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The Role of Domestic and Foreign Investors in a Simple Model of Speculative Attacks

Dennis P.J. Botman and Cees G.H. Diks

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Prepared by Dennis P.J. Botman and Cees G.H. Diks[1]

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Abstract

We introduce local and foreign investors in a simple model of speculative attacks. Local investors have less tolerance for overvaluation of the fixed exchange rate because they tend to incur lower costs when taking a short position and possess better information, and because of moral hazard created by discriminatory government guarantees. On the other hand, the prospect of higher taxation after a balance of payments crisis deters speculation by locals compared to foreign investors. Finally, the lower the degree of exchange rate pass-through, the more likely domestic investors are tp take the lead during capital flight.

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I.   Introduction

Recent theories of currency crises give a prominent role to the implications of asymmetric and private information for the behavior of speculators. These models, which belong to the class of global games, have been developed by Morris and Shin (2000) and Botman and Jager (2002). With the exception of Corsetti, Dasgupta, Morris, and Shin (2000) and Corsetti, Pesenti, and Roubini (2001), who in a global games setting analyze the role of large and small speculators for the timing of a speculative attack, these theories do not incorporate various other reasons, besides information, why investors are heterogeneous.

In this paper we develop a simple model of speculative attacks with incomplete information and several sources of investor heterogeneity. We relate these sources to investors being of domestic or foreign origin. The structure of the model is constrained by the complexity of the strategic interaction between these two types of investors, but brings to the front five reasons why the location of investors may give rise to heterogeneity: (i) access to information, (ii) costs of taking a short position, (iii) government guarantees, (iv) taxation, and (v) exchange rate pass-through. We will argue that these five elements create asymmetries between domestic and foreign investors regarding their incentives to speculate against a fixed exchange rate regime and that each party takes into account this asymmetry when formulating his or her own strategy.

Indeed, in the international finance literature in general there is much emphasis on the distinctive nature of domestic and foreign investors, with prominence being given to the role of information asymmetries. This relates to the presence of home bias as well as empirical studies that analyze the respective roles of domestic and foreign agents during episodes of domestic capital flight. Some studies find a prominent role for domestic investors as the following quote illustrates:

> the available data show that the pressure on Mexico's foreign exchange reserves during 1994, and in particular just prior to the devaluation, came not from the flight of foreign investors or from speculative position-taking by these investors, but from Mexican residents (IMF, 1995).

Frankel and Schmukler (1996, 1998) also report instances where local investors left their markets before international investors did at times of crises. Choe, Kho, and Stulz (2000) and Kim and Wei (1999) analyze data of South Korea to study trading patterns by resident and international investors, respectively. These papers report evidence for a short-lived informational advantage for individual stocks of domestic investors over foreign investors, specifically that international investors engage in positive feedback trading. Kaufmann, Mehrez, and Schmukler (1999) investigate whether enterprise managers have an information advantage about the countries they work on. Indeed, when looking at some recent crises countries, they find support for the hypothesis that local managers have private information. Also, they find that the local business communities anticipated the

crises in South Korea, Thailand, and Russia, but not in Indonesia and Malaysia. Choe, Kho, and Stulz (1999) find no support for the claim that the foreign equity investors played a destabilizing role during East Asia's emerging stock market crises.

Theoretical papers studying the flow of information and transparency have utilized different forms of heterogeneity. The interaction between informed and uninformed investors can easily give rise to herding behavior and contagion effects of a financial crises in one country on to another (see, for example, Calvo, and Mendoza, 1999).[2] Greenwald (1998) constructs a model with an asymmetry of information between well-informed local firm and bank managements and less informed outside investors. The information' based restrictions on financial markets are then shown to amplify rather than attenuate local disturbances.

However, one party having an information advantage is not the only reason why domestic and foreign investors might have different incentives to engage in capital flight. A second reason why location matters is that it affects the costs of taking a short position against a currency, with these costs usually being higher for foreign parties compared to their domestic counterparts. Typically, the cost of such a position for local players would be the opportunity cost of withdrawing their local currency deposits, which is equal to the deposit interest rate. For foreign players, however, the effective interest rate would be the local currency lending rate, which is usually higher than the deposit rate.

A third reason for asymmetric incentives for domestic and foreign agents can come from government guarantees. It is well known that private investment being, implicitly or explicitly, guaranteed by the government can give rise to moral hazard. Burnside, Eichenbaum, and Rebelo (2000) develop a model in which the government guarantees the repayment of loans made by foreign investors in the event of a devaluation. Chinn and Kletzer (2000) develop a model of twin crises in which the government offers deposit insurance as well as government guarantees that at least partially indemnify foreign investors.

Apart from informational differences, different costs of taking a short position, and government guarantees, a fourth reason why domestic and foreign investors can be distinguished is essentially the mirror image of government guarantees: taxation. A considerable amount of research has focused on tax and tax-like distortions that reduce returns and add risk to domestic financial and physical assets. An asymmetric probability of taxation could give rise to two-way capital flows, as is shown by Khan and Hague (1985); i.e., private capital flight occurring simultaneously with private foreign borrowing. The incentives for capital flight related to taxation issues could also come from the expectation of increased tax obligations created by the potential nationalization of private debt in the face of a financial crisis (see Eaton, 1987). If the government borrows abroad directly to finance public goods, the anticipation of increased tax obligations could also result in capital flight (see Eaton and Gersovitz, 1989). It is therefore plausible to assume

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[2] See Devenow and Welch (1996), for an overview of herding in financial economics. Benabou and Laroque (1992) focus on manipulation in assets markets by participants that have access to privileged information. Hirshleifer, Subrahmanyam, and Titman (1994) use a model to analyze trading behavior and equilibrium information acquisition when some investors receive common private information before others.

that domestic and international investors are treated, or affected, differently by taxes. It is also likely that taxes are increased after a financial crisis insofar as a cutoff from external financing makes tax smoothing difficult.

