Currency crisis contagion and the identification of transmission channels

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Abstract

Using quarterly data (1960–1998) for a set of 37 advanced and emerging market economies we find that countries face currency crises because of unsustainable macroeconomics fundamentals and contagion. In most cases considered, contagion works via the trade channel. In addition, the estimation results reveal that the probability of a crisis in a given country increases as the number of its neighboring countries in crisis increases implying the presence of neighborhood effects in the contagious spread of crisis. Our results also lend limited support to the notion that there is some contagion through capital markets.

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1. Introduction

The main objective of this paper is to test whether currency crises are contagious and to identify the channels through which crises are transmitted across countries. Many economists have now realized that a role was played by contagion in propagating the currency crises of emerging market economies in the 1990s. Different theoretical models have been recently developed suggesting different mechanisms by which crises have been transmitted across countries. But there is relatively little empirical consensus on how crises spillover across countries while the frequency and intensity of crises points to the urgency of additional empirical works to come up with solutions for crisis prevention, crisis management and crisis resolution.

Currency crises prior to 1990s did not appear to spread across countries with the virulence and speed observed recently. The earlier literature tried to explain the crises as the result of inconsistencies between fiscal and monetary policies and the existing exchange rate commitment (so called first generation models of currency crisis such as

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† See White (2000) for the different solutions suggested in the literature with respect to these three objectives: prevention, management and resolution.

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The collapse of the European Exchange Rate Mechanism (ERM) in 1992/93, the Mexican Peso crisis in 1994 and the Asian crisis in 1997 have, however, shifted the focus to models based on self-fulfilling expectations (Obstfeld, 1995) and on contagion (see Dornbusch, Park, & Claessens, 2000; Pericoli & Sbracia, 2003; Wolf, 1999 for a comprehensive survey of models of contagion).

The Asian financial crisis, for example, began in July 1997 with the Thai baht devaluation. It then spread to Malaysia, the Philippines, and Indonesia in the third quarter of 1997. Prior to the 1997 crisis, all these countries had a few common characteristics: an appreciating real exchange rate, large current account deficits and financial sector squeezes linked to overexposure to a property market whose prices had fallen sharply (see Krugman, 1998; Masson, 2004, 1999). But the currency pressures also quickly spread to Hong Kong, Singapore and Korea, economies with strong current account and fiscal positions. The crisis even jumped surprisingly to several emerging markets outside the region, notably to Brazil and Russia (see IMF, 1998, 2001). This experience coupled with the earlier crises in 1992/1993 and 1994/1995 led economists to suspect that crises in the 1990s were contagious.

In response to these events, several different theoretical models have been developed showing how crises end up spreading across countries. Some of the major models of contagion are based on trade linkage and macroeconomic similarities (Eichengreen, Rose, & Wyplosz, 1996; Gerlach & Smets, 1995; Goldstein, 1998), while other models are based on financial linkage, neighborhood effects, and exogenous shifts in investors’ beliefs (herd behavior) (Calvo, 2005; Calvo & Mendoza, 2000; Kaminsky & Reinhart, 2000; Masson, 2004, 1999). Despite the explosion of models of contagion, there still lacks a general consensus on empirical findings on the relevant contagion channels.

Existence of contagion has important implications. Because no open economy can insulate itself from what is happening in the rest of the world, to prevent contagious financial crises countries may need to adopt regionally or globally coordinated measures. But the specific measures that should be taken to prevent the spread of financial crisis presuppose knowledge of the relevant contagion channels.

If the trade contagion channel is relevant, countries may need to diversify their trade and/or fix their exchange rates collectively in order to avoid speculative attacks following loss of international competitiveness. At the extreme, international cooperation of the countries may lead to the creation of a common currency. If, on the other hand, the financial contagion channel is relevant, countries may need to impose capital controls. Others suggest that a lender of last resort, such as the World Bank or the IMF, would need to be instituted to neutralize the financial contagion channel by providing liquidity support.

As the foregoing discussion points out, the intensity and time clustering of the crises has now forced both policy makers and academics to focus on contagion as a principal culprit in the ensuing discussion. A number of questions have been raised in the literature. Why do currency and financial crises hit selected countries within a very close time period? Are those countries simultaneously under crisis hit by common shocks? Or do they have unsustainable fiscal and monetary policies or unsustainable current account positions to the extent that both countries face crises simultaneously? If each of these is not the case, why and how does a crisis in one country transmit to other selected countries that have sound macroeconomic fundamentals?

This paper is motivated by some of the above questions. More specifically, the paper addresses two interrelated questions (i) does a currency crisis in one country spread to other selected countries? (ii) What are the channels through which crisis spreads across countries? To address these questions, the paper estimates a panel probit model as in Eichengreen et al. (1996). A probit model is estimated because it allows us to test for the existence of contagion while also empirically identifying the transmission channels.

However, this paper is different from the Eichengreen et al. (1996) approach in at least two ways. First, the test for contagion is undertaken using crises identified by the extreme value theory. This represents a significant deviation from prior works in this area that employ ad hoc procedures to define crisis periods. The “standard” approach is to set a threshold constructed from the mean and standard deviations of an index measuring speculative pressures. Values of the index above this threshold are taken as indicators of crises. But there appears to be no consensus on the specification of the threshold applied (e.g., global mean plus 1.5 standard deviations as in Eichengreen et al., 1996 vs. country specific mean plus 3 standard deviations as in Kaminsky & Reinhart, 2000). We employ a more objective method by defining currency crisis periods using the extreme value theory.

This paper differs from Eichengreen et al. (1996) in a second way, as well. We add countries from Asia and Latin America to the OECD sample of Eichengreen et al. (1996) to form an expanded data set representing many different regions of the world. This allows for testing contagion on a broader basis while also allowing for contagion to operate through a fourth channel — the neighborhood channel. Using the objectively identified crises, the paper, therefore,
tests whether there is contagion among i) major trade partners/competitors, ii) countries with strong financial linkages such as among those having common creditors, iii) countries with similar macroeconomic fundamentals, and iv) neighbors.

Overall, the estimation results from different model specifications indicate that currency crises are contagious. In almost all cases considered, contagion works through the trade channel. The macroeconomic channel turns out significant in none of the estimations. Moreover, the estimation results reveal that the probability of a crisis in a given country increases as the number of neighboring countries in crisis increases. While the evidence for contagion through common bank lenders is not strong, the estimation results point towards the need for more empirical tests for the workings of contagion through capital markets at least for emerging economies in line with the Calvo (2005) argument for contagion.

The main conclusion of the paper is that currency crises are contagious. Contagion is regional and more specifically it operates through the trade channel. The main implication of this result is that countries could prevent contagion either by diversifying their trade base or fixing exchange rates collectively among major trade partners in order to avoid speculative attacks following loss of international competitiveness. At the extreme, countries may adopt a regional currency, which is the track followed by some of the European countries in creating the Euro, to prevent contagion among members.

The remainder of the paper is divided into four sections. A review of the theoretical and empirical literature is provided in Section 2. Section 3 discusses the method of study and data sources. Section 4 provides analysis of the empirical findings. The last section is devoted to conclusions and a discussion of implications of the results.

2. Literature review

A large number of studies have concluded that the Mexican crisis of 1994/95, the Asian crisis of 1997, the Russian crisis of 1998 and even the earlier ERM crisis of 1992/93 were contagious. Despite a general consensus that contagious currency crises are important phenomena, there is not yet a uniform definition of what constitutes contagion. In what follows a discussion of contagion definitions is presented.

