

KRISTIN J. FORBES
ROBERTO RIGOBON

Contagion in Latin America: Definitions, Measurement, and Policy Implications

The last two decades have shown that if any country in the world sneezes, Latin America catches pneumonia. A summary of Latin America's recent medical history would include the Mexican debt crisis in 1982, the Tequila effect in 1994, the Asian flu in 1997, the Russian cold in 1998, the Brazilian fever in 1999, and the Nasdaq rash in 2000. These increasingly frequent crises have attracted the attention of policy-makers and academics. Of particular interest is why many of these crises, which began as country-specific events, quickly affected countries and regions around the globe. Most people describe these patterns as contagion. One peculiarity about this literature is that although there is fairly widespread agreement about which of these events led to contagion in Latin America, there is no consensus on exactly what constitutes contagion or how it should be defined.

One preferred definition of contagion is the propagation of shocks in excess of that which can be explained by fundamentals.¹ A simple example shows the practical difficulties of using this definition for a discussion of contagion. In the month after the 1998 devaluation of the Russian ruble, the Brazilian stock market fell by over 50 percent. Was this contagion? Can this impact of Russia on Brazil be explained by any fundamental link-

Forbes and Rigobon are both with the Sloan School of Management at the Massachusetts Institute of Technology and the National Bureau of Economic Research (NBER).

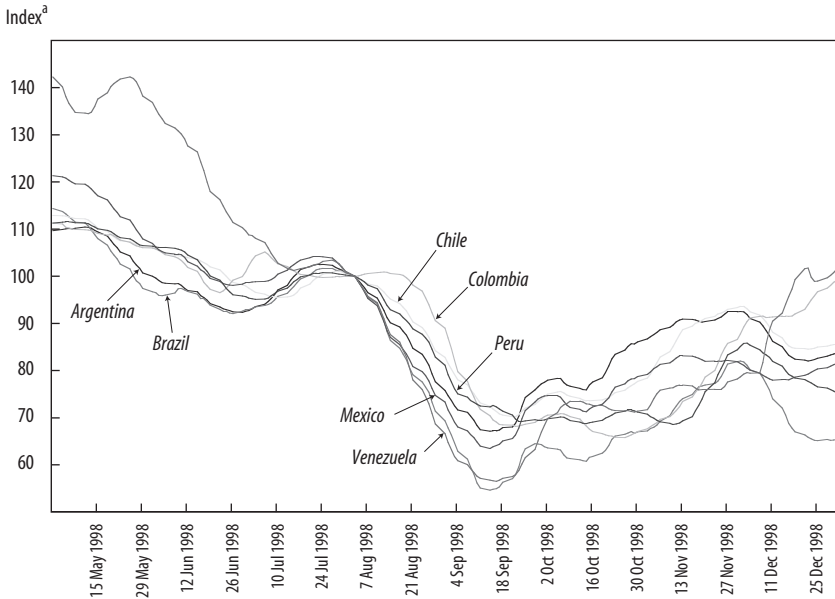
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1. For example, a shock to Mexico could affect stock prices in Argentina if the shock causes a depreciation of the Mexican peso that increases the competitiveness of Mexican exports relative to Argentine exports. This could, in turn, reduce the earnings and dividends of Argentine firms that compete with Mexican firms in third markets. Since the transmission of the initial shock from Mexico to Argentina can be explained by fundamentals (namely, competitiveness effects in third markets), this does not constitute contagion.

ages? A preliminary analysis would suggest not. Russia and Brazil have virtually no direct trade links; the two countries do not export similar goods that compete in third markets; and they have few direct financial links (such as through banks). Further analysis, however, might indicate that during the Russian crisis the market learned how the International Monetary Fund (IMF) would respond during the next currency crisis and what sort of rescue package it would implement. This learning process may have conveyed valuable information about potential rescue packages for the next countries that devalued their currencies or defaulted on their international debt.

An examination of stock market performance and public debt prices for countries in Latin America supports this interpretation. For example, figure 1 graphs aggregate stock market indexes for Argentina, Brazil, Chile, Colombia, Mexico, and Venezuela during the Russian crisis. Brazil and Venezuela, which were the two countries generally believed to be

FIGURE 1 . Latin American Stock Market Indexes during the Russian Crisis



Source: Authors' calculations based on stock market indexes reported by Datastream.
a. Indexes are based on rolling-average, ten-day returns (excluding holidays and weekends). They are normalized to 100 on 3 August 1998.

most vulnerable to a currency crisis or debt default, were most affected by the Russian crisis. A graph of public debt prices displays the same pattern: the countries that had the highest probability of requiring IMF assistance soon after the Russian crisis were the countries most affected by the shock.

This example shows one practical problem with a fundamentals-based definition of contagion. How can we measure these fundamentals, especially in the short run? An issue that is potentially even more problematic is the lack of agreement on which cross-country linkages constitute fundamentals. Does learning based on IMF behavior in Russia qualify as a fundamental? Given these significant problems, the literature on this topic has adopted several alternate, and more easily testable, definitions of contagion. One of the earliest of these definitions classifies contagion as a shift or change in how shocks are propagated between relatively normal periods and crisis periods. Another common definition labels contagion as including only the transmission of crises through specific channels, such as herding or irrational investor behavior. An even broader definition identifies contagion as any channel linking countries and causing markets to move together. This paper focuses on the first of these three definitions (for reasons discussed below), although it frequently provides analysis and discussion based on the broader definitions. To clarify terms and avoid any misunderstanding, we use the phrase *shift-contagion* when referring to this first and narrowest definition.

This discussion of how to define contagion is critically important for this paper's goal: to discuss and analyze contagion in Latin America during recent financial crises. The next section motivates the paper by examining recent patterns and correlations in bond markets and stock markets in Latin America. It finds a high degree of comovement within Latin America and across emerging markets in general, especially in bond markets, during both crisis and noncrisis periods. The paper then uses these trends in Latin America to discuss how contagion ought to be defined, as well as the advantages and disadvantages of alternate definitions. A brief survey of the theoretical literature on contagion follows, together with a summary of the econometric strategies traditionally used to test for its existence. Despite the range of strategies used, virtually all of this work concludes that contagion occurred during recent financial crises. The subsequent section, however, discusses several problems with this empirical work: heteroscedasticity, endogeneity, and omitted-variable bias. Tests for contagion that address

these problems find little evidence of shift-contagion in Latin America during recent financial crises. Instead, these results suggest that many countries in Latin America are always highly interdependent (with each other as well as the rest of the world), and these strong cross-country linkages do not change significantly during periods of crisis. The final section concludes and discusses several policy implications for Latin America.

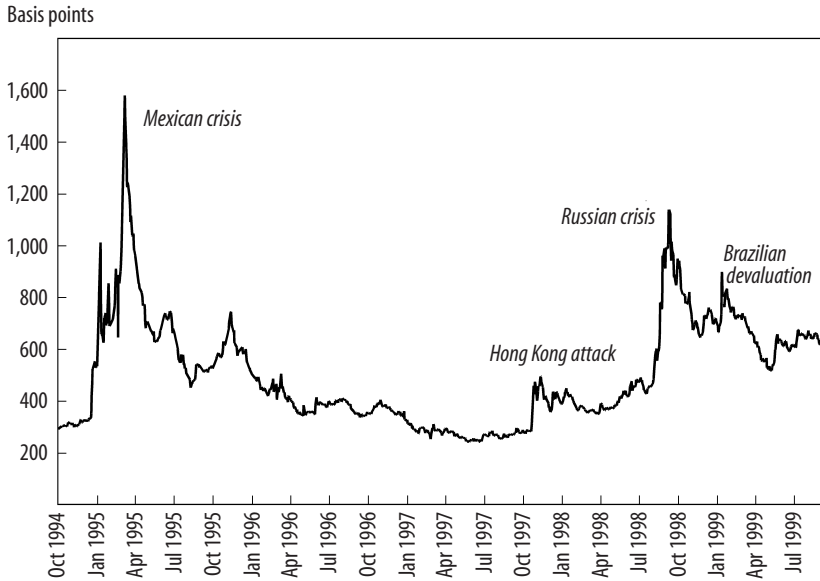
Contagion in Latin America? A First Glance

This section examines trends and relationships in bond and stock markets in Latin America. It documents how these markets were affected by the currency crises of the 1990s and measures the degree of comovement among Latin American markets and among emerging markets in general. These comparisons provide a preliminary test for contagion and raise a number of intriguing questions.

