Contagious Currency Crises: First Tests*

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Abstract
We address the fact that the incidence of speculative attacks tends to be temporally correlated; that is, currency crises appear to pass "contagiously" from one country to another. The paper provides a survey of the theoretical literature. We also provide empirical evidence consistent with the contagious nature of currency crises. We estimate that the existence of a currency crisis elsewhere in the world (whether successful or not) raises the probability of an attack on the domestic currency by 8 percent, even after taking account of a variety of domestic political and economic factors.

I. Introduction
The scope for currency crises to spill contagiously across countries has been hotly debated in the wake of the Mexican meltdown. A frequently cited justification for the $50 billion of assistance provided by the IMF, the U.S. and other G-7 governments in early 1995 was that the effects of the Mexican crisis, if allowed to play themselves out, would not be limited to that country; rather, other emerging markets would have experienced serious repercussions. Because the Mexican authorities had little incentive to internalize these externalities, multilateral intervention was justified. In support of this view observers cite the reserve losses, interest-rate increases and weakening exchange rates suffered by countries like Argentina and Thailand in the early weeks of 1995. The contrary view is that investors were discriminating in the countries they attacked. Currencies other than the Mexican peso were subjected to relatively little pressure, and only countries with large current-account deficits, overvalued real rates and other weak fundamentals felt much of an effect. The implication is that the

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Mexican bailout, to the extent that it was justified by fears of contagion, was uncalled for.

A similar controversy arose at the time of the 1992–93 crises in the European Monetary System. In 1992 it was argued that the French franc and the Irish punt came under attack as a result of the earlier crises experienced by the British pound and the Italian lira. In 1993 it was argued that the attack on the French franc threatened to spill over to other European currencies. The implication drawn was that foreign support of the franc was essential to prevent chaos from spreading contagiously throughout the EMS. The rebuttal was that only European countries whose fundamentals were weak were subjected to speculative attacks; others like the Netherlands remained immune because they appropriately aligned their economic policies to the maintenance of their currency pegs. If contagion existed, the implication went, only countries in particular economic and political circumstances were susceptible.

Clearly, the stakes for policy are immense. Ascertaining whether there exists contagion in foreign exchange markets and under what conditions contagious currency crises arise should be a high priority for empirical research in open-economy macroeconomics. It is remarkable therefore that there exists little systematic analysis of the question. Our goal in this appear is to take a first step towards filling this gap.

We use a panel of quarterly data for 20 industrial countries for the period 1959–93 to test for contagious currency crises. We ask whether the probability of a crisis in a country at a point in time is correlated with the incidence of crises in other countries at the same time, after controlling for the effects of political and economic fundamentals. The evidence is striking: a variety of tests and a battery of sensitivity analyses uniformly suggest that a crisis elsewhere in the world increases the probability of a speculative attack by an economically and statistically significant amount (our best estimate is eight percentage points), even after controlling for economic and political fundamentals in the country concerned. This would appear to be the first systematic evidence of the existence of contagious currency crises.

The remainder of our paper is organized as follows. Section II provides an overview of the theoretical literature on speculative attacks in foreign exchange markets, with special reference to contagion. Section III reviews related empirical studies. In Section IV we present new evidence on contagion. Section V concludes.

II. Theories of Speculative Attacks, Contagious and Otherwise

In this section we review the theoretical literature on speculative attacks in foreign exchange markets, starting with the seminal Krugman (1979)
model, proceeding to models of multiple equilibria, and concluding with models of contagious currency crises.¹

Speculative Attacks

Krugman's contribution was to show how inconsistencies between domestic economic conditions and an exchange rate commitment lead to the collapse of the currency peg. In his model, the overly expansionary stance of domestic policy causes domestic absorption to exceed production. The difference spills over into a balance-of-payments deficit, which the central bank finances by expending reserves. Eventually reserves fall to a critical threshold at which a speculative attack is launched, eliminating the authorities' remaining foreign assets. Once reserves are depleted, the exchange rate peg is abandoned, and the currency depreciates secularly over time, reflecting the more expansionary stance of policy at home than abroad.

This theory of balance of payments crises has produced four classes of insights. First, it helps to identify the relevant fundamentals. Most obviously, these should include macroeconomic determinants of the exchange rate and the balance of payments, as embodied in aggregative models of exchange rate determination and the literature on the monetary approach to the balance of payments. Given the forward-looking nature of these models, this list of determinants will necessarily include expected future values of the relevant series.² At the same time, the poor empirical performance of these models gives grounds for concern about the success with which speculative-attack models building on these foundations can be implemented empirically; we revisit this point below.³

Second, the Krugman model demonstrates how crises can erupt before official reserves, which decline secularly over time, actually hit zero. Currency speculation takes the form of purchases and sales of domestic currency for foreign assets. Those transactions arise as traders exchange assets among themselves so as to equalize rates of return and, more generally, to balance their portfolios, trading off risk and return. They provoke a crisis when no one in the market is willing to acquire domestic currency at the prevailing price (given by the pegged rate of exchange). Under these circumstances, the only counterpart on the short side of the market is the central bank. Speculators have an incentive to liquidate their holdings of domestic currency while the central bank retains sufficient

¹A recent survey is Blackburn and Sola (1993).
²That expected future fundamentals can themselves depend on whether a speculative attack occurs is what gives rise to the possibility of multiple equilibria, as we explain below.
³For evidence and surveys of the empirical performance of this class of models, see Meese and Rogoff (1983), Obstfeld and Rogoff (1995) and Obstfeld (1995).

reserves to absorb the volume of sales. The timing of the attack is determined such that its magnitude just suffices to eliminate the central bank's entire stock of reserves.

