Expectations and Contagion in Self-Fulfilling Currency Attacks

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May 14, 2008

Abstract

Self-fulfilling expectations are commonly believed to play an important role in the transmission of currency crises across countries. Formal models of contagion based on multiple equilibria, however, have been criticized for failing to explain basic patterns observed in the data; these criticisms have been taken as evidence against the self-fulfilling view. This paper argues that the importance of self-fulfilling beliefs is not so easily dismissed. A slightly richer model, based on the incomplete-information framework of Morris and Shin (1998), can generate contagion due to self-fulfilling beliefs while placing restrictions on observable variables that are broadly consistent with the empirical evidence.

Forthcoming in the *International Economic Review*. I thank David Cass, Roberto Chang, David Easley, Huberto Ennis, Paula Hernandez-Verme, Karl Shell, Hyun Shin, Max Stinchcombe, Laura Veldkamp, two anonymous referees, and seminar participants at Cornell, Texas A&M, the University of Pennsylvania, Queen Mary University of London, the University of Alberta, the Federal Reserve Bank of Richmond, the University of Texas - ITAM Workshop, the Cornell - Penn State Macro Workshop, and the 2005 World Congress of the Econometric Society for useful comments. Part of this work was completed while the author was a professor at the Instituto Tecnológico Autónomo de México (ITAM). The views expressed herein are those of the author and do not necessarily reflect those of the Federal Reserve Bank of New York or the Federal Reserve System.

1 Introduction

One of the most striking features of the currency crises of the 1990s was their contagiousness: a sharp devaluation of one currency was often followed by devaluations of other, sometimes seemingly unrelated, currencies. While many competing explanations have been offered for this phenomenon, no general consensus has emerged. One popular view holds that at least some episodes of observed contagion were driven by the self-fulfilling beliefs of market participants.[1] Models formalizing this view, however, have been criticized as lacking empirical content and, hence, failing to explain why the particular patterns of contagion observed in the data arise. This failure has been interpreted as strong evidence against the self-fulfilling view. This paper argues that the importance of self-fulfilling beliefs is not so easily dismissed. It shows how a richer model of currency crises can generate multiple equilibria, one where contagion occurs and another where it does not, while placing restrictions on observable variables that are broadly consistent with the empirical evidence.

In its simplest form, the standard explanation of how contagion could be caused by self-fulfilling beliefs goes as follows. A currency market with a fixed exchange rate regime can be viewed, as in Obstfeld (1996), as a coordination game. This game often has multiple equilibria, one where speculators attack the currency and a devaluation occurs and another where no one attacks and no devaluation occurs. Which equilibrium obtains depends entirely on the expectations of the market participants. A devaluation of one currency can, therefore, act as a signal that coordinates expectations on the crisis equilibrium in another currency market. In other words, if speculators believe that the Malaysian *ringgit* would experience a sharp devaluation were a currency crisis to occur first in, say, Thailand, then they will all choose to attack the *ringgit* after observing a crisis in Thailand and, as a result, contagion will occur.[2]

While many people find this view intuitively appealing and useful for thinking about the role of expectations in the spread of crises, it has been criticized along several dimensions, and rightly so. Most notably, this simple story is capable of explaining *any* correlation of outcomes across countries and hence has little or no empirical content. In other words, it does not explain why

[1] See, for example, Calvo (1998), Krugman (1999), and Masson (1999, 2001).

[2] If two countries are highly integrated, of course, (through trade, etc.) it is not entirely surprising that a crisis in one would have strong effects on the other. The importance of expectations is, therefore, most often stressed in cases where the two currencies are, at least in principle, not closely related. The crises in Russia and Brazil in 1998 is another oft-cited example.

the event "crisis in Thailand" should be the signal for speculators to attack in Malaysia and not the event "no crisis in Thailand" or "slight appreciation in Thailand". Nor does it explain why contagion is associated with major crises, while smaller devaluations have much more limited effects on other markets. The formal prediction of this theory is simply that whatever correlation agents expect between the outcomes of the two markets will be self-fulfilling.

This paper argues that the role of self-fulfilling beliefs in generating contagion across markets can be more subtle than the simple theory described above would suggest. In richer environments, expectations of contagion can be self-fulfilling without leaving the model devoid of empirical content. This fact is demonstrated by extending the incomplete-information model of Morris and Shin (1998) to allow speculators to trade on a second currency market. The resulting model admits multiple equilibria, but nevertheless places restrictions on the equilibrium correlation of outcomes across markets; these restrictions are consistent with the general patterns observed in the data. The failings of the simple theory described above, therefore, should not be taken to imply that self-fulfilling expectations are unimportant or can be safely disregarded as a possible explanation of contagion.

The model presented here consists of two markets that meet sequentially, with the domestic currency market preceded by a second, "foreign" currency market. The economic fundamentals of the two countries are assumed to be *uncorrelated*, which captures the idea that the values of the two currencies are, at least in principle, unrelated. When the domestic currency market meets, the model is exactly as in Morris and Shin (1998); due to its global-games structure, this market has a unique equilibrium when viewed in isolation. Notice that, in such a setting, events in the foreign market cannot act as a signal that influences speculators' equilibrium behavior.[3] Regardless of the outcome of the foreign market, the unique equilibrium in the domestic market must obtain.

In order for contagion to occur in this setting, speculators must choose to be active in both currency markets. When they do so, the outcome of the foreign market affects their wealth level and, hence, their behavior in the domestic market. In other words, when speculators are active in both markets, crises are transmitted across markets through a wealth channel. In this way, the analysis here is related to a number of previous papers that study how financial-market linkages, such as common creditors or common traders, can lead to the contagion of crises.[4] In the previous

3 See Heinemann and Illing (2002) on this point.

4 Examples include Allen and Gale (2000), Dasgupta (2004), Goldstein and Pauzner (2004), Kodres and Pritsker (2002), Kyle and Xiong (2001), and Lizarazo (2005).

literature, however, the financial linkages arise for fundamental reasons, such as investors choosing to diversify their portfolios across markets. The point of the present paper is that such linkages can also result solely from the belief that contagion will occur.

In keeping with the idea that the two currencies in this model are, in principle, unrelated, suppose that an individual speculator has no particular information advantage that would make speculating on the foreign currency profitable. If she expects the outcomes of the two markets to be uncorrelated, she will only choose to be active in the domestic market. If the same is true for all speculators, then no link will arise between the two markets in equilibrium. As a result, the outcome of the domestic market will be unaffected by events in the foreign market, fulfilling speculators' belief that the markets are uncorrelated. Contagion will not occur.

