \bar{\theta}_A \text{ and Soros attacks when } \mu_1 = \mu \big|\, x_{A2}\big] \Big\} \\
&= \text{Prob}\big[\theta_A \le \underline{\theta}_A \big|\, x_{A2}\big] \\
&\qquad\qquad + p_1 \int_{\underline{\theta}_A}^{\bar{\theta}_A} f(\theta_A |\, x_{A2}) \text{prob}\big[\text{Soros attacks when } \ \mu_1 = 0\big] d\theta_A \\
&\qquad\qquad + (1-p_1) \int_{\underline{\theta}_A}^{\bar{\theta}_A} f(\theta_A |\, x_{A2}) \text{prob}\big[\text{Soros attacks when } \ \mu_1 = \mu\big] d\theta_A \\
&= 1 - \frac{x_{A2} - \underline{\theta}_A}{2\epsilon} + p_1 \int_{\underline{\theta}_A}^{\bar{\theta}_A} \frac{1}{2\epsilon} \frac{\bar{x}_{A1}(\mu_1 = 0) - \theta_A}{2\epsilon} d\theta_A \\
&\qquad\qquad + (1-p_1) \int_{\underline{\theta}_A}^{\bar{\theta}_A} \frac{1}{2\epsilon} \frac{\bar{x}_{A1}(\mu_1 = \mu) - \theta_A}{2\epsilon} d\theta_A \\
&= 1 - \frac{x_{A2} - \underline{\theta}_A}{2\epsilon} + \frac{p_1}{4\epsilon^2} \left(\bar{x}_{A1}(\mu_1 = 0)\bar{\theta}_A - \frac{(\bar{\theta}_A)^2}{2} - \bar{x}_{A1}(\mu_1 = 0)\underline{\theta}_A + \frac{(\underline{\theta}_A)^2}{2} \right) \\
&\qquad + \frac{1-p_1}{4\epsilon^2} \left(\bar{x}_{A1}(\mu_1 = \mu)\bar{\theta}_A - \frac{(\bar{\theta}_A)^2}{2} - \bar{x}_{A1}(\mu_1 = \mu)\underline{\theta}_A + \frac{(\underline{\theta}_A)^2}{2} \right)
\end{aligned}
$$

A.2 Proof of Lemma 1

This is the direct result from (8), (9), (10), (11), and (12).

A.3 Proof of Proposition 1

It is necessary and sufficient to prove that it is optimal for a speculator to attack the currency if and only if he observes the private signal lower than or equal to the switching signal, provided that everyone else follows the switching strategy. To show this, it is sufficient to show that Prob [Attack is successful| x_{Ai}] $(i = 1, 2)$ is decreasing in the private signal x_{Ai} if everyone else follows the switching strategy. Because the expected payoff of attacking is increasing in Prob [Attack is successful| x_{Ai}], it is decreasing in the private signal x_{Ai} when Prob [Attack is successful| x_{Ai}] is decreasing in x_{Ai}. By construction, the switching signal makes the speculator indifferent between attacking and refraining from doing so: the expected payoff of attacking is zero when he observes the switching signal. If Prob [Attack is successful| x_{Ai}] is decreasing in x_{Ai}, the expected payoff of attacking is positive (negative) when the speculator observes the signal smaller (larger) than the switching signal. Therefore, it is optimal for the speculator to attack if and only if he observes the private signal lower than or equal to the switching signal, provided that Prob [Attack is successful| x_{Ai}] is decreasing in the private signal x_{Ai}. Prob [Attack is successful| x_{Ai}] can be written as follows.

$$\begin{aligned} & \text{Prob}\left[\text{Attack is successful}|\ x_{A1}\right] \\ = \ & 1 - \frac{x_{A1} - \bar{\theta}_A}{2\epsilon} \end{aligned} \tag{14}$$

$$\begin{aligned} & \text{Prob}\left[\text{Attack is successful}|\ x_{A2}\right] \\ = \ & 1 - \frac{x_{A2} - \underline{\theta}_A}{2\epsilon} + \frac{p_1}{4\epsilon^2}\left(\bar{x}_{A1}(\mu_1 = 0)\bar{\theta}_A - \frac{(\bar{\theta}_A)^2}{2} - \bar{x}_{A1}(\mu_1 = 0)\underline{\theta}_A + \frac{(\underline{\theta}_A)^2}{2}\right) \\ & + \frac{1 - p_1}{4\epsilon^2}\left(\bar{x}_{A1}(\mu_1 = \mu)\bar{\theta}_A - \frac{(\bar{\theta}_A)^2}{2} - \bar{x}_{A1}(\mu_1 = \mu)\underline{\theta}_A + \frac{(\underline{\theta}_A)^2}{2}\right) \end{aligned} \tag{15}$$