Bond Markets in Latin America

We begin our examination of trends in Latin American bond markets by focusing on the interest rate spread between Latin Eurobonds and the international interest rate (the stripped yield). Latin Eurobonds are mainly dollar-denominated bonds issued by governments and large firms located in Latin America. Figure 2 graphs the stripped yield of a weighted average of all Latin Eurobonds from October 1994 to July 1999. The figure shows that this spread between Latin Eurobonds and the international interest rate is highly volatile. For example, it fluctuated from a low of about 300 basis points during the relatively tranquil third quarter of 1994 to a high of about 1,600 basis points only a few months later during the Mexican peso crisis.

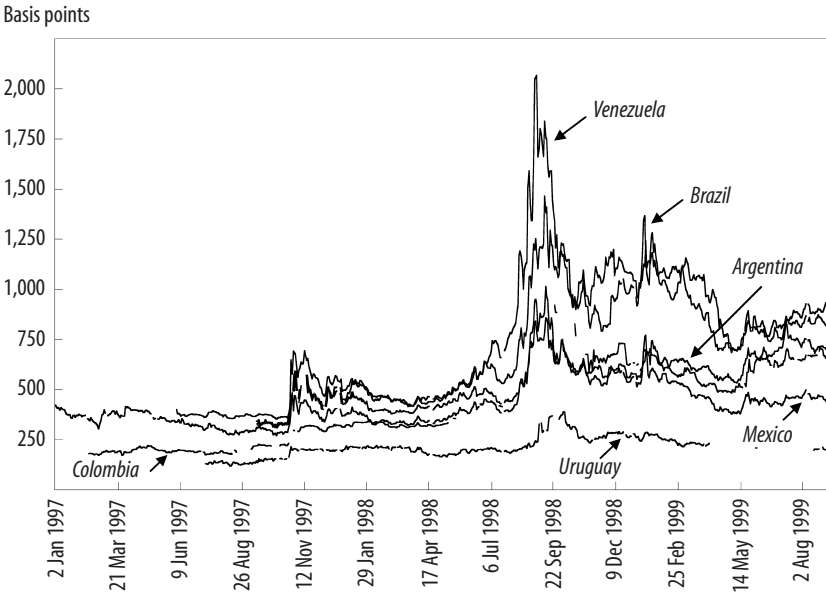
This spread between Latin Eurobonds and the international interest rate measures the average country default risk in Latin America. Why did shocks to Hong Kong and Russia have any impact on the default risk of countries in Latin America? Are the interrelationships between Latin America and Hong Kong or Russia large? To answer these questions, as well as to better understand how different Latin American countries are affected by regional crises (such as the 1999 Brazilian crisis), we examine the impact of these crises on specific bonds instead of on the aggregate Latin American index.

FIGURE 2 . Country Risk Volatility: Latin Eurobond Index Spread, 1994–99

Source: J.P.Morgan.

Figure 3 graphs the long-term sovereign spreads from January 1997 through December 1999 for six Latin American countries: Argentina, Brazil, Colombia, Mexico, Uruguay, and Venezuela. More specifically, these are the stripped yields on the Emerging Markets Bond Index Plus (EMBI+) constructed by J. P. Morgan. These indexes are mainly composed of Brady bonds, although they also include a small number of government and private dollar-denominated issues. Once again, it is immediately apparent that the risk premium for each country is highly volatile. However, the relative risk premiums between countries (that is, the differences in the risk premiums between any two countries) are remarkably stable. For example, the risk premium on Mexican debt jumped from about 350 basis points in early 1998 to about 850 basis points during the Russian crisis. The risk premium on Argentine debt rose from about 400 to 1,000 basis points over the same period. The relative risk premium between these two countries, however, was fairly stable and never rose above 125 basis points. In other words, the distance between any two lines on the graph is much more stable than any of the lines individually.

FIGURE 3 . Stable Relative Valuations: Spread on Long-Term Sovereign Bonds



Source: J.P.Morgan.

These patterns suggest that the volatility of the Latin Eurobond index (as reported in figure 2) is not driven by movements in the risk premium for any single country or any small subset of countries. The crises in Asia and Russia increased the risk premium in all Latin American countries. Even the Brazilian crisis in 1999 affected risk premiums throughout Latin America and not just in Brazil. Moreover, since each of these risk premiums is stripped, this comovement cannot be explained by movements in international interest rates. Why is there such a high degree of comovement in risk premiums for countries that are so different? Could it be caused by a common shock to the region? To answer these questions, it is useful to perform one final analysis of bond markets in Latin America: examine the correlations between bond yields in Latin America and those in other emerging markets.

Table 1 reports the cross-country correlations of stripped yields on Brady bonds from January 1994 through December 1999. The Latin American countries included in the table are Argentina, Brazil, Ecuador,

TABLE 1. Correlations in Stripped Yields on Brady Bonds for Selected Emerging Markets

Country	Argentina	Brazil	Bulgaria	Ecuador	Mexico	Morocco	Nigeria	Panama	Peru	Philippines	Poland	Russia	Venezuela
Argentina	1.00	0.99	0.96	0.98	0.99	0.99	0.99	0.98	0.99	0.96	0.97	0.87	0.97
Brazil		1.00	0.93	0.98	0.97	0.99	0.99	0.98	0.99	0.97	0.95	0.92	0.99
Bulgaria			1.00	0.95	0.96	0.95	0.94	0.92	0.94	0.87	0.89	0.81	0.92
Ecuador				1.00	0.97	0.98	0.97	0.97	0.98	0.94	0.92	0.93	0.98
Mexico					1.00	0.97	0.97	0.97	0.98	0.93	0.96	0.84	0.95
Morocco						1.00	0.98	0.99	0.99	0.94	0.94	0.90	0.97
Nigeria							1.00	0.98	0.99	0.97	0.97	0.89	0.97
Panama								1.00	0.99	0.96	0.96	0.89	0.97
Peru									1.00	0.96	0.96	0.91	0.98
Philippines										1.00	1.00	0.89	0.96
Poland											1.00	0.80	0.93
Russia												1.00	0.95
Venezuela													1.00

Source: Authors' calculations.

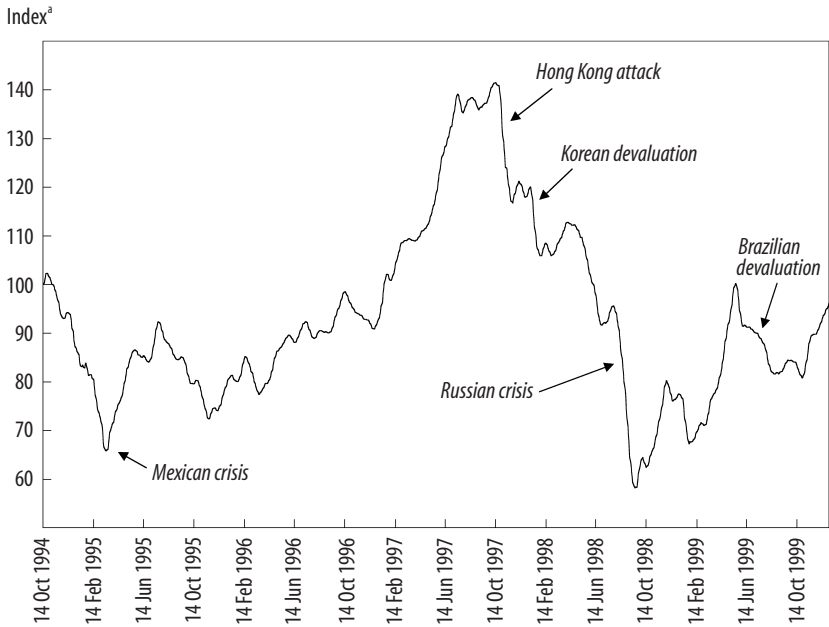
Mexico, Panama, Peru, and Venezuela. The other emerging markets are Bulgaria, Morocco, Nigeria, the Philippines, Poland, and Russia. This table clearly shows that the comovements in risk premiums, as measured by stripped interest rates on Brady bonds, are extremely high for all emerging markets and not just Latin America. The smallest cross-market correlation in the table is 80 percent. In fact, the correlation in country risk between Mexico and Morocco is 97 percent, between Brazil and Bulgaria 93 percent, and between Peru and the Philippines 96 percent. These country pairs have few similarities, other than that their names start with the same letter of the alphabet. Why are these markets so highly correlated over such a long period of time?

Stock Markets in Latin America

These patterns in Latin America (and emerging markets in general) are not unique to bond markets. Movements in stock markets, exchange rates, and interest rates show similar relationships, although in most cases they are not as extreme as for bond markets. For comparison, this section repeats the bond market analysis carried out above for stock markets.