A third implication of the basic model is that the central bank can only maintain a currency peg if it possesses adequate foreign exchange reserves. Once their reserves have been lost in the attack, the authorities have no choice but to abandon the peg. In the standard model, crises thus result in a transition to floating. The model thus implies that reserve stocks must be reconstituted before the exchange rate can be re-pegged. The standard formulation also helps us think about the meaning of "reserve adequacy". To defend the currency peg, the central bank must be capable of purchasing all of its liabilities that are put up for sale by other agents. In the standard model, the volume of sales is small; it corresponds to the decline in monetary base needed to ratify the fall in money demand associated with the higher interest rates that prevail following the shift from a pegged to a depreciating exchange rate. Normally, domestic residents continue to hold a significant proportion of the base following the collapse of the peg, since they need it for transactions purposes. But in highly dollarized economies, the transactions demand for domestic currency can be very small, as pointed out by, *inter alia*, Edwards (1989); in this case, the share of the monetary base subject to liquidation in a crisis may be quite large. More worrisome still is the possibility that the monetary authorities will also be required to purchase other domestic liabilities (i.e., M2) if the currency crisis provokes a banking crisis.4

A fourth implication of the standard model is that the authorities have little chance of fending off an attack. Even if the volume of speculative sales of domestic currency is less than the monetary base, the base still exceeds the net stock of foreign reserves of the central bank (except in very special circumstances like a fully backed currency board). In principle, the authorities can augment their gross reserves by borrowing abroad, possibly to the point where reserves exceed the base. But if borrowed reserves are used to finance sterilized intervention, the monetary base increases *pari passu*, and there is no level of gross reserves sufficient to repel an attack. If the authorities do not sterilize, then the attack can be repelled, but only at the cost of allowing the base to shrink and interest rates to rise. If a sizable proportion of the base is involved, the resulting interest rate increases may be so large that the exchange rate crisis precipitates a banking crisis. To avert the latter, the central bank may then have to resume sterilizing its

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4The link between financial and exchange crises is emphasized by Goldfajn and Valdés (1995) and is a point to which we return below.

intervention, which will again undermine its capacity to defend the currency peg.

**Multiple Equilibria**

A generic feature of theoretical macroeconomic models with rational expectations is that such models typically have multiple solutions. Since most of these solution paths do not converge to a steady state, standard practice for many years was to assume away divergent solutions by invoking transversality conditions. More recently however this non-uniqueness property — which allows for multiple equilibria — has become the basis for a literature on speculative bubbles and sun-spot equilibria. Obstfeld (1986, 1995), following a suggestion by Flood and Garber (1984), has provided examples of multiple equilibria and self-fulfilling attacks in foreign exchange markets. These offer a wholly new perspective on the causes of currency crises.

The possibility of multiple equilibria arises when market participants, while not questioning that current policy is compatible with the indefinite maintenance of the currency peg, anticipate that a successful attack will alter policy. In these circumstances, it is expected future fundamentals, conditional on an attack taking place, rather than current fundamentals and expected future fundamentals absent an attack, which are incompatible with the peg. Two equilibria thus exist: the first one features no attack, no change in fundamentals, and indefinite maintenance of the peg; the second one features a speculative attack followed by a change in fundamentals which validates, *ex post*, the exchange-rate change that speculators expected to take place.

In Obstfeld (1986), pre- and post-crisis policies are set arbitrarily. If an attack occurs, the government is simply assumed to shift policy in a more expansionary direction. The arbitrary nature of this contingent policy process is the obvious limitation of the model. Subsequently, Bensaid and Jeanne (1993), Ozkan and Sutherland (1995) and Obstfeld (1995) have proposed models of optimizing governments which find it in their self interest to follow the kind of contingent policy processes that can give rise to multiple equilibria and self-fulfilling attacks. Their analyses build on the literature on exchange rate escape clauses, in which it is optimal to maintain the currency peg under some circumstances and to abandon it under others: see Obstfeld (1991), De Kock and Grilli (1994) and Drazen and Masson (1994).

In these models, the behaviour of governments still derives from special utility functions. In this sense, the literature on multiple equilibria and self-fulfilling attacks in foreign exchange markets is merely a collection of
examples and special cases. This point is emphasized by Krugman (1996), who establishes two further results. First, he suggests that multiple equilibria are, paradoxically, less likely when the fundamentals are wrong. When fundamentals are clearly inconsistent with the prevailing currency peg, investors have little doubt that a crisis will ultimately occur, and the model quickly converges to the equilibrium in which the currency is attacked and devalued; only when fundamentals are "good enough" that there remains uncertainty about whether a crisis will eventually result do there exist multiple equilibria. Second, Krugman shows that if the public does not know the authorities preferences, there may be "testing" by the markets — that is, one may observe attacks that are unsuccessful but which reveal information about the preferences of the authorities.\(^5\)

Models of self-fulfilling attacks imply that "good" fundamentals may not suffice to avert currency crises. To prevent an attack unjustified by fundamentals, the credibility of the central bank must be such that markets rule out a relaxation of policy once the peg is abandoned. Obstfeld (1986) provides such an example: there, the expectation that the central bank will react to a crisis by implementing a policy which implies an exchange rate appreciation eliminates the risk of a self-fulfilling crisis.

Contagion

Very little theoretical work has analyzed the conditions under which currency crises can spread contagiously across countries. The first systematic theoretical treatment of this question was Gerlach and Smets (1995). Inspired by the links between the fall of the Finnish markka in 1992 and the subsequent attack on the Swedish krona, they consider two countries linked together by trade in merchandise and financial assets. In their model, a successful attack on one exchange rate leads to its real depreciation, which enhances the competitiveness of the country's merchandise exports. This produces a trade deficit in the second country, a gradual decline in the international reserves of its central bank, and ultimately an attack on its currency. A second channel for contagious transmission is the impact of crisis and depreciation in the first country on the import prices and the overall price level in the second. Post-crisis real depreciation in the first country reduces import prices in the second. In turn, this reduces its