Clearly from (14) and (15), Prob [Attack is successful| x_{Ai}] is decreasing in the private signal x_{Ai}.

A.4 Proof of Corollary 1

This is the direct result of Proposition 1.

A.5 Proof of Proposition 2

First, switching values need to be derived for the no-Soros case. Then these can be compared with those in the one-Soros case. I present the switching values in the no-Soros case below. But I do not present messy algebra which shows that the switching values in the one-Soros case are larger than those in the one-Soros case. It is available upon request.

There are two caveats. First, as explained above, in the no-Soros case there are *two* counterparts of $\bar{\theta}_A$, the switching value below which the peg is abandoned when *both* groups 1 and 2 attack. Second, however, in the no-Soros case there is *only one* counterpart of $\underline{\theta}_A$. This is because $\underline{\theta}_A$ is defined to be the threshold level of economic fundamentals up to which attacks by group 2 *alone* are enough to cause the collapse of the peg. Thus the counterpart of $\underline{\theta}_A$ is defined by:

$$\begin{aligned} \underline{\underline{\theta}}_A &= (1-\lambda)\text{Prob}\left[x_{A2} \leq \bar{\bar{x}}_{A2}|\ \underline{\underline{\theta}}_A\right] \\ &= (1-\lambda)\frac{\bar{\bar{x}}_{A2} - \underline{\underline{\theta}}_A}{2\epsilon} \end{aligned}$$

Clearly $\underline{\underline{\theta}}_A$ is unique as long as $\bar{\bar{x}}_{A2}$ is unique. Indeed, $\bar{\bar{x}}_{A2}$ can be shown to be unique. That is why $\underline{\underline{\theta}}_A$ is unique.

Taketa (2003) derives the switching values in the no-Soros case as follows. Comparing these with the switching values in the one-Soros case, Proposition 2 results after some algebra.

$$\underline{\underline{\theta}}_A = \frac{1-\lambda}{2\epsilon+(1-\lambda)}\left[2\epsilon+1-\frac{t}{D}-\frac{\mu}{D}\lambda(1-p_1)+\frac{2\epsilon t}{D}\right] \tag{16}$$

$$\begin{aligned}\bar{\bar{\theta}}_A(\mu_1=0) = \frac{1}{p_1}\Bigg[1-\frac{t}{D}-\frac{\mu}{D}\lambda(1-p_1)-\frac{(1-p_1)(1-\lambda)}{2\epsilon+(1-\lambda)}\Bigg\{\frac{2\epsilon}{1-\lambda}+1-\frac{t}{D}\\ -\frac{\mu}{D}\lambda(1-p_1)-\frac{1}{1-\lambda}\frac{2\epsilon t}{D}-\frac{2\epsilon\lambda}{1-\lambda}\frac{\mu}{D}\Bigg\}\Bigg]\end{aligned} \tag{17}$$

$$\begin{aligned}\bar{\bar{\theta}}_A(\mu_1=\mu) = \frac{1-\lambda}{2\epsilon+(1-\lambda)}\Bigg[\frac{2\epsilon}{1-\lambda}+1-\frac{t}{D}-\frac{\mu}{D}\lambda(1-p_1)-\frac{1}{1-\lambda}\frac{2\epsilon t}{D}\\ -\frac{2\epsilon\lambda}{1-\lambda}\frac{\mu}{D}\Bigg]\end{aligned} \tag{18}$$