Suppose, on the other hand, that speculators expect contagion to occur. Could this belief also be self-fulfilling? Consider a speculator who believes that a devaluation of the foreign currency will increase the likelihood of a domestic devaluation. Her marginal utility of wealth is higher in states of the world where a domestic devaluation is more likely, because in those states she is more likely to be able to leverage her wealth in a successful attack. Under this belief, therefore, she wants to increase the amount of wealth she brings to the *domestic* market in states of the world where the *foreign* currency devalues. The way to do this, of course, is to attack the foreign currency. Since all speculators face this same incentive, they will all choose to attack. In equilibrium, then, a crisis in the foreign market will raise speculators' wealth and enable them to take larger positions against the domestic currency. These larger positions, in turn, will increase the likelihood of a domestic devaluation, thus fulfilling the original expectation that contagion would occur.

To put things differently, in the environment studied here speculators have an incentive to be active in both currency markets if – and only if – they expect the outcomes of the markets to be correlated. In this way, the financial "links" that arise between the two markets depend on agents' expectations. This point is important, as it implies that empirical evidence regarding financial links as a source of contagion must be interpreted with caution. In particular, an empirical finding that common creditors or other financial links "explain" observed contagion does *not* demonstrate that expectations are unimportant or that contagion is an inevitable outcome. Rather, the observed links could themselves be a consequence of agents' (self-fulfilling) beliefs that contagion will occur.

Despite the fact that it can have multiple equilibria, one in which contagion occurs and another in which it does not, the model restricts the equilibrium correlation between the outcomes of the two markets. In particular, there must either be zero correlation or the occurrence of a crisis in one market must raise the probability of a crisis in the other. In other words, the model presented here offers a genuine explanation of the *contagion* of crises, as opposed to an arbitrary correlation of outcomes across markets. The model also places restrictions on the structure of the contagion equilibrium. The probability of a crisis in the second market, for example, is strictly increasing in the size of the devaluation in the first. The model predicts, therefore, that contagion should be most frequently observed following large devaluations. The model also predicts that a currency crisis is more likely to occur when domestic fundamentals are weak than when they are strong. Both of these predictions match what is observed in the data.

The fact that incomplete-information models can deliver interesting predictions even when multiple equilibria arise has also been highlighted in recent work by Angeletos *et al*. (2007a, b). It should be noted, however, that their predictions are of a somewhat different nature: they characterize situations where *all* equilibria of the model have a certain property. Here, the model does not predict whether or not contagion will occur. Instead, it predicts that if the outcomes of the two markets are related, the correlation must take a specific form. The primary reason for this difference is that the model here is designed to focus on the role of self-fulfilling beliefs; that is, it admits an equilibrium where no contagion occurs by design. The main point of the paper is that this fact does not leave the model devoid of empirical content. If contagion does occur, the model gives sharp predictions on what form it will take.

The remainder of the paper is organized as follows. The next section presents the model, which builds on Morris and Shin (1998) by adding the possibility of trading in a second currency market. Section 3 analyzes equilibrium in this model, while Section 4 derives some interesting properties of the contagion equilibrium. Section 5 contains a discussion of the results and, finally, Section 6 offers some concluding remarks.

2 The Model

There are two time periods, with a different currency market meeting in each period. In the second period, the domestic currency is traded for a real numeraire (called “dollars”); this is the market to which a crisis elsewhere may potentially spread. In the first period, a “foreign” currency is traded, also for dollars. Economic fundamentals are uncorrelated between the two markets.

From the standpoint of the domestic market, the foreign currency represents any market that agents perceive as a potential source of a contagious crisis. While the two currency markets are unrelated in terms of fundamentals, speculators have the ability to attack each of the currencies by selling it short. The outcome in each market is stochastic. The question of interest is whether – and how – the occurrence of a crisis in the foreign market affects the likelihood of a crisis in the domestic market.

The model is presented in two steps. I first describe the market for the domestic currency. Viewed in isolation, this market has a unique equilibrium; some properties of this equilibrium are discussed below. I then add the first-period market to the model so that the possibility of contagion across markets can be studied.

2.1 The domestic currency market

The model of the domestic currency market follows that in Morris and Shin (1998) closely; therefore, the description here is brief. The agents in this market are the domestic government and a $[0,1]$ continuum of identical speculators. The government has pegged the exchange rate at e^* dollars per unit of local currency. The economy is characterized by a fundamental "strength" $\theta \in \mathbb{R}$, which determines what the exchange rate would be in the absence of government intervention in the currency market. The variable θ captures the demand for the domestic currency for international trade, foreign direct investment, and other purposes. The exchange rate if the government takes no action will be given by $f(\theta)$, where f is continuous and strictly increasing. For some values of θ, the domestic currency will be overvalued at the pegged rate, that is, $f(\theta) < e^*$ will hold. The government must decide whether to take the actions necessary to maintain the peg or to abandon the peg and let the exchange rate fall to the market value $f(\theta)$.

A speculator has the ability to attack the domestic currency by selling it short. Short sales are limited by the speculator's wealth, which is denominated in dollars. In particular, each unit of wealth allows a speculator to short-sell one unit of the domestic currency.[5] Each speculator has w units of wealth available. Morris and Shin (1998) set $w = 1$ and provided an informal discussion of the comparative static results with respect to the level of wealth. Wealth enters the model here

[5] The exact relationship is not important, only that larger wealth allows the speculator to take a larger position. As is typical in such models, some type of constraint on short sales is necessary for an equilibrium to exist because attacking the currency is a one-way bet in some states. Having the constraint depend on a speculator's wealth is a standard way to capture the effects of credit constraints, margin requirements, and other features of reality that are absent from this simple model.

in a way that corresponds to their discussions. Speculators are risk neutral and, hence, their choice set is essentially binary: either a speculator will attack with all of her wealth or she will not attack at all. There is a cost t for each unit of the currency a speculator sells short; one can think of this cost as the interest rate differential between the domestic currency and dollars. If a speculator chooses to attack the currency, her net gain will be $w\left(e^{*}-f\left(\theta\right)-t\right)$ if the government abandons the peg and $\left(-wt\right)$ if the peg is maintained. It is assumed that there exists $\theta_0\in\mathbb{R}$ such that $f\left(\theta_0\right)=e^{*}-t$. Since the function f is strictly increasing, this assumption implies that speculators will find it profitable to attack the currency if and only if a devaluation occurs *and* θ is smaller than θ_0. In other words, a successful attack is profitable in some, but not all, states of the world.