\(^5\) While testing is not, strictly speaking, an example of self-fulfilling attacks since markets anticipations are not fulfilled, it is a case where the attack is unjustified by the fundamentals.
consumer price index and the demand for money by its residents. Their efforts to swap domestic currency for foreign exchange then deplete the foreign reserves of the central bank. This may shift the second economy from a no-attack equilibrium, in which reserves more than suffice to absorb the volume of prospective speculative sales and in which there consequently exist no grounds for a speculative attack, to a second equilibrium in which an attack can succeed and in which speculators thus have an incentive to launch it.\footnote{A similar argument is developed by Andersen (1994), building on escape-clause models of exchange-rate policy. In his model, the government is prompted to abandon its currency peg by a shock coming from outside the currency market. An exogenous deterioration in domestic competitiveness which increases domestic unemployment, for example, may give the authorities an incentive to opt for a more expansionary policy which reduced unemployment through surprise inflation, à la Barro and Gordon (1983) Andersen argues that his model provides a plausible description of exchange rate policy in Northern Europe in 1991–92, when the collapse of Soviet trade with the Nordic countries first aggravated unemployment in Finland, leading its government to adopt a more expansionary policy which required abandoning the currency peg, and which then spilled over to the exchange rates of the rest of Scandinavia.}

Buiter et al. (1996) use an escape-clause model of exchange rate policy to analyze the spread of currency crises in a system of $N + 1$ countries, $N$ of which (denoted the "periphery") peg to the remaining country (the "center"). The center is more risk averse than the others and is hence unwilling to pursue a cooperative monetary policy designed to stabilize exchange rates. A negative shock to the center which leads it to raise interest rates then induces the members of the periphery to reconsider their currency-pegging policy. If the members of the periphery cooperate, they may find it collectively optimal to leave the system — an extreme case of contagion. More generally, some subset of peripheral countries — those with the least tolerance for high interest rates — will find it optimal to leave the system under these circumstances, and contagion will be limited to this subset. Importantly, however, their decision to leave stabilizes the currency pegs of the remaining members of the system, because monetary expansion and currency depreciation by some members of the periphery provides an incentive for the center country, which now finds itself with an increasingly overvalued exchange rate, to relax its monetary stance, relieving the pressure on rest of the periphery. In this model, contagion is selective: the shock to the center spills over negatively to some members of the periphery but positively to others.

Another paper provides an analysis of contagious currency crises is Goldfajn and Valdés (1995). They focus on the role of illiquidity in finan-
cial markets. A key feature of their model is the introduction of financial intermediaries. These authors show how, in the presence of such intermediaries, small disturbances can provoke large-scale runs on a currency. Intermediaries supply liquid assets to foreigners unwilling to commit to long-term investments; that is, they provide maturity-transformation services. By offering attractive terms on liquid deposits, their presence augments the volume of capital inflow. But when, for exogenous reasons, foreign investors withdraw their deposits, intermediaries unable to costlessly liquidate their assets face the risk of failure. Hence, a bank run can produce a self-fulfilling banking crisis, cf. Diamond and Dibvig (1983), in the same way that a run on the currency can provoke a self-fulfilling exchange-rate crisis. Moreover, the run on intermediaries can spill over into a run on the currency as foreign investors withdraw their deposits and convert them into foreign exchange. These crises can spread contagiously to other countries when international investors encountering liquidity difficulties as a result of the banking crisis in one country respond by liquidating their positions in other national markets.

A related literature concerned with information, while not directly concerned with contagion in foreign exchange markets, provides a complementary approach to the issue. Shiller (1995) provides a model in which financial market participants share access to much of the same information (e.g. that which appears on Reuters screens) but interpret and process it in different ways. What they make of their shared information depends on their own experience, which in turn is shaped by local conditions which only they experience. Consequently, one market's reaction to a piece of new information can provide a signal about its global implications. It may suggest to traders in other markets how they too should react. The fact that one market draws dramatic conclusions from some information may overcome local culture in other markets and lead to a revision of expectations (an "information cascade"). In the present context, one can see how this effect could lead an attack on one exchange rate to prompt traders in other currency markets to attack those exchange rates as well.

A similar analysis, also based on informational issues, is Caplin and Leahy (1995). In their model, financial market participants expect a crisis but have diffuse priors over its timing. It is costly for traders to take a position in advance of a crisis, in other words to move too early. Each trader is unsure whether others share his or her belief that a crisis will eventually occur. They exchange "cheap talk" amongst themselves but draw inferences only from positions taken in the market. The result is normal market conditions ("business as usual") with no hint of crisis until it suddenly erupts. Once it occurs, however, market participants all claim that they knew that the crisis was about to happen and that they were readying themselves for the eventuality (they display "wisdom after the
fact”). This model can give rise to contagion insofar as a crisis somewhere in the world confirms individually-held suspicions in other markets.\textsuperscript{7}

III. Empirical Studies of Speculative Attacks, Contagious and Otherwise

While the literature on crises in foreign exchange markets is replete with models that highlight motives for and dynamics of speculative attacks, the process of systematically testing the predictions of those theories has barely begun. We put the emphasis in this last sentence on the word “systematically”. Otherwise convincing studies of currency crises frequently assemble evidence from biased samples of episodes. It is not just that they consider a selective sample of episodes in which currency pegs collapsed without confirming that the collapses they analyze are representative of the underlying population. It is that episodes in which pegs were abandoned are themselves unrepresentative of the population of speculative attacks. Some pegs are abandoned without a speculative attack. Others are repelled. Thus, studies like Dornbusch, Goldfajn and Valdés (1995) and Krugman (1996), while informative about the characteristics of the episodes they consider, do not provide a representative characterization of speculative attacks.

In Eichengreen, Rose and Wyplosz (1995) we seek to analyze currency crises systematically by constructing a measure of speculative attacks that excludes devaluations and flotations not taken in a climate of crisis and includes unsuccessful attacks. We compare these with actual devaluations and other changes in exchange rate arrangements. Our measure of crises is a weighted average of changes in the exchange rate, changes in international reserves which can be paid out in response to speculative pressure, and changes in the interest differential since interest rates can be raised to fend off an attack. (A more detailed description of the methodology is presented below.) We analyze the experience of some two dozen OECD economies since 1959.