Finally, insofar as agents care about the real instead of the nominal rate of return on their investment, the extent to which exchange rate changes are passed on into higher prices is important for the incentives of domestic agents. After all, by forcing a collapse of the currency through speculation, they face a higher price level at home and the extent to which the real value of speculative profits is offset through this channel depends on the size of exchange rate pass-through.

As a result of these five reasons, domestic and foreign investors can have different incentives to speculate against a fixed exchange rate regime. In addition, given that their payoffs depend on each other's actions, the strategic interaction between each player type is central. Agents do not only need to form an expectation about the likely information received by the other type, but also need to take into account the other forms of heterogeneity mentioned above in deciding their own strategy.

In a nutshell, the implications of the above types of investor heterogeneity in our model is as follows. Investors have an incentive to speculate because the exchange rate can be overvalued. The fact that overvaluation of the currency is crucial during episodes of capital flight is confirmed by the empirical evidence reported in Collier, Hoeffler, and Pattillo (1999).[3] As a result, the moment of speculation in our model is determined by a threshold value of the equilibrium exchange rate compared to the fixed exchange rate. When faced with a run against its currency, the home country becomes insolvent both because long-term investments can only be liquidated at a loss and because servicing external debt becomes too expensive. In the presence of a fixed exchange rate regime, the asset-liability and maturity mismatch facing the borrowing bank provides a subtle role for overvaluation of the exchange rate. In case the currency is perceived to be overvalued by a certain degree, it becomes optimal for investors to speculate against the fixed parity. However, they need to weigh the resulting speculation profits against the liquidation value of their claims, which has declined compared to their original investment. The expected profits from speculation depend critically on the number of speculators participating, the costs of taking a short position, as well as how accurate the agents can predict the extent of overvaluation. The expected cost of speculating, in terms of making a loss on the value of one's original investment, depends crucially on the other party's strategy, on whether or not this investment is guaranteed, to what extent the remaining claim is taxed, as well as the degree to which its real value declines after a devaluation.

This paper is organized as follows. In Section *II* we develop the model and clarify the effect of heterogeneity on the expected payoff functions of local and foreign investors. Next,

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[3] Although our model focuses on return differential incentives as the cause for capital flight, other reasons for capital flight are related to either portfolio diversification incentives or relative risk incentives (see Collier, Hoeffler, and Pattillo, 1999). About the latter, for example Stiglitz (1998) argues that the high correlation between returns on human and physical capital within a country means that domestic investors are less diversified and therefore should act in a more risk-averse manner.

in Section III we abstract from heterogeneity and solve for the critical value of the equilibrium exchange rate at which moment speculating becomes a dominant strategy for both player types. We first solve this symmetric model for the perfect information case, which proves a convenient methodology to solve the more complicated case in which speculators instead receive a noisy signal about the equilibrium exchange rate. In Section IV we analyze the general model with investor heterogeneity. Section V concludes.

II.   The Baseline Model

A.   The Agents

The model features home and foreign investors, with a fraction ϕ and $(1 - \phi)$, respectively, who have a claim outstanding against the home country. Throughout the paper we interpret this claim to be a loan to a commercial bank, although nothing stands in the way of the borrower being a firm or the government. Investors lend in their own currencies. Despite the fact that agents have invested in the home country, they continue to have the option of speculating against the home currency. This implies that in our setting speculation is not a one-sided bet, but each agent needs to take into account the effect of its speculation on the value of its claims. Apart from distinguishing investors in terms of location, the setup in this paper is therefore different from standard models of speculative attacks in which agents usually hold no claims in the country whose currency they attack, but only take a short position instead. Constructing the model in such a way that an agent has a dual role as an investor and a speculator has the advantage of enabling us to study heterogeneity between local and foreign players in a game-theoretic framework that is simple enough to generate some analytic results.

The incentive to speculate follows from the assumption that the home country has a fixed exchange rate regime, while the equilibrium or so-called shadow floating exchange rate, e_t, may deviate from this fixed value $\bar{e}$. The exchange rate is defined as the number of home currency per unit of foreign currency (i.e., a value of e_t below $\bar{e}$ indicates overvaluation of the fixed exchange rate). We do not model the behavior of e_t explicitly, and simply treat it as an exogenous variable following a (geometric) random walk. We focus on determining a critical value for e_t such that investors refuse to roll over their loans and start speculating.

Given that the bank in the home country has borrowed ϕ in local currency and $(1 - \phi)$ in foreign currency, its liabilities, l_t are:

$$l_t = \phi + \frac{(1 - \phi)}{e_t} \tag{1}$$

with $0 \leq \phi \leq 1$. The bank pays a real rate of return equal to r to each investor, regardless of origin. In addition, the bank is assumed to invest its borrowing into liquid and illiquid projects, with a fraction of λ and $(1 - \lambda)$ respectively. In case the latter assets are

liquidated, a fraction k of its value will be lost. With A representing the assets of the bank in the home country, we have:

$$A = \lambda + (1 - \lambda) k \qquad (2)$$

and $0 \le k \le 1$. In the absence of speculation, the assets and liabilities of the bank match. After all, in this case the fixed exchange rate regime survives, $e_t = \bar{e} = 1$, and the bank doesn't need to recall any illiquid investments it has made to service its debt. The assets also earn a real rate of return equal to r which is passed on to investors (with the foreign interest rate, r^*, normalized to zero).

B. The Structure of the Game

The central bank in the home country follows a very mechanical rule: it stands ready to use all its foreign exchange reserves, denoted by R, in the defense of the fixed exchange rate regime. Once the central bank runs out of reserves, the peg is abandoned and the currency floats freely forever at the value e_t. Also, the borrowing bank in the home country is assumed to follow a stylized rule: as soon as the exchange rate depreciates, the bank is insolvent, liquidates all its assets, and distributes them equally to all players. The decision process of home and foreign players is central to our approach. At each point in time, each investor needs to determine whether to continue to invest or whether to take a short position against the domestic currency instead. If a player decides to speculate, he or she needs to take into account that this can affect the real value of its claims on the bank. As a result, the structure of the game is as follows:

- Local and foreign investors decide simultaneously whether to continue to invest or to speculate against the fixed exchange rate regime based on their respective expected real rates of return following the receipt of the idiosyncratic signal about e_t. We assume that local players (and also foreign players) share their information and decide as a group whether to roll over their investments or, instead, to speculate against the fixed exchange rate. We thus treat the locals and the foreigners as two *representative agents* with possibly different information quality.