The government receives a value $v>0$ if the peg is maintained. It will choose to maintain the peg if and only if this benefit is greater than the cost of doing so. The cost of maintaining the peg depends on two things: the state of the economy and the size of the attack against the currency. This cost is represented by the function $c\left(\theta,z\right)$, where z is the size of the attack (*i.e.*, the number of units of domestic currency sold short). The function c is continuous, strictly increasing in z, and strictly decreasing in θ. Furthermore, $c\left(\theta,0\right)<v$ is assumed to hold for low enough values of θ. This condition implies that when fundamentals are bad enough, the government will abandon the peg even if no one attacks.

The timing of events within this market is as follows. Speculators begin with a common prior belief about θ that is represented by a normal distribution with mean y and standard deviation τ. This prior belief reflects all *public* information about θ. Each speculator then observes a *private* signal

$$x_i=\theta+\varepsilon_i,$$

where ε_i is a normally-distributed random variable with zero mean and a standard deviation of σ. Based on her posterior belief, each speculator decides whether or not to attack the currency. Next, the government observes the true value of θ and the size of the attack $z=w\alpha$, where α is the fraction of speculators who chose to attack. The government then decides whether to abandon or maintain the peg, and payoffs are realized.

The model presented so far is identical to that in Morris and Shin (1998), except that the wealth level of each speculator is treated parametrically and beliefs are given by normal rather than uniform distributions. For simplicity, the focus here is on the limiting case where the private signals become very precise (that is, σ goes to zero), which allows for a precise characterization of equilibrium. In particular, the results in Morris and Shin (2003) can be applied to show that there exists a cutoff point θ^* such that the peg will necessarily be abandoned in equilibrium if $\theta < \theta^*$ and will be maintained if $\theta > \theta^*$.[6] Moreover, this cutoff point can be characterized in the following way. Define $a(\theta, w)$ to be the smallest fraction of speculators (each with wealth w) whose attack would lead the government to abandon the peg when θ is the true state of the economy. That is, the function $a(\theta, w)$ is implicitly defined by

$$c(\theta, w \cdot a(\theta, w)) \equiv v.$$

It is straightforward to show that a is increasing in θ and decreasing in w. Define $g(\alpha, \theta, w)$ to be the net benefit of attacking when a fraction α of the other agents attack, that is,

$$g(\alpha, \theta, w) = \left\{ \begin{array}{c} w(e^* - f(\theta) - t) \\ -wt \end{array} \right\} \quad \text{if} \quad \left\{ \begin{array}{c} \alpha \geq a(\theta, w) \\ \alpha < a(\theta, w) \end{array} \right\}. \tag{1}$$

Then Morris and Shin (2003) show that the cutoff value θ^* must satisfy

$$\int_0^1 g(\alpha, \theta^*, w)\, d\alpha = 0.$$

In other words, an agent whose belief about the actions of other agents can be represented by a uniform distribution for α on $[0, 1]$ must be indifferent between attacking and not attacking at θ^*.

Using expression (1), the equation above can be rewritten as

$$[1 - a(\theta, w)]\, w(e^* - f(\theta) - t) + a(\theta, w)(-wt) = 0,$$

and therefore the equilibrium value of θ^* will solve

$$(1 - a(\theta^*, w))(e^* - f(\theta^*)) = t. \tag{2}$$

This expression implicitly defines θ^* as a function of w. In the analysis that follows, the properties of this function play a critical role. The proposition below, which was first shown by Heinemann (2000), states that when speculators have more wealth, the set of states in which a devaluation occurs becomes strictly larger.

[6] In other words, equilibrium in the incomplete-information game is essentially unique, where the qualifier 'essentially' refers to the fact that either outcome is possible in the (zero-probability) event that θ exactly equals the cutoff point θ^*.

Proposition 1 *The equilibrium cutoff value θ^* is strictly increasing in the wealth level of speculators w.*

A simple proof of this result can be obtained by implicitly differentiating (2).

Continuing to focus on the limiting case as σ goes to zero, consider the equilibrium expected utility of a speculator who enters this market with wealth w_i, which in principle could be different from the wealth level w of other speculators. If the realization of θ is less than $\theta^*(w)$, a devaluation occurs and the speculator will gain the amount $(e^* - f(\theta) - t)$ for each unit of wealth she has available. Her final wealth level, and hence her consumption, will then be

$$w_i \left(1 + e^* - f(\theta) - t\right).$$

If the realization of θ is higher than $\theta^*(w)$, the speculator takes no action and simply consumes her wealth.[7] Before she receives her signal, therefore, the speculator's marginal utility of wealth is equal to

$$1 + \int_{-\infty}^{\theta^*(w)} \left(e^* - f(\theta) - t\right) \phi(\theta)\, d\theta \equiv \mu(w), \tag{3}$$

where ϕ is the density function of the prior distribution for θ.

It is important to keep in mind that this marginal utility is independent of a speculator's own wealth level w_i because she is risk neutral. However, it depends on the wealth level w of the other speculators in the market because w determines the set of states in which a devaluation occurs. The impact of a change in w on the marginal utility of an individual speculator is given by

$$\mu'(w) = \left(e^* - f(\theta^*) - t\right) \phi(\theta^*) \frac{d\theta^*}{dw}. \tag{4}$$

It follows immediately from (2) and Proposition 1 that this expression is strictly positive: the more wealth the other speculators have, the higher is the marginal value of wealth for an individual speculator. In other words, this model exhibits a complementarity in *wealth levels*: wealth is more valuable in equilibrium when others are wealthier. This result is crucial to the analysis that follows.

Proposition 2 *A speculator's marginal utility of wealth μ is strictly increasing in the average wealth w.*

[7] Note that when σ is arbitrarily small, the speculator's signal about θ is very accurate and hence she is able to attack in precisely the set of states in which a devaluation occurs.

Notice that this complementarity in wealth levels is distinct from, and in addition to, the usual complementarity in *actions* in the model, whereby attacking the currency is more attractive when other agents attack.

The derivative in (4) can be used to identify situations where this wealth complementarity is likely to have the largest impact. Of particular interest is the term $\phi(\theta^*)$, which is the height of the density function for θ measured at the cutoff point θ^*. Roughly speaking, this term measures the amount of uncertainty speculators have about whether or not a devaluation will occur. Suppose, for example, that the expected value of speculators' prior belief about θ is well above θ^* and, hence, a devaluation is very unlikely. Then $\phi(\theta^*)$ will be small and the impact of a change in w on a speculator's marginal utility will also be small. The same will be true if speculators expect θ to be well below θ^*, so that a devaluation is very likely to occur. In this case, each speculator's marginal utility of wealth will be high, but it will again not be very sensitive to changes in the wealth of others. The wealth complementarity is strongest when speculators believe θ will very likely fall somewhere near the cutoff point θ^*. In these situations, a moderate change in total wealth w can have a large impact on the probability of a crisis, which in turn leads to a large change in the marginal utility of wealth.