Our findings on the causes and consequences of devaluations and revaluations are consistent with the predictions of mainstream models. Countries which devalue experience problems of external balance in the

\textsuperscript{7}An illustrative application of this model would be to the ERM crises of 1992–93. The story would go as follows. There was a widespread belief at the time that the ERM could not continue to operate indefinitely without a realignment. And yet its extraordinary stability since January 1987 led traders to accept the official view that the system could now function without further realignments. Extraneous circumstances (the political difficulties of ratifying the Maastricht Treaty) then triggered a crisis (which culminated in the devaluation of the Italian lira) which confirmed this belief. It revealed to all traders that what they privately believed all along was true — that realignments were still necessary.

period leading up to the event. Their trade deficits and reserve losses are associated with relatively expansionary monetary policies. In addition, the period leading up to devaluations is characterized by problems of internal balance as reflected in relatively high levels of unemployment; the expansionary monetary stance in these countries may be adopted partly in response to these domestic concerns. Broadly speaking, revaluations are mirror images of devaluations. Other events in foreign exchange markets, in contrast, resist generalization. For example, transitions between exchange rate regimes (like movements from fixed to floating rates) are largely unpredictable.

We find that countries susceptible to crises are those whose governments have pursued accommodating monetary policies leading to high inflation and reserve losses, generally in response to deteriorating conditions on the unemployment front. Initially, the current account moves into deficit, and the capital account worsens as the crisis nears. Countries which take last-minute steps to defend the currency by significantly reducing the rate of money growth sometimes succeed in defending the rate. Those which retrench less dramatically may still be forced to capitate but often do so without provoking a major crisis. In contrast, governments which rely on sterilized intervention to the exclusion of more fundamental policy adjustments are generally unable to avoid full-blown currency crises.

A few other studies have adopted this approach. For example, Moreno (1995) analyzes crises in the Pacific Basin economies from 1980 through 1994. He finds that periods of speculative pressure tend to be associated with large budget deficits and rapid rates of growth of domestic credit. There is some evidence that episodes of pressure arise when slow growth and relatively high inflation make it difficult for the government to maintain a stable exchange rate. In contrast, there is no evidence that indicators of external balance differ between crises and tranquil periods.

Kaminsky and Reinhart (1996) consider speculative attacks on currencies and banking crises, analyzing connections between the two. They focus on 20 countries in Asia, Europe, Latin America and the Middle East that experienced banking difficulties in the period 1970–95. Their index of currency crises is constructed as a weighted average of exchange rate changes and reserve changes (because the relevant interest rate data are lacking for some countries). In their sample, crises tend to be preceded by declining economic activity, weakening export sectors, falling stock

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*This evidence is consistent with models emphasizing the domestic determinants of external balance as well as with more recent models which focus instead on the decisions of governments concerned with internal balance and constrained by the exchange rate in their choice of policy response.

markets, and high real interest rates. In addition, crises are preceded by accelerating money growth and rapid rates of growth of the liabilities of the banking system. Banking crises are leading indicators of currency crises, but there are few instances where currency crises predict banking crises.

By comparison, empirical analyses of contagion are few. Typical of the literature are studies which provide informal comparisons of small groups of countries. Burki and Edwards (1995) contrast the experiences of Argentina, Brazil and Venezuela in the wake of the Mexican crisis with those of Chile and Colombia, suggesting that contagion, while present, was selective. Calvo (1996) provides a series of comparisons between Mexico and other countries in an effort to understand why some countries were more susceptible than others to the tequila effect.

We are aware of two statistical studies of contagion. Calvo and Reinhart (1995) report evidence of contagion in an econometric model in which capital flows to four small Latin American countries depend on the standard determinants but also on a contagion proxy, namely, capital flows to four large Latin American countries. Their results can be questioned, however, on the grounds that the flow of capital to neighboring countries is a less-than-ideal proxy for contagion and that the sample of countries is not random.

Schmukler and Frankel (1996) model contagion using data on closed-end country funds. Although their dependent variable, the level of stock prices, is different from the one with which we are concerned, the two are linked insofar as the rise in domestic interest rates needed to fend off an attack on the currency will tend to depress equity prices. Their evidence suggests that investors differentiated among countries to a greater extent after the 1994 Mexican crisis than after its 1982 predecessor. In the short run, a drop in Mexican prices tends to induce sell-offs in other markets motivated by the desire to raise cash; while there is evidence of contagion in Latin America in the long run as well, the long-run effect of a Mexican sell-off on Asian markets is positive.10

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9 Linkages between the stock market and the exchange rate are analyzed by Murphy (1989).

10 In a similar exercise, Valdés (1996) analyzes the secondary market prices of sovereign debt and shows that there exists a strong cross-country correlation of these prices even after controlling for macroeconomic fundamentals and “big news events” such as announcements of Brady Plan restructurings. This evidence of “contagion” in the markets for developing-country debt is much stronger than analogous evidence for the U.S. corporate bond market, where fundamentals explain essentially all of the observed correlation across issues, and than in a group of medium-sized OECD countries, where fundamentals again explain all of the observed correlation of credit ratings.

IV. Analyzing Contagion Systematically

We now test for the existence of "contagious" currency crises. The contagion effect with which we are concerned can be thought of as an increase in the probability of a speculative attack on the domestic currency which stems not from domestic "fundamentals" such as money and output but from the existence of a (not necessarily successful) speculative attack elsewhere in the world.