$$\begin{aligned}\bar{\bar{x}}_{A1}(\mu_1=0) = \frac{1}{p_1}\Bigg[1-\frac{t}{D}-\frac{\mu}{D}\lambda(1-p_1)-\frac{(1-p_1)(1-\lambda)}{2\epsilon+(1-\lambda)}\Bigg\{\frac{2\epsilon}{1-\lambda}+1-\frac{t}{D}\\ -\frac{\mu}{D}\lambda(1-p_1)-\frac{1}{1-\lambda}\frac{2\epsilon t}{D}-\frac{2\epsilon\lambda}{1-\lambda}\frac{\mu}{D}\Bigg\}\Bigg]+2\epsilon(1-\frac{t+\mu}{D})\end{aligned} \tag{19}$$

$$\begin{aligned}\bar{\bar{x}}_{A1}(\mu_1=\mu) = \frac{1-\lambda}{2\epsilon+(1-\lambda)}\left[\frac{2\epsilon}{1-\lambda}+1-\frac{t}{D}-\frac{\mu}{D}\lambda(1-p_1)-\frac{1}{1-\lambda}\frac{2\epsilon t}{D}-\frac{2\epsilon\lambda}{1-\lambda}\frac{\mu}{D}\right]\\ +2\epsilon(1-\frac{t+\mu}{D})\end{aligned} \tag{20}$$

$$\bar{\bar{x}}_{A2} = 2\epsilon+1-\frac{t}{D}-\frac{\mu}{D}\lambda(1-p_1)+\frac{2\epsilon t}{D} \tag{21}$$

A.6 Proof of Lemma 2

For any $\theta_A \leq \underline{\theta}_A$, the currency crisis happens in country A with probability one, irrespective of the Soros' type. Therefore, what happened in country A when $\theta_A \leq \underline{\theta}_A$, provides no information of the Soros' type. For any $\theta_A \geq \bar{\theta}_A$, the currency crisis will never happen in country A, irrespective of Soros' type. Therefore, what happened in country A when $\theta_A \geq \bar{\theta}_A$ provides no information of Soros' type. That is why no Bayesian updating occurs for any $\theta_A \notin \left[\underline{\theta}_A, \bar{\theta}_A\right]$.

$$\begin{aligned}
p_2(\theta_A \text{ such that } \theta_A \leq \underline{\theta}_A) &= \text{Prob}\left[\mu_1 = 0 \middle| \, \theta_A \text{ such that } \theta_A \leq \underline{\theta}_A\right] \\
&= \frac{\text{Prob}\left[\mu_1 = 0 \text{ and } \theta_A \text{ such that } \theta_A \leq \underline{\theta}_A\right]}{\text{Prob}\left[\theta_A \text{ such that } \theta_A \leq \underline{\theta}_A\right]} \\
&= \frac{q \times \text{Prob}\left[\theta_A \text{ such that } \theta_A \leq \underline{\theta}_A\right]}{\text{Prob}\left[\theta_A \text{ such that } \theta_A \leq \underline{\theta}_A\right]} \\
&= q \;=\; p_1 \qquad (22)
\end{aligned}$$

$$\begin{aligned}
p_2(\theta_A \text{ such that } \theta_A \geq \bar{\theta}_A) &= \text{Prob}\left[\mu_1 = 0 \middle| \, \theta_A \text{ such that } \theta_A \geq \bar{\theta}_A\right] \\
&= \frac{\text{Prob}\left[\mu_1 = 0 \text{ and } \theta_A \text{ such that } \theta_A \geq \bar{\theta}_A\right]}{\text{Prob}\left[\theta_A \text{ such that } \theta_A \geq \bar{\theta}_A\right]} \\
&= \frac{q \times \text{Prob}\left[\theta_A \text{ such that } \theta_A \geq \bar{\theta}_A\right]}{\text{Prob}\left[\theta_A \text{ such that } \theta_A \geq \bar{\theta}_A\right]} \\
&= q \;=\; p_1 \qquad (23)
\end{aligned}$$

(22) and (23) prove the first part of Lemma 2.