- If both players continue to invest, the fixed exchange rate regime remains in place, the bank is solvent, each player receives a real rate of return equal to r, and the game moves on to the next period where step (1) above is repeated until a sufficiently large fraction of local and/or foreign players decide to take a short position against the currency.

At most, speculators can short all the liquid assets, λ, and convert them into foreign currency. Whether this results in the depletion of the stock of foreign exchange reserves depends on the size of R relative to λ. In case $R > \lambda$ the fixed exchange rate regime will survive forever, but it needs to be abandoned in the more interesting case where $R \le \lambda$.

For simplicity we assume $R = \lambda$. Furthermore, we assume that $R \leq \min(\phi, (1 - \phi))$. This assumption implies that the short positions of either home or foreign investors will be sufficient to cause the collapse of the fixed exchange rate regime.

C.   Introducing Heterogeneity

Heterogeneity of home and foreign players affects their respective payoff functions and as a result their tolerance for overvaluation of the exchange rate. In our model, location of agents matters because of five considerations.

(1) Cost of a Short Pposition.

Taking a short position implies borrowing liquid assets from the bank in the home country at an interest rate r. These are denominated in the home currency and converted into foreign currency via the reserve position of the central bank. As a result, players have no incentive to take a larger short position than is necessary to deplete the stock of reserves. Thus, the size of the short position is equal to $\frac{R}{\phi}$ for home players if only they speculate, $\frac{R}{(1-\phi)}$ for foreign players if only they speculate, and $\frac{R}{\phi+(1-\phi)}$ for each party if both speculate. We assume an additional component to the cost of taking a short position, which in real terms is equal to c^h for local players and c^f for foreign players. Consequently, the total cost of taking a short position for local players if only they speculate, C^h equals:

$$C^h = r\frac{R}{\overline{p}\phi} + c^h \tag{3}$$

where $\overline{p}$ is the price level that prevails in the home country when the exchange rate is fixed (with $\overline{p}^*$ similarly defined for the foreign country). The total cost for foreign players if only they speculate equals:

$$C^f = r\frac{R}{\overline{p}^* (1 - \phi)} + c^f \tag{4}$$

and if both speculate their respective costs are given by:

$$C^h = r\frac{R}{\overline{p}} + c^h \quad \text{and} \quad C^f = r\frac{R}{\overline{p}^*} + c^f \tag{5}$$

It is important to realize that, after the short positions are settled, the bank again has A even though the country no longer has foreign exchange reserves and the exchange rate will be e_t and no longer $\overline{e}$.

(2) Quality of Information.

Concerning the signal about e_t, we consider a shadow exchange rate which follows a discrete time, discrete valued geometric random walk:

$$\log e_t - \log e_{t-1} = u\epsilon_t, \tag{6}$$

where $\{\epsilon_t\}$ is a sequence of independent, identically distributed random variables with $P[\epsilon_t = 1] = P[\epsilon_t = -1] = \frac{1}{2}$. That is, at each time, with probability $\frac{1}{2}$ the log exchange rate changes by either $+u$ or $-u$, each with probability $\frac{1}{2}$. At time $t-1$, e_{t-1} is public information, and both players (the local and foreign representative agents) receive signals regarding fundamentals that will determine the future exchange rate e_t. We model this with a signal $s_{i,t}$, $i \in \{h, f\}$ which is either $+1$ or -1, representing predictions $e_{t-1}e^u$ and $e_{t-1}e^{-u}$ for the future exchange rate, respectively. Differences in the accuracy of the two signals, as well as their dependence, are represented by the statistical properties of the signals. We assume that $s_{i,t}$ is independent of past signals and conditionally independent of the signal of the other party, given the true value of e_t. The signals for the home agents and foreign agents have probabilities q^h and q^f of being correct, respectively. Without loss of generality we may consider $q^h, q^f > \frac{1}{2}$, since otherwise an agent would use $1 - s_{i,t}$ as a signal. Typically we have in mind situations where the quality of the home signal is more accurate than that of the foreign signal, $q^h > q^f$.

(3) Government Guarantees.

We assume that investment of home players is guaranteed in such a way that they will always receive the nominal value of their initial investment, which is equal to unity. As a result, the government guarantee, denoted by g equals,

$$g = 1 - A = 1 - \lambda - (1 - \lambda)k \tag{7}$$

such that domestic players receive unity in total.

(4) Higher post-attack taxes.

To illustrate the implications of this form of heterogeneity, we will assume that domestic agents need to pay a tax on their claims on the bank after a successful attack, regardless of who initiated this attack. Denoting the tax rate by τ and using eq. (7), it follows that domestic players receive in real terms:

$$A_t^h = (1 - \tau)\frac{(A + g)}{p_t} = (1 - \tau)\frac{(\lambda + (1 - \lambda)k + g)}{p_t} \tag{8}$$

and foreign agents:

$$A_t^f = \frac{A}{p_t^*} = e_t\frac{(\lambda + (1 - \lambda)k)}{p_t^*} \tag{9}$$

where p_t^* is the price index in the foreign country and p_t is the price index in the home country.

(5) Exchange Rate Pass-Through.