Forbes and Rigobon (2001b) define contagion as a significant increase in cross-market linkages after a crisis in an individual country (or a group of countries) without taking a stance on how this shift occurred. They name this “shift-contagion”. Eichengreen et al. (1996) argue that there is contagion if the probability of a crisis in a given country increases conditional on the occurrence of a crisis elsewhere, after controlling for the standard set of macroeconomic fundamentals. In contrast to these two definitions, Masson (2004, 1999) defines contagion to mean only those transmissions of crises that cannot be identified with observed changes in macroeconomic fundamentals. Contagion according to Masson (2004, 1999) involves changes in expectations that are not related to changes in a country’s macroeconomic fundamentals.

Coinciding with the various definitions of contagion, there exist a variety of economic models that explain how crises are propagated internationally. Following Masson (2004, 1999), these models are divided in the literature into two major categories2. In the first category, crises spread resulting from economic interdependence among different countries. Accordingly, a crisis in one country spreads by changing the macroeconomic fundamentals of other countries. Some of the factors considered in this category for the simultaneous occurrence of currency crises are: common shocks, trade and direct financial linkages between countries. These are generally termed as “fundamental-based contagion” models (see Calvo & Reinhart, 1996; Kaminsky & Reinhart, 2000). In the second category, contemporaneous crises are modeled through shifts in the behavior of investors or other financial agents. Here, a crisis in one country triggers a crisis elsewhere without having any impact on their macroeconomic fundamentals. The crisis spreads because of changes in “market sentiment” or interpretation of existing information about the economy held by investors. In what follows, a review of some of the individual models of contagion in each category is presented.

2.1. Common shocks

A common shock, be it regional or global, may serve as the cause for the simultaneous occurrence of crisis across countries. Calvo and Reinhart (1996), for example, cited the sharp increase in the U.S. interest rates in the early 1980s
and 1994 as one major cause for the two Mexican crises in 1982 and 1994. Another recent example is the large appreciation of the dollar between 1995 and 1997 and the long lasting slowdown in Japanese growth that might together have contributed to the Asian crisis by weakening the external sector of Asian countries simultaneously (see Baig & Goldfajn, 1999).

2.2. Trade linkage

Trade linkages involving both bilateral and third party market competition could explain contagion through the possibility of loss of international competitiveness (price effects) and income effects (see Gerlach & Smets, 1995; Glick & Rose, 1999). When a country experiences a crisis marked by a significant currency depreciation, its major trade partners are negatively affected both through loss of competitiveness and through the fall in demand in the crisis country if the latter is experiencing economic downturn, too. The two effects, price and income, work in both the bilateral and third party export markets of the major trade partners. The impact of the spillover through the trade link could be even larger if we consider the possibility of cascading effects3.

2.3. Macroeconomic similarity

Due to incomplete information, investors treat all countries that look alike in their macroeconomic fundamentals as equal. Therefore, once one country is hit by a crisis, investors take this as a ‘wake-up call’ and view this as new information on what will happen in other countries with some similarities. Investors, then, attack these other countries that have macroeconomic fundamentals similar to those in the crisis country (Eichengreen et al., 1996; Goldstein, 1998). In this model, crisis spreads to the second country without necessarily having experienced deterioration in its macroeconomic fundamentals. Investors’ perception is what links crisis from one to another country.

2.4. Financial linkage

There are many mechanisms by which cross-boarder spillovers work through financial linkages. Some of the major ones cited in the literature include direct financial linkages, liquidity and incentive problems and herd behavior (see Dornbusch et al., 2000 for an elaborate classification). In some of these cases, crisis spreads by changing the fundamentals of other countries when there is, for example, direct financial linkage and in others without any impact on the fundamentals of the non-crisis countries.

Calvo (2005), for example, has built a model for contagion based on margin calls for liquidity4 and asymmetric information. In this model, the market is populated with informed and uninformed investors. Given this, a large depreciation of the currency and decline in equity prices in one country may lead to a large capital loss to some informed investors. These losses may induce these investors to sell off good securities in other emerging markets in order to raise cash in anticipation of a higher frequency of redemption. But the uninformed may misread this action of informed investors as a signal for low returns in this market. The action of the uninformed on account of a change in their perceptions then depresses equity and other asset prices in the country with healthy fundamentals.

Liquidity problems may also be faced by commercial banks that have their lending concentrated in particular regions. If these banks experience a marked deterioration of the quality of loans to one country, they may attempt to reduce the overall risk of their loan portfolio by reducing exposures in other higher risk investments elsewhere, including other countries. Kaminsky and Reinhart (2000) and Van Rijckeghem and Weder (2001) term this the role of common lenders for the contagious spread of crisis.

Calvo and Mendoza (2000) present a model of utility maximizing investors where the presence of fixed costs to gather and process country-specific information leads to herd behavior thereby creating the room for the contagious spread of crisis. Due to the fixed costs, most small investors may find it more advantageous to follow the investment patterns of large informed investors. According to their model, globalization increases contagion through herding by

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3 Consider three countries: A, B and C. Assume A and B are major trade partners. For some reason, A’s currency depreciates due to a crisis. Due to the price and income effects, B will be affected automatically. Country C is then affected through its trade linkages with both A and B.

4 A model of contagion based on liquidity is also given in Valdes (1995).
weakening incentives for gathering costly information while at the same time strengthening the incentives for imitating arbitrary market portfolios.

2.5. Empirical evidence

A great deal of the empirical literature on the test for contagion focuses on whether there is a fundamental change in the propagation of the transmission mechanism and on the identification of the contagion channels. The studies have looked at the co-movement of asset returns, volatility, and capital flows across countries using cross-market correlation coefficients, ARCH, Logit/Probit and VAR models.

Tests based on cross-market correlation coefficients are the most common and widely used approach to test for contagion. Under this approach, a significant increase in the correlation coefficient of asset returns between two markets after a crisis in one of them is considered as evidence of contagion. This is applied, among others, by Calvo and Reinhart (1996) and Baig and Goldfajn (1999). Using this approach, Calvo and Reinhart (1996) have shown an increase in the co-movement of weekly returns on equities and Brady bonds for Asian and Latin American emerging markets after the 1994 Mexican crisis. Baig and Goldfajn (1999), on the other hand, have provided evidence for a significant rise in the cross-country correlation among currencies and sovereign spreads of Indonesia, Korea, Malaysia, the Philippines and Thailand during the East Asian crisis period.

Forbes and Rigobon (2001b) and Rigobon (2002), however, argue that a marked increase in correlation among different countries’ markets may not be a sufficient proof of contagion. The rise in the post-shock correlation may be due to an increase in volatility following a crisis in one market. Thus, an increase in unadjusted correlation could simply be a continuation of strong transmission mechanisms that exist in more stable periods. When volatility adjusted correlation of stock indices of 28 countries is used, Forbes and Rigobon (2002) claim that there is no evidence of contagion during the 1987 U.S. stock market crash, the 1994 Mexican peso crisis, and the 1997 East Asian crisis.

The second most commonly used methodology to test for contagion, introduced in Eichengreen et al. (1996), is to examine whether the likelihood of crisis is higher in a given country when there is a crisis elsewhere. One advantage of this approach is that it readily allows statistical tests for the existence of contagion. The method also helps to investigate the channels through which contagion may occur, distinguishing, among others, trade and financial linkages.

Eichengreen et al. (1996) use a probit model and a panel of quarterly macroeconomic and political data covering 20 OECD countries from 1959 through 1993 to test for contagious currency crises. The results of their estimation show that the probability of a domestic currency crisis increases with a speculative attack elsewhere and that contagion is more likely to spread through trade linkages than through macroeconomic similarities. Trade as the relevant contagion channel is also supported by Glick and Rose (1999). But the trade weights in Eichengreen et al. (1996) reflect only bilateral trade linkages while Glick and Rose (1999) allow crises to spread only from “Ground Zero” (the first crisis) country without allowing for the possibility of cascading effects.