In a richer model, changes in total wealth would have other, general equilibrium effects. For example, the size of a devaluation might depend on the quantity of currency that was sold short, so that an increase in w would make a larger devaluation possible. This change would increase the prospective gain from attacking and, thus, raise an individual's marginal utility of wealth. Such an effect would reinforce the wealth complementarity described above. Conversely, wealthier speculators might borrow more of the domestic currency in order to sell it short, which could increase the cost of attacking the currency by driving up the domestic interest rate. This change would tend to decrease the magnitude of the wealth complementarity. While it would be interesting to study the effects of these and other changes to the basic model, the objective of the present paper is to derive the implications of the wealth complementarity for the contagion of crises across markets. The next subsection introduces a second currency market to the model so that such contagion can be studied.

2.2 Speculation on another currency

In the first period, speculators have an opportunity to attack another currency. This "foreign" currency can be interpreted as any market that agents perceive as a potential source of a contagious crisis. The foreign currency market meets before any of the activity described above takes place, including speculators receiving signals about the strength of the domestic economy. Each speculator begins the first period with one unit of wealth (a normalization).

The basic structure of the foreign currency market is exactly the same as that described above. The foreign government has pegged its exchange rate at e_F^* dollars per unit of foreign currency and must decide whether to maintain this peg or abandon it. The fundamental state of the foreign economy is denoted $\theta_F \in \mathbb{R}$, and speculators' initial belief about this variable is represented by a normal distribution with mean y_F and standard deviation τ_F. As above, the variable θ_F includes the effects of all influences on the value of the foreign currency other than the actions of the agents in this model. The variables θ and θ_F are uncorrelated; in other words, the economic fundamentals in the two countries are assumed to be completely unrelated.

If the peg is abandoned, the value of the foreign currency will be given by $f(\theta_F)$. The government receives a value v_F from maintaining the peg, and will do so if this value is greater than the cost $c_F(\theta_F, z_F)$, where z_F is the size of the speculative attack against the foreign currency. The same assumptions are placed on the functions f and c_F as in the previous subsection. Each speculator can choose to attack the foreign currency by selling it short, and short sales are again restricted by a speculator's wealth. Because she is risk neutral, a speculator will either attack the foreign currency with all of her wealth or not at all. There is a cost t_F for each unit of foreign currency sold short, so that the net gain of attacking per unit of wealth is $(e_F^* - f(\theta_F) - t_F)$ if the peg is abandoned and $(-t_F)$ if it is maintained.

The foreign currency market may differ from the domestic market in one key respect: the precision of the signals received by speculators about the state of the fundamentals θ_F. As described in Morris and Shin (2003), the prior belief about θ_F (or about θ in the domestic market) represents information that is *public*, as opposed to the *private* information in a speculator's idiosyncratic signal. The precision of speculators' signals can, therefore, be thought of as measuring the importance of private information relative to public information.[8] I argue below that the case where private information is unimportant in the foreign market is the most interesting for studying contagion across markets that are, in principle, unrelated.

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[8] See Hellwig (2002) for an in-depth analysis of public and private information in global games.

3 Self-Fulfilling Contagion

A *strategy* in the two-market game specifies (*i*) an action (attack or not attack) in the foreign market as a function of the speculator's signal in that market and (*ii*) an action in the domestic market as a function of both her signal and the realized fundamentals in the foreign market, as well as her signal in the domestic market. The analysis focuses on symmetric subgame-perfect equilibria, in which all speculators adopt the same strategy. In the cases studied below, all speculators have (essentially) the same information and, therefore, take the same action in the foreign currency market. Each thus carries the same wealth w, which may depend on the realized θ_F, to the domestic currency market. The unique equilibrium of this subgame, characterized by $\theta^* \left(w \left(\theta_F\right)\right)$, must then be played.

3.1 Defining contagion

The question of interest is under what conditions a crisis in the foreign currency market is transmitted to the domestic market. I will say that *contagion* occurs in a given equilibrium if the occurrence of a devaluation of the foreign currency raises the equilibrium probability of a devaluation in the domestic market; this statement is equivalent to the following definition.

Definition: *Contagion* is said to occur if a devaluation of the foreign currency strictly increases the equilibrium cutoff value θ^* in the domestic market.

The objective of the paper is to study how contagion can arise due to the self-fulfilling beliefs of market participants. Doing so requires that the two currency markets in the model be, at least in principle, unrelated. Capturing this idea requires not only assuming that the fundamentals θ and θ_F are uncorrelated, but also that speculators' information sets do not necessarily lead them to be active in both markets. If, for example, speculators have very precise information about both θ and θ_F, they will necessarily attack each currency in some states of the world. The outcome of the foreign market will then necessarily affect speculator behavior in the domestic market in some states and, hence, contagion will occur.[9] While this type of contagion may be of interest, its underlying cause is the assumed information structure of the model rather than self-fulfilling

[9] This approach would be very similar in spirit to those in Allen and Gale (2000), Goldstein and Pauzner (2004), Lizarazo (2005) and others. Those papers rely on a diversification motive for investors to operate in multiple markets rather than an information advantage; the important point, however, is simply that the two markets are fundamentally linked because the same set of agents naturally operates in each of them. In such a case, contagion of crises across markets will necessarily occur.

beliefs.

For studying the role of self-fulfilling beliefs, the information structure should instead be such that the speculators in the model are not naturally active in the foreign market. In the framework studied here, this requires that the signals speculators receive about foreign fundamentals not be very precise, so that attacking the foreign currency is always a risky action in equilibrium. To keep the model tractable, consider the extreme case where the idiosyncratic signal a speculator receives is completely uninformative. In other words, consider the limiting case where the standard deviation on the private signals goes to infinity and, hence, each speculator's posterior belief is equal to the common prior. In this case, the foreign market differs from the domestic market in two key respects: private information about θ_F is relatively unimportant and a speculator's belief about θ_F at the time the decision must be made is less precise.

Suppose further that parameter values are such that attacking the foreign currency is relatively unattractive to these speculators. To make this notion precise, let $\underline{\theta}_F$ be implicitly defined by

$$c_F\left(\underline{\theta}_F, 0\right) = v_F. \tag{5}$$

Then $\underline{\theta}_F$ is the state of fundamentals below which the foreign government will devalue even if no one attacks. Assume that the expected value of attacking the foreign currency when no one else attacks is negative, that is,

$$\int_{-\infty}^{\underline{\theta}_F} \left(e_F^* - f\left(\theta_F\right)\right) \phi_F\left(\theta_F\right) d\theta_F < t_F, \tag{6}$$

where ϕ_F is the density function for agents' beliefs about θ_F. Everything on the left-hand side of this inequality (including $\underline{\theta}_F$) is independent of t_F and, therefore, this condition simply requires that t_F not be too small. If this inequality were reversed, risk neutral speculators would always want to gamble in the foreign currency market. In such a case, links between the two markets would arise simply because both offer attractive trading opportunities to the same set of speculators and contagion between these markets would necessarily arise. Instead, condition (6) requires that, *a priori*, the foreign currency market represent an unattractive gamble to the speculators in the model.