Agents maximize real rates of return in their own currency. Therefore, the relationship between the exchange rate and the price level matters. If pass-through is smaller, the decline in the real value of the home agent's investment is smaller as well. Therefore, home agents benefit from smaller values of q. In general the level of pass-through is defined as:

$$q = e_t \frac{p_t}{p_t^*} \tag{10}$$

If $e_t = \bar{e} = 1$ we assume $p_t = \bar{p} = 1$. In addition, we assume that the foreign price level is constant, $p_t^* = \bar{p}^* = 1$. Then the relationship between changes in the exchange rate and changes in prices is given by:

$$e_t - \bar{e} = q \left(\frac{1}{p_t} - \frac{1}{\bar{p}} \right) \tag{11}$$

with $q = 1$ in the special case of full pass-through. Eq. (11) allows us to express the return from a short position in real terms. If only local investors speculate, their real profit from such a short position equals $\frac{1}{e_t} \frac{(\bar{e} - e_t)}{\phi p_t} R - C^h$. Foreign players also borrow the home currency and repay the loan at the exchange rate that prevails after the attack. Thus, if only foreign investors take a short position against the domestic currency, each investor's payoff from this position equals $\frac{(\bar{e} - e_t)}{(1 - \phi) p_t^*} R - C^f$. If both take a short position simultaneously, their respective payoffs are: $\frac{1}{e_t} \frac{(\bar{e} - e_t)}{p_t} R - C^h$ and $\frac{(\bar{e} - e_t)}{p_t^*} R - C^f$.

D. The Payoff Functions

We now have all ingredients in place to construct the gross payoffs for home agents, denoted by $\pi_t^{h,f}$, and for foreign agents, denoted by $\pi_t^{*h,f}$, with $h, f \in \{i, s\}$ depending on whether home or foreign players invest (i) or speculate (s). The space of pure strategies is $\{h, f\} \in \{i, i\}, \{s, i\}, \{i, s\}, \{s, s\}$. The real gross payoff to home and foreign agents if both continue to invest is equal to:

$$\pi_t^{i,i} = \pi_t^{*i,i} = r \tag{12}$$

Using (8), the gross payoff for home agents if only they speculate equals:

$$\pi_t^{s,i} = \frac{1}{e_t} \frac{(\bar{e} - e_t)}{\phi p_t} R - r \frac{R}{\bar{p} \phi} - c^h + (1 - \tau) \frac{(\lambda + (1 - \lambda) k + g)}{p_t} \tag{13}$$

in which case foreign agents receive, from (9):

$$\pi_t^{*s,i} = e_t \frac{(\lambda + (1 - \lambda) k)}{p_t^*} \tag{14}$$

If home agents invest, while foreign players speculate, their payoffs are equal to:

$$\pi_t^{i,s} = (1 - \tau) \frac{(\lambda + (1 - \lambda) k + g)}{p_t} \tag{15}$$

$$\pi_t^{*i,s} = \frac{(\bar{e} - e_t)}{(1 - \phi) p_t^*} R - r \frac{R}{\bar{p}^* (1 - \phi)} - c^f + e_t \frac{(\lambda + (1 - \lambda) k)}{p_t^*} \tag{16}$$

The payoff to home and foreign agents in case both speculate equals, respectively:

$$\pi_t^{s,s} = \frac{1}{e_t} \frac{(\bar{e} - e_t)}{p_t} R - r \frac{R}{\bar{p}} - c^h + (1 - \tau) \frac{(\lambda + (1 - \lambda) k + g)}{p_t} \tag{17}$$

$$\pi_t^{*s,s} = \frac{(\bar{e} - e_t)}{p_t^*} R - r \frac{R}{\bar{p}^*} - c^f + e_t \frac{(\lambda + (1 - \lambda) k)}{p_t^*} \tag{18}$$

In summary, the payoff matrix in terms of gross return per invested unit of an investor's own currency, denominated in the investor's own currencies, is given in Table 1.

Table 1. Payoff Matrix in the General Model

$(\pi_t^{h,f}, \pi_t^{*h,f})$	F invests	F speculates
H invests	$(1 + r)$, $(1 + r)$	$\pi_t^{i,s}$, $\pi_t^{*i,s}$
H speculates	$\pi_t^{s,i}$, $\pi_t^{*s,i}$	$\pi_t^{s,s}$, $\pi_t^{*s,s}$

III.   The Symmetric Equilibrium

Before analyzing the model with heterogeneity of investors we illustrate its properties by considering the symmetric case where home and foreign agents are identical. This is the case when their respective size is the same ($\phi = \frac{1}{2}$), the costs of taking a short position are equal ($c^h = c^f$), the quality of information is the same ($q^h = q^f$), there are no government guarantees ($g = 0$), no taxes ($\tau = 0$), and full pass-through of exchange rate changes into prices ($q = 1$). Then, the payoff matrix becomes as in Table 2.

It can be readily verified that the payoff matrix is symmetric as $\frac{1}{e_t p_t} = \frac{1}{p_t^*}$. Also, if the parameters are such that speculation is optimal for one party, then the best response by the other party is to speculate also, so that speculation by both parties (S, S) is a Nash equilibrium. We assume that the initial shadow exchange rate satisfies $e_0 \geq e^* + u$, so that

Table 2. Payoff Matrix in the Symmetric Case

$(\pi_t^{h,f}, \pi_t^{*h,f})$	F invests	F speculates
H invests	$(1+r),$ $(1+r)$	$(\frac{\lambda+(1-\lambda)k}{p_t}),$ $(\frac{(1-e_t)}{p_t^*}2R - r2R - c^f + e_t\frac{(\lambda+(1-\lambda)k)}{p_t^*})$
H speculates	$(\frac{1}{e_t}\frac{(1-e_t)}{p_t}2R - r2R - c^h + \frac{\lambda+(1-\lambda)k}{p_t}),$ $(e_t\frac{(\lambda+(1-\lambda)k)}{p_t^*})$	$(\frac{1}{e_t}\frac{(1-e_t)}{p_t}R - rR - c^h + \frac{\lambda+(1-\lambda)k}{p_t}),$ $(\frac{(1-e_t)}{p_t^*}R - rR - c^f + e_t\frac{(\lambda+(1-\lambda)k)}{p_t^*})$

initially (I, I) is also a Nash equilibrium. As a result, there are multiple Nash equilibria, which in a strict game-theoretical setting would lead to a coordination problem. For simplicity, we abstract from this issue here since we consider an initial state where all agents are already investing and merely decide whether to roll over their investments or not. The main problem is therefore to find the conditions under which (I, I) ceases to be a Nash equilibrium. The perfect and incomplete information cases are treated separately.