The same approach as that of Eichengreen et al. (1996) is also applied by De Gregorio and Valdes (2001) who have examined whether the crisis indicator of a country is explained by the initial macroeconomic conditions of the country and the weighted average of crisis indicators of other countries during the 1982 debt, the 1994 Mexican and the 1997 Asian crises. Their results indicate that there is a strong neighborhood effect. Trade links and similarity in pre-crisis growth also explain, to a lesser extent, which countries suffer more contagion. The evidence shows that the 1982 debt crisis was as contagious as the Asian crisis, while the Mexican crisis was considerably less so. Finally, both debt composition and exchange rate flexibility limit to some extent contagion, whereas capital controls do not appear to curb it. Some of these results are, however, refuted by Caramazza et al. (2004) who investigate the ERM, the 1994 Mexican, the Asian, and the Russian crises using the same approach. According to their results, the contagious nature of the Mexican, Asian and Russian crises does not differ much. Fundamentals, including trade and financial (common creditor) linkages and financial fragility, are highly significant in explaining crises, while exchange rate regimes and capital controls do not seem to matter.

Using a slightly different approach (by comparing the conditional and unconditional probability of a crisis), Kaminsky and Reinhart (2000) examine how trade and financial sector links influence the pattern of fundamentals-based contagion using monthly data from 20 industrial and developing countries from 1970 through 1998. According

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5 A good review of the various methods applied in contagion is provided in Forbes and Rigobon (2001a) and Rigobon (2002).
to their results, contagion is more regional and highly nonlinear. Furthermore, when the number of crises in a given cluster is high, the financial sector link via common bank lenders is a more powerful channel of fundamental-based contagion than are trade linkages. The importance of common bank lender is also supported in Van Rijckeghem and Weder (2001) and Hernandez and Valdes (2001). The results in the first study are obtained from a probit model while the second study estimates a pooled OLS model using data from 17 emerging market economies.

3. Methodology

The main objective of this paper is to provide answers to the two questions raised earlier: is the probability that a country faces a speculative attack affected by a crisis elsewhere? What are the most relevant contagion channels? To address these questions, a panel probit model is estimated using data from a set of 37 advanced and emerging market economies (see Appendix A for the list of sample countries and data descriptions). Our definition of contagion follows Eichengreen et al. (1996). There is contagion if the probability of a currency crisis is significantly affected by the occurrence of a crisis elsewhere. This approach, however, presupposes knowledge of periods of crisis in different countries linked in many possible ways.

Following Girton and Roper (1977), exchange market pressure (EMP), a weighted average of exchange rate changes, international reserve changes, and interest rate changes, is used to measure speculative pressure on a country and its currency (see also Eichengreen et al., 1996; Kaminsky & Reinhart, 2000)\(^6\). The EMP is a good index of currency crisis as it reflects different manifestations of speculative attacks, be they successful or otherwise. The argument is that the central bank of a country may allow the currency to depreciate in response to intense speculative attack against its currency. In some other cases, the bank may defend the currency by running down its foreign exchange reserves or by raising interest rate.

The exchange market pressure for country \(i\) at time \(t\) is, therefore, computed as:

\[
EMP_{it} = \alpha(\%\Delta e_{it}) + \gamma(\%\Delta r_{it} - \%\Delta r_{ct}) - \delta(\%\Delta r_{ct} - \%\Delta r_{ct})
\]

(1)

where \(e\) is the price of the center/reference country’s currency in terms of country \(i\)'s currency, \(r_{it}\) (\(r_{ct}\)) is the nominal interest rate of country \(i\) (center country) and \(r\) is the ratio of reserve to M1. Germany is taken as the center of reference for our OECD samples while US is taken as center for emerging market economies. \(\alpha\), \(\gamma\), and \(\delta\) are weights selected to equalize the volatilities of the three components of EMP\(_{it}\) so that — one component does not dominate the index\(^7\).

By definition, a currency crisis occurs when the realized exchange market pressure is “unusually large”. The main problem with this methodology is in defining the threshold that determines the largeness of the index. The approach used varies from study to study. For Eichengreen et al. (1996), a crisis occurs if the value of the exchange market pressure is 1.5 standard deviations above the mean of the full panel index. By contrast, Kaminsky and Reinhart (2000) set the cutoff point at 3 standard deviations above the mean value of the own country’s index.

Our paper applies an alternative and relatively more objective method of crisis identification based on extreme value theory. The main argument for this approach is that exchange rate changes during crisis periods (like the ERM attacks of 1992 and the Asian financial crisis of 1997) are outliers, making the distribution of exchange rate changes “fat-tailed” (see Pownall & Koedijk, 1999). The standard approach of Eichengreen et al. (1996), Kaminsky and Reinhart (2000), etc., lacks a theoretical justification in setting the threshold to identify the “unusually large” values of the EMP as indicators of currency crises. Our paper dispenses of the problem of identifying the right tail observations of the EMP as indicators of currency crisis by using an alternative approach.

To identify the frequency of outliers that are the results of successful and unsuccessful speculative attacks, we estimate the tail mass using the extreme value approach as first proposed in Pozo and Amuedo-Dorantes (2003). The extreme value theory, which has wide applications in measuring various forms of risks (both natural and in financial markets), allows us to determine the tail mass measured via the tail index. Since we cannot fit the EMP to a specific

\(^{6}\) Since most of the sampled countries did not have market determined interest rates in the 1970s and early 1980s, the crisis index in Kaminsky and Reinhart (2000) incorporates only reserve losses and depreciation.

\(^{7}\) \(\delta\) is one, \(\alpha\) is the ratio of the standard deviations of the third to the first components of EMP while \(\gamma\) is the ratio of the standard deviations of the third to the second components of EMP. Since the conditional variances of the three components of EMP are not constant, time varying weights are estimated using GARCH models.
parametric distribution, the threshold to identify the tail observations is determined using Monte Carlo simulation. A brief summary of the steps to estimate the tail index and periods of crisis is provided in Appendix B. These steps are applied to the EMP data of each country in our sample. Using our approach, we are able to capture major crisis periods, and periods with intense pressures absent full-fledged crisis in each country in our sample.

In Figs. 1 and 2, we provide the percentage of countries in crisis across time. Fig. 1 is plotted based on crisis periods from all the thirty-seven countries together while in Fig. 2 we use crises from a subset of twenty OECD countries. As shown in Figs 1 and 2, a large number of countries were in crisis in the early 1970s, 1978/79, 1987 and 1992/93. The early 1970s and 1978/79 correspond to the collapse of the Bretton Woods system and the Snake, respectively. The Snake was later replaced by the European Monetary System (EMS). The years 1987 and 1992/93 appear to correspond to the October 1987 U.S. stock market crash and the European Exchange Rate Mechanism (ERM) crisis, respectively.

Based on the standard approach of currency crisis identification (using the mean plus 1.5 standard deviations), a large number of countries were found in crisis in the early 1970s and 1992/93 (results are not reported here). Identification of crisis using the extreme value approach, as reported in Figs 1 and 2, captures additional major crisis years during 1978/79 and 1987 during which many countries were affected.

3.1. The model

This section specifies the model that is used to test whether the probability of a crisis in an individual country is affected by a weighted “crises elsewhere” variable while controlling for initial macroeconomic conditions in the country under question. According to a number of theoretical models reviewed in Section 2, currency crises may be contagious among major trade partners/competitors (trade), countries that have common lenders (finance), countries that have similar macroeconomic fundamentals (macroSim), and neighbors (neigh). To empirically identify the relevant contagion channel(s), each of the channels is captured by a weighted “crises elsewhere” variable where the weight is constructed to reflect the strength of that contagion channel.