Figure 4 begins by graphing an aggregate index for stock markets in Latin America. This index is a weighted average of the daily stock market indexes in U.S. dollars reported by Datastream. The countries included in the index are Argentina, Brazil, Chile, Colombia, Mexico, Peru, and Venezuela. The figure shares a number of features with figure 2 (which graphs the spread between the Latin Eurobond index and the international interest rate). Latin American stock and bond indexes are both highly volatile and are adversely affected by events in the rest of the world. For example, the aggregate Latin American stock market index falls from a high of about 140 before the Asian crisis to a low of about 60 after the Russian crisis. The index is not nearly as vulnerable to shocks that originate within Latin America as to shocks external to the region. For example, the index falls only from about 100 to 75 during the Brazilian crisis. Why do crises external to Latin America have such a disproportionately large impact on the region?

Next, figure 5 breaks this aggregate Latin American stock market index into its component parts. This figure graphs the stock market index for each of the seven Latin American countries forming the aggregate index above.

FIGURE 4 . Aggregate Latin American Stock Market Index

Source: Authors' calculations based on stock market indexes reported by Datastream.

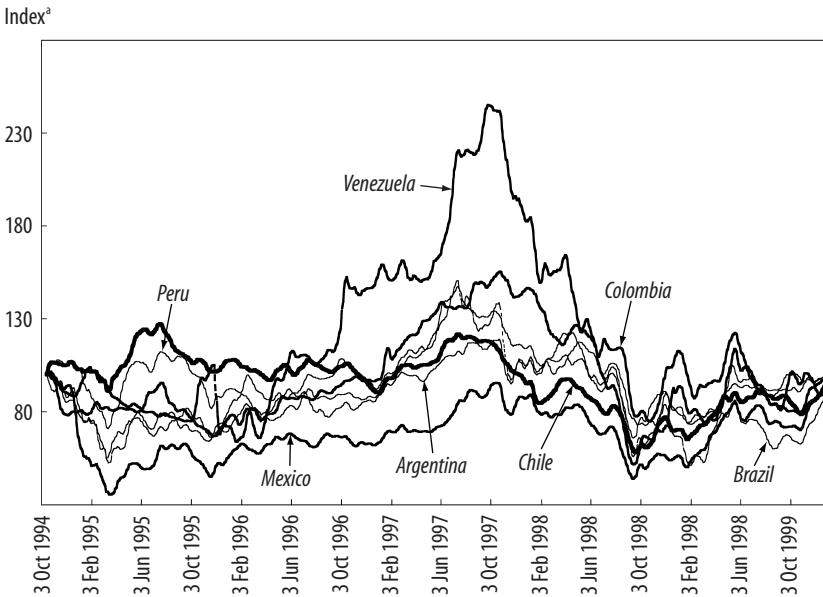
a. Indexes are ten-day, rolling-average, demeaned returns (excluding holidays and weekends). Weights for each country are calculated as the standard deviation for that country relative to the average standard deviation for the sample.

The figure shows that stock markets in most Latin American countries were highly volatile and tended to move together during recent currency crises.² Although this comovement is not as extreme as seen for Brady bonds, these patterns are still intriguing. Why do such different Latin American countries demonstrate such a high degree of correlation?

The final step in this analysis is to calculate the correlation between Latin American stock markets and those in other emerging markets. Table 2 calculates these correlations from January 1994 through December 1999 for seven Latin American countries (Argentina, Brazil, Chile, Ecuador,

2. In fact, the variance of the relative valuations between Latin American countries is one-tenth of the variance of the individual stock market returns.

FIGURE 5 . Stock Market Indexes for Selected Latin American Countries



Source: Authors' calculations based on stock market indexes reported by Datastream.

a. Indexes are ten-day, rolling-average, demeaned, daily, U.S. dollar returns (excluding holidays and weekends). They are normalized to 100 on 1 October 1994.

Mexico, Peru, and Venezuela) and six other emerging markets (Egypt, Hungary, Morocco, the Philippines, Poland, and Russia).³ This table shows that comovements in stock returns are high for a number of emerging markets—not just for stock markets within Latin America. The cross-market correlation between Argentina and Brazil is 78 percent. This is not surprising since these two markets are closely linked through channels such as trade. Less intuitive, however, is the cross-market correlation between Argentina and Hungary, which is also 78 percent. What do these two markets have in common? Stock markets in Peru and Russia are cor-

3. More specifically, this table reports the cross-market correlations in weekly U.S. dollar stock market indexes as calculated by Datastream. The countries in this table are slightly different from those in the table for bond markets because several countries included in the previous table do not have stock market data.

TABLE 2. Correlations in Stock Market Returns for Selected Emerging Markets

Country	Argentina	Brazil	Chile	Ecuador	Egypt	Hungary	Mexico	Morocco	Peru	Philippines	Poland	Russia	Venezuela
Argentina	1.00	0.78	-0.14	-0.31	0.48	0.78	0.71	0.38	0.41	-0.26	0.57	0.76	0.54
Brazil		1.00	0.08	-0.12	0.80	0.88	0.27	0.53	0.62	-0.20	0.43	0.87	0.52
Chile			1.00	0.63	0.04	-0.28	-0.06	-0.59	0.73	0.70	-0.22	0.31	0.43
Ecuador				1.00	-0.17	-0.42	-0.07	-0.60	0.43	0.45	-0.30	0.14	0.36
Egypt					1.00	0.78	-0.08	0.66	0.43	-0.23	0.20	0.74	0.29
Hungary						1.00	0.24	0.75	0.31	-0.47	0.51	0.70	0.34
Mexico							1.00	-0.16	0.25	-0.02	0.45	0.56	0.48
Morocco								1.00	-0.13	-0.73	0.14	0.13	-0.24
Peru									1.00	0.32	0.12	0.75	0.69
Philippines										1.00	0.07	0.02	0.25
Poland											1.00	0.50	0.38
Russia												1.00	0.90
Venezuela													1.00

Source: Authors' calculations.

related by 75 percent and in Brazil and Egypt by 80 percent. Intuition suggests that these countries have few similarities.

Conclusions: Bond and Stock Markets in Latin America

This examination of Latin American bond and stock markets has uncovered a number of patterns and generated several questions. Each of these patterns is strongest in bond markets but also holds true for stock markets, exchange rates, and interest rates. We begin with the patterns. First, stripped bond spreads and stock returns in Latin America are highly volatile, and this volatility is largely driven by external events, such as the Asian and Russian crises. Second, this volatility is not generated by any individual country or subset of countries within Latin America, but instead is shared by all countries in the region. In other words, the relative risk premiums and stock returns between countries are fairly stable. Finally, this comovement in risk premiums and stock returns is high among many emerging markets, not just among countries in Latin America. This series of patterns has generated a number of questions. Why are risk premiums and stock returns in Latin America so significantly affected by events outside of the region? Why do risk premiums and stock returns across such diverse Latin American countries show such a high degree of comovement? And why are movements in bond and stock markets so highly correlated in emerging markets around the world?

Defining Contagion

The previous section documented a high degree of comovement in Latin American bond and stock markets. It also discussed the high correlation between very diverse emerging markets around the world. This raises the question of whether such a high degree of comovement is evidence of contagion, as well as the policy implications of these strong cross-market relationships. Before addressing these issues, it is necessary to define exactly what constitutes contagion.

As mentioned in the introduction, in the month after the 1998 devaluation of the Russian ruble, the Brazilian stock market fell by over 50 percent. Even without a precise definition, most people would agree that this

transmission of a shock from Russia to Brazil was contagion. On 13 January 1999 the Brazilian stock market crashed by about 13 percent and the Argentine stock market fell by about 9 percent. One day later the Brazilian market rose by about 23 percent and the Argentine market recovered by about 11 percent. Did these events constitute contagion? Similarly, if the U.S. stock market crashes and this has a significant impact on the Mexican market, is this considered contagion?

These sorts of examples show the difficulty in defining contagion. This paper defines contagion as a significant increase in cross-market linkages after a shock to an individual country (or group of countries). This was the most common definition of financial contagion before the crises of the late 1990s. Since then a number of additional definitions have been proposed, although there is little consensus on which definition should be used. This paper uses the phrase *shift-contagion* instead of simply contagion to differentiate this precise definition from the numerous other definitions that currently exist. The term *shift-contagion* is sensible because it not only clarifies that contagion arises from a shift in cross-market linkages, but also avoids taking a stance on how the shift occurred. Cross-market linkages can be measured by a number of different statistics, such as the correlation in asset returns, the probability of a speculative attack, and the transmission of shocks or volatility.