A. Perfect Information

We define the critical exchange rate e^* as the largest possible value the exchange rate can take such that (I, I) continues to be a Nash equilibrium when $e_t > e^*$. Notice that, by the above assumptions, $e^* \leq 1$.

By comparing the payoff for deviating alone $(\pi_t^{*i,s} = \pi_t^{s,i})$ with that of continuing to invest $(1+r)$, one finds that deviating becomes optimal as soon as the following condition is satisfied:

$$e_t \left[\lambda + (1-\lambda)k - 2R\right] > 1 + r - (1-r)2R + c. \tag{19}$$

Since we assumed this relation not to hold for $e_t = 1$, and the payoffs are valid only in case the exchange rate collapses, we focus on solutions of the form:

$$0 < e_t < e_{\text{PI}}^* < 1$$

with e_{PI}^* denoting the critical exchange rate in the case of perfect information. The middle inequality states that the condition in eq. (19) must be of the form $e_t < e_{\text{PI}}^*$, which implies $\lambda + (1-\lambda)k - 2R < 0$, or $R > \frac{\lambda+(1-\lambda)k}{2}$, giving:

$$e_t < e_{\text{PI}}^* = \frac{(1-r)2R - 1 - r - c}{2R - \lambda - (1-\lambda)k}, \tag{20}$$

where the denominator is positive. Requiring $0 < e_{\text{PI}}^* < 1$ gives the additional condition:

$$\lambda + (1-\lambda)k < 1 + r + c + 2rR < 2R.$$

Because $0 < \lambda + (1 - \lambda)k < 1$ and $1 + r + c + 2rR > 1$, the first inequality is always satisfied, while the second can be rephrased as:

$$R > \frac{1 + r + c}{2(1 - r)}.$$

As long as fundamentals have not deteriorated to the extent as given by eq. (20), we are in the business as usual case as in Caplin and Leahy (1994): investors all decide to roll over existing loans and speculation is silent. It can also be inferred that the depreciation of the exchange rate at which moment speculating becomes a dominant strategy is smaller if (i) the real interest rate is lower; (ii) the costs of taking a short position are smaller; (iii) the liquidation value of existing claims is larger (higher λ or k); and (iv) the amount of international reserves devoted to defending the exchange rate is larger.[4]

B.   Incomplete Information

Local and foreign agents face uncertainty about $i)$ the true value of the exchange rate e_t, and $ii)$ the signal of the other player. Since the agent is not certain about his opponent's signal, the resulting game is an incomplete information game. Applying Harsanyi's (1967,68) "nature moves first" approach, we can rewrite this game in terms of a complete, imperfect information game. In such a game there are two types of home players, denoted by H^+ and H^-, depending on the sign of their signal $+$ or $-$. Similarly, there are two types of foreign players, F^+ and F^-, respectively. A strategy now consists of a pair of actions for each type. For example a strategy in which player H^+ invests with probability α_1, and player H^- with probability α_2 can be represented as $\{\alpha_1, \alpha_2\}$.

In the symmetric case, the payoffs for the two possible exchange rates, $e_t = e_{t-1}e^{\pm u}$, are as given in Table 2. However, agents now face uncertainty about e_t when they make their decisions. Only e_{t-1} is known, and e_t given e_{t-1} is a random variable, regarding which they received a signal $s_{i,t}$, known to be correct with probability $q_h = q_f = q_0$.

With e_{PI}^* as in eq. (20) if both $e_{t-1}e^u$ and $e_{t-1}e^{-u}$ are larger than e_{PI}^*, it is not optimal for either party to speculate. Similarly, if both $e_{t-1}e^u$ and $e_{t-1}e^{-u}$ are smaller than e_{PI}^*, both players speculate regardless of the signal received. Therefore, the interesting case is,

$$e_{t-1}e^{-u} < e_{\text{PI}}^* < e_{t-1}e^u.$$

with e_{PI}^* as in eq. (20).

In order to get some insight into the extended form game, consider player H^+, the home player with a positive signal. The expected payoff for H^+ to investing, given player F's

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[4]The latter conclusion is conditional on our assumption that regardless of the amount of reserves a speculative attack by either party is always successful and follows from taking the first derivative of e_{PI}^* with respect to R which is positive as $(1 - r)[\lambda + (1 - \lambda)k] < (1 + r + c)$.

strategy $(\alpha_F(I|F^+), \alpha_F(I|F^-))$ is:

$$P[+u, F^+|H^+]\{\alpha_F(I|F^+)\pi_{t,+}^{i,i} + (1 - \alpha_F(I|F^+))\pi_{t,+}^{i,s}\}$$
$$+P[-u, F^+|H^+]\{\alpha_F(I|F^+)\pi_{t,-}^{i,i} + (1 - \alpha_F(I|F^+))\pi_{t,-}^{i,s}\}$$
$$+P[+u, F^-|H^+]\{\alpha_F(I|F^-)\pi_{t,+}^{i,i} + (1 - \alpha_F(I|F^-))\pi_{t,+}^{i,s}\}$$
$$+P[-u, F^-|H^+]\{\alpha_F(I|F^-)\pi_{t,+}^{i,i} + (1 - \alpha_F(I|F^-))\pi_{t,-}^{i,s}\},$$

where $\pi_{t,+}^{ab}$ denotes the payoff that player H obtains if the exchange rate increases, and H plays a and F plays b. Similarly, $\pi_{t,-}^{ab}$ denote the payoff for player H in case of decreased fundamentals, under the actions a and b of player H and F, respectively. For instance, from comparison with Table 2 one observes that $\pi_{t,+}^{i,s} = (\lambda + (1 - \lambda)k)e_{t-1}e^{+u}$, and $\pi_{t,-}^{i,s} = (\lambda + (1 - \lambda)k)e_{t-1}e^{-u}$.