Under this condition, there is an equilibrium of the model in which contagion does not occur. To see this, consider the problem of an individual speculator who believes that no other speculators will attack the foreign currency. If she were to attack, her expected wealth entering the domestic currency market would be

$$1+\int_{-\infty}^{\underline{\theta}_F}\left(e_F^*-f\left(\theta_F\right)\right)\phi_F\left(\theta_F\right)d\theta_F-t_F<1.$$

Her marginal utility of wealth in the domestic market will equal $\mu\left(1\right),$ as defined in (3), regardless of the realization of θ_F. She would, therefore, choose not to attack. Thus, there is an equilibrium where no speculator attacks the foreign currency and all enter the domestic currency market with a wealth level of one. The equilibrium cutoff in the domestic market is given by $\theta^*\left(1\right)$, independent of the realization of θ_F, and no contagion occurs. This discussion is summarized in the following proposition.

Proposition 3 *If* (6) *holds, there exists an equilibrium in which no speculator attacks the foreign currency and no contagion occurs.*

This result simply demonstrates that contagion between the two currency markets need not arise in equilibrium.

3.2 The contagion equilibrium

Now suppose that speculators believe contagion will occur. Could such beliefs be self-fulfilling? The next proposition shows that, for values of t_F that are not too large, the answer is affirmative. Define

$$\underline{t}_F\equiv\int_{-\infty}^{\underline{\theta}_F}\left(e_F^*-f\left(\theta_F\right)\right)\phi_F\left(\theta_F\right)d\theta_F,$$

so that condition (6) can be rewritten as $t_F>\underline{t}_F$. Then the result can be stated as follows.

Proposition 4 *If* (6) *holds, there exists* $\bar{t}_F>\underline{t}_F$ *such that* $t_F<\bar{t}_F$ *implies the existence of an equilibrium in which all speculators attack the foreign currency and contagion occurs.*

Proof: Suppose all speculators but one are attacking the foreign currency and consider the decision problem of the remaining speculator. The total size of the attack against the foreign currency in this case will be $z_F=1$ and, therefore, the foreign government will defend the peg if and only if

$$c_F\left(\theta_F,1\right)<v_F.$$

Let $\widehat{\theta}_F$ denote the value of θ_F for which the above relationship holds with equality; if no such value exists, let $\widehat{\theta}_F = \infty$. If almost all speculators are attacking the foreign currency, then a devaluation will occur for $\theta_F < \widehat{\theta}_F$ but not for $\theta_F > \widehat{\theta}_F$. Define $w(\theta_F)$ to be the wealth level of each speculator who attacks the foreign currency, measured after payoffs in the foreign market are realized. Then we have

$$w(\theta_F) = \left\{ \begin{array}{c} 1 + e^* - f(\theta_F) - t_F \\ 1 - t_F \end{array} \quad \text{if} \quad \begin{array}{c} \theta_F < \widehat{\theta}_F \\ \theta_F > \widehat{\theta}_F \end{array} \right\}. \tag{7}$$

If the speculator in question attacks the foreign currency, her wealth entering the domestic currency market will also be equal to $w(\theta_F)$. If she does not attack, her wealth level will be equal to one. Recalling that the marginal utility of wealth in the domestic market is given by $\mu(w)$ as defined in (3), her total expected utility if she attacks the foreign currency is

$$\int_{-\infty}^{\infty} \mu(w(\theta_F))\, w(\theta_F)\, \phi_F(\theta_F)\, d\theta_F$$

and her total expected utility if she does not attack is

$$\int_{-\infty}^{\infty} \mu(w(\theta_F))\, \phi_F(\theta_F)\, d\theta_F.$$

The expected gain from attacking can therefore be written as

$$\int_{-\infty}^{\widehat{\theta}_F} \mu(w(\theta_F))\,(e_F^* - f(\theta_F) - t_F)\,\phi_F(\theta_F)\, d\theta_F + \int_{\widehat{\theta}_F}^{\infty} \mu(w(\theta_F))\,(-t_F)\,\phi_F(\theta_F)\, d\theta_F. \tag{8}$$

Suppose we evaluate this expression at $\underline{t}_F$. Recall that $\underline{t}_F$ satisfies

$$\int_{-\infty}^{\underline{\theta}_F} (e_F^* - f(\theta_F) - \underline{t}_F)\,\phi_F(\theta_F)\, d\theta_F + \int_{\underline{\theta}_F}^{\infty} (-\underline{t}_F)\,\phi_F(\theta_F)\, d\theta_F = 0.$$

Using the definition of $\widehat{\theta}_F$ and condition (5), we clearly have $\widehat{\theta}_F > \underline{\theta}_F$. Furthermore, we know from (7) that $w(\theta_F) > 1$ holds for $\theta_F < \widehat{\theta}_F$ and $w(\theta_F) < 1$ holds for $\theta_F > \widehat{\theta}_F$. Together, these relationships imply that the value of (8) evaluated at $t_F = \underline{t}_F$ is strictly positive. Since (8) is continuous and monotone in t_F, there exists a value $\overline{t}_F > \underline{t}_F$ such that for any $t_F < \overline{t}_F$ there is an equilibrium in which all speculators attack the foreign currency.

The fact that contagion occurs in this equilibrium follows directly from (7) and Proposition 1. When all speculators are attacking the foreign currency, the wealth levels they carry into the domestic market depends on the realization of θ_F, in particular on whether or not θ_F is low enough that a devaluation occurs. Since the equilibrium cutoff value θ^* is strictly increasing in this wealth level, contagion must occur. ■

To see why this contagion equilibrium exists, notice that other speculators attacking the foreign currency makes attacking more attractive to an individual in two ways. First, the attack makes a devaluation of the foreign currency more likely, as reflected in the above calculations by the relationship $\widehat{\theta}_F > \underline{\theta}_F$. This effect represents the complementarity in actions that is standard in coordination games. The second, and more interesting, effect is that the attack by others will induce a correlation between the returns in the two markets, and this correlation will make attacking more attractive to an individual.