We analyze a panel of quarterly macroeconomic and political data covering twenty industrial countries from 1959 through 1993 (a total of 2800 observations). We pose the following question: is the incidence of a currency crisis in a particular country at a given point in time (e.g., France in the third quarter of 1992) correlated with the incidence of a currency crisis in a different country (e.g., the U.K.) at the same point in time, even after taking into account the effects of current and lagged domestic macroeconomic and political influences? The finding of a strong positive partial correlation is consistent with the existence of contagion, since it implies that speculative attacks are temporally correlated even after conditioning on domestic factors. Still, it is difficult to interpret this as definitive proof of contagion, since it may in fact reflect not contagion but an unmeasured common shock to economic fundamentals which strikes a number of countries simultaneously, rather than actual spillovers from one country to another.11

Measuring Currency Crises

The first issue that must be confronted is how to determine when a speculative attack has occurred. Having addressed this issue in a number of previous papers, e.g. Eichengreen, Rose and Wyplosz (1995, 1996), we provide only a summary of our thinking here.

Currency crises cannot be identified with actual devaluations, revaluations and instances in which the currency is floated, for two reasons.12 First, not all speculative attacks are successful. The currency may be supported through the expenditure of reserves by the central bank or by foreign central banks and governments.13 Alternatively, the authorities may repel attacks by raising interest rates and adopting other policies of austerity. Further, many realignments are taken deliberately in tranquil periods, possibly to preclude future attacks.

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11 We return to this point below.
12 We refer to such actual changes in explicit exchange rate policy as "events" and think of them as overlapping in part with the currency crises that we are interested in.
13 And occasionally by the actual or threatened imposition of capital controls.
Ideally, an index of speculative pressure would be obtained by employing a structural model of exchange rate determination, from which one would derive the excess demand for foreign exchange. In practice, however, empirical models linking macroeconomic variables to the exchange rate have little explanatory power at short and intermediate horizons.\textsuperscript{14} In the absence of an empirically valid macro-model, we resort to an \textit{ad hoc} approach, the underlying intuition for which is derived from the well-known model of exchange market pressure due to \textcite{GirtonRoper1977}. The idea is that an excess demand for foreign exchange can be met through several (not mutually exclusive) channels. If the attack is successful, depreciation or devaluation occurs. But the monetary authorities may instead accommodate the pressure by running down their international reserves or deter the attack by raising interest rates. As a measure of speculative pressure, we therefore construct a weighted average of exchange rate changes, reserve changes, and interest rate changes. All of these variables are measured relative to those prevailing in Germany, the reference country. Germany is a logical choice for a center country, since it has had a strong currency throughout the postwar era, and has been a critical member of all important OECD fixed exchange rate systems (including the Bretton Woods System, the EMS, and the "snake" preceding the EMS).\textsuperscript{15}

The index of exchange market pressure then becomes:

$$\text{EMP}_{i,t} \equiv [\alpha \% \Delta e_{i,t} + (\beta \% \Delta (i_{i,t} - i_{G,t})) + \gamma (\% \Delta r_{i,t} - \% \Delta r_{G,t})],$$

where $e_{i,t}$ denotes the price of a DM in $i$'s currency at time $t$; $i_{G}$ denotes the short German interest; $r$ denotes the ratio of international reserves;\textsuperscript{16} and $\alpha$, $\beta$, and $\gamma$ are weights.

We define crises as extreme values of this index.

$$\text{Crisis}_{i,t} = \begin{cases} 1 & \text{if} \text{EMP}_{i,t} > 1.5\sigma_{\text{EMP}} + \mu_{\text{EMP}} \\ 0 & \text{otherwise} \end{cases}$$

where $\mu_{\text{EMP}}$ and $\sigma_{\text{EMP}}$ are the sample mean and standard deviation of EMP, respectively.

A critical step is weighting the three components of the index. An obvious option is an unweighted average, which has the advantage of simplicity. But since the volatility of reserves, exchange rates and interest

\textsuperscript{14}Frankel and Rose (1995) provide a recent survey.

\textsuperscript{15}Of course, idiosyncratic German shocks then acquire disproportionate importance. However, German unification is typically considered to be the only important such shock; our sensitivity analysis indicates that our results do not stem from this event.

\textsuperscript{16}Following \textcite{GirtonRoper1977}, $r$ is actually the ratio of reserves to narrow money (M1).
differential is very different, we instead weight the components so as to equalize the volatilities of the three components, thereby preventing any one of them from dominating the index. Below, we check the sensitivity of our results to this scheme.

We identify quarters in which our index of speculative pressure is at least one and a half standard deviations above the sample mean as instances of speculative attacks (although we again test for sensitivity with respect to this arbitrarily-chosen threshold). To avoid counting the same crisis more than once, we exclude the later observation(s) when two (or more) crises occur in successive quarters. Thus, our "exclusion window" is one quarter (though again we vary this parameter). We refer to our non-crisis observations as "tranquil" periods and use these as the control group.\textsuperscript{17}

Our choices of a one quarter exclusion window (so that each country contributes no more than two observations annually) and a 1.5 standard deviation outlier threshold produce a sample of 77 crises and 1179 periods of tranquility.\textsuperscript{18}

The crisis observations are not randomly distributed. There are clusters of speculative attacks in 1973 (at the time of the breakup of the Bretton Woods system) and in 1992 (at the time of the European currency crises). A time-series plot of the number of crises in each quarter is provided as Figure 1.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{crises_per_quarter.png}
\caption{Crisis Per Quarter}
\end{figure}

\textsuperscript{17}Just as we do not allow crises in successive quarters to count as independent observations by excluding the latter, we also do not allow two successive periods of tranquility to count as independent observations. We do this by applying our exclusion window to periods of both crisis and tranquility.

\textsuperscript{18}However, missing data will preclude use of some of these observations.
The Data

Most of the financial and macroeconomic variables are taken from the CD-ROM version of the International Monetary Fund’s *International Financial Statistics* (IFS). The data set is quarterly, spanning 1959 through 1993 for twenty industrial countries. It has been checked for transcription and other errors and corrected. Most of the variables are transformed into differential percentage changes by taking differences between domestic and German annualized fourth-differences of natural logarithms and multiplying by a hundred.