Crucial for the expected payoffs for player H are the joint conditional probabilities on the direction of change of the fundamental, and player F's signal. These probabilities are given by

$$P[+u, F^+|H^+] = P[+u, F^+, H^+]/P[H^+] = \tfrac{1}{2}q_f q_h / \tfrac{1}{2} = q_f q_h$$
$$P[-u, F^+|H^+] = P[-u, F^+, H^+]/P[H^+] = (1 - q_f)(1 - q_h)$$
$$P[+u, F^-|H^+] = P[+u, F^-, H^+]/P[H^+] = (1 - q_f)q_h$$
$$P[-u, F^-|H^+] = P[-u, F^-, H^+]/P[H^+] = q_f(1 - q_h)$$

In short-hand notation, the expected payoff for player H^+ from investing, given the strategy of the foreign player, is

$$q_f q_h \{\alpha_F^+ \pi_{t,+}^{i,i} - (1 - \alpha_F^+)\pi_{t,+}^{i,s}\}$$
$$+(1 - q_f)(1 - q_h)\{\alpha_F^+ \pi_{t,-}^{i,i} - (1 - \alpha_F^+)\pi_{t,-}^{i,s}\}$$
$$+(1 - q_f)q_h\{\alpha_F^- \pi_{t,+}^{i,i} - (1 - \alpha_F^-)\pi_{t,-}^{i,s}\}$$
$$+q_f(1 - q_h)\{\alpha_F^- \pi_{t,-}^{i,i} - (1 - \alpha_F^-)\pi_{t,+}^{i,s}\}.$$

Similarly, the expected payoff for player H^+ from speculating, given the opponent's strategy, is

$$q_f q_h \{\alpha_F^+ \pi_{t,+}^{s,i} - (1 - \alpha_F^+)\pi_{t,+}^{s,s}\}$$
$$+(1 - q_f)(1 - q_h)\{\alpha_F^+ \pi_{t,-}^{s,i} - (1 - \alpha_F^+)\pi_{t,-}^{s,s}\}$$
$$+(1 - q_f)q_h\{\alpha_F^- \pi_{t,+}^{s,i} - (1 - \alpha_F^-)\pi_{t,-}^{s,s}\}$$
$$+q_f(1 - q_h)\{\alpha_F^- \pi_{t,-}^{s,i} - (1 - \alpha_F^-)\pi_{t,+}^{s,s}\}.$$

By comparing the expected payoffs of investing and speculating, we can determine player H^+'s best response to any given strategy $\{\alpha_F^+, \alpha_F^-\}$ of the foreign players. Similarly, one can determine the best response for the home agent H^-, as well as for players F^+ and F^-.

A Nash equilibrium is defined as a pair of strategies $(\{\alpha_H^+, \alpha_H^-\}, \{\alpha_F^+, \alpha_F^-\})$ in which each agent of each type plays best response to the strategy of the other player. That is, if α_H^+ is the best response of player H^+ to $\{\alpha_F^+, \alpha_F^-\}$, α_H^- is the best response of player H^- to $\{\alpha_F^+, \alpha_F^-\}$. As in the full information case, the game has a Nash equilibrium in pure strategies, denoted by $(\{0, 0\}, \{0, 0\})$, in which both players speculate. To see this, it suffices to verify from Table 2 that regardless of the true shadow exchange rate e_t it is

always optimal for a player to speculate if the other player does so with certainty. Therefore, as in the full information case, speculation by both players is a Nash equilibrium.

Investing by both players of both types is denoted by the pair of strategies $(\{1,1\}, \{1,1\})$. As soon as it becomes optimal for one of the types of one of the players to deviate, this pair of strategies is no longer a Nash equilibrium. For player H^+ we obtain the following condition for speculating:

$$
\begin{aligned}
q_f q_h \pi_{t,+}^{i,i} + (1 - q_f)(1 - q_h)\pi_{t,-}^{i,i} & \\
+ (1 - q_f)q_h \pi_{t,+}^{i,i} + q_f(1 - q_h)\pi_{t,-}^{i,i} & \\
< \quad & q_f q_h \pi_{t,+}^{s,i} \\
& + (1 - q_f)(1 - q_h)\pi_{t,-}^{s,i} \\
& + (1 - q_f)q_h \pi_{t,+}^{s,i} \\
& + q_f(1 - q_h)\pi_{t,-}^{s,i}
\end{aligned}
$$

or:

$$
q_h \pi_{t,+}^{i,i} + (1 - q_h)\pi_{t,-}^{i,i} < q_h \pi_{t,+}^{s,i} + (1 - q_h)\pi_{t,-}^{s,i}.
$$

By using Table 2 this can be seen to give the following condition under which it is optimal for H^+ to speculate:

$$
1 + r < (1 - r)2R - c + e_{t-1}\left(\lambda + (1 - \lambda)k - 2R\right)\left(q_h e^u + (1 - q_h)e^{-u}\right). \tag{21}
$$

For player H^- it is optimal to speculate if:

$$
1 + r < (1 - r)2R - c + e_{t-1}\left(\lambda + (1 - \lambda)k - 2R\right)\left(q_h e^{-u} + (1 - q_h)e^u\right) \tag{22}
$$

Both these instability conditions are similar to those found in the perfect information case (eq. 19) provided that we replace e_t by $e_{t-1}[q_h e^u + (1 - q_h)e^{-u}]$ and $e_{t-1}[q_h e^{-u} + (1 - q_h)e^u]$, respectively. We conclude that $(\{1,1\}, \{1,1\})$ is no longer a Nash equilibrium if either $e_{t-1}[q_h e^u + (1 - q_h)e^{-u}] < e_{PI}^*$ or $e_{t-1}[q_h e^{-u} + (1 - q_h)e^u] < e_{PI}^*$. Because $q_h e^{-u} + (1 - q_h)e^u$ and $q_h e^u + (1 - q_h)e^{-u}$ are both positive, and $q_h e^{-u} + (1 - q_h)e^u < q_h e^u + (1 - q_h)e^{-u}$, the second inequality is sufficient for instability. This was to be expected, since agents receiving a negative signal will deviate earlier (i.e. have a larger critical value of e_{t-1} below which they speculate). In summary, in the symmetric case, with $q_h = q_f = q_0$, investing always, $(\{1,1\}, \{1,1\})$, ceases to be a Nash equilibrium if:

$$
e_{t-1} < \frac{e_{PI}^*}{q_0 e^{-u} + (1 - q_0)e^u},
$$

Besides the conclusions we derived for the perfect information case, two additional insights are obtained in the incomplete information case studied here. The expected depreciation of the exchange rate such that speculating becomes the dominant strategy is lower if the signal about the exchange rate is more accurate (higher q_0) and the fluctuation in the equilibrium exchange rate is larger (u larger).