We can isolate this second effect, which derives from the complementarity in wealth levels, by imposing a stronger condition than (6) on the cost t_F. Define

$$\widehat{t}_F \equiv \int_{-\infty}^{\widehat{\theta}_F} \left(e_F^* - f\left(\theta_F\right)\right) \phi_F\left(\theta_F\right) d\theta_F. \tag{9}$$

When $t_F > \widehat{t}_F$ holds, the expected return to attacking the foreign currency is negative even when all other speculators are attacking. Nevertheless, equilibrium contagion can still occur. To see this, rewrite (9) as

$$\int_{-\infty}^{\widehat{\theta}_F} \left(e_F^* - f\left(\theta_F\right) - \widehat{t}_F\right) \phi_F\left(\theta_F\right) d\theta_F + \int_{\widehat{\theta}_F}^{\infty} \left(-\widehat{t}_F\right) \phi_F\left(\theta_F\right) d\theta_F \equiv 0 \tag{10}$$

and compare this equation to the expected utility gain from attacking the foreign currency in (8). We know that $w\left(\theta_F\right) > 1$ holds when a devaluation occurs in the foreign market (i.e., for $\theta_F < \widehat{\theta}_F$) and $w\left(\theta_F\right) < 1$ holds when it does not. Since $\mu\left(w\right)$ is a strictly increasing function, the expression in (8) puts more weight on the positive term and less weight on the negative term, relative to (10). Since the expression in (10) equals zero by definition, that in (8) must be strictly positive when evaluated at $\widehat{t}_F$. By continuity, therefore, the expected utility gain from attacking the foreign currency will be positive for an open interval of values of t_F above $\widehat{t}_F$, even though the expected *return* from attacking in these cases is negative. This discussion is summarized in the following corollary.

Corollary 1 *Contagion can occur even when, in equilibrium, the expected return to attacking the foreign currency is negative.*

Note that if $t_F > \widehat{t}_F$ holds, not attacking the foreign currency would be a dominant strategy if the effects of the domestic market (summarized by the μ function) were ignored. The foreign market would then have a unique equilibrium in which no speculator attacks. In other words, expectations-driven contagion can occur *even if each currency market has a unique equilibrium* when viewed in isolation.

This result clearly highlights the implications of the complementarity in wealth levels. Each speculator has an incentive to make the same risky trade(s) that others are making, because doing so shifts wealth into states of nature where a domestic devaluation is more likely. In this way, the wealth complementarity generates a complementarity in "outside" trading activity, whereby the attractiveness of a risky position increases with the number of other speculators that hold it.[10] The consequence, as shown in Corollary 1, is an equilibrium in which each speculator places a seemingly unattractive bet in another currency market simply because everyone else is doing so. This result would hold even if the outcome of the foreign market were exogenous, completely independent of the actions of the speculators in the model. In other words, it is not the case that a coordination motive *per se* in the foreign market is generating the multiplicity of equilibrium in this model. Rather, the complementarity in wealth levels in the domestic market *creates* a coordination motive if some risky trade is commonly available to the speculators.

3.3 A sunspots interpretation

The results above can be interpreted in a way that closely mirrors the classic paper of Cass and Shell (1983). They studied a standard Walrasian economy augmented to include "sunspots," a random variable that is completely *extrinsic* in the sense that it has no effect on economic fundamentals. They showed two ways in which sunspots can matter, one fairly obvious and the other much less so. First, suppose that the underlying economy (without sunspots) has multiple equilibria. Then the realization of the sunspot variable might act as a signal that coordinates agents on one equilibrium or another; the sunspot equilibrium constructed this way is simply a randomization over the equilibria of the underlying economy. The second, and more interesting, case is when agents can trade assets whose payoffs depend on the realization of the sunspot variable. In this case, they showed that even when the underlying economy has a unique equilibrium, there can be equilibria where sunspots affect allocations. If agents believe that the relative prices of commodities will

[10] This effect is similar in spirit to that studied by Hellwig and Veldkamp (2008), who show how a complementarity in actions can lead to a complementarity in the choice of what information to obtain.

depend on the sunspot state, they may want to use the asset market to transfer wealth across states. In some cases, this reallocation of wealth can cause the original expectations about prices to be fulfilled.

In the model presented here, one can interpret the devaluation state of the foreign currency as a "sunspot-like" variable.[11] Whether or not this currency devalues has no effect on the preferences of agents in the model nor on the fundamental state θ of the domestic economy. If speculators do not trade in the foreign currency market, contagion could only occur if the domestic currency market (in isolation) had multiple equilibria, so that events in the foreign market could act as a coordinating signal. This simple multiple-equilibrium view of contagion is analogous to the first type of Cass-Shell sunspot equilibrium described above. Discussion (and criticism) of the role of self-fulfilling beliefs in generating contagion of currency crises has focused on this particular view.

The incomplete-information approach used here, however, leads to a unique equilibrium in the domestic currency market in isolation and, hence, rules out this simple type of contagion. The contagion equilibrium identified in Proposition 4 instead resembles the second, richer type of Cass-Shell sunspot equilibrium: speculators' belief that the probability of a domestic devaluation will differ across "sunspot" states is self-fulfilling because it leads them to trade in the foreign currency market and thereby transfer wealth across these states. The analogy with Cass and Shell (1983) is not exact, of course. Their model requires heterogeneous agents for sunspot-contingent trade to occur in equilibrium; here the homogeneous speculators are implicitly trading with the foreign central bank in the "sunspot" market.[12] Nevertheless, the mechanisms behind the Cass-Shell sunspot equilibrium and the contagion equilibrium identified here are, at a fundamental level, very similar.

This type of mechanism also appears in DeMarzo *et al.* (2004, 2007), who study pure exchange economies with imperfect financial markets. They also identify situations where a sunspot-like equilibrium arises because an individual agent's marginal utility of wealth is increasing in the wealth levels of at least some other agents. In their models, this wealth complementarity arises because the agents will be competing for some scarce resource, such as consumption of a particular good or in a particular time period. An increase in the wealth of the other agents will drive up the

[11] See Spear (1989) for an interesting model in which the equilibrium price in each of two markets acts as a "sunspot-like" variable for the other market.

[12] In addition, Cass and Shell (1983) require that some agents be restricted from trading before the sunspot state is realized; otherwise the first welfare theorem would guarantee that sunspots do not matter. In the present model, all speculators can be granted access to the foreign market.

price of this resource, which (under some conditions on preferences) leads an individual to value wealth more at the margin. This mechanism differs from the one presented here, where an increase in the wealth of other speculators improves the available investment opportunities, which makes wealth more valuable to the individual. Despite this difference, the papers share in common the feature that a complementarity in wealth levels leads agents to “herd” into some risky trade and results in a sunspot-like equilibrium in the spirit of Cass and Shell (1983).