We employ the following variables: total non-gold international reserves (IFS line 1ld); period-average exchange rates (line rf); short-term interest rates (money market rates (line 60b) where possible, discount rates otherwise (line 60)); exports and imports (both measured in dollars, lines 70d and 71d, respectively); the current account (line 77a.d, converted to domestic currency) and the central government budget position (line 80), both measured as percentages of nominal GDP (frequently line 99a); long-term government bond yields (line 61); a nominal stock market index (line 62, which sets 1990 = 100); domestic credit (line 32); M1 (line 34); M2 (line 35 + M1); the CPI (line 64); and real GDP (usually line 99a.r). We also use the real effective exchange rate as a measure of competitiveness (line reu, which uses normalized relative unit labor costs), though this variable is only available from 1975.

We also utilize a number of labor market indicators not included in IFS. Data on total employment, the unemployment rate, and the business sector wage rate were drawn from the OECD’s *Main Economic Indicators*. To capture political conditions we construct indicators of governmental electoral victories and defeats, using Keesing’s *Record of World Events* and Banks’ *Political Handbook of the World*.

Finally, we use a list of exchange market “events” (devaluations, flotations, changes in exchange rate band widths and so forth). These are gleaned from the IMF’s annual report on *Exchange Arrangements and Exchange Restrictions*. These volumes also provide us the basis for constructing with dummy variables indicating the presence of capital controls.

The available data on international reserves are less than ideal for a number of well-known reasons. Off-balance sheet transactions, third-party intervention, stand-by credits, and foreign liabilities, all of which are relevant for foreign exchange intervention, tend to be omitted or incom-

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19 The countries in our sample include (in order of IMF country number): the U.S., U.K., Austria, Belgium, Denmark, France, Italy, Netherlands, Norway, Sweden, Switzerland, Canada, Japan, Finland, Greece, Ireland, Portugal, Spain and Australia, along with our center country, Germany.
pletely reported. In addition, short-duration attacks (especially unsuccessful ones) may not be evident in quarterly data. Finally, subtle changes in actual or anticipated capital controls, while difficult to measure, may in fact be quite important, especially when countries are mounting defenses against speculative attacks.

**Statistical Analysis**

We can now test for the existence of contagion. We test the null hypothesis that the incidence of currency crises elsewhere in the world at the same point in time does not affect the probability of a speculative attack on the domestic currency. While our model attempts to control for the influence of a wide range of current and lagged macroeconomic variables, it is non-structural. This is one reason for viewing our evidence (which turns out to be inconsistent with the null at standard confidence levels) as consistent with, but not definitive proof of, contagion.

We estimate a binary probit model, linking our dependent variable (an indicator variable which takes on a value of unity for a speculative attack and zero otherwise) to our controls with maximum likelihood, including additional regressors to capture the effects of macroeconomic and political influences which affect crisis incidence. We cast our net as widely as possible, including: (1) the presence of capital controls; (2) electoral victory or defeat of the government; (3) the growth of domestic credit; (4) inflation; (5) output growth; (6) employment growth; (7) the unemployment rate; (8) the central government budget surplus (+) or deficit (−), expressed as a percentage of GDP; and (9) the current account surplus/deficit (again, a percentage of GDP). All these variables are included as deviations from German values.

Since the literature on currency crises does not provide much guidance about the time horizon for these influences, we consider a range of plausible alternatives. At the short end of the spectrum, we allow only contemporaneous influences to affect the probability of a crisis. We then allow for explanatory variables lagged up to two quarters, one year, and two years. We allow these lagged influences to operate jointly with the contemporaneous variables or by themselves (as would be appropriate if lags in data collection or processing preclude the consideration of contemporaneous developments). To conserve degrees of freedom, we model the lags using moving averages. Rather than including the first and second lags of inflation separately, for example, we include only a single term which is the average inflation differential in the two preceding quarters.

This leads us to estimate the following model:

\[ \text{Crisis}_{t,i} = \omega D(\text{Crisis}_{t,i}) + \lambda I(L)_{t,i} + v_{t,i} \]

where

\[ D(\text{Crisis}_{j,i}) = \begin{cases} 1 & \text{if Crisis}_{j,i} = 1, \text{ for any } j \neq i \\ 0 & \text{otherwise.} \end{cases} \]

and where \( I(L)_{j,i} \) is an information set of ten contemporaneous and/or lagged control regressors; \( \lambda \) is the corresponding vector of nuisance coefficients; and \( \epsilon \) is a normally distributed disturbance representing a host of omitted influences which affect the probability of a currency crisis.

The null of interest is \( H_0: \omega = 0 \). We interpret evidence of the null as being inconsistent with a contagion effect.

Results

Benchmark results are presented in Table 1. Its five columns correspond to five assumptions about the appropriate time horizon for the regressors. Since probit coefficients are not easily interpretable, we report the effects of one-unit (percentage point) changes in the regressors on the probability of a crisis (also expressed in percentage points), evaluated at the mean of the data. We tabulate the associated z-statistics, which test the null of no effect. Statistics which are inconsistent with the null at the five percent level are printed in bold. Diagnostics are reported at the foot of the table, including a test for the joint significance of all the coefficients.

The results are consistent with the existence of a contagion effect which is economically important and statistically significant. A speculative attack elsewhere in the world increases the probability of a domestic currency crisis by around eight percentage points.

The impact of the other regressors is not dramatic, though a few effects are worth noting. For example, higher inflation and unemployment are associated with increases in the odds of an attack. Generally speaking, however, the absence of robust partial correlations provides grounds for caution against over-interpreting the results.

Sensitivity analysis is reported in Table 2. We consider six perturbations of our basic model. First, we change the definition of a speculative attack by raising the outlier threshold on our exchange market pressure index to two standard deviations (from one and a half) and by widening the exclusion band width to two quarters (from one). This marginally increases the magnitude of the contagion variable, although the change is not statistically significant. Second, we change the definition of a speculative attack by doubling the weight on actual exchange rate changes in our tripartite index. This has no discernible impact on the coefficient on the contagion variable. Third, we drop post-1978 data so as to focus on the pre-EMS period. This increases the magnitude of the contagion coefficient further.