IV.   Equilibrium with Investor Heterogeneity

In this section we consider the implications of heterogeneity for the results obtained in the symmetric case. In particular, we are interested in whether the critical level of the exchange rate is different for domestic and foreign investors. Hence, from here onwards, we assume that the relationship between the exchange rate and prices is given by eq. (10) and the payoffs are as in eqs. (13)–(18). We continue to assume that $\bar{e} = 1$ and $\bar{p} = \bar{p}^* = 1$. We will first derive the critical exchange rate under perfect information, which will provide the basis for the critical value under incomplete information similar to the symmetric case discussed above.

A.   Perfect Information

Investing always is no longer a Nash equilibrium as soon as it becomes optimal for one of the two players to deviate from investing always. The locals will deviate if:

$$\pi_t^{s,i} > 1 + r,$$

and the foreigners will do so if:

$$\pi^{*i,s} > 1 + r.$$

We denote the critical values of the exchange rate for the locals and foreigners by $e_{H,PI}^*$ and $e_{F,PI}^*$, respectively. It is optimal for the locals to speculate if

$$1 + r < \frac{1 - e_t}{q\phi}R - r\frac{R}{\phi} - c^h + (1 - t)(\lambda + (1 - \lambda)k + g)e_t,$$

or:

$$1 + r - \left(\frac{1}{q} - r\right)\frac{R}{\phi} + c^h < \left[(1 - t)(\lambda + (1 - \lambda)k + g) - \frac{R}{q\phi}\right]e_t.$$

This is of the form $e_t < e_{H,PI}^*$ if the term in square brackets is negative, in which case the inequality can be rephrased as:

$$e_t < e_{H,PI}^* = \frac{(1 - qr)R - q\phi(1 + r + c^h)}{R - q\phi(1 - t)(\lambda + (1 - \lambda)k + g)}. \tag{23}$$

It can be readily verified that this reduces to eq. (20) in the symmetric case ($q = 1$, $\phi = \frac{1}{2}$, $c^h = c^f = c$, $t = 0$, and $g = 0$).

For foreigners it is optimal to speculate if:

$$1 + r < \frac{1 - e_t}{1 - \phi}R - r\frac{R}{1 - \phi} - c^f + [\lambda + (1 - \lambda)k]e_t,$$

that is, if:

$$1 + r - \frac{1 - r}{1 - \phi}R + c^f < \left[\lambda + (1 - \lambda)k - \frac{R}{1 - \phi}\right]e_t.$$

This can be stated in the form $e_t < e_F^*$ if $\lambda + (1-\lambda)k - \frac{R}{1-\phi} < 0$, in which case it reads:

$$e_t < e_{F,PI}^* = \frac{(1-r)R - (1-\phi)(1+r+c^f)}{R - (1-\phi)(\lambda + (1-\lambda)k)}, \tag{24}$$

In summary, in the perfect information case, investing always is no longer a Nash equilibrium if:

$$e_t < \max(e_{H,PI}^*, e_{F,PI}^*).$$

Eqs. (23) to (24) incorporate the six potential causes of heterogeneity between domestic and foreign investors we discussed in Section II. The different incentives faced by each party affect the critical value of the exchange rate as follows. First of all, to the extent that domestic investors make up a larger fraction of the total pool of investors, they require a larger depreciation of the exchange rate than foreign investors. The reason is that the larger the group of investors that join the speculation, the larger the competition for international reserves among them and the smaller the profit from the short position.

Second, insofar as the fixed costs of taking a short position are smaller for domestic residents, $c^h < c^f$, domestic investors would switch to speculating at a level of the equilibrium exchange rate lower than foreign investors. Thirdly, the presence of government guarantees essentially ensures domestic investors of the full value of their original investment. As a result, their liquidation value is larger compared to foreign investors and their critical value of the exchange rate is correspondingly higher. Fourthly, the reverse is true for post-crisis taxation. Since a tax is assumed to be levied on resident investors only, their residual claims decline and other things equal foreign investors would have stronger incentives to attack the fixed exchange rate regime reflected in a higher critical value.

Finally, since the derivative of $e_{H,PI}^*$ with respect to q is negative, the smaller the extent of pass-through of exchange rates into prices, the higher the critical value of the exchange rate. Thus, lower pass-through is beneficial for domestic agents because, when the exchange rate depreciates, the liquidation value of their original investment in real terms declines by less.

B.   Incomplete Information

As in the symmetric case, in the incomplete information case it suffices to replace the payoffs with (subjective) expected payoffs given the signal that the players received and the previous exchange rate e_{t-1}. For the local player H^+, who received a positive signal, the conditions to deviate from investing always is:

$$1 + r < \frac{1 - \bar{e}_t^{H+}}{q\phi}R - r\frac{R}{\phi} - c^h + (1-t)(\lambda + (1-\lambda)k + g)\bar{e}_t^{H+}. \tag{25}$$

where:

$$\bar{e}_t^{H+} = E_{t-1}[e_t | e_{t-1}, s_t = +u] = e_{t-1}[q_h e^u + (1-q_h)e^{-u}].$$

This leads, in analogy with the symmetric case, to the following condition for the H^+ player to speculate:

$$e_{t-1}[q_h e^u + (1-q_h)e^{-u}] < e_{H,PI}^*.$$

Similarly we obtain, for H^-:

$$e_{t-1}[q_h e^{-u} + (1 - q_h)e^u] < e^*_{\text{H,PI}},$$

which is weaker (a negative signal leads to speculation more easily). For the foreign representative agents of type F^+ and F^- we find:

$$e_{t-1}[q_f e^u + (1 - q_f)e^{-u}] < e^*_{\text{F,PI}}.$$

$$e_{t-1}[q_f e^{-u} + (1 - q_f)e^u] < e^*_{\text{F,PI}}.$$

We summarize the condition for the loss of investment as a Nash equilibrium in pure strategies as:

$$e_{t-1} \leq e^* = \max\left(e^*_H, e^*_F\right).$$

where $e^*_H = \frac{e^*_{\text{H,PI}}}{q_h e^{-u} + (1-q_h)e^u}$ and $e^*_F = \frac{e^*_{\text{F,PI}}}{q_f e^{-u} + (1-q_f)e^u}$. In case the exchange rate e_{t-1} is between the two critical values, the instability can be attributed to one group of investors only (that with the largest critical value). Insofar as domestic investors possess better information than foreign investors, locals will start speculating sooner, i.e., at lower levels of expected exchange rate overvaluation.