Next, suppose the currency crisis happened for $\theta_A \in \left[\underline{\theta}_A, \bar{\theta}_A\right]$. This means that Soros attacked country A. In turn, it implies that Soros observed the private signal lower than or equal to the switching signal.

$$\begin{aligned}
p_2 &= \text{Prob}\left[\mu_1 = 0 \middle| \text{ Crisis happens for } \theta_A \in \left[\underline{\theta}_A, \bar{\theta}_A\right]\right] \\
&= \frac{\text{Prob}\left[\mu_1 = 0 \text{ and Crisis happens for } \theta_A \in \left[\underline{\theta}_A, \bar{\theta}_A\right]\right]}{\text{Prob}\left[\text{Crisis happens for } \theta_A \in \left[\underline{\theta}_A, \bar{\theta}_A\right]\right]} \\
&= q \times \text{Prob}\left[\theta_A \in \left[\underline{\theta}_A, \bar{\theta}_A\right] \text{ and } x_{A1} \leq \bar{x}_{A1}(\mu_1 = 0)\right] \\
&\quad \times \Big\{ q \times \text{Prob}\left[\theta_A \in \left[\underline{\theta}_A, \bar{\theta}_A\right] \text{ and } x_{A1} \leq \bar{x}_{A1}(\mu_1 = 0)\right] \\
&\quad + (1-q) \times \text{Prob}\left[\theta_A \in \left[\underline{\theta}_A, \bar{\theta}_A\right] \text{ and } x_{A1} \leq \bar{x}_{A1}(\mu_1 = \mu)\right] \Big\}^{-1} \qquad (24)
\end{aligned}$$

The following inequality comes from Corollary 1.

$$\begin{aligned}
&\text{Prob}\left[\theta_A \in \left[\underline{\theta}_A, \bar{\theta}_A\right] \text{ and } x_{A1} \leq \bar{x}_{A1}(\mu_1 = 0)\right] \\
&> \text{Prob}\left[\theta_A \in \left[\underline{\theta}_A, \bar{\theta}_A\right] \text{ and } x_{A1} \leq \bar{x}_{A1}(\mu_1 = \mu)\right] \qquad (25)
\end{aligned}$$

(24) and (25) imply $p_2 > q = p_1$, proving the second part of Lemma 2. The third part can be proven similarly.

A.7 Proof of Proposition 3

From Lemma 2, three possible p_2 exist depending on what has happened in country A. For each of these three possible beliefs, we can prove Proposition 3 exactly the same as the proof of Proposition 1.

A.8 Proof of Proposition 5

This is the direct result from Lemma 1, Lemma 2 and Proposition 3.

A.9 Proof of Corollary 3

This is the direct result from Proposition 5.

A.10 Proof of Proposition 4.

Consider first an additional benefit that the chicken Soros enjoys in period 2 by deceiving and then consider a cost of deceiving that the chicken Soros has to pay in period 1. The chicken Soros has an incentive to mimic the bull Soros if and only if the benefit exceeds the cost. I show that the cost outweighs the benefit as long as ϵ is sufficiently small.

Assume the chicken Soros succeeds in deceiving and the small speculators update their belief such that Soros is more likely to be bull. The benefit of deceiving depends on to what extent the small speculators become more aggressive in period 2. The larger the Bayesian updating is, the larger the change in the small speculators' behavior. In other words, if the Bayesian updating is not large, the benefit is relatively small because the small speculators' behavior does not change very much. Remember that there is *no* difference in aggressiveness between the bull Soros and the chicken Soros when $\epsilon = 0$. Intuitively speaking, the aggressiveness difference is very small when ϵ is close to zero. In fact, from (10) and (11), the following can be shown.

$$\lim_{\epsilon \longrightarrow 0} (\bar{x}_{A1}(\mu_1 = \mu) - \bar{x}_{A1}(\mu_1 = 0)) = 0 \tag{26}$$

Notice that (24) and (26) imply $p_2^{\mathrm{C}} \longrightarrow q$ as $\epsilon \longrightarrow 0$. Similarly, it can be shown that $p_2^{\mathrm{NC}} \longrightarrow q$ as $\epsilon \longrightarrow 0$. Therefore, $p_2^{\mathrm{C}} - p_2^{\mathrm{NC}} \longrightarrow 0$ as $\epsilon \longrightarrow 0$. From (12), the following holds.

$$\bar{x}_{A2}(p_2 = p_2^{\mathrm{C}}) - \bar{x}_{A2}(p_2 = p_2^{\mathrm{NC}}) = \frac{\mu}{D}\lambda(p_2^{\mathrm{C}} - p_2^{\mathrm{NC}}) \tag{27}$$