A non-structural model is used to estimate the probability of a crisis in country $i$ and period $t$. This is specified to be:

$$P(C_{it} = 1) = \text{prob} \left[ \beta_0 + \beta'X_{it} + \gamma_1\text{trade}_{it} + \gamma_2\text{finance}_{it} + \gamma_3\text{macroSim}_{it} + \gamma_4\text{neigh}_{it} + \epsilon_{it} > 0 \right]$$

where $i=1,...,N$, $t=1,...,T$ and $\epsilon_{it}$ (with $\epsilon_{it} = U_i + V_{it}$) is the sum of the group or heterogeneity effect ($U_i$) and an idiosyncratic error ($V_{it}$). $V_{it}$ is assumed to be standard normal and uncorrelated across countries and over time. Unless $U_i$ (the group effect) is zero, estimation of a pooled probit model of (2) ignoring $U_i$ will result in inconsistent estimates. If $U_i$ and one or more of the regressors are correlated, we have a fixed effect probit model. In the latter case, the $U_i$ is

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8 Since Germany and the US are used as the center of references, the actual number of countries in Fig. 1 is 35 while the actual number in Fig. 2 is 19.
treated as a parameter to be estimated along with the $\beta$'s and $\gamma$'s. But estimation of $U_i$ along with the $\beta$'s and $\gamma$'s introduces “an incidental parameters problem” in addition to being computationally difficult in a situation where there are a large number of groups (see Wooldridge, 2002).

When $N$ is large in a linear model, the group effects can be removed using the results of partitioned regression. But the partitioned regression does not apply in a nonlinear probit model. Since the probit model does not lend itself well to the fixed effect treatment, the literature resorts to a random effect probit specification. Here $U_i$ is treated as an unobserved random variable drawn along with the other variables. Further, it is assumed that

$$U_i|Z_i \sim N(0, \sigma_u^2)$$

where $Z_i$ is a vector of the left-hand side variables in Eq. (2). In this specification, the relative importance of the unobserved group effect is given by:

$$\rho = \frac{\sigma_u^2}{(1 + \sigma_u^2)}.$$  (4)

The random effect probit specification is justified if $\rho$ is statistically different from zero. If not, Eq. (2) is estimated by pooled probit.

$X_{it}$ is a vector of macroeconomic control variables. The variables in $X_{it}$ are the growth rate of money ($m2$), inflation from the CPI, the growth rate of domestic credit, the growth rate of real GDP, the percentage of government budget balance relative to GDP, the percentage of current account relative to GDP, and the unemployment rate. Each variable is entered as deviation from the corresponding variable of the center country, Germany for the OECD sample and the US for emerging economies.

The variables in vector $X_{it}$ are included in line with the arguments of the first generation models of speculative attacks. These models predict co-movements between speculative attacks and adverse developments in the fundamental determinants of the exchange rates. In these models, diverging fundamentals are viewed as being inconsistent with a given parity and are interpreted by market participants as a signal that realignment will occur sooner or later. This expectation leads to an immediate speculative attack against the currency resulting in crisis in country $i$ independently of the contagious spread of crises from other countries.

Next, on the right hand side of Eq. (2), are variables that capture the various channels by which contagion may take place. Trade$_{ij}$ is the trade contagion channel. It is measured by the weighted average of crises elsewhere, \[ \sum_{j=1}^{n-1} m_{ij}^{\text{trade}} C_{jt}, \] \[ j \neq i, \] with $n$ representing the number of countries in the sample. The weight ($m_{ij}^{\text{trade}}$) is constructed to reflect the extent of trade linkage or competition between country $i$ and country $j$. When crises happen in some countries (say $j$, $j+1$, and $j+3$) at time $t$, all may not have an equal impact on the probability of a speculative attack on the currency of country $i$. Given this, different weights are assigned to crises in other countries based on the extent of trade linkage or competition between $i$ and each of the other countries. Thus, the coefficient on the trade linkage variable, $\gamma_1$, measures the trade-weighted effect of
Table 1
Test of contagion: Data from 20 OECD sample countries (1960:1–1998:4), panel probit model

<table>
<thead>
<tr>
<th>Regressors</th>
<th>Absolute trade and financial link weights</th>
<th>Relative trade and financial link weights</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>Constant</td>
<td>−0.30 (−30.80)</td>
<td>−0.31 (−30.65)</td>
</tr>
<tr>
<td>Trade contagion</td>
<td>0.46 (2.07)**</td>
<td>0.65 (1.96)**</td>
</tr>
<tr>
<td>Financial contagion</td>
<td>−0.76E−01 (−0.35)</td>
<td>0.58E−01 (0.17)</td>
</tr>
<tr>
<td>Macro contagion</td>
<td>0.19 (1.11)</td>
<td>−0.12 (−0.46)</td>
</tr>
<tr>
<td>Growth of M2</td>
<td>−0.85E−02 (−3.90)***</td>
<td>−0.85E−02 (−3.92)***</td>
</tr>
<tr>
<td>Growth of D. credit</td>
<td>0.53E−02 (2.77)***</td>
<td>0.57E−02 (2.99)***</td>
</tr>
<tr>
<td>Growth of real GDP</td>
<td>−0.58E−03 (−0.38)</td>
<td>−0.59E−03 (−0.39)</td>
</tr>
<tr>
<td>Inflation</td>
<td>0.27E−03 (0.06)</td>
<td>−0.78E−03 (−0.16)</td>
</tr>
<tr>
<td>% of current account/GDP</td>
<td>−0.13E−02 (−0.55)</td>
<td>−0.13E−02 (−0.54)</td>
</tr>
<tr>
<td>% of govt. deficit/GDP</td>
<td>−0.47E−02 (−2.07)**</td>
<td>−0.46E−02 (−2.03)**</td>
</tr>
<tr>
<td>Unemployment rate</td>
<td>0.44E−02 (2.32)**</td>
<td>0.44E−02 (2.32)**</td>
</tr>
<tr>
<td>Number of observation</td>
<td>1930</td>
<td>1930</td>
</tr>
<tr>
<td>Joint tests for slopes (\chi^2) (10)</td>
<td>339.07</td>
<td>340.86</td>
</tr>
<tr>
<td>Joint tests for no contagion (\chi^2) (3)</td>
<td>306.80</td>
<td>308.59</td>
</tr>
<tr>
<td>Test for the significance of (\rho)</td>
<td>0.377</td>
<td>0.339</td>
</tr>
</tbody>
</table>

Due to missing observations for some countries, the data are unbalanced. Figures in parenthesis are z-statistics. Critical values from the standard normal table: *** 1% (≈2.575), ** 5% (=1.96), and * 10% (≈1.645).

crises elsewhere on the probability of a crisis or speculative attack on the currency of the representative sample country. If \(\gamma_1\) is statistically different from zero, it will be taken as an evidence for contagion via trade linkages.

Finance, is a measure of the financial linkage weighted crises elsewhere and is given by \(\sum_{j=1}^{n-1} m_{ij}^{\text{finance}} c_{jt}, j \neq i\). If external lending banks\(^9\) are closely/equally important to countries \(i\) and \(j\), the financial linkage weight \(m_{ij}^{\text{finance}}\) is assigned a larger value. Based on this, the statistical significance of \(\gamma_2\) is taken as an evidence for contagion via common lenders or financial linkages.

Similarly, macroSim, is a measure of the macroeconomics similarity weighted crises elsewhere and is given by \(\sum_{j=1}^{n-1} m_{ij}^{\text{macro}} c_{jt}, j \neq i\). The macro weight \(m_{ij}^{\text{macro}}\) is assigned a larger value if countries \(i\) and \(j\) have similar macroeconomic fundamentals. Based on this, the statistical significance of \(\gamma_3\) is taken as an evidence for contagion via macroeconomic similarity. Lastly, neigh, is the neighborhood effect dummy, and it takes a value of 1 at time \(t\) for country \(i\) if one of \(i\)’s neighbors is in a crisis at time \(t\).

