

‘Large’ vs. ‘small’ players: A closer look at the dynamics of speculative attacks*

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Abstract

What is the role of “large players” like hedge funds and other highly leveraged institutions in speculative attacks? In recent theoretical work, large players may induce an attack by an early move, providing information to smaller agents. In contrast, many observers argue that large players are in the rear so as to benefit from a positive interest rate differential. We propose a model that allows the large player to move early, late or both. Using data on currency trading by foreign and local players, where foreign players generally are larger than local, we find that foreign players moved last in three attacks on the Norwegian krone (NOK) during the 1990s. After the Russian moratorium in 1998 there was a contemporaneous attack on the Swedish krona (SEK) in which foreign players moved early. Interest rates did not increase in Sweden so there was little to gain by a delayed attack.

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1 Introduction

Currency crises often seem only loosely connected to economic fundamentals. This observation has encouraged a large and growing literature seeking to understand why, when and how currency crises occur. The role of large players is often emphasized in the public debate. Many observers and politicians have denounced hedge funds and other highly leveraged institutions, especially foreign, for manipulating exchange rates during speculative pressure. This interest has also been reflected in the academic literature. A key contribution is Corsetti, Dasgupta, Morris, and Shin (2004), who extend the model of Morris and Shin (1998) by introducing a single large player that might have superior information. The work by Corsetti et al. (2004) has inspired a number of contributions, both theoretical (Banner, 2005)¹ and experimental (Taketa, Suzuki-Lffelholz, and Arikawa, 2009).

However, when confronting the model of Corsetti et al. (2004) with empirical evidence, there is a potential problem concerning the timing of the actions of the large player. In their model, the large player will move early so as to signal his information to the small players, thereby inducing an attack. This is in contrast to the experiences from the ERM and Asia currency-crises, where Tabellini (1994) and IMF (1998) argue that the large players moved in the rear because they wanted to benefit from positive interest rate differentials.

We extend the Corsetti et al. model by incorporating this benefit from a late attack in the analysis, making the large player's entry decision depend on the size of the various gains and costs. An early attack will affect the information and thus also the behavior of the small players, as in Corsetti et al., but at the cost of moving to a currency with lower interest rate. By waiting to the last stages of the attack, the large player may profit from the higher interest rates. The latter alternative may be best if the attack is sufficiently likely so that an early "push" to the small players is viewed as unnecessary.

To explore the implications of the model empirically, we consider three cases of speculative pressure on the Norwegian krone (NOK), and one case for the Swedish krona (SEK). The Norwegian cases are: (i) The attack during the European-wide ERM-crisis in December 1992; (ii) the NOK-specific attack in January 1997; and (iii) the attack in the

¹Banner (2005) shows that, by adding a public signal in a model otherwise close to Corsetti et al. (2004), large players are more important when public signals are weak. Another related paper is Guimarães and Morris (2007), who show that the larger funds the players in general can raise the more likely is a successful attack.

crisis that followed the Russian moratorium in August 1998. The third crisis is also our Swedish case. Norway had a fixed exchange rate in 1992, while the exchange rate was a managed float in 1997 and 1998. Sweden had officially a floating exchange rate regime in 1998, but had intervened on several occasions since the ERM-crisis in 1992–93. Even under such regimes, speculators may take currency positions in the belief that monetary authorities will change the monetary regime, or at least allow for a considerable change in the exchange rate, in the near future.² Such beliefs may be triggered by economic developments making a (implicit) dual mandate of price stability and macroeconomic stability unsustainable.

For Norway we have weekly data on spot and forward currency trading by Norwegian banks with foreigners and with Norwegian non-bank customers. Anecdotal evidence from the Norwegian market suggests that the foreign investors are leveraged institutions, or “large players”, while locals can be viewed as “small players”. Both the triennial survey of foreign exchange markets, and our data, suggest that the volume of trading by foreigners is larger than trading by Norwegians. Yet reports from Norwegian banks suggest that there are fewer foreign agents than local, implying that the foreign agents on average are considerably larger than the Norwegians. Using foreigners as proxy for larger players seems particularly reasonable for periods of speculative pressure where foreigners can raise more funds than locals.

In Sweden several banks, assigned as “primary dealers”, report to the Sveriges Riksbank their buying and selling of spot and forward against locals and foreigners. Conversations with central bank officials indicate that these two data sets may cover as much as 80-90% of all trading in NOK and SEK.

The data set used are in several ways unique for the study of speculative attacks. Corsetti, Pesenti, and Roubini (2002) and Cai, Cheung, Lee, and Melvin (2001) study the role of large players during the Asian crisis of 1997 and 1998 using the US Treasury Bulletin reports. Unlike these studies we have information on the trading of *both* foreign and domestic players in the periods around a speculative attack, and our data covers almost the total market for the currencies under investigation. The data set of Carrera’s (1999) study of the Mexican crisis of 1994 is also very detailed, but covers only one crisis.

²See e.g. Calvo and Reinhart (2002) who argue that even if a country officially adopts a “flexible” exchange rate, they often tend to limit the fluctuations of the exchange rate.

With our long time series on trading we can also analyze several distinct relevant episodes. Finally, while the above mentioned studies have focused on the Emerging markets we focus on two European economies. This adds a new dimension to the empirical findings in this field.³

Our results suggest that the behavior of foreign and domestic players differs before and during speculative attacks. In line with the observations of Tabellini and the IMF, we find that foreign (large) players moved last during the three attacks on the Norwegian krone (NOK). Regression analysis also indicates that the trading of foreign players is most important for triggering the actual attack. This is consistent with our theoretical model, which predicts that if the probability of a successful attack is high, large players will choose to move late if there is some gain from waiting, e.g., a high interest rate differential. However, during the attack on the Swedish krona (SEK) in 1998, it was the foreign players that moved early. This is consistent with our model as in this case interest rate differentials did not increase during the attack, so there was little to gain for the foreign players by a delayed attack.

The work by Morris and Shin (1998) and Corsetti et al. (2004) have spurred a number of contributions where the aggregate information is endogenized, see Angeletos, Hellwig, and Pavan (2006, 2007), Angeletos and Werning (2006) and Hellwig, Mukherji, and Tsyvinski (2006). This is an important innovation, which among other things also opens up for the possibility of a multiplicity of equilibria. However, as we consider a model with both large and small players, endogenising the aggregate information is beyond the scope of the present paper.

In section 2 we present the model and discuss some empirical implications. Section 3 contains a description of our data and the institutional framework of the exchange rate regime. Section 4 describes the empirical methodology and our results. Section 5 concludes.

³The two data set used here have previously been studied by Rime (2000) (Norway) and Bjønnes, Rime, and Solheim (2005) (Sweden).

2 The Model

Corsetti, Dasgupta, Morris and Shin (2004) (henceforth CDMS) analyze a model with a large player and a continuum of small players. Under sequential trading, the large player speculates first, so as to create a signal affecting the behavior of the small agents. However, as mentioned by CDMS, the IMF, and Tabellini (1994), there is empirical evidence indicating that large players often are in the rear in speculative attacks.

Here we extend the theoretical framework of CDMS by allowing for a richer timing structure. We want to capture that players who spend more resources, and are more active, than other players, also have more options. Such players, which we shall refer to as large players, may speculate in a sufficiently large amount so that it puts pressure on the exchange rate. The pressure on the exchange rate may lead other players to expect a successful attack, leading them to join the attack, which again will increase the probability of success. However, early speculation is usually costly, as it may involve borrowing in the currency under attack, where the interest rate typically is high. An alternative is to wait until there is more information as to whether the attack succeeds. This option involves lower costs due to a shorter time with a negative interest rate differential. However, it also involves the risk of being so late that the devaluation has already occurred, and/or the central bank has spent its reserves, removing the possibility of profit. Furthermore, late speculation implies that one does not lead the others to attack, implying a risk that the others revert their speculative positions so that the attack fails. Then it would be too late to cause the exchange rate to fall. Finally, late speculation requires that one follows the market closely, and has the ability to trade rapidly, which may involve some investments in technology.

We follow CDMS and consider a stylized economy where the central bank aims at keeping the exchange rate within a certain interval, either a well defined, publicly known, narrow target zone, or a less explicit dirty float policy. There is a single large player, and a continuum of small players indexed to $[0, 1]$. The players may attack the currency by short selling the currency, i.e. borrow domestic currency and sell it for dollars. The small players taken together have a combined limit to short selling the domestic currency normalized to 1, while the large player has access to credit allowing him to take a short position up to the limit $L > 0$.

In contrast to CDMS, we assume that trade may take place in three periods. In period 1 and 2, there is a cost $t \in (0, 1)$ per unit of short selling, reflecting trading costs and possible interest rate differential.⁴ The costs are normalized so that the payoff to a successful attack on the currency, leading to a devaluation/depreciation of the currency, is given by 1, and the payoff from refraining from attack is 0. Thus, the net payoff for small players of a successful attack on the currency is $1 - t$, while the payoff to an unsuccessful attack is $-t$.

Finally, players also have the possibility to wait and then join whenever a successful attack takes place, which we refer to as period 3. This strategy requires that one follows the market closely, to be able to move rapidly at the right moment. We assume that players must incur a fixed cost $z > 0$, which is independent of the size of the speculation, to have the option of speculating in period 3.⁵ The benefit from waiting until this late stage is that the speculation period is much shorter, implying much lower costs associated with the interest rate differential under speculation. For notational simplicity, without affecting the qualitative results, we set the unit trading costs in period 3 to zero. However, as discussed above, waiting also involves disadvantages. Again, we adopt stylized assumptions. First, in period 3 it is too late to affect whether the attack succeeds. Second, waiting involves a probability $q > 0$ that one attacks too late, after the exchange rate has fallen, resulting in zero profit.

Following CDMS, we let the strength of the economic fundamentals of the exchange rate regime be indexed by a random variable θ .⁶ This can be interpreted as a reduced form of the central bank reaction function, indicating how much reserves the bank is willing to use in the defense. If the fundamentals support the current regime, i.e. are strong, the central bank is willing to use more reserves in the defense. The strength of the speculative attack is measured by the amount used by the players attacking the currency. Whether the current exchange rate regime is viable depends on the strength of the economic fundamentals relative to the strength of the speculative attack. Note that it would be reasonable to assume that the probability q is decreasing in θ , the intuition being that with weaker fundamentals, the exchange rate regimes falls faster, with greater

⁴Ideally, one would want to endogenize the interest rate during the attack, along the lines of Hellwig et al. (2006) and Tarashev (2007). However, in these papers there is no role for the large player, and combining these two elements is a challenging task, that is beyond the scope of the present paper.