Since $p_2^{\mathrm{C}} - p_2^{\mathrm{NC}} \longrightarrow 0$ as $\epsilon \longrightarrow 0$,

$$\lim_{\epsilon \longrightarrow 0} (\bar{x}_{A2}(p_2 = p_2^{\mathrm{C}}) - \bar{x}_{A2}(p_2 = p_2^{\mathrm{NC}})) = 0 \tag{28}$$

Therefore, the change in the small speculators' behavior, $\bar{x}_{A2}(p_2 = p_2^{\mathrm{C}}) - \bar{x}_{A2}(p_2 = p_2^{\mathrm{NC}})$, is arbitrarily small for sufficiently small ϵ. It means that the benefit of deceiving becomes arbitrarily small when ϵ is close to zero, because the benefit of deceiving is increasing in $\bar{x}_{A2}(p_2 = p_2^{\mathrm{C}}) - \bar{x}_{A2}(p_2 = p_2^{\mathrm{NC}})$ and is zero when $\bar{x}_{A2}(p_2 = p_2^{\mathrm{C}}) - \bar{x}_{A2}(p_2 = p_2^{\mathrm{NC}}) = 0$.

Next, consider the cost of deceiving for the chicken Soros. In order to deceive, the chicken Soros has to mimic the bull Soros in period 1. That is, the chicken Soros must use the bull Soros' switching signal $\bar{x}_{A1}(\mu_1 = 0; p_1 = q)$, instead of his own $\bar{x}_{A1}(\mu_1 = \mu; p_1 = q)$. By definition of $\bar{x}_{A1}(\mu_1 = 0; p_1 = q)$, the following holds.

$$\text{Prob}\left[\theta_A \leq \bar{\theta}_A | \ \bar{x}_{A1}(\mu_1 = 0)\right] D - t = 0 \tag{29}$$

Thus when the chicken Soros mimicking the bull Soros observes $\bar{x}_{A1}(\mu_1 = 0; p_1 = q)$, his expected payoff is the following.

$$\text{Prob}\left[\theta_A \leq \bar{\theta}_A | \ \bar{x}_{A1}(\mu_1 = 0)\right] D - t - \mu = -\mu \tag{30}$$

Because the chicken Soros mimicking the bull Soros must attack whenever he observes the signal lower than or equal to $\bar{x}_{A1}(\mu_1 = 0; p_1 = q)$ to deceive the small speculators, the term $-\mu$ can be thought of as the deceiving cost. When he observes $\bar{x}_{A1}(\mu_1 = 0; p_1 = q)$, the benefit must be enough to compensate the cost $-\mu$. Remember, however, that the benefit is arbitrarily close to zero when $\epsilon \longrightarrow 0$. So given $-\mu$, one can choose sufficiently small ϵ such that the cost outweighs the benefit. Therefore, the chicken Soros does not have any incentive to mimic the bull Soros when ϵ is sufficiently small.

Furthermore, it needs to be proven that there is no pooling equilibrium. In the pooling equilibrium, the chicken Soros and the bull Soros use the same switching sinal and $p_1 = p_2 = q$. Suppose there is a pooling equilibrium where the chicken Soros and the bull Soros use the same switching sinal: $\bar{x}_{A1}(\mu_1 = 0) = \bar{x}_{A1}(\mu_1 = \mu) = \bar{x}_{A1}$. Notice that the following must hold.

$$\text{Prob}\left[\theta_A \leq \bar{\theta}_A | \ \bar{x}_{A1}\right] D - t = 0 \tag{31}$$

If $\text{Prob}\left[\theta_A \leq \bar{\theta}_A | \ \bar{x}_{A1}\right] D - t > 0$, there exists a $\bar{x}^*_{A1}$ $(< \bar{x}_{A1})$ such that for any signal $x_{A1} \in [\bar{x}^*_{A1}, \ \bar{x}_{A1}]$, it is optimal for the bull Soros to attack. If $\text{Prob}\left[\theta_A \leq \bar{\theta}_A | \ \bar{x}_{A1}\right] D - t < 0$, there exists a $\bar{x}^*_{A1}$ $(> \bar{x}_{A1})$ such that for any signal $x_{A1} \in [\bar{x}_{A1}, \ \bar{x}^*_{A1}]$ it is optimal for the bull Soros to attack. This is because the bull Soros loses nothing when he reveals his type. Thus in any pooling equilibrium, (31) must hold. It means that (30) must hold in any pooling equilibrium. Using the same logic as presented above, one can show a profitable deviation always exists as long as ϵ is sufficiently small, because the cost of using the same signal as the bull Soros (parallel to the deceiving cost above) is greater than its benefit (parallel to the benefit of deceiving above).