V.   Strategic Interaction

As soon as investing always under all circumstances is no longer a Nash equilibrium, strategic interaction between the local and foreign players becomes important. To determine the optimal response, the players then have to take into account the probability that the other player invests/speculates. Harsanyi's (1967) approach is suitable for this setting, and depending on the exact parameter values of the model discussed above, the extended form game can be examined for Nash equilibria, either in pure or mixed strategies, that may become important as soon as investing always is no longer a Nash equilibrium. For particular choices of the model parameters, this may be analytically feasible, but for the general model discussed so far, it is practically impossible to formulate an extensive list of the possible Nash equilibria that may arise under various choices of model parameters.

We have seen that through better information, lower costs of a short position, and government guarantees, local agents have a lower tolerance for overvaluation for the fixed exchange rate. On the other hand, the prospect of higher taxation after a collapse of the fixed exchange rate regime, or a high degree of pass-through, deters speculation by local investors. To be consistent with the empirical evidence cited in the introduction that local investors appear to take the lead, the former needs to outweigh the latter considerations to give rise to $e^*_F < e^*_H$. However, both players, the local as well as the foreign representative agent, can determine e^*_F and e^*_H, so that these can be treated as common knowledge. Both players therefore know that they are in a stage with strategic interaction, in which they have to take the probability into consideration that the other party deviates from continuing to invest. This may lead to mixed strategy Nash equilibria for both agents of

both types. However, the situation here is simplified somewhat by the fact that for type H^-, speculating is a dominant strategy. Therefore, among the two types of local players, at most one (H^+) randomizes. This leaves one degree of freedom (α_H^+, the probability of investing for player H^+) for the local players' strategy. Typically it will be impossible to choose α_H^+ in such a way that both the foreign players (of each type) randomize, unless the (linear) indifference curves for F^+ and F^- cross exactly at the border $\alpha_H^- = 0$ of the strategy space consisting of the unit square with coordinates (α_H^-, α_H^+). In summary, if $e_F^* < e_H^*$, the local player speculates upon receipt of a negative signal, and the local player randomizes under no more than one out of two possible signals.

As soon as $e_t < e^*$, the fixed exchange rate regime in the model is unstable as expressed in the following theorem. If $e_{t-1} < e^*$, the probability per time unit for the exchange rate to collapse is at least 50%. **Proof**: The condition $e_{t-1} < e^*$ implies that at least one of the two players with a negative signal will speculate (and successfully attack the fixed exchange rate) regardless of the action of the other player. The unconditional probability for that player to receive a negative signal $\frac{1}{2}q + \frac{1}{2}(1 - q) = \frac{1}{2}$, where q is either q_h or q_f. The possibility that the other player also speculates only increases the probability of a successful attack. □

Theorem 1 applies regardless of the behavioral assumptions that one may impose to study the interaction of the agents after investing always ceases to be a Nash equilibrium. It relies on the fact that speculation becomes a dominant strategy for at least one of the two parties if the exchange rate is below the critical value e^*.

VI. Summary and Conclusions

In this paper we used a simple model to study the consequences of locational heterogeneity of investors for the timing and determinants of a speculative attack. In our framework as long as fundamentals, as formalized by the extent to which a currency is overvalued, have not deteriorated sufficiently, investment by local and foreign agents is in the business as usual phase. This silence of investment is disturbed as soon as the perceived fundamentals have deteriorated enough to trigger speculation. The main contribution of this paper is to argue that this trigger point can be different for domestic and foreign investors. On the one hand, the reason for this difference is that the parties' expected speculative profit depends on their costs of taking a short position, their group size, or their uncertainty about the equilibrium exchange rate. On the other hand, the expected costs of speculating in terms of losses made on their initial investment differs. This liquidation value is not the same to the extent that government guarantees or higher post-attack taxes are taken into account. Finally, the extent of exchange rate pass-through was shown to be an important channel through which domestic agents are deterred from speculating as it reduces the real value of their original claim on the home country.

The empirical evidence cited in the introduction suggests that the domestic agents often

take the lead during periods of capital flight. This can be understood from our model insofar as local investors incur lower costs when taking a short position, have better information about the fundamental exchange rate, and receive an investment guarantee. However, these effects need to dominate the effect of an exchange rate depreciation on higher prices in the home country. Furthermore, local investors will be more reluctant to speculate if they represent a larger fraction of the initial assets invested, which is usually the case due to home bias, as well as when their taxes increase after a collapse of the fixed exchange rate regime.

A shortcoming of our model, as well as most other models in this literature, is that the central bank does not optimize its response to the strategies followed by speculators, whether domestic or foreign. Although it may prove too difficult to solve for the equilibrium of the resulting game, incorporating the central bank as an additional player in the setup above, or the government for that matter in terms of its provision of guarantees as well as its taxation, would be the natural way to derive optimal and timeconsistent economic policies.

Additionally, one could consider introducing additional forms of uncertainty regarding the incentives of the other investor. This would bring to the front the strategic interaction between the two investor types, although solving for the resulting equilibrium would become increasingly complicated as discussed above. It would also be interesting to add agents to the model that are not investing in the home country, but are purely looking after speculation profits. In that case, one of the equilibria might be simultaneous speculation against the home currency, and new capital inflows into the home country as investors may want to protect the value of their initial investments.

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