⁵Such fixed costs can be subscription to necessary trading systems, or cost for maintaining a relationship with a bank that gives a “hot-line” access to the trading room.

⁶The fundamental’s (improper) prior distribution is uniform over the real line.

risk that delayed speculation ends up being too late to be profitable. This could be incorporated in the present model, but the implications would not warrant the added complexity. Thus, we assume q to be a fixed parameter.

Given the fixed costs involved to be able to speculate in period 3, the small players are too small to profit, thus they will choose to do their speculation in the periods before. However, for the large player, the savings on trading costs and interest rate differential are sufficient to cover the fixed information costs, thus the large player may want to trade in period 3. For notational simplicity, we assume that the large player will incur these fixed costs for his other business activities, so we do not incorporate these costs in the further analysis.

The assumption that speculation in period 3 cannot affect whether the attack succeeds, is clearly strong. In reality, if there were a massive speculative attack from the small players, an attack from the large players might be sufficient to enforce a devaluation. However, the assumption involves a vast simplification of the analysis. With this assumption, there is no need for other players to make forecasts about the large player's behavior in period 3. Furthermore, the assumption also captures an important element of realism; if an attack is seen not succeed, many players may revert their positions, and it would be too late for the large player to induce a successful attack by increasing his speculation.⁷

As noted by CDMS, there is no gain for small players from speculating in period 1, as this involves less information, and each of them is too small to affect the behavior of the others. On the other hand, for the large player, speculation in period 1 is better than speculation in period 2, as speculation in period 1 encourages speculation by the small players. For the large player there is nothing to learn from waiting till period 2, as the small players will not speculate in period 1.

Under these assumptions, whether a speculative attack is successful depends on the speculation in periods 1 and 2, relative to the strength of the economic fundamentals. Let ξ denote the mass of small players that speculate, and λ denote the speculation of the large player in period 1.

⁷Note that the assumption that many small players may revert their position if the attack fails, is not inconsistent with our assumption that they will not incur the fixed costs of continuous monitoring to be able to speculate in period 3. Even if none of the small players follow the market continuously, at each point in time there will always be some of the small players who follow the market at that time, and these players may revert if the attack does not succeed.

Then the exchange rate will fall if and only if

$$\xi + \lambda \geq \theta. \tag{1}$$

If $\theta < 0$ the exchange rate will depreciate irrespective of whether a speculative attack takes place. We therefore restrict attention to the case where $\theta > 0$.

2.1 Information

The small players observe a private signal that yields information about the fundamentals as well as the amount of early speculation of the larger player. A typical small player i observes

$$x_i = \theta - \lambda + \sigma \varepsilon_i, \tag{2}$$

where $\sigma > 0$ is a scaling-constant to the variance of the signal x . The individual specific noise ε_i is distributed according to a smooth symmetric and single-peaked density $f(\cdot)$ with mean zero, and $F(\cdot)$ as the associated c.d.f. The noise ε_i is assumed to be i.i.d. across players. Note that the small players cannot distinguish the information they obtain about the fundamentals from the information about the speculation of the larger player; they only observe a noisy signal of the difference between the two. This departs from the assumption in CDMS, who assume that the players in period 2 can observe the actions taken by the large player in period 1. However, even if the small players cannot observe the large player's action in period 1, and thus cannot condition on this action, the large player may still affect the actions of the small players by affecting their signals via the choice of early speculation. The reason for this restriction is mainly technical; as we allow the large player also to delay speculation until period 3, his behavior is more complex than in CDMS, implying that the analysis of the signalling effect of the speculation in period 1 would be exceedingly difficult. However, in our view it also captures an element of realism: while rumors may give small players a strong indication whether large players trade, there is no disclosure requirements in FX markets so the small players cannot know the extent of large players' trade. Furthermore, a large player may have an incentive to encourage the belief that he trades, to induce speculation by others, suggesting that small players should be careful when interpreting such loose information. Here we take this position to

the extreme, by assuming that small players cannot distinguish trade by the large player from other information.

The larger player observes

$$y = \theta + \tau\eta, \tag{3}$$

where $\tau > 0$ is a scaling-constant to the variance of the signal, and the random term η is distributed according to a smooth symmetric and single-peaked density $g(\cdot)$ with mean zero. To obtain explicit solutions, we assume further that $g(\cdot)$ is strictly increasing for all negative arguments, and strictly decreasing for all positive arguments. $G(\cdot)$ is the associated c.d.f. We assume that noise in the information is sufficiently large so that the probability for a successful attack, as seen by the large player, always is strictly positive.

2.2 Analysis

As usual in such models, we solve by use of backwards induction. Whether the attack is successful is determined in period 2, thus we may start by considering the action of the small players in this period, given the prior decision of the large player in period 1. Then we consider the decision of the large player whether to initiate an early attack. An eventual late attack by the large player will be the residual of his credit L after any early speculation.

Following CDMS, we will assume that the small players follow trigger strategies in which players attack the currency if the signal falls below a critical value x^* .⁸ As in the analysis of CDMS, the unique equilibrium of the model is characterized by two critical values: x^* and a critical value for the fundamental θ less the early speculation of the large player λ , so that if $\theta - \lambda \leq (\theta - \lambda)^*$, the currency will fail.

These critical values can be derived in the same way as in the analysis of the benchmark case in section 2.2.1 of CDMS. First we consider the equilibrium given the trigger strategies, then we consider the optimal trigger strategies. Given the trigger strategy, a small player i will attack the currency if his signal $x_i \leq x^*$. The probability that this occurs is a function

⁸CDMS show that there are no other equilibria in more complex strategies.

of the true state of the economy, $\theta - \lambda$, as follows

$$\begin{aligned} \text{prob}[x_i \leq x^* | \theta - \lambda] &= \text{prob}[\theta - \lambda + \sigma \varepsilon_i \leq x^*] \\ &= \text{prob}\left[\varepsilon_i \leq \frac{x^* - (\theta - \lambda)}{\sigma}\right] = F\left(\frac{x^* - (\theta - \lambda)}{\sigma}\right). \end{aligned}$$

Since there is a continuum of small players, and their noise terms are independent, there is no aggregate uncertainty as to the behavior of the small agents. Thus, the mass of small players attacking, ξ , is equal to this probability. As $F(\cdot)$ is strictly increasing, it is apparent that the incidence of the speculative attack is strictly decreasing in $\theta - \lambda$, i.e. it is greater, the weaker the strength of the economic fundamentals, less the early speculation of the large player.

A speculative attack will be successful if the mass of small players that speculate exceeds the strength of the economic fundamentals, less the early speculation of the large player, i.e. if

$$F\left(\frac{x^* - (\theta - \lambda)}{\sigma}\right) \geq \theta - \lambda.$$

Thus, the critical value $(\theta - \lambda)^*$, for which the mass of small players who attack is just sufficient to cause a devaluation, is given by the equality

$$F\left(\frac{x^* - (\theta - \lambda)^*}{\sigma}\right) = (\theta - \lambda)^*. \quad (4)$$

For lower values, where $\theta - \lambda \leq (\theta - \lambda)^*$, the incidence of speculation (the left hand side of (4)) is larger, and the strength of the fixed exchange rate (the right hand side of (4)) lower, implying that an attack will be successful. Correspondingly, for higher values, where $\theta - \lambda > (\theta - \lambda)^*$, the incidence of speculation is lower, and the strength of the fixed exchange rate larger, implying that an attack will not succeed.

Let us then derive the optimal trigger strategies of the small players. A player observes a signal x_i , and, given this signal, the success-probability of an attack is given by

$$\begin{aligned} \text{prob}[\theta - \lambda \leq (\theta - \lambda)^* | x_i] &= \text{prob}[x_i - \sigma \varepsilon_i \leq (\theta - \lambda)^*] \\ &= \text{prob}\left[\varepsilon_i \geq \frac{x_i - (\theta - \lambda)^*}{\sigma}\right] = 1 - F\left(\frac{x_i - (\theta - \lambda)^*}{\sigma}\right) = F\left(\frac{(\theta - \lambda)^* - x_i}{\sigma}\right), \end{aligned}$$

where the last equality follow from the symmetry of $f(\cdot)$, $F(\nu) = 1 - F(-\nu)$. The expected payoff of attacking the currency for player i , per unit of speculation, is thus

$$(1-t)F\left(\frac{(\theta-\lambda)^* - x_i}{\sigma}\right) - t\left(1 - F\left(\frac{(\theta-\lambda)^* - x_i}{\sigma}\right)\right) = F\left(\frac{(\theta-\lambda)^* - x_i}{\sigma}\right) - t.$$

In an optimal trigger strategy, the expected payoff of attacking the currency must be zero for the marginal player, i.e. the optimal cutoff x^* in the trigger strategy is given by

$$F\left(\frac{(\theta-\lambda)^* - x^*}{\sigma}\right) = t. \quad (5)$$

To solve for the equilibrium, we rearrange (5) to obtain $(\theta-\lambda)^* = x^* + \sigma F^{-1}(t)$. Substituting into (4), we get

$$\begin{aligned} (\theta-\lambda)^* &= F\left(\frac{x^* - (x^* + \sigma F^{-1}(t))}{\sigma}\right), \text{ or} \\ (\theta-\lambda)^* &= F(-F^{-1}(t)) \\ &= 1 - F(F^{-1}(t)) = 1 - t. \end{aligned}$$

Thus, the critical values are

$$(\theta-\lambda)^* = 1 - t, \text{ and} \quad (6a)$$

$$x^* = 1 - t - \sigma F^{-1}(t). \quad (6b)$$

These critical values correspond to the critical values in CDMS, the only novelty being the addition of the early speculation of the large player λ .

We then consider the decision of the large player of whether to speculate in period 1, and if so, by how much. There is no uncertainty in the aggregate behavior of the small players, so the large player can anticipate their speculation perfectly, except for the noise in his own signal. From (6) a devaluation will take place if the fundamental $\theta \leq \theta^* \equiv 1 - t + \lambda$.