A.11 Proof of Proposition 6

Taketa (2003) shows that previous events in country A under a certain range of economic fundamentals reveals group 1's type completely: $p_2 = 1$ if the crisis happens in country A under the certain range of economic fundamentals, while $p_2 = 0$ if the crisis does not happen in country A under the certain range of economic fundamentals. Using this and from (18) and (19), the following results.

$$\tilde{\theta}_B^{\text{No Soros}}(Y_A = 1) = \bar{\bar{\theta}}_A(\mu_1 = 0; p_2 = 1) = 1 - \frac{t}{D} \tag{32}$$

$$\tilde{\theta}_B^{\text{No Soros}}(Y_A = 0) = \bar{\bar{\theta}}_A(\mu_1 = \mu; p_2 = 0) = 1 - \frac{t}{D} - \frac{\lambda\mu}{D} \tag{33}$$

Relative severity of contagion in the no-Soros case is therefore

$$\bar{\bar{\theta}}_A(\mu_1 = 0; p_2 = 1) - \bar{\bar{\theta}}_A(\mu_1 = \mu; p_2 = 0) = \frac{\lambda\mu}{D} \tag{34}$$

As $\epsilon \longrightarrow 0$,

$$\bar{\theta}_B(p_2) \longrightarrow 1 - \frac{t}{D} - \frac{\lambda\mu}{D}(1 - p_2) + \frac{1}{2}\frac{\lambda}{1-\lambda} \tag{35}$$

Note that $\tilde{\theta}_B^{\text{One Soros}}(Y_A = 1) = \bar{\theta}_B(p_2 = p_2^{\text{C}})$ and $\tilde{\theta}_B^{\text{One Soros}}(Y_A = 0) = \bar{\theta}_B(p_2 = p_2^{\text{NC}})$. Relative severity of contagion in the one-Soros case in the limiting case ($\epsilon \longrightarrow 0$) is therefore

$$\bar{\theta}_B(p_2 = p_2^{\text{C}}) - \bar{\theta}_B(p_2 = p_2^{\text{NC}}) = \frac{\lambda\mu}{D}(p_2^{\text{C}} - p_2^{\text{NC}}) \tag{36}$$

Since $0 < p_2^{\text{C}} - p_2^{\text{NC}} < 1$, from (34) and (36)

$$\tilde{\theta}_B^{\text{No Soros}}(Y_A = 1) - \tilde{\theta}_B^{\text{No Soros}}(Y_A = 0) > \tilde{\theta}_B^{\text{One Soros}}(Y_A = 1) - \tilde{\theta}_B^{\text{One Soros}}(Y_A = 0) \tag{37}$$

in the limiting case where $\epsilon \longrightarrow 0$. By continuity, inequality (37) holds for sufficiently small ϵ, which proves the first part of Proposition 6. From (32) and (35), it can be shown that

$$\tilde{\theta}_B^{\text{No Soros}}(Y_A = 1) - \tilde{\theta}_B^{\text{One Soros}}(Y_A = 1) > 0 \tag{38}$$

if and only if

$$\frac{\mu}{D}(1 - p_2^{\text{C}}) > \frac{1}{2}\frac{1}{1-\lambda} \tag{39}$$

which can hold provided that λ is not too close to one. If inequality (38) holds in the limiting case where $\epsilon \longrightarrow 0$, it also holds where ϵ is sufficiently small, which proves the second part of Proposition 6.

A.12 Proof of Proposition 7

Suppose $\mu_1 = 0$. Also assume that group 2 *knows* $\mu_1 = 0$ due to financial disclosure of Soros' type. In this case, $p_1 = p_2 = 1$. Because contagion happens if and only if $p_2 > p_1$, financial disclosure eliminates contagion. However, from Lemma 1, financial disclosure makes countries more vulnerable to crises.

A.13 Proof of Proposition 8

This is a direct result of Proposition 6.

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