This definition of contagion has a number of advantages. First, it is empirically useful since it easily translates into a simple test for contagion (by testing if cross-market linkages change significantly after a shock). Second, it is extremely valuable in drawing policy conclusions, a topic that is discussed in more detail in the conclusions. Finally, this definition is consistent with our intuition and preconceptions of what constitutes contagion. As mentioned above, for example, the Argentine stock market fell and rose with the Brazilian market during the crisis of January 1999. Brazil and Argentina are located in the same geographic region, have many similarities in terms of market structure and history, and have strong direct linkages through trade and finance. These two economies are closely connected in all states of the world. It is not surprising, therefore, that a large negative shock to one country is quickly passed on to the other. If this transmission of a shock from Brazil to Argentina is a continuation of the same cross-market linkages that exist during more tranquil periods (and not a shift in these linkages), then this should not be considered *shift-contagion*.

This definition of contagion, however, is not universally accepted. Some economists argue that if a shock to one country is transmitted to another, even if there is no significant change in cross-market relationships, this transmission constitutes contagion. The impact of a U.S. stock market crash on the Mexican market would thus be considered contagion. Other economists argue that it is impossible to define contagion based on simple tests of changes in cross-market relationships. Instead, they argue that it is necessary to identify exactly how a shock is propagated across countries, and that only certain types of transmission mechanisms (such as herding or irrational investor behavior) constitute contagion.

These broader definitions of contagion also have several advantages. For example, intuition suggests that Mexico and Morocco have little in common. These countries are located in different regions of the world, have very different market structures and histories, and have few direct linkages through trade or finance. In other words, there are few fundamental linkages between these two nations. According to these broader definitions of contagion, if a shock to Mexico has a significant impact on Morocco, it would qualify as contagion. We demonstrated above, however, that the correlation in country risk between Mexico and Morocco (as measured by stripped interest rates on Brady bonds) was 97 percent. Even if this cross-market correlation remains constant, a shock to Mexico would have a significant impact on the risk premium in Morocco. According to the stricter definition of contagion used in this paper, therefore, this transmission of a shock from Mexico to Morocco would not qualify as shift-contagion. Even if this is not an example of shift-contagion, it is obviously puzzling that these two markets are so highly correlated in any state of the world. We use the term interdependence to describe this scenario and differentiate it from the concept of shift-contagion. In other words, interdependence describes situations in which countries show a higher degree of comovement in all states of the world than can be explained by fundamentals.

To summarize, we define contagion as a significant increase in cross-market linkages after a shock. This definition implies that if two markets are highly correlated after a crisis, it is not necessarily contagion. It is only shift-contagion if the correlation between the two markets increases significantly. Agreement with this definition is not universal, but it does concur with an intuitive understanding of contagion. It also provides a straightforward method of testing for the existence of contagion.

Theoretical Literature

The theoretical literature on how shocks are propagated internationally is extensive and has been well summarized in a number of other works.⁴ For the purpose of this paper, however, it is useful to divide this broad set of theories into two groups: crisis-contingent and non-crisis-contingent theories. Crisis-contingent theories are those that explain why transmission mechanisms change during a crisis and therefore why cross-market linkages increase after a shock. Non-crisis-contingent theories assume that transmission mechanisms are the same during a crisis as during more stable periods; cross-market linkages thus do not increase after a shock. Evidence of shift-contagion would support the group of crisis-contingent theories, while no evidence of contagion would support the group of non-crisis-contingent theories.

Crisis-Contingent Theories

Crisis-contingent theories of how shocks are transmitted internationally can be divided into three mechanisms: multiple equilibria, endogenous liquidity, and political economy. The first mechanism, multiple equilibria, occurs when a crisis in one country is used as a sunspot for other countries. Masson shows how a crisis in one country could coordinate investors' expectations, shifting them from a good to a bad equilibrium for another economy and thereby causing a crash in the second economy.⁵ Mullainathan argues that investors imperfectly recall past events.⁶ A crisis in one country could trigger a memory of past crises, which would cause investors to recompute their priors (on variables such as debt default) and assign a higher probability to a bad state. The resulting downward movement in prices would occur because memories (instead of fundamentals) are correlated. In both of these models, the shift from a good to a bad equilibrium and the transmission of the initial shock are therefore driven by a change in investors' expectations or beliefs and not by any real linkages. This branch of theories can explain not only the bunching of crises, but also why speculative attacks occur in economies that appear

4. For example, see Claessens, Dornbusch, and Park (2001); Forbes (2000b).

5. Masson (1998).

6. Mullainathan (1998).

to be fundamentally sound.⁷ These qualify as crisis-contingent theories because the change in the price of the second market (relative to the change in the price of the first) is exacerbated during the shift between equilibria. In other words, investors change their expectations after the crisis in the first economy, and they thus transmit the shock through a propagation mechanism that does not exist during stable periods.

A second category of crisis-contingent theories is endogenous liquidity shocks. Valdés develops a model in which a crisis in one country can reduce the liquidity of market participants.⁸ This could force investors to recompose their portfolio and sell assets in other countries in order to continue operating in the market, to satisfy margin calls, or to meet regulatory requirements. Similarly, if the liquidity shock is large enough, a crisis in one country could increase the degree of credit rationing and force investors to sell their holdings of assets in countries not affected by the initial crisis. Calvo develops another model of endogenous liquidity based on asymmetric information among investors.⁹ Informed investors receive signals about a country's fundamentals and are hit by liquidity shocks (margin calls) that force them to sell their holdings. Uninformed investors cannot distinguish between a liquidity shock and a bad signal, and they therefore charge a premium when the informed investors are net sellers. In both of these models, the liquidity shock leads to an increased correlation in asset prices. This transmission mechanism does not occur during stable periods, but only occurs after the initial shock.

A final transmission mechanism that can be categorized as a crisis-contingent theory is political contagion. Drazen uses the European devaluations in 1992–93 to develop a model based on the assumption that central bank presidents are under political pressure to maintain their countries' fixed exchange rates.¹⁰ When one country decides to abandon its peg, this reduces the political costs to other countries of abandoning their respective pegs, which increases the likelihood that these countries will switch exchange rate regimes. Exchange rate crises may therefore be bunched together. Once again, transmission of the shock occurs through a mechanism that did not exist before the initial crisis.

7. This point is raised by Radelet and Sachs (1998) and Sachs, Tornell, and Velasco (1996).

8. Valdés (1996).

9. Calvo (1999).

10. Drazen (1998).

This group of crisis-contingent theories suggests a number of very different channels through which shocks could be transmitted internationally: multiple equilibria based on investor psychology; endogenous-liquidity shocks that cause a portfolio recomposition; and political economy affecting exchange rate regimes. Despite the different approaches and models used to develop these theories, they all share one critical implication: the transmission mechanism during (or directly after) the crisis is inherently different from any that existed before the shock. The crisis causes a structural shift, so that shocks are propagated via a channel that does not operate in stable periods. Each of these theories could thus explain the existence of shift-contagion.

Non-Crisis-Contingent Theories

The remaining theories explaining how shocks could be propagated internationally would not generate shift-contagion. These theories assume that transmission mechanisms after an initial shock are not significantly different from those operating before the crisis. Instead, any large cross-market correlations after a shock are a continuation of linkages that existed before the crisis. These channels are often called real linkages since many (although not all) are based on economic fundamentals. These theories can be divided into four broad channels: trade, policy coordination, country reevaluation, and random aggregate shocks.

The first transmission mechanism, trade, could work through several related effects.¹¹ If one country devalues its currency, this would have the direct effect of increasing the competitiveness of that country's goods, which could potentially increase exports to a second country and hurt domestic sales within the second country. The initial devaluation could also have the indirect effect of reducing export sales from other countries that compete in the same third markets. Either of these effects could have a direct impact on a country's exports and output; if the loss in competitiveness is severe enough, it could increase expectations of an exchange rate devaluation or lead to an attack on another country's currency.

11. Gerlach and Smets (1995) first developed this theory with respect to bilateral trade, and Corsetti and others (2000) use micro-foundations to extend this to competition in third markets. For empirical tests of the importance of trade, see Eichengreen, Rose, and Wyplosz (1996); Glick and Rose (1999); Forbes (2000a, 2000b).

The second non-crisis-contingent transmission mechanism is policy coordination. This mechanism links economies because one country's response to an economic shock could force another country to adopt certain policies. For example, a trade agreement might include a clause in which lax monetary policy in a country forces other member countries to raise trade barriers.