The probability that an attack succeeds can be written as

$$\begin{aligned} \text{prob}[\theta \leq 1 - t + \lambda|y] &= \text{prob}[y - \tau\eta \leq 1 - t + \lambda|y] = \\ &= \text{prob}\left[\frac{y - \lambda - (1 - t)}{\tau} \leq \eta|y\right] = G\left(\frac{1 - t + \lambda - y}{\tau}\right), \end{aligned}$$

where we again use the symmetry of the distribution. If the attack succeeds, the large player will also want to speculate in period 3, so that the total speculation is L . However, there is also a risk, occurring with probability q , that the speculation in period 3 comes too late, so that the large player only profits from his early speculation λ . The expected payoff by attacking in the amount $\lambda \geq 0$ at an early stage is thus

$$E\pi = G\left(\frac{1 - t + \lambda - y}{\tau}\right) (L(1 - q) + \lambda q) - t\lambda,$$

The first order condition for an interior solution λ^* is

$$\frac{\partial E\pi}{\partial \lambda} = g\left(\frac{1 - t + \lambda^* - y}{\tau}\right) \frac{1}{\tau} (L(1 - q) + \lambda q) + G\left(\frac{1 - t + \lambda - y}{\tau}\right) q - t = 0. \quad (7)$$

As $E\pi$ is a continuous function of λ , defined over the closed interval $[0, L]$, we know that there exists an optimal amount of early speculation λ , that maximizes the expected profits. However, the optimal λ is not necessarily unique, nor is it necessarily interior, given by the first order condition. In fact, if the costs of early speculation, t , are sufficiently small, the optimal early speculation is equal to the credit constraint L . Furthermore, if the risk that the late speculation is too late, q , is sufficiently large, then the optimal early speculation is either zero or equal to the credit constraint L .

Proposition 1 *i. For given values of the other parameters, there exists a critical value for the costs of early speculation $\underline{t} > 0$ such that if $0 < t < \underline{t}$, then the optimal early speculation is equal to the upper constraint, $\lambda = L$*

ii. For given values of the other parameter, and for any given $\kappa > 0$, there exists a critical value $\bar{q} < 1$ such that if $1 > q > \bar{q}$, then the optimal early speculation is either approximately zero or approximately equal to the upper constraint, $\lambda < \kappa$ or $\lambda \in [L - \kappa, L]$.

The proof is in Appendix A. The intuition for these results are as follows. If early speculation is very cheap, i.e. t is very small, early speculation inducing small players to speculate is clearly the more profitable alternative. As the large player is risk neutral, he will then speculate to his limit L . Likewise, if late speculation is very likely not to succeed, either the large player abstains from speculation, or he speculates by the full amount in period 1. In this case, it can not be optimal to speculate less than the credit constraint, because if speculation involves positive expected profits, increasing the early speculation will be even more profitable.

The further analysis of the model is rather involved. To make some progress, we restrict attention to the limit case where there is no risk associated with late speculation, i.e. that $q = 0$. Then, the expected payoff by attacking in the amount $\lambda \geq 0$ at an early stage reads

$$E\pi = LG \left(\frac{1 - t + \lambda - y}{\tau} \right) - t\lambda,$$

and the first order condition for an interior solution λ^* is

$$\frac{\partial E\pi}{\partial \lambda} = Lg \left(\frac{1 - t + \lambda^* - y}{\tau} \right) \frac{1}{\tau} - t = 0. \quad (8)$$

Note first that if $Lg(0) \frac{1}{\tau} - t < 0$ (which is equivalent to $g(0) < \frac{\tau t}{L}$), then it is never optimal to speculate early, as this implies that $\frac{\partial E\pi}{\partial \lambda} < 0$ for all y and λ (recall that the density $g(\cdot)$ has its maximum for the argument zero). The intuition is straightforward: if the gain from a successful speculative attack (L) is too small relative to the cost of speculation (t) and the effect of attempts to induce a speculative attack ($g(\cdot)$ and τ), then it will never be profitable to try to induce a speculative attack. This is more likely the less precise is the signal of the large player (τ is large), the greater the costs of early speculation (t large), and the smaller the limit of the large player (L small). In the sequel, we shall assume that $g(0) > \frac{\tau t}{L}$, implying that it will be profitable to induce a speculative attack under some circumstances, as will be discussed below.

The second order condition for an interior solution is

$$\frac{\partial^2 E\pi}{\partial \lambda^2} = L \cdot g' \left(\frac{1 - t + \lambda^* - y}{\tau} \right) \frac{1}{\tau^2} < 0.$$

From the second order condition it follows that the optimal λ^* must satisfy $\frac{1-t+\lambda^*-y}{\tau} > 0$, so that $g'(\cdot) < 0$.⁹

Restricting attention to the interval $\frac{1-t+\lambda-y}{\tau} > 0$, so that $g'(\cdot) < 0$, and hence the inverse of $g(\cdot)$ is defined, we can solve (7) for the optimal λ :

$$\begin{aligned} \frac{1-t+\lambda^*-y}{\tau} &= g^{-1}\left(\frac{\tau t}{L}\right), \text{ or} \\ \lambda^* &= y - (1-t) + \tau g^{-1}\left(\frac{\tau t}{L}\right). \end{aligned} \quad (9)$$

Let y^{Lo} be the value of y for which the optimal early speculation λ^* is zero, i.e.

$$y^{Lo} = 1 - t - \tau g^{-1}\left(\frac{\tau t}{L}\right). \quad (10)$$

Proposition 2 *Assume that $q = 0$ and $g(0) > \frac{\tau t}{L}$.*

- i. Then there exist critical values y^{Hi} and y^{Lo} such that if the signal of the large player y is below or above these critical values, $y \leq y^{Lo}$ or $y \geq y^{Hi}$, then the optimal strategy is not to speculate early, i.e. set $\lambda = 0$.*
- ii. If $y \in (y^{Lo}, y^{Hi})$, the optimal strategy is to speculate early, setting $\lambda = \lambda^* > 0$, where λ^* is given by (9).*
- iii. An increase in the noise in the signal of the large player, τ , has an ambiguous effect on the optimal early speculation by the large player, λ^* .*
- iv. An increase in the speculation costs t has an ambiguous effect on the optimal early speculation by the large player, λ^* .*
- v. Conditional on the combined state $y + t$, an increase in the speculation costs t leads to a lower optimal early speculation by the large player, λ^* .*

The proof is in Appendix B. The intuition behind the proposition is the following. If the signal of the large player y is low (below y^{Lo}), reflecting that the fundamentals θ is low, the large player will view a devaluation as so likely that he will not find it profitable to incur the costs by early speculation, even if this would increase the probability of a

⁹For $\frac{1-t+\lambda-y}{\tau} < 0$, we have $g'(\cdot) > 0$ implying that $\frac{\partial^2 E\pi}{\partial \lambda^2} > 0$, so that a solution to (7) would be a local profit minimum.

devaluation. Thus, in this case the large player will only speculate in period 3. Note that this result hinges critically on the assumption that $q = 0$. If there is a risk that the large player may be too late to profit from a speculative attack ($q > 0$), this will provide a strong incentive to speculate early if fundamentals are bad, cf. Proposition 1.

We also find that the large player will not speculate early if the signal y is high (above y^{Hi}), reflecting that the fundamentals θ is high, as in this case it will be too costly to raise the probability of a devaluation. However, for interior values of y , the gain from increasing the probability of a successful speculative attack by an early speculation of the large player is sufficiently large to outweigh the costs, and the large player will indeed speculate early. Note that (9) and (10) yield $\lambda^* = y - y^{Lo}$, implying that the optimal early speculation λ^* is increasing one for one in the signal y in the interval (y^{Lo}, y^{Hi}) , starting at zero for y^{Lo} and reaching its maximum for y^{Hi} . However, for $y \geq y^{Hi}$, optimal early speculation is zero.

There is no clear relationship between the early speculation of the large player and the noise in his information, as captured by the parameter τ . As noted above, if the signal is very imprecise (τ so large that $g(0) < \frac{\pi t}{L}$), the large player will never want to speculate early. However, for smaller values of τ , an increase in τ has an ambiguous effect on the amount of early speculation. The intuition is that with more precise information, the large player knows better how much early speculation which is required to ensure the optimal probability of an attack. Thus, precise information will reduce the early speculation when less is needed, and increase early speculation when more is required.

The ambiguous effect of an increase in the speculation costs on the amount of early speculation reflects two opposing effects. On the one hand, higher speculation costs makes it more costly to speculate early, which has a dampening effect on the amount of early speculation. On the other hand, higher speculation costs will reduce speculation by small players, inducing the large player to do more early speculation himself (cf. equation (9)). If one considers the effect of speculation costs conditional on the combined state of the signal and the effect of small players' speculation, $y + t$, then only the first effect remains, and higher speculation costs have a negative impact on the amount of early speculation.

The large player's choice of early speculation is illustrated in Figures 1(a) and (b). Assume that the large player observes a signal $y' \in (y^{Lo}, y^{Hi})$. If the large player does

not speculate early, a devaluation will nevertheless take place if the fundamentals are sufficiently low, which, given the signal y' , requires that the noise term $\eta \geq \frac{y'-(1-t)}{\tau}$. In Figure 1 (a), this probability is captured by the area below the bell shaped density function $g(\cdot)$ that is to the right of the signal (although in the figure, we multiply $g(\cdot)$ by L/τ so that it is measured in revenue terms, i.e. it represents the expected marginal revenue from speculation). If the large player speculates in quantity λ , the probability that the attack succeeds increases to the combined shaded area to the right in the figure, representing the probability that $\eta \geq \frac{y'-\lambda-(1-t)}{\tau}$.