The weights are constructed based on the methodologies applied in Eichengreen et al. (1996) for macroeconomic similarity, Glick and Rose (1999) for trade linkage, and Van Rijckeghem and Weder (2001) for financial linkage.

4. Estimation results

The panel probit model specified in Eq. (2) above is estimated using quarterly data from 37 countries. The data cover the period from 1960:1 to 1998:4 for some countries and a shorter period for others. As stated in the data Appendix, in the case of most emerging market economies, there are no quarterly data for government budget balance, unemployment, and GDP. The missing quarterly GDP series are generated using the SAS expand procedure for most of the emerging market countries. In order to check the sensitivity of the results to these data problems, estimation is made for two separate cases. The first case covers the 20 OECD countries that have complete data for the seven macroeconomic focus variables. The second case uses data from all the 37 countries but controlling for only five fundamental macroeconomic variables\(^10\).

\(^9\) While the assumption of common bank lenders as a measure of financial linkage is reasonable for the 1970s and 1980s, this assumption might not hold for the 1990s and later when other capital markets become more important especially for emerging market economies. However, the available data does not allow us to add the impact of other capital markets into the financial linkage channel.

\(^10\) The macroeconomic similarity weights in the second case are constructed based on the similarity of the five macroeconomic focus variables: growth rate of M2, growth rate of credit, growth rate of real GDP, inflation and the percentage of current account relative to GDP.
Estimation results for the two cases are reported in Tables 1–3. In all cases considered, the estimated coefficients are marginal effects evaluated at the mean values of the regressors. The tables also report the associated z-statistics (in parentheses) and some diagnostic tests. The diagnostic tests include joint tests for the significance of all the coefficients, joint test for the significance of all the contagion channels and test for the significance of the group effect (or $\rho$). In all cases, the null of no group (or random) effect cannot be rejected. Based on this test result, the model is estimated by pooling the data from all the sample countries. As the results show, there is no single instance where the null hypothesis that all the contagion channels are jointly insignificant is not rejected. In other words, all the contagion channels taken jointly are statistically different from zero.

### Table 2
Test of contagion with neighborhood effects captured by a dummy variable: Extended data from 37 sample countries (1960:1–1998:4), panel probit model

<table>
<thead>
<tr>
<th>Regressors</th>
<th>Absolute trade and financial link weights</th>
<th>Relative trade and financial link weights</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>Constant</td>
<td>$-0.31 (-37.91)$</td>
<td>$-0.31 (-37.9)$</td>
</tr>
<tr>
<td>Trade contagion</td>
<td>0.42 (2.02)**</td>
<td>0.71 (4.22)**</td>
</tr>
<tr>
<td>Financial contagion</td>
<td>0.32 (1.61)</td>
<td>-0.35E-01 (-0.44)</td>
</tr>
<tr>
<td>Macro contagion</td>
<td>$-0.96E-01 (-0.81)$</td>
<td>$-0.15E-01 (-0.11)$</td>
</tr>
<tr>
<td>Neighborhood dummy</td>
<td>0.29E-01 (2.30)**</td>
<td>0.23E-01 (1.74)**</td>
</tr>
<tr>
<td>Growth of M2</td>
<td>$-0.32E-02 (-2.93)**</td>
<td>$-0.31E-02 (-2.83)**</td>
</tr>
<tr>
<td>Growth of D. credit</td>
<td>0.25E-02 (2.65)**</td>
<td>0.25E-02 (2.60)**</td>
</tr>
<tr>
<td>Growth of real GDP</td>
<td>$-0.29E-03 (-0.38)$</td>
<td>$-0.29E-03 (-0.37)$</td>
</tr>
<tr>
<td>Inflation</td>
<td>0.47E-03 (0.43)</td>
<td>0.43E-03 (0.39)</td>
</tr>
<tr>
<td>% of current account/GDP</td>
<td>0.13E-03 (0.20)</td>
<td>0.19E-03 (0.29)</td>
</tr>
<tr>
<td>Number of observation</td>
<td>3301</td>
<td>3301</td>
</tr>
<tr>
<td>Joint tests for slopes $\chi^2$ (9)</td>
<td>289.02</td>
<td>272.40</td>
</tr>
<tr>
<td>Joint tests for no contagion $\chi^2$ (4)</td>
<td>525.896</td>
<td>527.28</td>
</tr>
<tr>
<td>Test for the significance of $\rho$</td>
<td>0.651</td>
<td>0.637</td>
</tr>
</tbody>
</table>

Due to missing observations for some countries, the data are unbalanced. Figures in parenthesis are z-statistics. Critical values from the standard normal table: *** 1% ($\approx 2.575$), ** 5% ($=1.96$), and * 10% ($\approx 1.645$).

### Table 3
Test of contagion with neighborhood effects captured by the number of neighbors in crisis: Extended data from 37 sample countries (1960:1–1998:4), panel probit model

<table>
<thead>
<tr>
<th>Regressors</th>
<th>Absolute trade and financial link weights</th>
<th>Relative trade and financial link weights</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>Constant</td>
<td>$-0.30 (-43.21)$</td>
<td>$-0.30 (-41.70)$</td>
</tr>
<tr>
<td>Trade contagion</td>
<td>0.89E-01 (0.39)</td>
<td>0.27 (1.38)</td>
</tr>
<tr>
<td>Financial contagion</td>
<td>0.46 (2.21)**</td>
<td>$-0.25E-01 (-0.31)$</td>
</tr>
<tr>
<td>Macro contagion</td>
<td>$-0.10 (-0.83)$</td>
<td>0.16 (1.06)</td>
</tr>
<tr>
<td>Neighborhood dummy</td>
<td>0.16E-01 (4.96)**</td>
<td>0.17E-01 (4.75)**</td>
</tr>
<tr>
<td>Growth of M2</td>
<td>$-0.29E-02 (-2.65)**</td>
<td>$-0.28E-02 (-2.57)**</td>
</tr>
<tr>
<td>Growth of D. credit</td>
<td>0.25E-02 (2.63)**</td>
<td>0.25E-02 (2.65)**</td>
</tr>
<tr>
<td>Growth of real GDP</td>
<td>$-0.71E-04 (-0.09)$</td>
<td>$-0.11E-03 (-0.14)$</td>
</tr>
<tr>
<td>Inflation</td>
<td>0.54E-03 (0.49)</td>
<td>0.48E-03 (0.43)</td>
</tr>
<tr>
<td>% of current account/GDP</td>
<td>0.25E-03 (0.36)</td>
<td>0.29E-03 (0.40)</td>
</tr>
<tr>
<td>Number of observation</td>
<td>3301</td>
<td>3301</td>
</tr>
<tr>
<td>Joint tests for slopes $\chi^2$ (9)</td>
<td>309.29</td>
<td>292.70</td>
</tr>
<tr>
<td>Joint tests for no contagion $\chi^2$ (4)</td>
<td>546.17</td>
<td>529.58</td>
</tr>
<tr>
<td>Test for the significance of $\rho$</td>
<td>0.651</td>
<td>0.637</td>
</tr>
</tbody>
</table>

Due to missing observations for some countries, the data are unbalanced. Figures in parenthesis are z-statistics. Critical values from the standard normal table: *** 1% ($\approx 2.575$), ** 5% ($=1.96$), and * 10% ($\approx 1.645$).
Table 4
Test of contagion: Data from 17 emerging market economies (1960:1–1998:4), panel probit model

<table>
<thead>
<tr>
<th>Regressors</th>
<th>Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>−0.30 (−22.46)</td>
</tr>
<tr>
<td>No. of crises in emerging economies</td>
<td>5.11E−02 (9.99)***</td>
</tr>
<tr>
<td>Growth of M2</td>
<td>−4.66E−05 (−0.04)</td>
</tr>
<tr>
<td>Growth of D. credit</td>
<td>6.86E−04 (0.7)</td>
</tr>
<tr>
<td>Growth of real GDP</td>
<td>−4.57E−04 (−0.51)</td>
</tr>
<tr>
<td>Inflation</td>
<td>−1.06E−03 (−0.89)</td>
</tr>
<tr>
<td>% of current account/GDP</td>
<td>8.50E−05 (0.14)</td>
</tr>
<tr>
<td>Number of observation</td>
<td>1233</td>
</tr>
<tr>
<td>Joint tests for slopes $\chi^2$ (6)</td>
<td>102.09</td>
</tr>
</tbody>
</table>

Due to missing observations for some countries, the data are unbalanced. Figures in parenthesis are z-statistics. Critical values from the standard normal table: *** 1% (≈ 2.575), ** 5% (=1.96), and * 10% (= 1.645).