4 Properties of Equilibrium Contagion

It is fairly easy to see that the equilibria identified in Propositions 3 and 4 are the only symmetric, pure-strategy equilibria of the model.[13] In other words, it is not the case that contagion of crises is merely one of many possible correlations that may arise in equilibrium. Either there is no correlation between the outcomes of the two markets or a crisis in the foreign market will *raise* the equilibrium probability of a domestic crisis. This prediction derives from the fact that events in the foreign market can only affect the domestic currency if speculators choose to be active in both markets. When they are active in both markets, the structure of the model determines the correlation between the market outcomes.

This structure generates other interesting predictions associated with the contagion equilibrium as well. For example, Proposition 1 and expression (7) together show that a larger devaluation of the foreign currency will increase the set of state θ for which a domestic devaluation occurs, leading to the following corollary.

Corollary 2 *In the contagion equilibrium, the probability of a domestic currency crisis is strictly increasing in the size of the devaluation of the foreign currency.*

In other words, a large devaluation is more likely to prove contagious than a smaller one. Another prediction of the model is that the occurrence of a domestic currency crisis is negatively correlated with *domestic* economic fundamentals. When θ is higher, a larger devaluation of the foreign currency is required in order to provoke a domestic devaluation. Hence crises will occur

[13] When both of these equilibria exist, there is also a mixed strategy equilibrium (or, equivalently, an asymmetric pure strategy equilibrium) in which speculators are indifferent between attacking and not attacking the foreign currency. While this equilibrium is not studied here, it is easy to see that contagion occurs in the equilibrium through the same mechanism: some speculators will bring more wealth to the domestic market following a devaluation of the foreign currency.

less frequently when domestic fundamentals are strong and more frequently when fundamentals are weak.

Corollary 3 *In the contagion equilibrium, the probability of a domestic currency crisis is strictly decreasing in θ, the state of domestic fundamentals.*

It is important to bear in mind that neither of these relationships need hold under the simple multiple-equilibrium view of contagion. When the outcome of the foreign currency market acts only as a signal, a small devaluation could serve as the signal to attack the domestic currency just as well as a large one could. In addition, for all values of θ in the multiple equilibrium region, the likelihood of a domestic currency crisis would be independent of domestic fundamentals, as a domestic crisis would occur if and only if the appropriate signal is received.[14] The model here, in contrast, yields clear predictions that are consistent with the correlations observed in the data: a more severe currency crisis is more likely to prove contagious, and a domestic crisis is more likely to occur when domestic economic fundamentals are weak.

In addition to these qualitative properties of the contagion equilibrium, it is interesting to look at the potential magnitude of the contagion effect. How large can the impact of a foreign devaluation on the domestic currency market be? One way of measuring the size of this impact is to compare the probability of a domestic crisis when the foreign currency devalues with that when the foreign currency does not devalue. Specifically, define the magnitude of the contagion effect to be

$$\psi = \mathrm{Prob}\left[\theta < \theta^* \mid \theta_F < \theta_F^*\right] - \mathrm{Prob}\left[\theta < \theta^* \mid \theta_F > \theta_F^*\right],$$

where θ^* and θ_F^* are the equilibrium cutoff values for domestic and foreign fundamentals, respectively. In the equilibrium with no contagion, the probability of a domestic crisis is independent of events in the foreign market and, hence, ψ is zero. The results above show that ψ is always positive in the contagion equilibrium. The following proposition shows that ψ can be arbitrarily close to one; that is, the impact of the foreign market on the probability of a domestic crisis can be arbitrarily large in the contagion equilibrium.

Proposition 5 *For any $\lambda < 1$, there exist parameter values such that $\psi > \lambda$ holds in the contagion equilibrium.*

[14] This fact is commonly used to criticize multiple-equilibrium models. See, however, Ennis (2003) and Ennis and Keister (2005).

This proposition shows that the outcomes of the two currency markets can be almost perfectly correlated, even though there is no correlation at all between the economic fundamentals. To see why, suppose the prior belief about domestic fundamentals is concentrated around the cutoff point associated with a wealth level of one. That is, suppose y (the mean of the prior belief about θ) is equal to $\theta^* (1)$ and τ (the variance of this belief) is very small. In the contagion equilibrium, all speculators attack the foreign currency. If the foreign currency does not devalue, they lose money and enter the domestic market with a wealth level lower than one. By Proposition 1, the equilibrium cutoff in the domestic market will then be smaller than $\theta^* (1)$ and, hence, the likelihood of a domestic crisis will be small. The more concentrated the prior distribution is around $\theta^* (1)$ (that is, the smaller is τ), the lower the probability of a domestic crisis will be. If the foreign currency does devalue, on the other hand, the speculators will enter the domestic market with a wealth level greater than one. Again using Proposition 1, the equilibrium cutoff in the domestic market will now be larger than $\theta^* (1)$ and the likelihood of a domestic crisis will be large. By choosing a small value of $\tau,$ this probability can be made arbitrarily close to one. To summarize, when the domestic fundamentals are very likely to fall in the "critical region" around $\theta^* (1)$, the contagion effect will be very strong and the outcomes of the two markets will be highly correlated.

5 Discussion

Many aspects of the model studied here are fairly special, but they do not seem essential for the main message. The results rely on two basic features that are likely to appear in a wide range of environments. The first is that speculators take a larger position against the domestic currency when their wealth is higher. In the model, this feature derives from risk neutrality and the assumed short-sales constraint, but in a more general setting it could emerge from market imperfections that generate credit constraints or margin requirements for speculators. Such imperfections seem important in reality; hedge funds in particular are reported to gain access to additional credit and/or capital following periods of high returns (see, for example, Financial Stability Forum 2000, p.124). Alternatively, it could arise if speculators received imprecise private signals about domestic fundamentals, so that attacking the domestic currency is a risky undertaking, and their preferences exhibited decreasing absolute risk aversion.[15] There is also informal evidence from the Asian cri-

[15] See Guimaraes and Morris (2007) for a study of the interaction between risk aversion and changes in agents' wealth in a global-games model of currency crises.

sis that the decision making process itself in investment banks and hedge funds can lead to this type of behavior. Market participants commented that "when Thailand devalued, those who had been arguing for short positions had their positions within their institutions strengthened," which, in turn, led to more aggressive shorting of other currencies.[16]

The second key feature behind the results is that these larger positions in the domestic market make a devaluation of the domestic currency more likely. This relationship would likely appear in any model of currency attacks. The well-known model employed here demonstrates how these two features interact to generate the complementarity in speculators' wealth levels in a clear and transparent way. The features themselves, however, are likely to appear in a variety of settings, bringing with them the potential for the type of self-fulfilling contagion identified here.