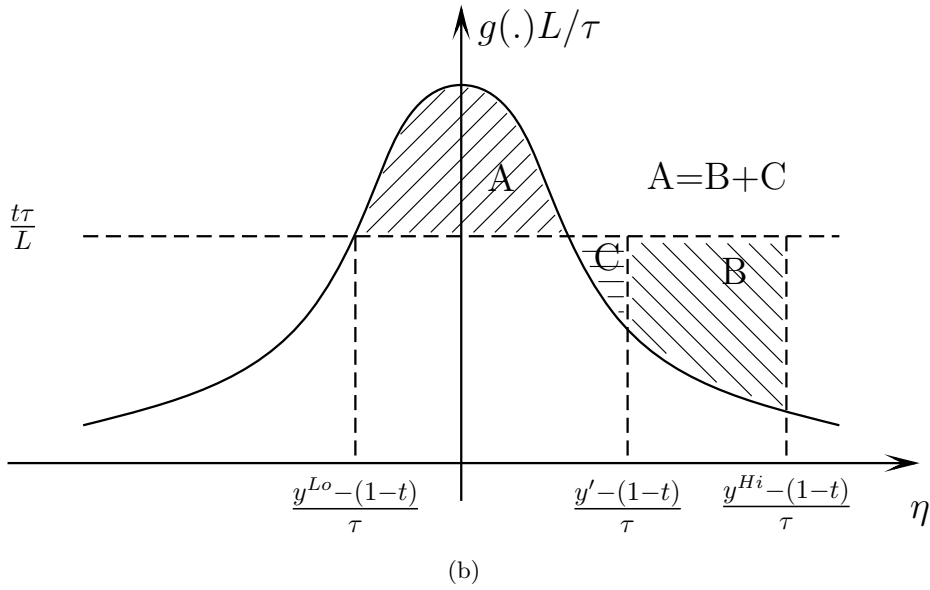
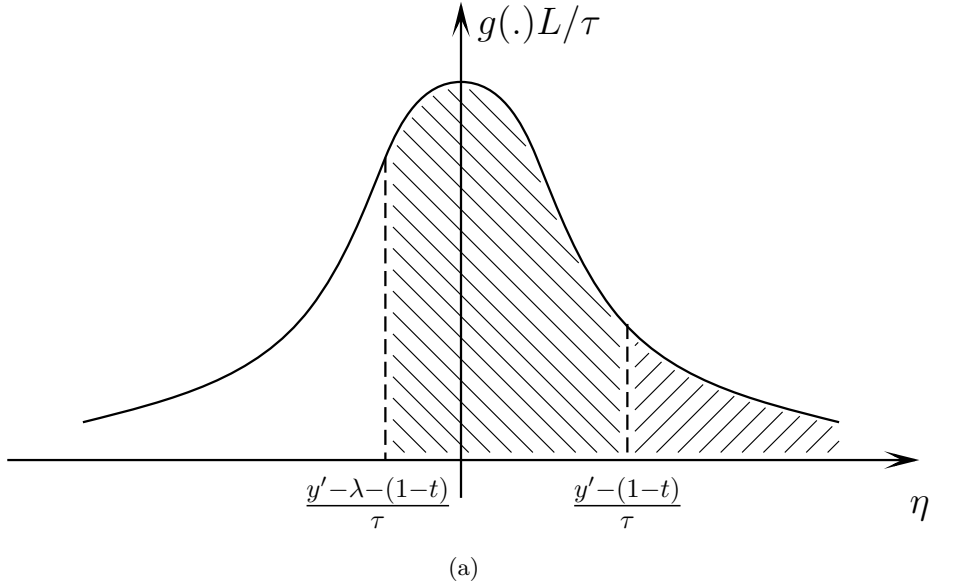
Figure 1(b) illustrates the optimal early speculation, given the signal y' . If the large player makes a marginal early speculation, the expected marginal revenue $g\left(\frac{y'-(1-t)}{\tau}\right) \frac{L}{\tau}$ is lower than the marginal cost t (given by the horizontal dashed line), thus a marginal early speculation will not be profitable. However, if the large player makes a larger early speculation, the marginal revenue curve comes above the marginal cost line, implying that if the player speculates early, the marginal profits from increasing the speculation is positive, as seen by the area A being larger than the area C. The optimal early speculation is given by $\lambda^* = y' - y^{Lo}$, for which expected marginal revenue $g\left(\frac{y'-\lambda^*-(1-t)}{\tau}\right) \frac{L}{\tau}$ is equal to marginal costs t . Thus for all $y \in (y^{Lo}, y^{Hi})$, early speculation in the optimal amount, ensuring that $y - \lambda = y^{Lo}$, will be profitable for the large player. However, for a signal y^{Hi} , the expected gain from early speculation, even in the optimal amount, is zero. This is illustrated in Figure 1(b), by area B+C (the loss from some early speculation where expected marginal revenue is below marginal costs) is equal to area A (the gain from additional early speculation where expected marginal revenue is greater than marginal costs). For values $y \geq y^{Hi}$, early speculation is not profitable.

Hence, the optimal early speculation λ^* is strictly increasing in the interval (y^{Lo}, y^{Hi}) , starting at zero for y^{Lo} and reaching its maximum for y^{Hi} , and then falls to zero again for $y \geq y^{Hi}$.

3 Data and description of crises

Norges Bank and Sveriges Riksbank collect data from market making banks on net spot and forward transactions with different counterparties. From Norges Bank we have weekly observations starting in 1991 on Norwegian market making banks' trading with foreign-

Figure 1: Early speculation (λ) by large player



Note: Figure a: For signal y' and early speculation λ , the probability that the attack is successful is given by the shaded area below the bell shaped curve, representing the probability that $\eta \geq \frac{y' - \lambda - (1-t)}{\tau}$.
 Figure b: Marginal cost of early speculation ($\frac{t\tau}{L}$) is given by the dotted horizontal line. The bell-shaped curve, $g(\cdot)L/\tau$, represents the marginal gain. For $y \in (y^{Lo}, y^{Hi})$ the optimal strategy is to speculate early, setting $\lambda = \lambda^*$. If the large player observes y' , the gain from speculating early in the amount $\lambda^* = y' - y^{Lo}$ is indicated by area A minus area C.

ers, locals, and the central bank. Foreign participants are typically dominated by financial investors, especially in periods of turbulence. In the data set from Sveriges Riksbank, we have weekly observations starting in 1993 on both Swedish and foreign market making banks' trading with non-market making foreign banks and with Swedish non-bank customers. The first group can be taken to represent financial investors (see Bjønnes et al., 2005). Descriptive statistics for the Norwegian transactions are shown in Table 3 in the appendix, both for the whole period with data and for the specific crises.¹⁰

3.1 Three crisis periods in Scandinavia

The three crisis periods that we analyze are (i) the ERM-crisis and the depreciation of the Norwegian krone in December 1992; (ii) the appreciation of the Norwegian krone in January 1997; and (iii) the crisis in both Norway and Sweden following the Russian moratorium in August 1998. Figure 2 shows the NOK/EUR and SEK/EUR exchange rates, together with the Norwegian sight deposit rate and the Swedish discount rate and the 3-month interest rate differential against Germany for the two countries, from the beginning of 1990 until the end of 2000.¹¹ The three crises are indicated with grey areas. The key dates for the attacks can be identified e.g. from the financial press.¹² The descriptive statistics on trading in Table 3 confirm that there are major movements in the expected direction during the identified events.

Figure 3 shows some series on the state of the macroeconomy in Norway and Sweden during the 1990s. Vertical lines mark the crises. The two graphs for Norway illustrate that two of the crises in Norway coincided a downturn in the economy (1992 and 1998), and one with a peak (1997).

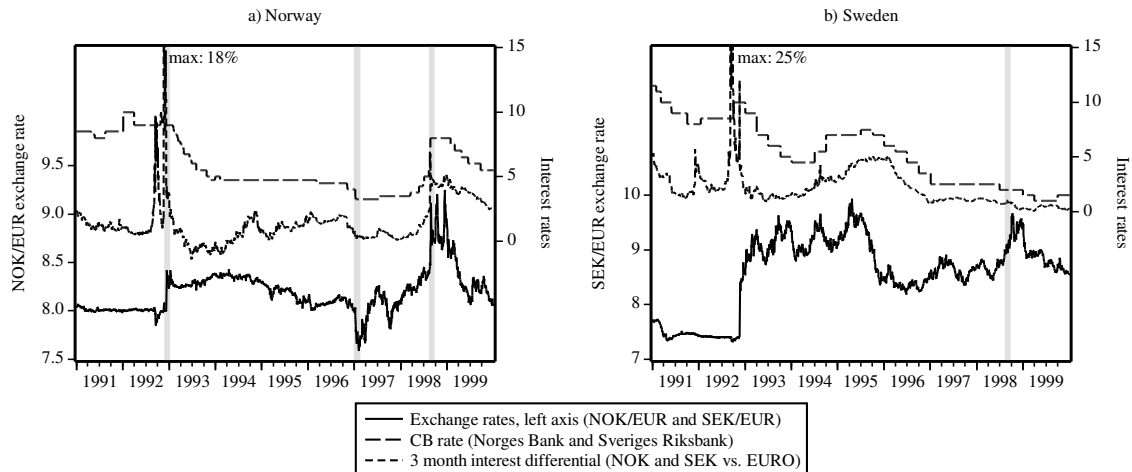
Prior to the ERM-crisis of 1992 the NOK was pegged to the ECU, with fluctuation bands of $\pm 2.5\%$. However, the pressure within the ERM combined with the downturn in Norway led markets to expect a devaluation of the Norwegian krone. During the fall 1992, Finland, Italy, the UK, and finally Sweden were forced to abandon their fixed pegs. During this

¹⁰Interested readers are referred to Rime (2000) and Bjønnes et al. (2005) for further descriptions on the Norwegian and Swedish data sets, respectively.

¹¹The euro was introduced Jan. 1, 1999. Before 1999 we adjust the NOK/DEM and SEK/DEM exchange rates for the DEM/EUR-conversion.

¹²The three periods are also identified in a crisis index (see e.g. Eichengreen, Rose, and Wyplosz, 1995, for a description), which takes into account that speculative pressure may materialize through interest rate changes instead of exchange rate changes (results available on request).

Figure 2: Exchange rate, Central bank rate, and 3-month interest rate differential: Norway and Sweden



Note: Daily observations on exchange rates (left axis), and central bank rate and interest differential (right axis). Exchange rates are local currency pr. euro, using ECB conversion rate for deutsche mark vs euro. Interest rate differentials are local interbank interest rate less German interbank interest rate. Shaded areas indicate the crises.

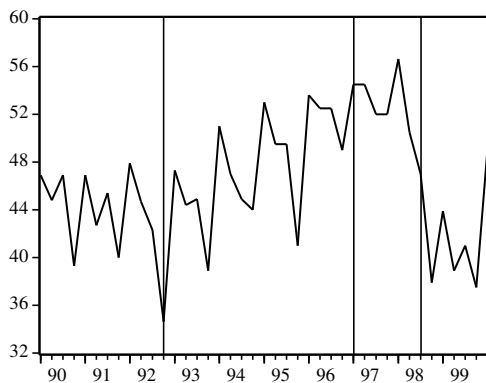
period Norges Bank repeatedly increased its key rate to reduce capital outflows. However, on December 10, 1992, Norges Bank was forced to abandon the fixed ECU-rate. The exchange rate stabilized in the interval between 8.3 and 8.4 against the ECU, implying a change of about 10% from middle rate to middle rate.