Table 1 presents the results for the panel probit model of currency crisis based on data from the 20 OECD countries. Examination of the coefficients on the contagion channels (trade, finance and macroeconomic similarity)\(^{11}\) should indicate to us whether crisis elsewhere increases the probability of crisis in country i. In column A, the tests are made using absolute trade and financial linkage weights. According to the results reported in this column, currency crises are contagious. The test results also reveal that contagion works through the trade channel. In column B of Table 1, relative trade and financial linkage weights are used in place of the corresponding absolute weights to check the robustness of our results with respect to the weights used to construct the contagion channel. According to the estimation results reported in this column, contagion still works via the trade channel. This result supports Eichengreen et al. (1996) and Glick and Rose (1999) who have found that crises are contagious among major trade partners/competitors. The other two contagion channels, finance and macroeconomic similarity, are statistically insignificant in either case.

Overall, the results in Table 1 indicate that currency crises are contagious and contagion works via the trade channel. In addition to this, the results in Table 1 support some of the predictions of the first generation models of speculative attacks. According to those models, currency crisis is the result of inconsistency between macroeconomic fundamentals and the exchange rate commitment. According to the results reported in Table 1, the probability of currency crisis increases with an increase in the growth rate of domestic credit, the percentage of government budget deficits (absolute value), and the unemployment rate, all measured relative to the corresponding variables of the reference country. It is interesting that more rapid growth of M2 is related to a decrease in the probability of crisis. This could be a reflection of the impact on crisis of greater monetization of the economy. A more sophisticated financial structure may lead to better cushioning from financial crisis once we control for “excessive” money creation, in the form of realized inflation rates and the government budget.\(^{12}\)

Tables 2 and 3 present estimation results based on data from the 37 countries, and include emerging market economies from various regions around the globe. Estimations reported in Tables 2 and 3 add a fourth contagion channel that captures the neighborhood/regional effect of a crisis. The neighborhood effect of a crisis is captured by the neighborhood dummy variable that takes a value of 1 for country i at time t if there is a currency crisis at time t in at least one of i’s neighbors and zero otherwise.

The estimation results remain the same whether the tests are made using absolute trade and financial linkage weights (column A) or the corresponding relative weights (column B). According to the results reported in Table 2, there is

\(^{11}\) Since most of the 20 OECD countries are in the same region, the neighborhood contagion channel is not tested.

\(^{12}\) In the case that we expect a positive coefficient on M2 growth, it could be that the negative coefficient is an indicator of multicollinearity among the right hand side variables in the model. We explore this by looking at their correlation matrix and principal components. From both analyses, the growth rate of M2 is found to have high correlations with inflation and the growth rate of credit. We have further tested multicollinearity using the condition index/number. Because the problem and focus is on the right hand side variables, we use an OLS regression model to calculate the condition number (see Menard, 2001). The test results show the presence of multicollinearity (which may explain the unexpected sign due to some possible interactions among the correlated variables). To see the consistency of the results, we have also re-estimated the probit model without the growth rate of M2 (results are reported in Appendix C). Overall the impacts of the other variables on the probability of crisis remain similar. As before, currency crisis is contagious via the trade channel. The unemployment rate and government budget deficits also continue to have impacts on the probability of currency crisis.
contagion. Currency crises are contagious among major trade partners/competitors and neighbors. The other two contagion channels: finance, and macroeconomic similarity are statistically insignificant.

In Table 3, the neighborhood dummy variable is replaced by the neighborhood variable. The latter is the number of neighboring countries in currency crisis in place of a 0, 1 dummy variable. Unlike the previous two tables, the impact of trade linkage is statistically insignificant while contagion appears to work via the financial linkage channel. As in Table 2, currency crises continue to be contagious among those that do have neighbors in crises. The importance of the neighborhood variable, specified as the number of neighbors in crisis, in propagating crisis is also reported in Kaminsky and Reinhart (2000). But in this case the neighborhood variable might be capturing the workings of contagion through capital markets as the correlation between the number of neighbors in crisis and herding behavior as described by Calvo (2005) is likely to be positive. To further explore this possibility we re-estimated the model using data from the emerging market economies only along with the number of emerging economies in crisis as a regressor in place of all the contagion channels reported in Tables 1–3. The goal is to test (albeit crudely) contagion via capital markets in line with Calvo (2005) who explains contagion via herding behavior due to the presence of informed and uninformed investors in the emerging economies capital markets. According to the results reported in Table 4, the number of emerging economies in crisis is found to raise the probability of crisis. Thus, currency crises in emerging market economies may also be driven by herding behavior emanating mainly in the capital markets.

Impacts from some of the control variables included in Tables 2 and 3 continue to be consistent with the predictions of the first generation models of currency crisis. As in the previous case, an increase in the growth rate of domestic credit relative to the reference country significantly increases the probability of currency crisis, while M2 growth reduces that probability.13 These results are not directly comparable with those in Table 1 as the size and composition of the sample countries and the number of control variables are different in the two cases. However, they do by and large confirm that countries with unsustainable macroeconomic fundamentals are prone to currency crisis.

Overall, the results from the OECD and the full samples provide a number of consistent conclusions. In both cases, currency crisis is contagious and contagion seems to work through the trade channel. The regression results also provide some evidence for the working of contagion through financial linkages at least for emerging economies. Further, many of the predictions of the first generation models of speculative attacks are supported by the estimation results suggesting that increases, relative to the figures in the reference country, in the absolute value of government budget deficits, unemployment and domestic credit increase the probability of currency crisis.

Identification of crisis using the extreme value approach helps us avoid the subjectivity of the standard approach of crisis identification in setting the threshold level. By doing so, we are able to get consistent results with regard to the identification of the relevant contagion channels.

5. Conclusions

This paper estimates a panel probit model for a set of 37 countries using quarterly data from 1960 to 1998 to test whether currency crises are contagious and to identify the channels through which crises spread across countries. The paper has made two major contributions. First, it identifies crises using a relatively more objective method based on the extreme value theory. As discussed earlier, the results of the test for the relevant contagion channel(s) are sensitive to the level of the commonly applied threshold used to identify crises. Second, it considers all four contagion-channels simultaneously instead of only trade and macroeconomic similarities (as tested by Eichengreen et al., 1996; Glick & Rose, 1999) or only trade and finance (as tested by Kaminsky & Reinhart, 2000). In addition to the trade, finance and macro similarity channels, we also include the neighborhood effects channel.