The third propagation mechanism, country reevaluation or learning, argues that investors gain experience during a shock to one country, and they may apply the lessons learned to other countries with similar macroeconomic structures and policies.¹² For example, if a country with a weak banking system is discovered to be vulnerable to a currency crisis, investors may reevaluate the strength of banking systems in other countries and adjust their expected probabilities of a crisis accordingly.

The final non-crisis-contingent transmission mechanism argues that random aggregate or global shocks could simultaneously affect the fundamentals of several economies. For example, a rise in the international interest rate, a contraction in the international supply of capital, or a decline in international demand (such as for commodities) could simultaneously slow growth in a number of countries. Asset prices in any countries affected by this aggregate shock would move together (at least to some degree), such that cross-market correlations between affected countries could increase directly after the shock.

Previous Empirical Evidence: Contagion Exists

The empirical literature testing whether contagion exists is even more extensive than the theoretical literature explaining how shocks can be transmitted across countries. Since this literature is so extensive and has been well summarized elsewhere, we do not attempt to survey this work here.¹³ Instead, we simply describe the four general strategies used to test for contagion and the essence of each strategy's findings. Many of these

12. This includes models of herding and informational cascades, such as Chari and Kehoe (1999) and Calvo and Mendoza (1998).

13. For detailed surveys of empirical tests for contagion, see Forbes and Rigobon (2001); Baig and Goldfajn (1998); Claessens, Dornbusch, and Park (2001). For tests of contagion covering periods from the debt crisis of 1982 through the Asian crisis, see De Gregorio and Valdés (2001).

empirical tests use the same definition of contagion as specified above (that is, shift-contagion), although some of the more recent studies use a broader or less well-specified definition. The key point of this review is that virtually all of the previous work on this topic has concluded that contagion—no matter how it is defined or tested for—occurred during the crisis under investigation.

The most common strategy for testing for contagion is based on cross-market correlation coefficients. These tests measure the correlation in returns between two markets during a stable period and then test for a significant increase in this correlation coefficient after a shock. If the correlation coefficient increases significantly, this suggests that the transmission mechanism between the two markets increased after the shock and that contagion occurred. Virtually all papers using this testing strategy reach the same general conclusion: cross-market correlation coefficients increase significantly (at least for some countries) after a currency crisis, indicating that contagion occurred during the period under investigation.

A second approach to testing for contagion is to use an autoregressive conditional heteroscedasticity (ARCH) or generalized ARCH (GARCH) framework to estimate the variance-covariance transmission mechanisms across countries. These tests generally indicate that volatility was transmitted from one country to the other. A third testing strategy uses simplifying assumptions and exogenous events to identify a model and directly measure changes in the propagation mechanism. These papers generally find that a crisis in another country or news in another country increased the probability of a crisis occurring elsewhere in the world (especially in the same region).

A final series of tests for contagion focuses on changes in the long-run relationship between markets instead of on any short-run changes after a shock. These papers use the same basic procedures as above, except that they test for changes in the cointegrating vectors between stock markets instead of in the correlation coefficients or variance-covariance matrices. This approach is not an accurate test for contagion, however, since it assumes that real linkages between markets (that is, the non-crisis-contingent theories such as trade) remain constant over the entire period. If tests show that the cointegrating relationship increases over time, this could represent a permanent shift in cross-market linkages instead of contagion. Moreover, because these tests focus on such long time periods, they could miss brief periods of contagion (such as after the Russian collapse of 1998).

A variety of different econometric techniques have thus been used to test whether contagion occurred during a number of financial and currency crises. The transmission of shocks has been measured by cross-market correlation coefficients, GARCH models, probit models, and cointegration techniques. The cointegration analysis is not an accurate test for contagion because of the long time periods under consideration. Results based on the other techniques, however, all arrive at the same general conclusion: contagion occurred. The consistency of this finding is remarkable given the range of techniques used and periods investigated.

Contagion Reinterpreted as Interdependence

Although the tests for contagion described above appear straightforward, they may be biased in the presence of heteroscedasticity, endogeneity, and omitted variables. This section begins with a coin example to show how heteroscedasticity can affect tests for contagion. It then presents a simple model to clarify exactly how heteroscedasticity, endogeneity, and omitted variables could bias estimates of the transmission of shocks. The section concludes with an overview of recent empirical work that has corrected for each of these problems and found that virtually no contagion occurred during recent financial crises. These studies show that large cross-market linkages after a shock are simply a continuation of strong transmission mechanisms that exist in more stable periods. We refer to these strong transmission mechanisms that exist in all states of the world as interdependence, in order to contrast these linkages with new transmission mechanisms that occur only during crisis periods (shift-contagion).

A Coin Example: The Effect of Heteroscedasticity on Tests for Contagion

A coin-flipping exercise provides a simple example of how heteroscedasticity can bias the standard tests for changes in cross-country transmission mechanisms after a crisis. Suppose that there are two related games. In the first game, a player flips one coin. If it comes up heads, the player wins the coin, and if it is tails, the player loses the coin. The game can be played with either a penny or a special \$100 coin. In the second game, the same player again flips a coin—this time a quarter—and either wins

TABLE 3. Coin Scenario 1

<i>Outcome of game 1 (penny)</i>	<i>Outcome of game 2 (quarter)</i>	<i>Final payoff^a (in cents)</i>
Heads (+1)	Heads (+25)	+25.1
Heads (+1)	Tails (-25)	-24.9
Tails (-1)	Heads (+25)	+24.9
Tails (-1)	Tails (-25)	-25.1

a. Final payoff is 10 percent of outcome of game 1 plus outcome of game 2.

with heads or loses with tails. The payoff after the second game depends on the outcome of the first game. For simplicity, assume that the payoff is always 10 percent of the outcome of the first game plus the outcome of the second game. Table 3 lists the possible payoffs (in cents) after both games have been played, given that the first game is played with a penny. Since the final payoff is equal to the outcome of the second game (25 cents) plus or minus a tenth of a penny, the outcome of the first coin toss has a negligible impact on the payoff. Therefore, when the first game is played with a penny, the correlation between the two games is close to zero (0.4 percent, to be exact) and the outcomes of the two games are almost independent.

Table 4 outlines the possible payoffs (again in cents) when the first game is played with a \$100 coin instead of a penny. The final payoff is now equal to the 25-cent outcome of the second game plus or minus ten dollars. In this case, the outcome of the second toss, instead of the first, has a negligible impact on the payoff. The correlation between the two games is now almost one (97 percent), and the outcomes of the two games are clearly dependent on each other.

The critical point of this exercise is that in both scenarios, the propagation of shocks from the first game to the second is always 10 percent. The correlation coefficient, however, increases from almost zero in the

TABLE 4. Coin Scenario 2

<i>Outcome of game 1 (\$100 coin)</i>	<i>Outcome of game 2 (quarter)</i>	<i>Final payoff^a (in cents)</i>
Heads (+10,000)	Heads (+25)	+1,025
Heads (+10,000)	Tails (-25)	-975
Tails (-10,000)	Heads (+25)	+975
Tails (-10,000)	Tails (-25)	-1,025

a. Final payoff is 10 percent of outcome of game 1 plus outcome of game 2.

one-cent scenario to almost one in the \$100 scenario. This coin example is directly applicable to measuring the transmission of shocks across countries. The first coin toss represents a country that is susceptible to a crisis. When the country is stable, volatility is low; this scenario is represented when the first game is played with a penny. When the economy becomes more vulnerable to a crisis, volatility increases, which is the scenario when the first game is played with the \$100 coin. The crisis occurs when the outcome of the \$100 coin is tails. The second toss represents the rest of the world; this round is always played with a quarter, but the payoff depends on the outcome in the first country. As the coin example clearly shows, even though the underlying transmission mechanism remains constant (at 10 percent) in both situations, the cross-market correlation in returns increases significantly after the crisis. Consequently, tests for contagion based on correlation coefficients would indicate that shift-contagion occurred, even though there was no fundamental change in how shocks are propagated across markets. Tests for contagion based on GARCH models are subject to the same bias, since the variance-covariance matrices central to these tests are directly comparable to the correlation coefficients. In both types of tests, this inaccurate finding of contagion results from the heteroscedasticity in returns across the two different states (that is, the two different coins for the first toss).

Heteroscedasticity also biases tests for contagion that use probit models or conditional probabilities, although this bias works through a slightly different mechanism. A minor variant on the coin game shows how the bias occurs with these testing methodologies. Assume that now the player is only interested in knowing whether the final payoff of the game is positive (labeled as one) or negative (labeled as zero). The restated outcomes of the game are listed in table 5.