In the aftermath of the ERM-crisis, Norway chose a managed float regime with an obligation to stabilize the exchange rate in a medium-term sense. During the fall of 1996 there was pressure against the NOK, and a number of newspaper reports referred to the role of foreigners speculating in a Norwegian appreciation.¹³ According to the press, market participants believed that the strong Norwegian economy and emerging inflationary pressure would force the Norwegian government to adopt an inflation targeting regime. Inflation targeting would allow Norges Bank to raise interest rates to fight inflation and dampen a potential boom, but it was also expected to involve a potentially steep appreciation of the NOK. The pressure peaked in January 1997 and the cost of a DEM in NOK fell by more than 5% over a period of 14 days (largest changes on Jan. 8th – 10th). However, the regime was not changed, and Norges Bank continued to defend the exchange rate by lowering its key rate and intervening in the market.

The 1998-crisis was a joint crisis in Norway and Sweden and took place at the same

¹³For instance, on November 5, 1996, the leading business newspaper in Norway (Dagens Næringsliv) reported that foreign analysts “believe in stronger NOK” (Mathiassen (1996)). On November 6, Norges Bank lowered its key rate.

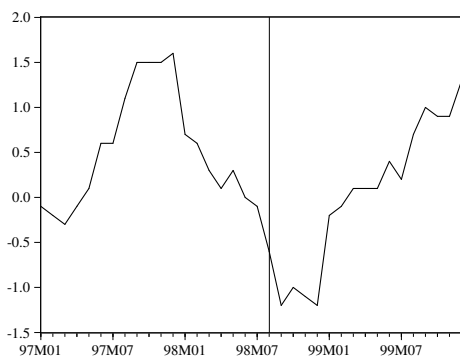
Figure 3: Illustrative macro series for the Norwegian and Swedish economy



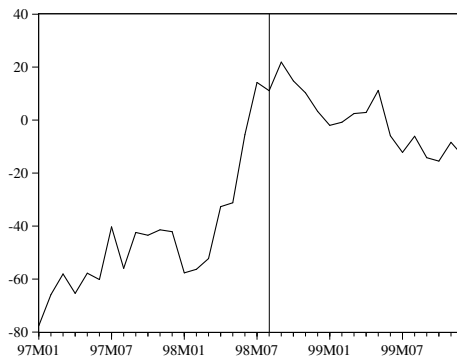
(a) Norway: Expected employment in manufacturing (Business survey)



(b) Norway: Composite leading indicator



(c) Sweden: Consumer Price Index (YoY change)



(d) Sweden: Employment expectations (Business survey)

Note: Panel a) is a diffusion index, with index above 50 indicates increasing growth. The composite index in panel b) contains the following components: Retail sales; Job vacancies; Judgment on capacity utilisation; New export orders; Share prices; and Yield on government bonds. Positive numbers in Panel d) indicate that more people have replied that the variable in question will increase. Vertical lines indicate the crises. Sources: a) Statistics Norway; b) OECD; c) Statistics Sweden; d) DG ECFIN.

time as the Russian moratorium-crisis. When Russia in August 1998 first announced a possible devaluation of the rouble and then a week later, on August 24, a moratorium on all debt payments, this triggered massive international uncertainty. Investors withdrew from small currencies, including the NOK and SEK.

During the spring of 1998 Norway experienced a slowdown in growth, and many commentators argued for monetary and fiscal stimulus in order to spur growth. Again, market participants had for some time expected a switch to inflation targeting, but this time to stimulate growth with lower interest rates. However, when the NOK/DEM depreciated in July and August, Norges Bank increased its key rate to defend the currency, see Figure 2.

In Sweden, inflation had been falling for some time, and was now far below the inflation target of 2% (adopted in 1993), see Figure 3c. Thus, Sveriges Riksbank did not adjust its key rate in response to changes in the exchange rate during this period, cf. Figure 2, in spite of more positive employment expectations Figure 3d. The difference in monetary regimes implied that in Norway, delayed speculation would involve a benefit from the interest rate differential, while in Sweden, the interest rate was unchanged involving no reason to postpone speculation.

4 Results

The model presented in section 2 is stylized, with the aim to illustrate a mechanism for delayed speculation, and does not lend itself easily to structural estimation. E.g., we cannot observe the signals of the players, and data on the macroeconomy can not be used as proxies for the purpose of estimations because they do not vary sufficiently over the rather short calendar time-span of a typical crises. In stead we will test the empirical implications of the model, in view of the data that is available to us. In particular, we focus on the following two issues: (i) The sequence of move of the large (foreign) and small (local) players, and (ii) which players trigger the actual change in the exchange rate.

This choice is based on the key predictions of the model: If fundamentals are very weak, i.e., a successful attack is very likely, and early speculation is costly (e.g. high interest rate differential), large players will delay speculation in order to reap the interest rate benefit, while small players will move early. If fundamentals are somewhat stronger, but a successful attack nevertheless possible, or if the interest rate benefit is small, large

players may move early as well in order to induce small players to join in on the attack. If early speculation is sufficiently cheap, e.g. due to low interest rate differential, the large player may speculate early only. Typically the fall in the exchange rate will be triggered by the players who move late, so in the case where large players only speculate early, it will be the small players who trigger the exchange rate change (and vice versa).

For the four attacks we study, the key difference relates to the difference in monetary regime between Norway and Sweden. Norway had an exchange rate target to be reached in the medium term, and in all the three attacks, the Norges Bank used the policy rate and interventions to defend the exchange rate. In contrast, Sverige had an inflation target. The speculation against the SEK coincided with low and falling inflation, and the Sveriges Riksbank did not raise the interest rate. Thus, there was no benefit to be reaped from postponing the speculative sales of Swedish currency. Since foreigners can raise more funds on short notice we will treat foreigners as large players.

To test for the sequence of moves of the large and small players during the speculative attacks, we will use the statistical concept of Granger causality. Granger causality is not an economic definition of causality, but might be useful to distinguish between which group of players move first or last. Granger causality is tested by running regressions like

$$y_t = \alpha_0 + \sum_{i=1}^k \alpha_i y_{t-i} + \sum_{i=1}^k \beta_i x_{t-i} + \varepsilon_t. \quad (11)$$

There is *absence* of Granger causality from x to y if estimation of y on lagged values of y and lagged values of x is equivalent to an estimation of y on only lagged values of y , i.e., the joint hypothesis of $\beta_1 = \dots = \beta_k = 0$ is not rejected. If this hypothesis is rejected for say x in the equation for y , while not rejected in case of y in a similar equation for x , we say we have one-way Granger causality from x to y .

We distinguish between Granger causality during the crises, and in normal (pre-crisis) periods. When choosing the crises-periods for the Granger causality test we take the crisis dates as our starting point. We end the crisis-period as soon as there are any signs that the exchange rate has stabilized, i.e., when the crisis is over. The beginning of the crises-period is determined in the following way: We go backwards in time from the end of the crisis until the first signs of no turmoil. Then we add observations in the beginning if

needed in order to ensure that the sample is sufficiently long for statistical analysis. The number of crisis-observations and the exact dates are reported in Table 1.

The pre-crisis periods are defined as the 40 observations prior to the crisis-period defined above. This balances the need for a sufficient number of observations without mixing crisis periods and calm periods. Notice that for the study of sequence of moves we believe this approach is better than following a crisis index as it may be the position-taking of the players that will eventually elicit the interest rate and exchange rate changes that are captured by the crisis index.

The results from the Granger causality tests are shown in Table 1. We regress the net trading used in the attack (flows) on lags of locals' and foreigners' flows. We use dummies to differentiate between crisis period and pre-crisis period, and p-values are in parenthesis. The number of lags are determined from the Schwarz and Akaike information criterions.¹⁴ In Table 4 in the appendix we present a similar system using all flows which confirm the results.¹⁵

For the three Norwegian crises we see that lagged speculation of local players during the crisis-period has a significant positive effect on the speculation of foreign players, while the lagged speculation of foreign players has no significant effect on the local players' speculation. Thus, locals Granger cause foreigners. This is in line with the model since in all three cases interest rate differentials changed in such a way to make it more costly to speculate early, implying that large players (foreigners) might gain from delaying the attack.

Figs. 4 and 5 visualize the results from the Granger causality analysis. In Figure 4(a) we see the levels of net trading in spot and forward for local and foreign players in the period from May 1992 to January 1993. The first sign of any changes is when foreigners start selling NOK forward from early August 1992. At this time the interest rate differential was very small. In November 1992 speculative activity emerged in two forms: Local players sold NOK spot and foreigners sold NOK forward.

Figure 4(b) shows the 1997-crisis from August 1996 to February 1997. In the period

¹⁴We choose lags based on the shortest positive lag selected by these two criterions. The weekly frequency employed makes us prefer shorter lags in order to match the theoretical model.

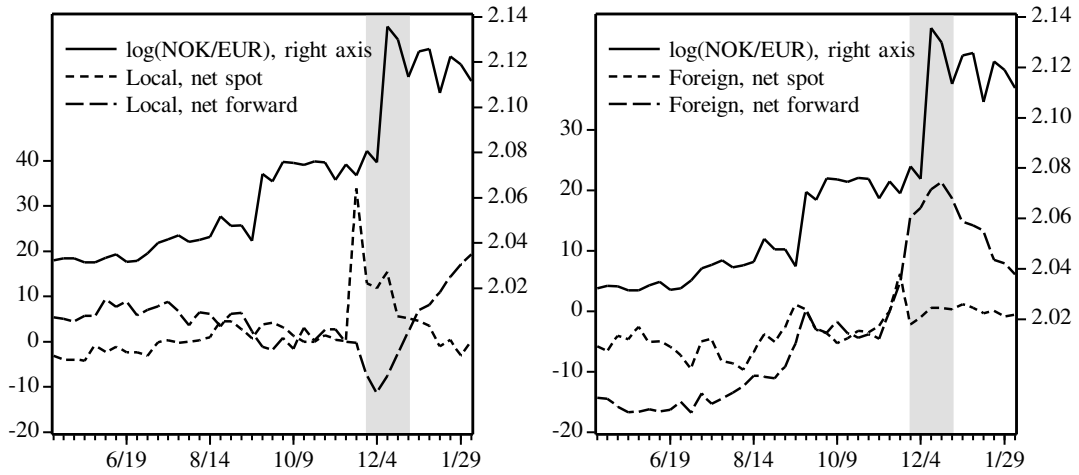
¹⁵A summary of other results for the crisis and pre-crisis periods, for different lag-structures and VAR-formulations, and for method robust to outliers, indicate that the results are rather robust, and is available upon request.