Our paper has also attempted to overcome some of the shortcomings of previous studies. The trade linkage weights are computed based on countries trade relations in both their respective bilateral and third party export markets instead of based only on bilateral imports and exports as applied in Eichengreen et al. (1996). In Glick and Rose (1999) and Van Rijckeghem and Weder (2001), crisis spreads only from “ground zero countries” (the countries where the crisis begins) to others. In practice, there is a possibility of cascading in that a crisis spreads to a second country causing a

13 As in the previous case with the OECD sample, we have re-estimated the model dropping M2 growth due to its potential collinearity with some of the other macroeconomic fundamentals. The overall results remain unchanged (results are not reported).
third country to receive pressure from both the first and second victims. Crises in this paper are allowed to spread from any country, allowing for the possibility of cascading effects.

A number of different model specifications are estimated for a panel of 37 advanced and emerging countries. For comparability purpose, we also estimate the model for a subset of 20 OECD countries. According to the estimation results from different model specifications, the probability of a currency crisis in a given country is significantly increased by a crisis elsewhere. The results also reveal that increases in the domestic credit expansion, government budget deficits (absolute value), unemployment rate and inflation (in a few cases) do also significantly increase the probability of a currency crisis. These results are consistent with many of the major crises around the world. One example is the 1997 Asian financial crisis. Countries with unsustainable macroeconomic fundamentals such as Thailand, Malaysia, the Philippines, and Indonesia were the first victims in the Asian crisis. All these countries were believed to have experienced appreciating real exchange rates, large current account deficits and financial sector squeezes linked to overexposure to property markets whose prices had fallen sharply prior to July 1997 (see Masson, 1999; Krugman, 1998). But the pressures also spread to Hong Kong, Singapore and Korea, countries with strong current account and fiscal positions. The crisis even jumped surprisingly to several emerging markets outside the region, notably to Brazil and Russia (see IMF, 1998, 2001).

Though countries can prevent the initiation of a currency crisis by pursuing policies that result in sound internal and external macroeconomic balances, currency crisis can still spread to such countries. The prevention, resolution and management of the contagious spread of the crises may require coordinated actions among different countries in the world. The appropriate specific measures to contain contagion, be they regional or global, depend on knowledge of the contagion channels.

Among the four possible contagion channels considered, the test results in our paper reveal the importance of trade linkages as a relevant contagion channel. The macroeconomic similarity channel turns out significant in none of the estimations. But the estimation does point out that the probability of crisis increases as the number of neighboring countries in crisis increases suggesting that contagion begets contagion. The neighborhood variable may also be capturing the working of contagion via capital markets in line with Calvo’s argument. However, the importance of financial linkages via common bank lenders and also other capital markets need further empirical tests.

Overall, contagion is regional and more specifically it operates through the trade channel. What policies can be pursued to prevent contagion? One possibility is that countries could prevent contagion by diversifying their trade base. This would weaken the impact of one country in crisis on its trading partners. Another possibility is for countries to fix their exchange rates with major trade partners collectively in order to avoid speculative attacks following loss of international competitiveness. Such a policy, however, may lead to destabilizing speculation if the collective agreement is not firm and credible. At the extreme, countries may adopt a regional currency, which is the track followed by some of the European countries in creating the Euro, to prevent contagion among members through competitive devaluation.

Appendix A

A.1. Sample countries

- OECD countries (20):
  - Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, UK and USA.
- Emerging market economies (17):
  - Argentina, Brazil, Colombia, Ecuador, Mexico, Peru, South Africa, Turkey, Indonesia, Israel, Korea, Malaysia, New Zealand, Philippines, Singapore, Sri Lanka and Thailand.

A.2. Variables used and data sources

- Period-average exchange rate-local per German Mark (IFS CD-ROM, usually line rf)
- Short-term interest rate given by money market rate (IFS, line 60b) if available or the discount rate (IFS, line 60) otherwise.
- Total non-gold international reserves (IFS, line 1L.D)
- Domestic credit (IFS, line 32)
• M1 (IFS, line 34)
• M2 (IFS, M1 plus line 35)
• GDP (IFS, line 99b)
• Real GDP (IFS, usually line 99b.r)
• CPI (IFS, line 64)
• The Current account balance in domestic currency (IFS, usually line 78ALD)
• Government budget balance (IFS, line 80)
• Unemployment rate (IFS, line 67r)

A.3. Trade linkage weights

Trade weights are constructed using the average annual aggregate bilateral trade flows from 1980 to 1992 to 160 countries in the world. The data are obtained from the Center for International Data at University of California, Davis. [http://www.internationaldata.org].

A.4. Financial linkage weights (to reflect common sources of bank credit)

Weights to reflect financial linkages are constructed using data on consolidated bank lending from 19 major industrial countries to the sample countries.

– The 19 countries that report bank lending by nationality of lending institutions are: Austria, Belgium, Canada, Denmark, Finland, France, Germany, Ireland, Italy, Japan, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Taiwan, UK and USA.
– The data are obtained from the Bank for International Settlements (BIS). The lending institutions in each creditor country include commercial banks, saving banks, saving and loan associations, credit unions or cooperatives, building societies, and post office savings banks or other government-controlled savings banks. The principal forms of resources these institutions lend to other countries are deposits and balances placed with banks, loans and advances to banks and non-banks, holdings of securities and participation. Lending is to the public, banks and non-bank private sector.

Complete data on consolidated bank loan statistics to almost all of the sample countries are, however, available starting from 1999. Semi-annual data are available for most of the emerging market economies starting from 1985. So, the financial linkage weights are constructed based on the average claims of lending institutions in each reporting country to each of the sample countries over the period 1999:2, 1999:4 and 2000:1 to 2001:1.

A.5. Data interpolation

Though unbalanced, there are complete macroeconomic data for the 19 OECD member countries (excluding Germany) but not for the other 17 emerging market economies. Quarterly data for GDP, unemployment, current account and government budget deficits are either not available or missing for certain periods for some or all of the emerging market economies. Data for the current account are unavailable for Colombia, Ecuador, Malaysia, Singapore and Turkey. For these countries, trade balance on goods and services is taken as a proxy to the current account balance. There are no quarterly data for GDP for all the 17 emerging countries except Israel, Korea, Mexico and South Africa. The missing quarterly GDP series are interpolated from the annual GDP series using the SAS expand procedure. In this procedure, a cubic spline curve is fitted to the input (annual) series, and then the output (quarterly series) is computed from this interpolating curve.

To check the reliability of the procedure, quarterly GDP series is interpolated from the annual US GDP. The interpolated series is then compared with the actual US quarterly GDP series. The two quarterly series are reasonably close to each other (Plots are available from the authors on request.). Missing government budget deficits are also generated through the same interpolation procedure but comparison of the resulting interpolated-quarterly series with the actual quarterly series for countries with the data diverge significantly. In addition, there is no complete quarterly as well as annual data for unemployment for the 17 emerging market economies. Due to these reasons, the panel estimation for the 37 countries is undertaken with five instead of seven macroeconomic control variables.
Appendix B

B.1. Application of the extreme value theory to identify periods of currency crisis

Due to the prevalence of events like the October 1987 stock market crash, the Asian financial crises of 1997–98, and the hedge fund (or Russian) crisis of 199814, the distributions of exchange rate changes and other asset returns have fat-tails. Given this, almost all the empirical studies on the identification of contagion channels take ‘unusually large’ values of the crisis index (exchange market pressure) as indicators of currency crisis. The standard approach is to set a threshold using the mean and standard deviations of the EMP and take the ‘unusually large’ values of the EMP relative to the threshold as indicators of crisis. But this approach has no theoretical justification in setting the level of threshold.