Fourth, we limit the sample to EMS observations; here we get strikingly large contagion effects, with slope derivatives almost three times the size of the benchmark result in the first column of Table 1. Fifth, we employ only observations where capital controls are present. Here, the coefficient on the contagion variable is indistinguishable from the benchmark result. Finally, we substitute for crises elsewhere in the world exchange market "events" elsewhere in the world (e.g., actual devaluation or transitions to floating rates), a perturbation which leaves the baseline results relatively unaffected. These tests confirm the key finding of this paper. Namely, a speculative attack elsewhere in the world significantly increases the odds of an attack on the domestic currency. But they do not allow us to distinguish among the various theories of contagion. For example, the relatively large

Table 1. Probit results

<table>
<thead>
<tr>
<th></th>
<th>MA of Contemporaneous</th>
<th>MA of Contemporaneous + 2 lags</th>
<th>MA of Contemporaneous + 4 lags</th>
<th>MA of Contemporaneous + 8 lags</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crisis elsewhere</td>
<td>7.45 (3.8)</td>
<td>8.33 (4.0)</td>
<td>8.14 (4.3)</td>
<td>8.72 (4.0)</td>
</tr>
<tr>
<td>Capital controls</td>
<td>−1.66 (0.7)</td>
<td>0.22 (0.1)</td>
<td>0.66 (0.3)</td>
<td>0.48 (0.2)</td>
</tr>
<tr>
<td>Government victory</td>
<td>−4.24 (1.0)</td>
<td>−1.71 (0.3)</td>
<td>−0.60 (0.2)</td>
<td>5.30 (1.6)</td>
</tr>
<tr>
<td>Government loss</td>
<td>−3.45 (0.9)</td>
<td>−7.44 (1.3)</td>
<td>−3.34 (1.2)</td>
<td>2.49 (0.8)</td>
</tr>
<tr>
<td>Credit growth</td>
<td>0.19 (1.8)</td>
<td>0.11 (0.8)</td>
<td>0.10 (1.2)</td>
<td>−0.00 (0.0)</td>
</tr>
<tr>
<td>Inflation rate</td>
<td><strong>0.75 (3.5)</strong></td>
<td><strong>0.57 (2.4)</strong></td>
<td>0.40 (1.9)</td>
<td><strong>0.59 (2.1)</strong></td>
</tr>
<tr>
<td>Output growth</td>
<td>0.21 (0.6)</td>
<td>−0.39 (0.9)</td>
<td>−0.50 (1.4)</td>
<td>−0.74 (1.3)</td>
</tr>
<tr>
<td>Employment growth</td>
<td>0.37 (0.7)</td>
<td>0.86 (1.5)</td>
<td>0.78 (1.5)</td>
<td>1.08 (1.6)</td>
</tr>
<tr>
<td>Unemployment rate</td>
<td><strong>0.86 (3.0)</strong></td>
<td><strong>0.96 (3.2)</strong></td>
<td><strong>0.92 (3.5)</strong></td>
<td><strong>1.04 (3.3)</strong></td>
</tr>
<tr>
<td>Budget position/GDP</td>
<td>0.47 (1.9)</td>
<td>0.41 (1.6)</td>
<td>0.35 (1.5)</td>
<td>0.46 (1.6)</td>
</tr>
<tr>
<td>Current account/GDP</td>
<td>−0.23 (0.8)</td>
<td>−0.36 (1.1)</td>
<td>−0.51 (1.9)</td>
<td>−0.42 (1.2)</td>
</tr>
<tr>
<td>Number of observations</td>
<td>645</td>
<td>626</td>
<td>703</td>
<td>608</td>
</tr>
<tr>
<td>McFadden's $R^2$</td>
<td>0.15</td>
<td>0.12</td>
<td>0.13</td>
<td>0.12</td>
</tr>
<tr>
<td>Joint test for slopes of $y^2$ (11)</td>
<td><strong>55</strong></td>
<td><strong>46</strong></td>
<td><strong>53</strong></td>
<td><strong>43</strong></td>
</tr>
</tbody>
</table>

Notes: Probit slope derivatives ($\times$ 100, to convert into percentages) and associated z-statistics (for hypothesis of no effect). Model estimated with a constant, by maximum likelihood. Slopes significantly different from zero at the 0.05 value are in bold.

Contagion coefficient for the EMS subsample and the fact that "events" matter as much as crises point to the operation of the competitiveness channel modeled by Gerlach and Smets (1995) and Andersen (1994). But these results are also compatible with theories that emphasize the information-coordination effect of exchange market events.

We performed a number of further robustness checks that are not reported here. These include adding a lagged contagion term, which represents the incidence of a currency crisis (in a different country) in the preceding quarter (as opposed to contemporaneously); adding cross products of the contagion term and the remaining regressors; adding