Table 1: Granger causality test for flows: Crisis and pre-crisis

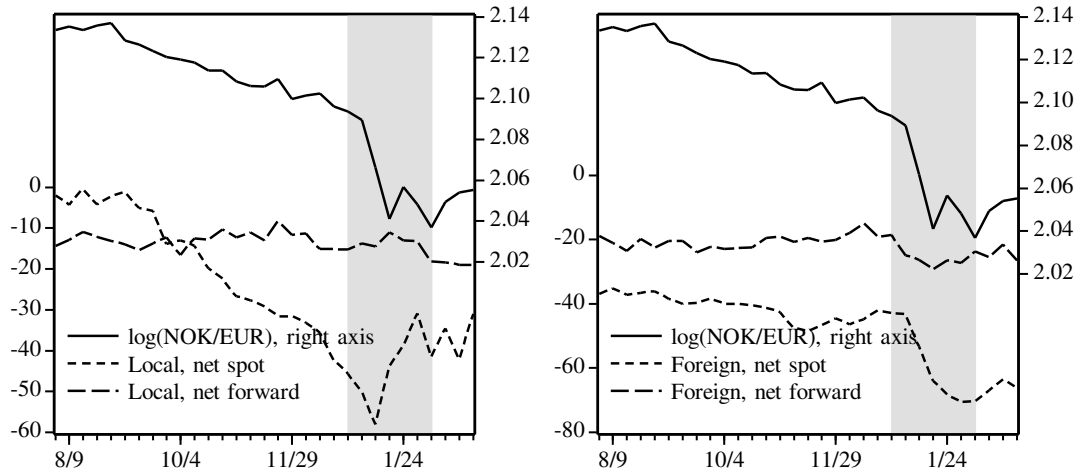
	Norway						Sweden	
	1992		1997		1998		1998	
	Foreigners	Locals	Foreigners	Locals	Foreigners	Locals	Foreigners	Locals
Constant	0.352 *(0.09)	0.177 (0.44)	-0.305 (0.13)	-1.092 *(0.07)	-0.441 (0.33)	0.789 (0.14)	0.010 (0.92)	-0.244 *** (0.00)
Crisis: Foreigners, lagged	0.357 ** (0.02)	0.098 (0.71)	0.573 *** (0.00)	-0.721 (0.11)	0.030 (0.91)	-0.009 (0.98)	-0.153 (0.41)	0.350 ** (0.03)
Crisis: Locals, lagged	0.208 *** (0.00)	-0.420 *** (0.00)	0.184 ** (0.04)	-0.401 ** (0.03)	0.341 *** (0.00)	-0.379 *** (0.00)	-0.190 (0.39)	0.332 (0.13)
Crisis: Locals, 2nd lag					0.316 ** (0.01)			
Pre-crisis: Foreigners, lagged	-0.208 ** (0.01)	-0.021 (0.82)	-0.268 *** (0.00)	-0.136 (0.33)	-0.080 (0.39)	0.017 (0.94)	0.388 * (0.07)	-0.263 * (0.05)
Pre-crisis: Locals, lagged	0.014 (0.91)	-0.124 (0.22)	0.077 ** (0.03)	-0.315 *** (0.00)	0.141 (0.34)	-0.403 *** (0.00)	0.094 (0.75)	0.048 (0.83)
Pre-crisis: Locals, 2nd lag							0.490 *** (0.00)	
adj.R ²	0.23	0.13	0.21	0.12	0.03	0.11	0.07	0.06
Durbin-Watson	2.17	2.23	1.91	1.80	1.88	2.29	2.08	2.06
Observations	81		70		71		71	
Crisis-observations	41		30		31		31	
Crisis period	May 1, 1992 – Feb 2, 1993		Aug 9, 1996 – Feb 28, 1997		May 8, 1998 – Dec 4, 1998		May 8, 1998 – Dec 4, 1998	

Note: Net-trading by Foreigners (Large players) and Locals (Small players) estimated within a system on lagged trading of large and small players, with dummies for pre-crisis period and crisis period. p -values in parenthesis. All equations use one lag, except for both Norway and Sweden in 1998 where we use two lags of Local's trading in the Foreigners-specification during the crisis-period and pre-crisis period, respectively. In Norway, Locals always speculate in spot, while Foreigners speculate with spot in 1997 and with forward in 1992 and 1998. For the Swedish 1998 crisis we estimate using difference of net spot position for Foreigners and difference of forward position for Locals. Significance at 1%, 5%, and 10% are indicated using ***, **, and *, respectively.

Figure 4: The exchange rate and the level of net positions: Norway during the 1992 ERM-crisis (a) and the 1997-attack (b).



(a) The 1992 ERM-crisis



(b) The 1997-attack

Note: Exchange rates (solid lines) measured along the right axis and positions (dotted lines) on the left axis. A negative position indicates a net holding of NOK, implying that an increasing curve indicates selling of NOK. Grey areas indicate the triggering of the crisis. The positions of locals are in the left column.

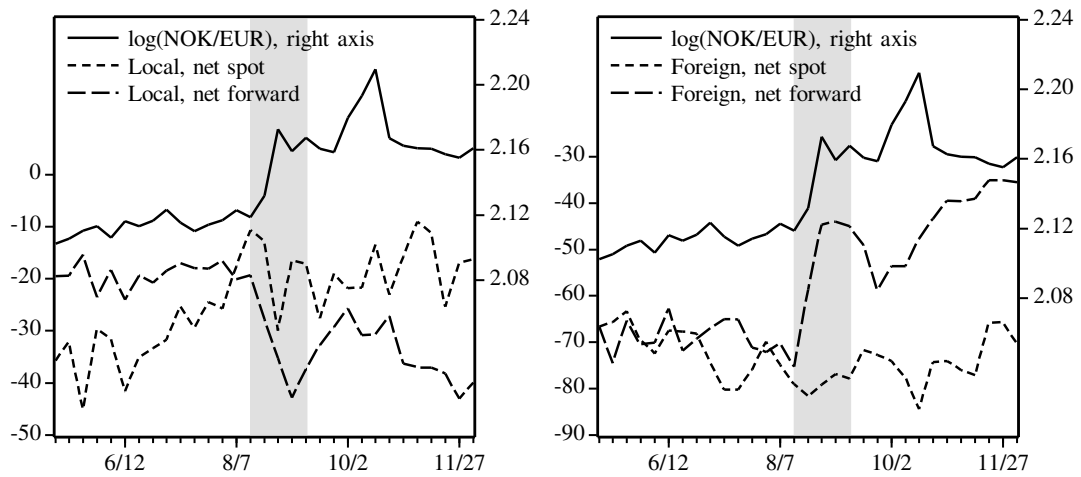
from September to December 1996 local players accumulated spot foreign currency positions as the exchange rate was steadily appreciating, while foreigners did not change their net positions. During the speculative attack in the first weeks of 1997, the central dates were January 6-7, 1997, foreigners were buying NOK spot while locals were selling NOK spot.

For the Swedish 1998-crisis there is some evidence that foreigners Granger cause locals, as lagged speculation of foreigners is significant in the local player regression. This result is also consistent with the model since large players (foreigners) did not have a gain from waiting as Sveriges Riksbank did not increase interest rates; hence risk-adjusted gains by moving late were lower. In Sweden, no change in monetary policy was expected, indicating a higher fundamental θ , and a higher signal y . On the other hand, lower Swedish interest rates meant that speculation costs were lower, i.e. lower t . For small players, high θ and low t have opposing effects, leaving the impact on speculation indeterminate. For large players, however, it follows from Proposition 2, v, that, keeping the sum of the signal and the speculation costs, $y + t$, constant, an increase in speculation costs leads to less early speculation by the large player. In other words, in the speculative attack in Sweden, where interest rates were low, we would expect more early speculation by the large player.

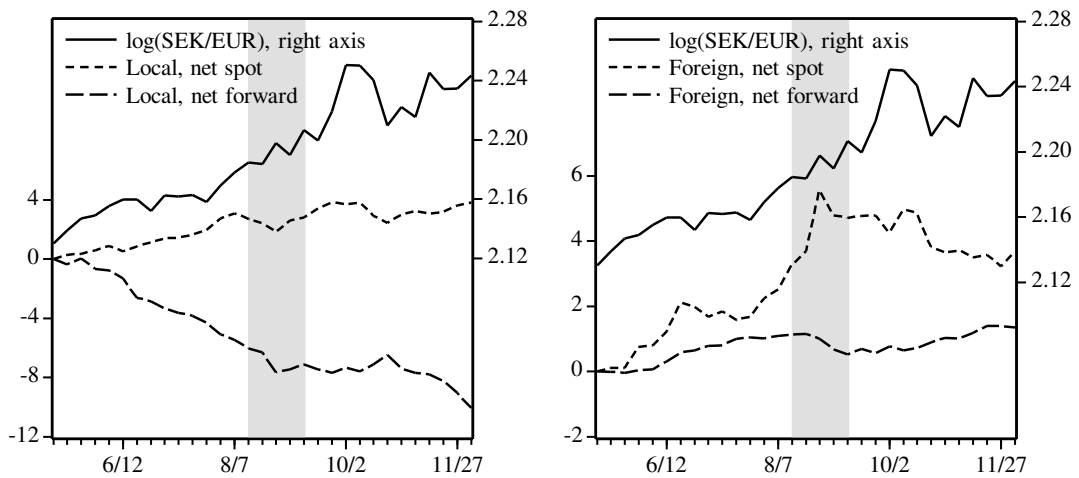
Figures 5(a) and 5(b) show NOK/DEM and SEK/DEM exchange rates and the level of net positions during the period from May 1998 to December 1998. Again we see that in Norway locals were accumulating foreign currency spot during the summer. When the foreigners attacked in August they did so in the forward market. This sale of NOK was matched by locals buying NOK forward. In Sweden the foreigners were selling SEK in July and August, with a peak around the Russian moratorium. Locals, on the other hand, were taking the other side as there were no intervention by the Sveriges Riksbank.

Finally, from Table 1 we see that the crisis pattern discussed above is not representative for the pre-crisis periods. The coefficient on lagged flow of foreign players is negative in the pre-crisis period of all three attacks on Norwegian krone, while it is positive during the crisis-periods. In 1997 there is positive feedback from the locals to the foreigners in the pre-crisis period, but since the foreigners' own lagged flow is negative we can not call this speculative herding. This is consistent with the idea of the model that trading sequences during an attack are different from non-crisis periods.

Figure 5: The exchange rate and the level of net positions: The 1998 Russian moratorium crisis in Norway (a) and Sweden (b).



(a) Norway



(b) Sweden

Note: Exchange rates (solid lines) measured along the right axis and positions (dotted lines) on the left axis. A negative position indicates a net holding of local currency, i.e., NOK or SEK, implying that an increasing curve indicates selling of NOK or SEK. Grey areas indicate the triggering of the crisis. The positions of locals are in the left column.