A probit regression estimating how the outcome of the first game (that is, the state of the first country) affects the probability of the outcome in

TABLE 5. Coin Scenario 3^a

		<i>First coin (penny)</i>		<i>First coin (\$100 coin)</i>	
		<i>Heads</i>	<i>Tails</i>	<i>Heads</i>	<i>Tails</i>
<i>Second coin (quarter)</i>	<i>Heads</i>	1	1	1	0
	<i>Tails</i>	0	0	1	0

a. A value of one indicates that the final outcome of the game is positive; a value of zero indicates that the final outcome is negative.

the second game (that is, the payoff in the second country) could be written as follows:

$$\Pr[y_t > 0] = \gamma \Pr[x_t > 0].$$

The table shows that $\gamma = 0$ when the first toss is done with a penny (that is, the first economy is stable), but $\gamma = 1$ when the first toss is done with the \$100 coin (that is, the economy is more volatile).¹⁴ Tests for contagion therefore suggest that the magnitude of the transmission mechanism increased. The underlying transmission mechanism between the two economies, however, remained constant at 10 percent in both states. Therefore, the finding of shift-contagion is erroneous. Once again, the underlying bias results from the heteroscedasticity in returns across the two different states.

A slightly different way of interpreting these results and the impact of heteroscedasticity on tests for contagion is to reframe the last coin game in terms of conditional probabilities. Before the game starts, if you do not know which coin is being used (that is, what state the country is in), then the probability that the outcome is negative at the end of the two tosses is 1/2. This is the unconditional probability of a negative final outcome (that is, of a crisis in the second country). On the other hand, if you use the \$100 coin and the outcome of the first toss is tails (that is, the first country is in a crisis), then the probability that the final outcome is negative is 1. This is the conditional probability of a negative final outcome. When we compare cross-market relationships after a crisis, we are implicitly testing for an increase from the unconditional to the conditional probability, and as shown in the example, this probability can increase when only the variance increases. An increase in this probability does not necessarily indicate a change in the propagation mechanism. Tests for contagion after a crisis, which are conditional probabilities by definition, will thus be biased and can incorrectly suggest that contagion occurred.

This series of examples based on coin tosses is clearly a simplification of the real-world transmission of shocks across countries. Moreover, the example is extreme since the variance of outcomes increases by 10^8 when the fictional country moves from the stable to the volatile state (that is,

14. The fact that heteroscedasticity biases coefficient estimates in nonlinear regressions is well known. See Horowitz (1992, 1993); Manski (1975, 1985).

when we switch coins in the first coin toss). Despite this simplification, the point of the exercise is clear. Tests for contagion in the presence of heteroscedasticity are inaccurate. No matter which of the testing procedures is used, heteroscedasticity biases the results toward finding contagion, even when the underlying propagation mechanism is constant and no shift-contagion actually occurred.

A Model: The Effects of Heteroscedasticity, Endogeneity, and Omitted Variables on Tests for Contagion

In addition to heteroscedasticity, two other problems with the standard tests for contagion are endogeneity and omitted variables. A simple model clarifies how all three of these problems can bias tests for changes in cross-market transmission mechanisms. Assume that there are two countries whose stock market returns are x_t and y_t and which are described by the following model:

$$(1) \quad y_t = \beta x_t + \gamma z_t + \varepsilon_t,$$

$$(2) \quad x_t = \alpha y_t + z_t + \eta_t,$$

$$(3) \quad E[\eta_t' \varepsilon_t] = 0, \quad E[z_t' \varepsilon_t] = 0, \quad E[z_t' \eta_t] = 0,$$

$$(4) \quad E[\varepsilon_t' \varepsilon_t] = \sigma_\varepsilon^2, \quad E[\eta_t' \eta_t] = \sigma_\eta^2, \text{ and } E[z_t' z_t] = \sigma_{z_t}^2,$$

where ε_t and η_t are country-specific shocks that are assumed to be independent but are not necessarily identically distributed. Also, without loss of generality, assume that the returns have a mean of zero. Unobservable aggregate shocks, such as changes in global demand, exogenous liquidity shocks, or changes in the international interest rate, are captured by z_t (which has been normalized for simplicity); they affect both countries. Note that z_t is assumed to be independent of x_t and y_t .¹⁵ Since shocks are transmitted across countries through real linkages, the stock markets are expected to be endogenous variables ($\alpha, \beta \neq 0$). Finally, it is worth noting that the variance of the idiosyncratic shocks changes through time to reflect the heteroscedasticity discussed above.

15. It is possible to drop this assumption by interpreting equations 1 and 2 as reduced forms and expressing z_t as an innovation in a third equation.

Tests for contagion estimate whether the propagation mechanisms (α , β , or γ) change significantly during a crisis. In an earlier paper, we present a proof that shows that heteroscedasticity in market returns can bias estimates of cross-market correlations.¹⁶ For any distribution of the error terms, the unadjusted correlation coefficient will be biased upward when market volatility increases after a crisis.¹⁷ In fact, this unadjusted correlation coefficient is an increasing function of the market variance. The intuition behind this bias is the same as in the coin example described earlier. If the variance of x_t goes to zero in equation 1, then all of the innovations in y_t are explained by its idiosyncratic shock (ϵ_t), and the correlation between x_t and y_t is zero. On the other hand, if x_t experiences a shock and its variance increases, then a greater proportion of the fluctuation in y_t is explained by x_t . In the limit, when the variance of x_t is so large that the innovations in ϵ_t are negligible, then all of the fluctuations in y_t are explained by x_t , and the cross-market correlation will approach one. Basically, changes in the relative variance of the two shocks modify the noise-to-signal ratio and bias correlation estimates. The critical point, however, is that the propagation (β) between x_t and y_t remains constant. Since there is no significant change in how shocks are transmitted across markets, no contagion occurred. Given that the correlation coefficient is biased upward after a shock, tests could incorrectly conclude that the propagation mechanism increased and contagion occurred.

A second problem with this simple model is endogeneity. Equations 1 and 2 are clearly endogenous, and it is impossible to identify these equations and estimate the coefficients directly. Tests based on correlation coefficients or GARCH models, for example, cannot differentiate between shifts in the coefficients or shifts in the variances (that is, heteroscedasticity).

A final problem with this model is omitted variables. When the variance of z_t increases, the cross-market correlations are biased in the same way as when the variance of x_t increases (as discussed above). When the variance of the aggregate shock is larger, the relative importance of the component common to both markets grows, and the correlation between the two markets increases in absolute value. This bias from omitted aggregate shocks could be large and could have a significant impact on tests for contagion.

16. Forbes and Rigobon (1999).

17. Ronn (1998) presents a proof for the special case in which the errors are distributed as bivariate normal.

Tests for Contagion: Adjusting for Heteroscedasticity, Endogeneity, and Omitted Variables

In the model of equations 2 through 4, it is impossible to adjust for heteroscedasticity, endogeneity, and omitted variables without making more restrictive assumptions or incorporating additional information. Nevertheless, several papers try to correct for one or more of these problems and explore how these corrections affect tests for contagion. This section summarizes a number of papers that use a variety of different approaches, identification assumptions, and model specifications to adjust for these problems. Each paper finds that transmission mechanisms were fairly stable during recent financial crises. Since contagion is defined as a significant increase in cross-market linkages after a shock, this suggests that little shift-contagion occurred during these crises.

The first paper to address the problem of heteroscedasticity in tests for contagion is one of our own earlier studies, in which we simplify the above model by assuming that there is no feedback from stock market y_t to x_t (in other words, that $\alpha = 0$).¹⁸ We further assume that there are no exogenous global shocks (that is, that $z_t = 0$). Both of these assumptions are possible based on what the literature calls near-identification. In that paper, x_t is always the country under crisis, and the variance of returns in the crisis countries increases by more than ten times during their respective collapses. It is therefore realistic to assume that the entire shift in the variances is due to the change in the volatility of the idiosyncratic shock to country x_t . This means that at least during the crises, the contribution of the other two shocks (the aggregate shock z_t and the other country shock η_t) is negligible. Any bias from endogeneity and omitted variables should thus be small during the period under examination.