This paper has employed the extreme value theory to determine the frequency of ‘unusually large’ exchange market pressures by estimating its tail index (γ). There are two procedures to estimate the tail index γ (=1/α). The first method is to estimate it by maximum likelihood. The second procedure is a non-parametric estimation method first proposed by Hill (1975). A number of studies have shown that the Hill index is a more efficient estimator than the maximum likelihood estimator as the former has a smaller asymptotic variance (γ^2/m) compared to the variance of the ML estimator (1 + γ)^2/m (see Jansen & De Vries, 1991; Koedijk et al., 1992 among others). Note, m is a fraction of the sample size (n) where n>m.

To compute the Hill estimator, define X_{(1)} ≤ X_{(2)} ≤ ... ≤ X_{(n)} as the ascending order statistics from samples X_1, X_2, ..., X_n of n consecutive exchange market pressures, X_i. The proposed Hill estimator is given by:

\[ \hat{\gamma}_H = 1/\hat{\alpha} = \frac{1}{m} \sum_{i=1}^{m} [\log X_{(n+1-i)} - \log X_{(n-m)}] \]  

where m is the largest order statistics used to compute \( \hat{\gamma}_H \) and n is the sample size. \( \hat{\gamma}_H \) is a consistent estimator of γ and is asymptotically normally distributed (see Koedijk et al., 1992):

\[ (\hat{\gamma}_H - \gamma) \sqrt{m} \sim N(0, \gamma^2). \]  

(B2)

Generally, m in both the MLE and Hill-estimator should increase with the sample size n but it should be small relative to the overall sample size n (see Jansen & De Vries, 1991; Wagner & Marsh, 2000). This is given by the following asymptotic condition:

\[ m(n) \to \infty, \frac{m(n)}{n} \to 0, \text{ as } n \to \infty. \]  

(B3)

The Hill estimator has, however, the problem of selecting the m largest order statistics that goes into the estimation of the tail index. A number of studies exploit the properties of \( \hat{\gamma}_H \) to select m. One way is to compute \( \hat{\gamma}_H \) for different m and to select an m value in the region over which the estimated \( \hat{\gamma} \) is more or less constant (see Hols & De Vries, 1991). Jansen and De Vries (1991), Hols and De Vries (1991), Koedijk et al. (1990), and Longin and Solnik (2001), among others, use simulation to select the optimal m by exploiting the asymptotic normality of \( \hat{\gamma} \). They conduct Monte Carlo experiment to find the level of m, conditional upon a sample size n and df. \( F(x) \), for which the mean squared error (MSE) for \( \hat{\gamma} \) is the minimum. A good estimate of the tail index is obtained only if the correct tail observations given by m are known. If we choose only a few tail observations, our parameter estimates will be inefficient with large standard errors. On the other hand, if we choose too many observations, our parameter estimates will be biased, as observations not belonging to the tails are included in the estimation process. The Monte Carlo simulation method is, therefore, helpful in optimizing the trade-off between the bias and the inefficiency mentioned above.

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14 In statistics, extremes of a random process refer to the lowest observation (the minimum) and the highest observation (the maximum) over a given period. In financial markets, extreme price movements correspond to stock market crashes, bond market collapses or currency crises during extraordinary periods. These observations are frequently named as extreme values (see Longin, 2000).
The main point is to determine the largest exchange market pressures and specify these as indicators of currency crises. The number of these extreme values is given by \( m \), which is used to locate the specific periods/times at which the tail observations occur. To determine \( m \), we apply the simulation steps by Longin and Solnik’s (2001). These are:

1. Simulate \( S \) time-series containing \( n \) observations of exchange market pressure from each known Student-\( t \) distributions with \( \alpha \) degrees of freedom where \( \alpha \) ranges from 1 to \( K \). \( \alpha \) in our simulation is allowed to take values from 1 to 5 with increment of 0.2 and from 5 to 10 with increment of 0.5. The theoretical distributions include a sum stable distribution for \( \alpha \) equals 1 (see Jansen & De Vries, 1991). The lower the degree of freedom, the fatter the distribution as the tail index \( \gamma \) is related to \( \alpha \) by \( \gamma = 1/\alpha \) (Longin & Solnik, 2001).

2. For different number \( m \) of extreme exchange market pressures, estimate a tail index \( \hat{\gamma}(m, \alpha) \) corresponding to the \( s \)th simulated time-series from the student-\( t \) distribution with \( \alpha \) degree of freedom. Longin and Solnik (2001) allows \( m \) to vary from 1% to 20% of \( n \). \( n \) is the sample size of the actual exchange market pressures data.

3. Compute the mean square error \( \text{MSE}(\{\hat{\gamma}(m, \alpha)\}_{s=1, \ldots, S}) \) of the \( S \) tail index estimates for a particular student-\( t \) distribution with \( \alpha \) degree of freedom and a particular value of \( m \). Repeatedly compute the MSE for different values of \( m \) but for a particular student-\( t \) distribution of \( \alpha \) degrees of freedom. Then, select the optimal \( m \), denoted by \( m^*(\alpha) \), that minimizes the MSE for that particular student-\( t \) distribution with \( \alpha \) degrees of freedom. Then, repeatedly choose optimal values of \( m \) for different student-\( t \) distributions. A total of \( K \) optimal values of \( m^*(\alpha) \), \( \{m^*(\alpha)\}_{s=1, \ldots, K} \), will be selected for the \( K \) possible theoretical distributions.

4. Using each of the \( K \) optimal values of \( m \) obtained in step 3, compute the tail index estimate using the actual exchange market pressure data, \( \hat{\gamma}(m^*(\alpha)) \) using Hill (1975) tail index estimator. \( K \) number of \( \hat{\gamma} \) tail indexes are estimated from the actual exchange market pressure data, for \( \alpha \) varying from 1 to \( K \).

The main objective of the whole exercise is to get one optimal number of extreme exchange market pressures, \( m^{**} \). Select that single number of extreme exchange market pressures, \( m^{**} \), corresponding to which the tail index estimate from the actual data (from step 4) is statistically the closest to the corresponding tail index of the theoretical distribution. Once \( m^{**} \) is obtained, define all the observations corresponding to the \( m^{**} \) largest observations as periods of crisis.

Appendix C

Test of contagion without growth of M2: Data from 20 OECD sample countries (1960:1–1998:4)\(^6\), panel probit model

<table>
<thead>
<tr>
<th>Regressors</th>
<th>Absolute trade and financial link weights</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>-0.31 (−31.98)</td>
</tr>
<tr>
<td>Trade contagion</td>
<td>0.49 (2.13)**</td>
</tr>
<tr>
<td>Financial contagion</td>
<td>-0.11 (−0.48)</td>
</tr>
<tr>
<td>Macro contagion</td>
<td>0.21 (1.20)</td>
</tr>
<tr>
<td>Growth of D. credit</td>
<td>0.16E−02 (0.94)</td>
</tr>
<tr>
<td>Growth of real GDP</td>
<td>-0.96E−03 (−0.63)</td>
</tr>
<tr>
<td>Inflation</td>
<td>-0.83E−03 (0.17)</td>
</tr>
<tr>
<td>% of current account/GDP</td>
<td>-0.24E−02 (−0.97)</td>
</tr>
<tr>
<td>% of govt. deficit/GDP</td>
<td>-0.41E−02 (−1.82)*</td>
</tr>
<tr>
<td>Unemployment rate</td>
<td>0.44E−02 (2.30)**</td>
</tr>
<tr>
<td>Number of observation</td>
<td>1930</td>
</tr>
<tr>
<td>Joint tests for slopes ( \chi^2(9) )</td>
<td>323.85</td>
</tr>
</tbody>
</table>

Due to missing observations for some countries, the data are unbalanced. Figures in parenthesis are \( z \)-statistics. Critical values from the standard normal table: *** 1% (≈ 2.575), ** 5% (≈ 1.96), and * 10% (≈ 1.645).

References