The second question is which group was most active during the actual crisis. To answer this question we regress changes in the exchange rate on contemporaneous changes in flows and macro variables, with dummies for the crises. Due to problems of multicollinearity we run separate regressions for locals and foreigners. The dummies are selected so that the focus is on what happens during the actual speculative attack. Hence, the dummy is set equal to one for the week prior to the attack, the week with attack, and any following week with large changes in the exchange rate. This gives us three crisis-observations (dummy equals one) for 1992 and 1998, and four for 1997. The results are in Table 2.

Table 2: Crisis-regressions

Note: Regression of NOK and SEK-return on first-difference of flows, interest differential and first-difference log oil price. t -values in parenthesis below coefficient estimates. Asteriks indicate level of significance, ** for 1% significance-level and * for 5% level. Flow-impact during crises are constructed using a dummy on flows.

	dlog(NOK/DEM)		dlog(SEK/DEM)	
	Foreigners	Locals	Foreigners	Locals
Constant	-0.00013 (-0.17)	0.00046 (0.50)	0.0005 (1.02)	-0.0001 (-0.20)
Interest rate diff	-0.00062 (-1.07)	-0.00240 (-3.77)**	0.0174 (5.24)**	0.0189 (5.56)**
Oil price	-0.02894 (-1.45)	-0.03162 (-1.47)	-0.0175 (-1.99)*	-0.0180 (-2.01)*
92-crisis, spot	0.00839 (3.75)**	-0.00147 (-1.39)		
92-crisis, forward	0.00687 (4.29)**	0.00432 (1.68)		
97-crisis, spot	0.00226 (3.31)**	0.00088 (1.10)		
97-crisis, forward	0.00034 (0.23)	-0.00903 (-2.50)*		
98-crisis, spot	0.00238 (1.15)	-0.00183 (-4.01)**	0.0033 (0.66)	0.0027 (0.18)
98-crisis, forward	0.00167 (4.44)**	-0.00152 (-2.20)*	-0.0078 (-0.29)	-0.0070 (-0.71)
Spot	-0.00053 (-1.76)	0.00056 (3.00)**	0.0079 (5.82)**	-0.0058 (-4.18)**
Forward	0.00026 (0.82)	-0.00007 (-0.20)	0.0067 (5.59)**	-0.0037 (-2.70)**
AR(1)	-0.22184 (-2.06)*	-0.06703 (-0.59)	-0.1829 (-4.11)**	-0.1513 (-3.41)**
adj. R^2	0.41	0.35	0.14	0.12
DW	2.11	2.04	2.00	1.99

In the regressions we include the 3-month interest rate differential against Germany

and the log-differenced oil price as macroeconomic variables. The rows labeled “Spot” and “Forward” report the coefficients and t -values for flows outside the actual crisis, while the other rows are the effect of flow in the different crisis.

From the analysis above, we would expect that the foreigners were instrumental in the three Norwegian crises as in the foreigners delayed their attack towards the end. This should be reflected in significant and positive coefficients when the speculation is successful, as players buy currency (positive flow) when speculating on a depreciation (positive change in the exchange rate), and sell (negative flow) when speculating on an appreciation (negative change in the exchange rate). In the 1992- and 1998-crises, foreigners speculated forward (as they had less spot available), while they used spot in the 1997-appreciation crisis. We would also expect that the locals’ flow is insignificant in all three crisis in the case of Norway, or at least not positive as a negative coefficient would imply provision of liquidity to the foreigners. From Table 2 we see that these expectations are largely borne through.

For Sweden we do not find any significant effects during the 1998-crisis. Given the evidence that foreigners Granger caused locals, we would expect that at least the locals’ flows were positive and significant. However, Figure 5 seems to suggest that it is the foreigners that are most active in the crisis week, and that the period when the SEK actually jumped was somewhat later.

The impact of the flows in the crisis is also of economic significance. For the 1992-case we find that the size effect of forward flow on the NOK/DEM exchange rate is 0.69% per billion NOK sold, or about 5% per 1 billion USD equivalent.¹⁶ The comparable numbers for the 1997- and 1998-events are about 1.6% per 1 billion *spot*-USD for 1997 and about 1.2% per 1 billion *forward*-USD for 1998. As a comparison, Evans and Lyons (2002) report an effect from flows to the DEM/USD exchange rate of about 0.5% per 1 billion USD equivalent. The larger effect of given currency trade that we find seems reasonable given that the periods we are studying here naturally is reflected by higher uncertainty than the more normal period studied by Evans and Lyons. The lower numbers for 1997 and 1998, compared to 1992, might be due to increased liquidity over time and less rigid monetary regimes.

¹⁶The average NOK/USD rate over the period 1992-2000 was 7.4.

5 Conclusion

We study the dynamics of speculative attacks. The problem of connecting currency crises to fundamentals has led to a discussion of possible manipulation of exchange rates, especially by large foreign players like hedge funds and other highly leveraged institutions. To analyze this we extend the model of Corsetti et al. (2004) by incorporating the costs and benefits of "early" versus "late" speculation by the large player. The model of Corsetti et al. (2004) predicts that large players may move early in an attack in order to induce small players to attack. It has, however, been argued by Tabellini (1994) and the IMF that large players move in the rear in currency crises in order to reap the benefit from higher interest rate differentials.

In our model the large players may choose to speculate early, incurring trading and interest rate costs, but also providing a signal to the small players, possibly inducing them to speculate. However, the large player may also choose to wait with the speculation, reaping the benefit of a positive interest rate differential while waiting, but also missing the opportunity to influence the smaller players, as well as risking being too late to join the attack. The smaller players will not speculate as early as the large player, as they cannot affect the behavior of other players. Nor will they want to incur the costs of continuous monitoring that is required to be able to join the speculation at a late stage.

The theoretical model is used as a framework for an empirical analysis of four speculative attacks in Norway and Sweden during the 1990s.: The ERM-attack in 1992 on the Norwegian krone; the 1997 appreciation crisis in Norway; and the August 1998 crisis following the Russian moratorium. The latter event is especially interesting, as in this case we can compare the effects of an international event on two similar neighboring countries, but where the monetary regimes differed. We have data for net currency trading of foreign and local traders in Norway and Sweden. Foreigners trade on average larger volumes than locals. We therefore believe it is reasonable to proxy Large players with foreigners and Small players with locals.

As most of the related literature, we use a stylized theoretical model where players have private information, making it difficult to test empirically many of the theoretical predictions. However, the model does have predictions regarding the sequence of trading and which players trigger the attack, that can be explored empirically. The sequence of

trading is tested with Granger causality tests, while the triggering of the attacks is tested with regression analysis. We find that local players lead the foreign players in all cases except the 1998-crisis in Sweden. This is in line with the model since the Norwegian central bank used interest rates to defend the krone in all cases, implying that it was profitable to delay the attack in Norway for players that have sufficient capacity that they were able to enter a later stage, as we argue apply for more of the foreign traders. In contrast, the Swedish central bank did not change its interest rate during the depreciation crisis in 1998, implying that there was no gain by delaying the attack in Sweden. The regression analysis shows that it was the foreigners that triggered the attack in all cases. Regrettably, we cannot condition on the signal of the players in the regressions. The fact that all attacks were successful may, however, indicate that fundamentals in Norway in all three cases were in the region where large players preferred to move in the rear.

This paper is to the best of our knowledge the first that is able to study speculative attacks with data on the trading of both large (foreign) and small (local) players.

A Proof of Proposition 1

Proof. *i.* Note from (7) that for $t = 0$, $\frac{\partial E\pi}{\partial \lambda} > 0$ for all λ , as the other terms are always positive. Thus, for $t = 0$, $\lambda = L$ is optimal. By continuity of $\frac{\partial E\pi}{\partial \lambda}$, it follows that $\frac{\partial E\pi}{\partial \lambda} > 0$ for all λ , also for sufficiently small positive values of t . Let \underline{t} denote the supremum of all t for which $\frac{\partial E\pi}{\partial \lambda} > 0$ for all λ . It follows that $\lambda = L$ is optimal for all $t < \underline{t}$.

ii. Consider first the case where $q = 1$. If expected profits is negative for all $\lambda > 0$, then clearly $\lambda = 0$ is optimal. If there exists a $\lambda' > 0$ for which expected profits is positive, i.e. $E\pi(\lambda') = \left(G\left(\frac{1-t+\lambda'-y}{\tau}\right) - t\right) \lambda' > 0$, it follows that $\left(G\left(\frac{1-t+\lambda'-y}{\tau}\right) - t\right) > 0$. Thus, in this case we know that the derivative of the expected profits,

$$E\pi'(\lambda) = \left(G\left(\frac{1-t+\lambda-y}{\tau}\right) - t\right) + G'\left(\frac{1-t+\lambda-y}{\tau}\right) \frac{\lambda}{\tau} > 0 \quad \text{for all } \lambda \geq \lambda'$$

as both terms are strictly positive for $\lambda \geq \lambda'$. It follows that if it is possible to obtain positive expected profits by early speculation, then the large player wants to speculate by the maximum feasible amount L . Thus, it follows that for $q = 1$, the optimal λ is either zero or equal to L . By continuity of $E\pi$ it follows that for any given $\kappa > 0$, we can always choose a q sufficiently close to unity that the optimal λ is either within $[0, \kappa]$ or within $[L - \kappa, L]$. ■

B Proof of Proposition 2

We begin with a few definitions. The expected payoff given an early speculation λ^* is given by

$$E\pi^* = L \cdot G\left(\frac{1-t+\lambda^*-y}{\tau}\right) - t\lambda^* = L \cdot G\left(g^{-1}\left(\frac{\tau t}{L}\right)\right) - t\left(y - (1-t) + \tau g^{-1}\left(\frac{\tau t}{L}\right)\right), \quad (12)$$

where we use Equation (9) to substitute out for λ^* .