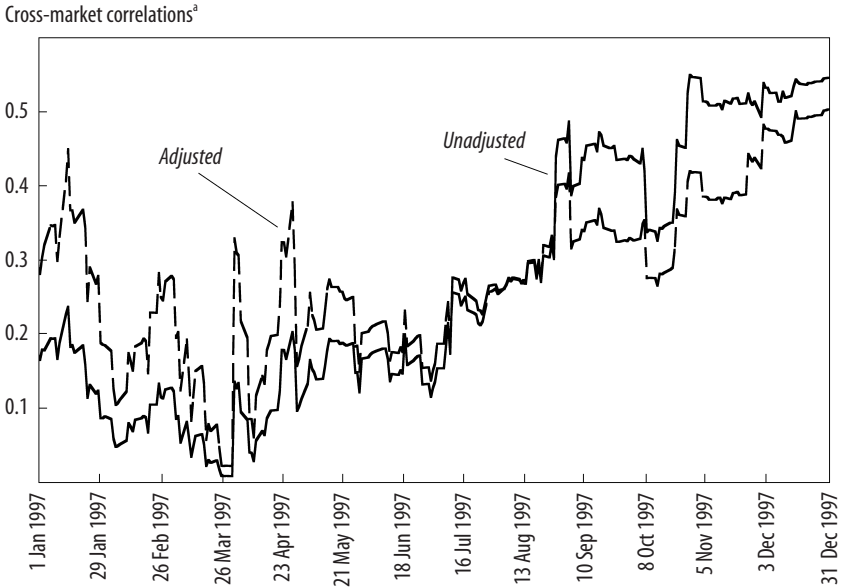
After establishing this framework, we extend Ronn's proof for the case of a general distribution function for the error terms.¹⁹ We show why the unadjusted correlation coefficient is biased upward after a shock and describe a simple technique for adjusting for this bias.²⁰ Basically, we

18. Forbes and Rigobon (1999).

19. Ronn (1998).

20. The basis for this adjustment was proposed by Rob Stambaugh in a discussion on Karolyi and Stulz (1996) at the National Bureau of Economic Research (NBER) Conference on Financial Risk Assessment and Management (May 1995). In the mathematical literature, the oldest reference we have found is Liptser and Shiriaev (1977, chap. 13), which refers to this adjustment as the theorem on normal correlation.

FIGURE 6 . Cross-Market Correlations in Stock Returns: Hong Kong and the Philippines



Source: Kristin Forbes and Roberto Rigobon, 1999, "No Contagion, Only Interdependence: Measuring Stock Market Co-Movements," Working Paper 7267, Cambridge, Mass.: National Bureau of Economic Research.
 a. Correlations are calculated as quarterly moving averages.

calculate both the conditional correlation, ρ_i^c , (that is, the unadjusted correlation coefficient) and the relative increase in the conditional variance in the crisis country (δ). We then use equation 5 to calculate the unconditional correlation coefficient, ρ_i . We compare the conditional and unconditional cross-market correlations during the tranquil month before the crisis and during the crisis.²¹

$$(5) \quad \rho_i = \frac{\rho_i^c}{\sqrt{1 + \delta, [1 - (\rho_i^c)^2]}}$$

A simple graph clarifies the intuition behind this adjustment and illustrates how it can have a significant impact on tests for contagion. Figure 6

21. The derivation of equation 5 assumes that there is no endogeneity or omitted-variable bias.

graphs the correlation in stock market returns between Hong Kong and the Philippines during 1997. The dashed line is the unadjusted (or conditional) correlation in daily returns (ρ_t^c), and the solid line is the adjusted (or unconditional) correlation (ρ_t). While the two lines tend to move together, the bias generated by changes in market volatility (that is, heteroscedasticity) is clearly significant. During the relatively stable period in the first half of 1997, the unadjusted correlation is always lower than the adjusted correlation. During the relatively tumultuous fourth quarter, in contrast, the unadjusted correlation is significantly greater than the adjusted correlation. Tests based on the unadjusted correlations would find a significant increase in cross-market correlations in the fourth quarter and would therefore indicate contagion. Because the adjusted correlations do not increase by nearly as much, a test based on these unconditional correlations might not suggest contagion.

In the same paper, we perform an extensive set of tests for shift-contagion based on both the unadjusted and adjusted correlation coefficients. We use daily data for a variety of developed and emerging market stock indexes (up to twenty-eight countries) and test for contagion during three periods of market turmoil: the 1987 U.S. stock market crash, the 1994 Mexican peso collapse, and the 1997 East Asian crisis. In each case, we test for a significant increase in the cross-market correlation coefficient between a long, stable period before the crisis and the period directly after the crisis. We control for a variety of other variables, such as lagged stock market returns and interest rates in the two relevant countries and the United States. The results are striking. Tests based on the conditional correlation coefficients find evidence of contagion in a significant number of countries—about 50 percent of the sample during the Asian crisis and the U.S. crash and about 20 percent of the sample during the Mexican collapse. Most of the significant changes following the Mexican crisis occur with Latin American countries.

When the same tests are based on the unconditional correlation coefficients, however, the incidence of contagion falls dramatically—to zero in most cases. An extensive sensitivity analysis evaluates the impact of adjusting the frequency of returns and lag structure; modifying period definitions; altering the source of contagion; varying the interest rate controls; and using returns denominated in local currency instead of dollars. In each case, the central result does not change, although the exact number of cases of contagion is highly dependent on the specification estimated.

The paper concludes that when contagion is defined as a significant increase in cross-market relationships and correlation coefficients are adjusted for heteroscedasticity, virtually no contagion occurred during the 1987 U.S. stock market crash, the 1994 Mexican tequila crisis, or the 1997 East Asian crisis.

Lomakin and Paiz make the same simplifying assumptions described above to address this problem of heteroscedasticity in tests for contagion in bond markets.²² Instead of testing for a significant change in cross-market correlation coefficients, however, they use a probit analysis to compute the likelihood that one country will have a crisis given that another country has already experienced one. The study focuses on Brady bonds, so their data set mainly consists of Latin American economies. They show that probability estimates will be biased in the presence of heteroscedasticity and that it is impossible to identify the direction of this bias. Although this paper is still a work in progress, preliminary results suggest that adjusting for heteroscedasticity can have a significant impact on defining the threshold used to identify crisis periods. When Lomakin and Paiz use the adjustment proposed in our own paper to correct the variance-covariance matrices, the number of crises and the strength of cross-country linkages are both reduced significantly.

Rigobon makes a different set of simplifying assumptions to directly identify his tests for contagion.²³ His key assumption is that during a crisis, the variance of the disturbances increases in only one market. On this basis, he develops a test in which the joint null hypothesis is that only one of the variances of the structural shocks increases and the transmission mechanism is stable. The test is therefore rejected if either the transmission mechanism changes (that is, if contagion occurs) or if the variances of two or more disturbances increase. Rigobon then uses this methodology to test whether the cross-country propagation of shocks is fairly stable between stock markets during the Mexican, East Asian, and Russian crises. He estimates the same basic model as in our earlier paper.²⁴ In tests for contagion within one month of each crisis, he finds that transmission mechanisms increase significantly in less than 15 percent of the cross-country pairs (and in less than 7 percent following the Mexican crisis).

22. Lomakin and Paiz (1999).

23. Rigobon (1999).

24. Forbes and Rigobon (1999).

A sensitivity analysis indicates that model specification can affect results, but in most cases when the results change significantly, there is more than one crisis during the tumultuous period (which increases the chance of the test being rejected). Rigobon concludes that transmission mechanisms were fairly stable and that shift-contagion occurred in less than 10 percent of the stock markets during recent financial crises. Arias, Hausmann, and Rigobon extend this analysis to test for the existence of shift-contagion in sovereign bond markets.²⁵ They find that cross-country relationships are stable during the currency crises in Mexico, Thailand, Hong Kong, and Korea; the only significant increase is between Argentina and Brazil during the Russian crisis.

Finally, Rigobon proposes a new methodology that uses heteroscedasticity to identify parameters when the model and data suffer from omitted-variable bias and endogeneity.²⁶ Under certain conditions, this methodology can be used to test for the stability of parameters across periods and can therefore indicate if shift-contagion occurred. Details of this test are described in the appendix. Using this procedure, Rigobon finds that the relationship between Brady bonds in Argentina and Mexico was stable between 1994 and 1999, indicating that shift-contagion did not occur between these two markets during this period.

In summary, shift-contagion in stock and sovereign-bond markets has been studied extensively. Tests for parameter stability have been performed for a number of different frequencies and base currencies, using a variety of different methodologies and econometric techniques. These tests have also been performed for a range of periods, extending from the debt crisis in 1982 to the Brazilian crisis in 1999. Without exception, papers using tests that do not adjust for heteroscedasticity find significant regime changes. In the case of Latin America, these tests consistently find evidence of shift-contagion within this region during the debt crisis in 1982 and the tequila crisis in 1994.