Notice that the model predicts that existing financial links between markets are necessary for contagion to occur; this prediction is broadly consistent with the results in the empirical literature (see, for example, Kaminsky and Reinhard, 2000). Importantly, the model shows that empirical evidence on the sources of contagion should be interpreted with care. An empirical finding that financial links are useful predictors of the spread of crises does not imply that contagion is driven by underlying economic fundamentals nor that it is an inevitable outcome. Rather, these links could arise solely as a result of the (self-fulfilling) expectation that contagion will occur.

Determining whether observed instances of contagion were driven primarily by self-fulfilling beliefs or by some underlying, fundamental link between countries is a difficult task. The general problem is that observing behavior in one equilibrium of a model does not necessarily convey information about whether other equilibria exist. It might be difficult, for example, to distinguish the contagion equilibrium of the model presented here from the unique equilibrium of a model where speculators are necessarily active in both markets and contagion must occur. One possible approach would be to specify a richer model where contagion is due to self-fulfilling beliefs for some parameter values and to fundamental links for others. Estimating the parameters of the model may then shed light on the underlying source of contagion.[17] Further research is needed to understand what methodologies could be used to determine the role expectations have played in driving the observed spread of crises across countries.

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[16] NBER Project on Exchange Rate Crises in Emerging Market Countries, Session on Malaysia, http://www.nber.org/crisis/malaysia_report.html

[17] See Lubik and Schorfheide (2004) for a discussion of the issues involved in estimating models that potentially have multiple equilibria.

Angeletos and Werning (2006) and Hellwig *et al.* (2006) have shown how extending the standard model of currency attacks to allow agents to trade in some type of market can lead to multiplicity of equilibrium. The same type of result obtains here, but for a different reason. In the other papers, the asset price reveals information about the fundamental state of the domestic economy and/or the actions of other agents. Here, in contrast, the outcome of the foreign currency market contains no information about domestic fundamentals or other speculators' actions in the domestic market. Instead, the foreign market simply offers speculators an opportunity to change their wealth levels in a coordinated way. It is the combination of this common trading opportunity and the wealth complementarity in the domestic market that leads to multiplicity of equilibrium.

This comment points out that, strictly speaking, the first-period market in the model need not be a foreign currency market. The same results would obtain for any type of risky bet that is commonly available to speculators. However, there are several reasons why the most natural interpretation is as another currency market. One is related to investor behavior: individuals tend to favor a particular category (or categories) of assets, based on existing expertise, informational constraints, or perhaps behavioral rules. Barberis *et al.* (2005) refer to investors are operating within a particular "habitat" and provide evidence of investor behavior being consistent with this view. If currency speculators are going to coordinate their actions on some type of risky activity, it seems natural for another currency market to play this role.

Another key feature of the first-period market is that it must lead to potentially significant changes in the wealth of speculators over a relatively short period of time. As shown in the discussion following Proposition 5, the effects studied here are largest when the domestic fundamentals are likely to be in the critical area around θ^*. At such times, the attractiveness of attacking the foreign currency if others are doing so is very high. Suppose, however, that accumulating wealth in the first market takes some time and that, during this time, the domestic fundamentals may drift away from the critical zone. Such a delay would sharply diminish an individual's incentive to trade there. For this reason, the effects highlighted here would tend to be small if the outside trading opportunity is viewed as, say, holding stocks.[18] The effects will be substantially larger for an activity like attacking another currency, where profits can accumulate much more quickly.

[18] Moreover, a currency attack that was made possible by wealth gained through an increase in equity markets over several years would not likely be identified as an instance of "contagion." Such events may very well happen: strong returns in equity markets in the mid 1990s led to a substantial increase in the assets controlled by global hedge funds, which, in turn, may have affected the course of events during the Asian crisis (see, for example, Financial Stability Forum, 2000, pp. 111-113). However, such correlations seem less likely to be the result of the forward-

If the first-period market is indeed some foreign currency market, which currency would speculators coordinate on? The model is silent on this question, but reasoning similar to that used above can shed some light on the issue. Large changes in the wealth of others create the largest incentives for an individual agent to enter the foreign market. One might expect, therefore, for a currency where there is substantial uncertainty – and the possibility of sizable gain – to attract the most attention. Developing ways to address this question more formally is a potentially interesting topic for future research.

6 Concluding Remarks

While self-fulfilling expectations are commonly believed to play an important role in the spread of currency crises across countries, existing multiple-equilibrium explanations of contagion have many undesirable properties. This paper has shown how the incomplete-information approach of Morris and Shin (1998) can be used to generate a model in which contagion is driven by self-fulfilling expectations, but which nevertheless places restrictions on observable variables that are consistent with basic patterns observed in the data. These restrictions derive from the fact that, under the global-games approach, contagion can only occur when speculators' beliefs lead them to be active in both markets.

The key observation in the paper is that if speculators expect contagion to occur, they have an incentive to enter both markets in order to benefit from the correlation in outcomes. These actions then create a wealth channel through which a crisis is propagated across markets, fulfilling the original expectations. Although the immediate cause of contagion is this financial link between markets, the role of expectations is paramount; speculators only choose to enter both markets if they expect contagion to occur.

The model used here follows Obstfeld (1996), Morris and Shin (1998) and others in viewing currency crises as being caused by speculative attacks. Real world currency crises are complex phenomena and many of their features are obviously not captured by this model. For example, during times of crisis investors who hold real assets in a country tend to pull out, selling these local-currency denominated assets and placing further pressure on the value of the currency. Goldstein

looking behavior in the model, where agents are active in the outside market *because* they want to improve their ability to act in the domestic market. In contrast, this forward-looking behavior seems natural for speculators evaluating short-term positions in different currency markets.

and Pauzner (2004) have used a global-games model to show how contagion can occur through a wealth channel when investors facing losses in one market choose to sell holdings in another market in order to decrease the riskiness of their overall portfolio. The contagion in their model is not the result of self-fulfilling beliefs, however; it derives from the fact that investors initially chose to enter both markets in order to diversify their portfolios.

Introducing such investors into the type of model studied here may open up new channels for self-fulfilling contagion. Consider, for example, an agent holding an illiquid asset denominated in the foreign currency. Suppose he believes a devaluation of the foreign currency is likely, but he is unable to sell the asset or short the foreign currency. If he expects the outcome of the two currency markets to be correlated, he would have an incentive to short the domestic currency instead. Significant amounts of such *proxy hedging* reportedly took place during the Asian crisis (Financial Stability Forum, 2000, pp. 117-8). If other agents follow this strategy, their actions could increase the likelihood of a domestic devaluation and, potentially, justify the initial belief that the market outcomes are correlated. Integrating such effects into a formal model and studying the resulting potential for self-fulfilling contagion seems a promising area for future research.

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