The expected payoff from not speculating early, yet entering at a late stage in the amount L (at zero cost), is

$$E\pi^0 = L \cdot G\left(\frac{1-t-y}{\tau}\right). \quad (13)$$

Proof. Consider first the interval $y < y^{Lo}$. In this interval we know that $\frac{\partial E\pi}{\partial \lambda} = L \cdot g\left(\frac{1-t+\lambda-y}{\tau}\right) \frac{1}{\tau} - t < 0$, as it follows from the derivation above that

1. $\frac{\partial E\pi}{\partial \lambda} = 0$ for $y = y^{Lo}$ and $\lambda = 0$.
2. $g'(\cdot) < 0$ for all $y < y^{Lo}$ (as $g(\cdot)$ is strictly decreasing for all positive arguments, and $\frac{1-t-y^{Lo}}{\tau} > 0$)

It follows that in this interval the optimal early speculation is zero, $\lambda = 0$ (as we do not allow negative speculation)

We then restrict attention to $y > y^{Lo}$. Define the difference between the profit under optimal early speculation and the profit with no early speculation $W(y) \equiv E\pi^* - E\pi^0$. Using (12) and (13), we obtain

$$W(y) = L \cdot G\left(g^{-1}\left(\frac{\tau t}{L}\right)\right) - t\left(y - (1-t) + \tau g^{-1}\left(\frac{\tau t}{L}\right)\right) - L \cdot G\left(\frac{1-t-y}{\tau}\right).$$

We have that $W(y^{Lo}) = 0$, as it is optimal to set the early speculation to zero for $y = y^{Lo}$. Furthermore, note that the derivative of W in the point $y = y^{Lo}$ is also zero, i.e.,

$$\begin{aligned} \frac{\partial W(y^{Lo})}{\partial y} &= -t + L \cdot g\left(\frac{1-t-y^{Lo}}{\tau}\right) \frac{1}{\tau} \\ &= -t + L \cdot g\left(\frac{1-t - (1-t - \tau g^{-1}(\frac{\tau t}{L}))}{\tau}\right) \frac{1}{\tau} = -t + L \frac{\tau t}{L \tau} = 0. \end{aligned}$$

Consider first the interval for y satisfying $\frac{1-t-y^{Lo}}{\tau} > \frac{1-t-y}{\tau} \geq 0$. It is clear that in this interval $\frac{\partial W}{\partial y} > 0$, since $g(\cdot)$ is strictly decreasing for positive arguments, implying that $g(\cdot)$ is greater for smaller arguments (i.e., for $y \geq y^{Lo}$). It follows that $W(y) > 0$ in this interval; this implies that it is profitable to speculate early in a quantity $\lambda^* > 0$ in this interval.

Then consider all y satisfying $\frac{1-t-y}{\tau} < 0$. We have

$$\frac{\partial^2 W}{\partial y^2} = -L \cdot g'\left(\frac{1-t-y}{\tau}\right) \frac{1}{\tau^2} < 0,$$

implying that W is strictly concave. As W clearly goes to minus infinity as y converges to infinity, there is a unique value y^{Hi} for which $W(y^{Hi}) = 0$. Thus, for $y > y^{Hi}$, then $W(y) < 0$, implying that early speculation is not profitable, i.e. set $\lambda = 0$. However, in the interval $y \in (y^{Lo}, y^{Hi})$, $W(y) > 0$, implying that early speculation is profitable, in the amount λ^* .

The derivative of the optimal early speculation λ^* with respect to the noise in the signal τ is (using (9))

$$\frac{\partial \lambda^*}{\partial \tau} = -g^{-1} \left(\frac{\tau t}{L} \right) - \tau g^{-1'} \left(\frac{\tau t}{L} \right) \frac{t}{L}$$

where the first term is negative and the second positive (as $g^{-1'} \left(\frac{\tau t}{L} \right) = 1/g'(\cdot) < 0$), implying that the sign is indeterminate (we have no restrictions ensuring which of the terms is greater in absolute value).

The derivative of the optimal early speculation λ^* with respect to speculation costs t is (using (9))

$$\frac{\partial \lambda^*}{\partial t} = 1 + \tau g^{-1'} \left(\frac{\tau t}{L} \right) \frac{\tau}{L}$$

where the first term is positive and the second negative, implying that the sign is indeterminate (we have no restrictions ensuring whether the second term is greater or smaller than unity in absolute value).

The derivative of the optimal early speculation λ^* with respect to speculation cost t , conditional on the combined state $y + t$ is (using (9))

$$\frac{\partial \lambda^*}{\partial t} \Big|_{y+t=\text{constant}} = \tau g^{-1'} \left(\frac{\tau t}{L} \right) \frac{\tau}{L} < 0.$$

■

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C Tables

Table 3: Descriptive statistics and correlations matrixes for Norwegian flows

Note: Descriptive statistics for flows (panel a), and correlation matrix between flows (panel b), over the whole sample, and each of the crisis-periods as defined in Table. Numbers in bold indicate the variables discussed in Section 3. 1.

		Large		Small		
		Spot	Forward	Spot	Forward	
Whole sample	a)	Mean	-0.04	0.05	0.03	-0.16
		Median	-0.28	-0.07	0.04	-0.06
		Maximum	21.05	16.58	33.87	15.80
		Minimum	-22.25	-20.06	-20.97	-10.38
		Std. Dev.	3.78	4.03	5.45	3.05
		Observations	469	469	469	469
	b)	Large spot	1			
		Large forward	-0.128	1		
		Small spot	-0.254	-0.308	1	
		Small forward	0.098	-0.336	-0.090	1
1992	a)	Mean	0.09	0.49	0.18	0.40
		Median	-0.13	-0.17	-0.13	0.73
		Maximum	6.22	10.95	33.87	4.84
		Minimum	-8.37	-4.77	-20.97	-7.05
		Std. Dev.	2.46	2.79	6.76	2.90
		Observations	41	41	41	41
	b)	Large spot	1			
		Large forward	-0.071	1		
		Small spot	0.630	-0.094	1	
		Small forward	0.084	-0.601	0.105	1
1997	a)	Mean	-0.98	-0.25	-0.97	-0.16
		Median	-0.67	0.10	-1.96	-0.19
		Maximum	3.47	4.14	14.23	4.65
		Minimum	-10.81	-6.38	-10.61	-4.95
		Std. Dev.	3.27	2.72	5.71	2.32
		Observations	30	30	30	30
	b)	Large spot	1			
		Large forward	0.165	1		
		Small spot	-0.371	-0.372	1	
		Small forward	-0.130	-0.395	0.214	1
1998	a)	Mean	-0.21	1.07	0.54	-0.56
		Median	-0.94	0.50	0.80	0.06
		Maximum	11.25	16.58	15.37	5.45
		Minimum	-6.87	-9.70	-17.08	-9.04
		Std. Dev.	4.58	5.93	8.07	4.49
		Observations	31	31	31	31
	b)	Large spot	1			
		Large forward	0.076	1		
		Small spot	-0.597	-0.523	1	
		Small forward	0.055	-0.372	-0.211	1

Table 4: Granger causality test on all flows: Norway, 1992, 1997 and 1998

Note: Difference of net-position (flows), both spot and forward, of large and small players estimated within a system on lagged flows of large and small players, with dummies for pre-crisis period and crisis period. p -values in parenthesis. All equations use one lag, except in 1998 where we use two lags of small's spot trading in the large-specification during the crisis-period.

		1992								
		Small spot		Small forward		Large spot		Large forward		
Crisis	Constant	0.359	(0.18)	0.339	(0.09)	0.649	(0.01)	0.284	(0.14)	
	Small spot	-0.631	(0.00)	-0.153	(0.04)	-0.241	(0.00)	0.186	(0.01)	
	Small forward	-0.505	(0.09)	0.009	(0.97)	0.009	(0.95)	-0.159	(0.16)	
	Large spot	0.968	(0.17)	0.185	(0.49)	0.196	(0.23)	0.113	(0.66)	
Pre-crisis	Large forward	-0.197	(0.67)	-0.363	(0.05)	-0.102	(0.45)	0.273	(0.10)	
	Small spot	0.031	(0.78)	0.240	(0.24)	0.295	(0.21)	-0.365	(0.00)	
	Small forward	0.117	(0.25)	-0.437	(0.00)	0.022	(0.90)	-0.150	(0.14)	
	Large spot	-0.140	(0.12)	-0.040	(0.77)	-0.160	(0.34)	0.331	(0.00)	
		Large forward	-0.003	(0.99)	0.191	(0.20)	-0.004	(0.99)	-0.267	(0.01)
adj. R^2		0.19		0.15		0.06		0.26		
DW		2.29		2.14		2.03		2.19		
		1997								
		Small spot		Small forward		Large spot		Large forward		
Crisis	Constant	-1.195	(0.03)	-0.342	(0.25)	-0.320	(0.12)	0.056	(0.84)	
	Small spot	-0.328	(0.00)	-0.130	(0.02)	0.241	(0.01)	0.276	(0.00)	
	Small forward	-0.188	(0.51)	-0.446	(0.02)	0.060	(0.78)	0.086	(0.47)	
	Large spot	-0.771	(0.12)	-0.107	(0.06)	0.545	(0.00)	0.101	(0.13)	
Pre-crisis	Large forward	0.543	(0.15)	-0.254	(0.06)	0.538	(0.03)	-0.243	(0.00)	
	Small spot	-0.425	(0.00)	0.209	(0.11)	0.035	(0.55)	-0.082	(0.49)	
	Small forward	-0.519	(0.01)	-0.013	(0.92)	-0.218	(0.03)	-0.061	(0.68)	
	Large spot	-0.199	(0.29)	0.090	(0.68)	-0.266	(0.16)	-0.297	(0.32)	
		Large forward	-0.113	(0.46)	0.067	(0.45)	-0.015	(0.93)	-0.373	(0.12)
adj. R^2		0.14		0.10		0.29		0.13		
DW		1.86		1.95		1.84		1.89		
		1998								
		Small spot		Small forward		Large spot		Large forward		
Crisis	Constant	0.995	(0.12)	-0.079	(0.87)	-0.582	(0.18)	-0.115	(0.86)	
	Small spot	-0.513	(0.03)	0.093	(0.48)	-0.013	(0.96)	0.312	(0.02)	
	Small forward	-0.486	(0.09)	-0.257	(0.22)	0.136	(0.64)	-0.396	(0.35)	
	Large spot	0.127	(0.67)	0.011	(0.96)	-0.083	(0.66)	0.056	(0.71)	
Pre-crisis	Large forward	-0.289	(0.53)	-0.371	(0.00)	0.067	(0.84)	-0.073	(0.73)	
	Small spot	0.118	(0.53)	-0.119	(0.37)	-0.381	(0.00)	0.187	(0.52)	
	Small forward	0.159	(0.58)	-0.047	(0.67)	-0.247	(0.22)	0.036	(0.90)	
	Large spot	1.075	(0.00)	-0.012	(0.95)	-0.897	(0.00)	0.125	(0.66)	
		Large forward	0.353	(0.00)	-0.114	(0.37)	-0.178	(0.07)	-0.008	(0.95)
		Small spot, 2nd lag							0.412	(0.03)
adj. R^2		0.22		0.11		0.14		-0.01		
DW		2.20		1.84		1.99		1.99		