Table 2. Sensitivity analysis

<table>
<thead>
<tr>
<th></th>
<th>2 Quarter Window, 2a Threshold</th>
<th>Increased Weight on Exchange Rates</th>
<th>Pre-1979</th>
<th>EMS</th>
<th>Only Immobile Capital</th>
<th>With Contemporaneous Events</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crisis elsewhere</td>
<td>9.38 (3.5)</td>
<td>7.42 (3.3)</td>
<td>12.31 (2.8)</td>
<td>19.90 (3.4)</td>
<td>7.88 (2.9)</td>
<td>6.99 (3.4)</td>
</tr>
<tr>
<td>Capital controls</td>
<td>2.43 (1.1)</td>
<td>-0.50 (0.2)</td>
<td>5.41 (0.8)</td>
<td>10.05 (2.0)</td>
<td>N/A</td>
<td>0.18 (0.1)</td>
</tr>
<tr>
<td>Government victory</td>
<td>5.67 (2.0)</td>
<td>4.48 (0.9)</td>
<td>-9.52 (0.8)</td>
<td>2.22 (0.3)</td>
<td>-1.64 (0.2)</td>
<td>-1.13 (0.2)</td>
</tr>
<tr>
<td>Government loss</td>
<td>-1.74 (0.4)</td>
<td>-1.90 (0.3)</td>
<td>-14.57 (1.2)</td>
<td>-1.57 (0.3)</td>
<td>-4.71 (0.7)</td>
<td>-6.60 (1.2)</td>
</tr>
<tr>
<td>Credit growth</td>
<td>0.09 (0.8)</td>
<td>0.09 (0.6)</td>
<td>0.34 (1.3)</td>
<td>0.13 (0.7)</td>
<td>0.22 (1.2)</td>
<td>0.14 (1.0)</td>
</tr>
<tr>
<td>Inflation rate</td>
<td>0.26 (1.4)</td>
<td>0.47 (1.7)</td>
<td>0.17 (0.4)</td>
<td>0.01 (0.0)</td>
<td><strong>0.59 (2.0)</strong></td>
<td><strong>0.58 (2.4)</strong></td>
</tr>
<tr>
<td>Output growth</td>
<td>0.19 (0.8)</td>
<td>-0.07 (0.1)</td>
<td>-0.97 (1.1)</td>
<td>-0.70 (0.9)</td>
<td>-0.68 (1.2)</td>
<td>-0.40 (0.9)</td>
</tr>
<tr>
<td>Employment growth</td>
<td>1.27 (2.6)</td>
<td>0.52 (0.8)</td>
<td>-0.12 (0.1)</td>
<td>1.51 (1.1)</td>
<td>0.37 (0.5)</td>
<td>0.87 (1.5)</td>
</tr>
<tr>
<td>Unemployment rate</td>
<td>0.19 (0.8)</td>
<td>0.45 (1.4)</td>
<td><strong>4.06 (3.0)</strong></td>
<td>1.44 (1.7)</td>
<td><strong>0.91 (2.4)</strong></td>
<td><strong>0.99 (3.2)</strong></td>
</tr>
<tr>
<td>Budget position/GDP</td>
<td>0.05 (0.3)</td>
<td>0.47 (1.7)</td>
<td>1.16 (1.6)</td>
<td>-0.10 (0.3)</td>
<td>0.38 (1.1)</td>
<td>0.40 (1.5)</td>
</tr>
<tr>
<td>Current account/GDP</td>
<td>-0.47 (1.9)</td>
<td><strong>-0.89 (2.6)</strong></td>
<td>-1.48 (1.7)</td>
<td>0.08 (0.2)</td>
<td>-0.23 (0.5)</td>
<td>-0.36 (1.1)</td>
</tr>
<tr>
<td>Number of observations</td>
<td>326</td>
<td>623</td>
<td>233</td>
<td>224</td>
<td>425</td>
<td>626</td>
</tr>
<tr>
<td>McFadden's R²</td>
<td>0.32</td>
<td>0.09</td>
<td>0.17</td>
<td>0.21</td>
<td>0.11</td>
<td>0.12</td>
</tr>
<tr>
<td>Joint test for slopes χ² (11)</td>
<td>55</td>
<td>36</td>
<td>31</td>
<td>28</td>
<td>28</td>
<td>45</td>
</tr>
</tbody>
</table>

Notes: Probit slope derivatives (×100, to convert into percentages) and associated z-statistics (for hypothesis of no effect). Model estimated with a constant, by maximum likelihood. Slopes significantly different from zero at the 0.05 value are in bold. All regressors are expressed as equally weighted moving averages of contemporaneous and two quarterly lags.
money growth, long interest rates, wages, exports and imports to the standard set of explanatory variables; using Huber-White covariance estimators instead of standard ones; and separating out the effects of contemporaneous and lagged regressors. Again, none of these tests disturbs our central finding that speculative attacks in other countries significantly increase the odds of a currency crisis.\footnote{One of the few indications of sensitivity stems from the inclusion of year-specific controls; this results in point estimates of $\omega$ of around 4 percent, and correspondingly marginally statistical evidence against the hypothesis $H_0: \omega = 0$. Since contagion would result in the clustering of speculative attacks over time which could be well picked up by time-specific fixed effects, it is hard to interpret this result. Also, controlling for the IMF's real effective exchange rate (computed using relative normalized unit-value costs) reduces both the sample size (since the series is only available from 1975) and the magnitude of $\omega$ by around a half. The estimate of $\omega$ falls to around four percent and is of more marginal statistical significance.}

V. Conclusion

We have reviewed the theoretical and empirical literatures on crises in foreign exchange markets with an eye toward the prevalence of contagion. While the possibility of contagious currency crises is a pressing policy issue, the debate surrounding it points up the limitations of existing research. The literature is replete with theoretical models highlighting the motives for and dynamics of speculative attacks on pegged currencies and potential channels of contagion, but empirical work has lagged behind. Stories of contagion abound, but systematic empirical analysis is lacking.

Here we have taken a first step toward such an analysis. A battery of empirical specifications fails to reject, at high levels of significance, the hypothesis of contagion. Our central finding is that a speculative attack elsewhere in the world increases the odds of an attack on the domestic currency by eight percent.

A limitation of our approach is the difficulty of distinguishing the effects of crises in neighboring countries (contagion \textit{per se}) and from the effects of global shocks (unobserved environmental factors). This situation is familiar to epidemiologists, for whom the problem is one of determining whether the spread of a virus reflects the contagious nature of the germ or the disease-conducive nature of the environment. The strategy adopted there has been to place additional structure on the problem. In future work we plan to adopt a similar approach, asking for example whether countries with close commercial and macroeconomic ties are particularly susceptible to contagion. We plan to weight our measure of currency crises in neighboring countries by measures of the economic proximity of neighbors (for example, by the share of the two countries' trade which they conduct with one another, or by the similarity of their monetary and fiscal policies). This
approach would better distinguish contagion *per se* from the effects of common unobservable shocks. It would better identify the channels through which contagious currency crises are transmitted.

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