As argued above, however, these tests are misspecified in the presence of heteroscedasticity, endogeneity, and omitted-variable bias. When tests for structural change use procedures to adjust for these problems, they find minimal evidence of parameter instability. For example, the relationship between Mexico and Argentina has been subject to profound scrutiny in

25. Arias, Hausmann, and Rigobon (1999).

26. Rigobon (2000b).

the literature. The stock market returns, sovereign bonds, and domestic interest rates of these two countries have been analyzed using very different samples and frequencies. When better techniques are used to analyze these cross-market relationships, tests are usually unable to reject the hypothesis that propagation mechanisms between these two countries were stable between tranquil periods and crises.

Conclusions and Policy Implications

This survey of recent empirical work testing for contagion makes several critical points. First, tests for contagion that do not correct for heteroscedasticity are biased. When market volatility increases, which tends to happen during crises, these tests will overstate the magnitude of cross-market relationships. Consequently, tests for contagion that do not adjust for heteroscedasticity may suggest that contagion occurred, even when cross-market transmission mechanisms were stable and shift-contagion did not occur.

Second, each of the papers that corrects for heteroscedasticity shows that the bias from this problem is significant and affects estimates of contagion during recent financial crises. These papers use a variety of different approaches, identification assumptions, and model specifications. They find that transmission mechanisms were fairly stable during recent financial crises. Given that contagion is defined as a significant increase in cross-market linkages after a shock, this suggests that little contagion occurred during these crises.

Finally, these empirical papers find that, even though cross-market linkages do not increase significantly after a shock, these linkages are surprisingly high in all states of the world. In other words, strong transmission mechanisms after a shock are a continuation of strong linkages that exist during stable periods. In an earlier work, we differentiate this situation from shift-contagion by referring to the existence of strong transmission mechanisms in all states of the world as interdependence.²⁷ Recent empirical work that adjusts for heteroscedasticity, endogeneity, or omitted variables thus finds no contagion, only interdependence.

27. Forbes and Rigobon (1999).

These key results are not surprising in light of the analysis of Latin American bond and stock markets. We showed above that the comovement in risk premiums and stock returns is surprisingly high for countries within Latin America. These comovements are also high for a range of emerging markets around the world. This high degree of comovement over long periods of time reflects this empirical finding of excess interdependence. Similarly, two of the figures in this paper indicate that although Latin American countries are extremely vulnerable to events outside the region, relative risk premiums and relative stock returns between countries are fairly stable. In other words, cross-market relationships appear fairly constant during crisis and noncrisis periods. This supports the empirical finding of no contagion when contagion is defined as a shift in cross-market linkages.

These central results have a number of important policy implications for Latin America. One motivation for this extensive literature on contagion is to better understand how to reduce a country's vulnerability to external shocks. If crises are transmitted largely through temporary channels that exist only after a crisis, then short-run isolation strategies, such as capital controls, could be highly effective in reducing the effect of a crisis originating elsewhere in the world. On the other hand, if crises are transmitted mainly through permanent channels that exist in all states of the world, then these short-run isolation strategies will only delay a country's adjustment to a shock. They will not prevent the country from being affected by the crisis.

Although this paper has not identified exactly how shocks are transmitted internationally, it has suggested which groups of transmission mechanisms were and were not important during recent financial crises. As explained above, theoretical work explaining how shocks are propagated can be divided into two groups: crisis-contingent and non-crisis-contingent channels. Crisis-contingent channels imply that transmission mechanisms change during a crisis, whereas non-crisis-contingent channels imply that transmission mechanisms are stable during both crises and tranquil periods. Since the empirical evidence discussed in this paper finds that cross-market linkages do not change significantly during recent financial crises, this evidence suggests that most shocks are transmitted through non-crisis-contingent channels, such as trade, country reevaluation, and aggregate shocks. There is little support for the crisis-contingent transmission channels, such as those based on multiple equilibria, endogenous liquidity, or political economy.

This division between crisis-contingent and non-crisis-contingent channels is the critical distinction for evaluating the effectiveness of short-run

isolation strategies. Recent crises appear to have been transmitted mainly through non-crisis-contingent channels, which are long-term linkages that exist in all states of the world. Short-run isolation strategies may be able to temporarily delay the transmission of a crisis from one country to another, but they cannot prevent the necessary fundamental adjustment through these long-term linkages. As a result, short-run isolation strategies, such as capital controls, will have only a limited effectiveness in reducing a country's vulnerability to shocks elsewhere in the world.²⁸

Moreover, not only does this paper imply that the benefits of short-run isolation strategies are limited, but an extensive literature documents that these strategies could be extremely costly. Since crises are largely transmitted through long-run linkages such as trade, learning by market participants, and financial sector linkages, any policies aimed at reducing a country's vulnerability to a crisis would have to reduce these linkages. This would imply, for example, limiting trade flows with other countries or reducing the transparency of domestic institutions and regulatory processes (to reduce learning). Implementing such policies would be both difficult and extremely costly. Would the cost of reduced gains from trade or less transparent institutions be worth any potential reduction in country vulnerability? Since most of the recent evidence suggests that the transmission of shocks depends on long-term fundamental linkages, there is no easy or obvious solution for building Latin America's immune system.

Appendix: Tests of Shift-Contagion in a Generalized Framework

In this appendix, we examine the validity of some of the tests discussed above in a broader and more general framework, using a variant of the model discussed in the text.²⁹ Specifically, assume that country returns during tranquil times are described by a factor model:

$$x_t = \alpha y_t + \eta_t$$

$$y_t = \beta x_t + \varepsilon_t$$

28. This result is consistent with Edwards (1998), who finds that capital controls had little effect in the transmission of the Mexican crisis across Latin America.

29. This appendix was motivated by comments from Andrea Repetto. We thank her for providing us with this excellent interpretation of our test for contagion.

where the properties of the structural shocks are $E(\varepsilon_t) = E(\eta_t) = E(\varepsilon_t \eta_t) = 0$, $E(\varepsilon_t^2) = \sigma_\varepsilon^2$, and $E(\eta_t^2) = \sigma_\eta^2$. Also assume that there is a crisis in country x_t and that during the crisis the structural model becomes

$$x_t = \alpha y_t + \eta_t + \lambda \eta_t,$$

$$y_t = \beta x_t + \varepsilon_t + \phi \eta_t.$$

In this model, shift-contagion (as defined in the paper) is captured by the assumption that $\phi \neq 0$. This implies that the propagation of shocks during the crisis is different from that which exists during more tranquil periods. The crisis, or the increase in the variance of country x_t , is reflected in the assumption that $\lambda > 0$.

The relevant question is whether there exists a test that has power against the hypothesis $\phi = 0$ when $\lambda > 0$. In this model, correlation estimates, principal components analysis, and ordinary least squares (OLS) estimates are known to be biased and inconsistent. Standard tests for stability (namely, Chow tests) are also inconsistent. Finally, the correlation adjustment discussed in the main text cannot be implemented because $\beta \neq 0$. It is therefore impossible to draw accurate inferences about parameter stability without making further assumptions. Most of the papers in the literature use exclusion restrictions to solve this problem. This paper has used the assumption that $\beta = 0$ to develop the correlation adjustment, on the basis of near-identification. Other recent papers have experimented with a number of different assumptions.

We now explore an alternative identification procedure that does not require any additional exclusion restrictions to test for parameter stability. This is a new test developed by Rigobon for stationary variables (finite variance).³⁰ The identifying assumption for the test is based on the form of the heteroscedasticity. In particular, if the heteroscedasticity in a subsample is explained by a shift in variances of only a subset of the structural shocks, then it is possible to test for structural change, even in the presence of endogeneity and omitted variables.

Financial crises are examples of a situation in which the short-term variance in a set of emerging markets can be largely explained by the increase in the volatility of the country (or countries) experiencing the crisis.

30. Rigobon (2000b).

Rigobon's test has a simple form in the bivariate setting. If the parameters are stable and the heteroscedasticity is explained by a subset of the shocks, then the change in the covariance matrix is less than full rank. Formally, the two covariance matrices are as follows:

$$\mathbf{\Omega}_1 = \frac{1}{(1 - \alpha\beta)^2} \begin{bmatrix} \beta^2\sigma_\eta + \sigma_\varepsilon & \beta\sigma_\eta + \alpha\sigma_\varepsilon \\ \beta\sigma_\eta + \alpha\sigma_\varepsilon & \sigma_\eta + \alpha^2\sigma_\varepsilon \end{bmatrix}$$

for the tranquil period and

$$\mathbf{\Omega}_2 = \frac{1}{(1 - \alpha\beta)^2} \begin{bmatrix} (\beta + \beta\lambda + \phi)^2\sigma_\eta + \sigma_\varepsilon & & \\ & (\beta + \beta\lambda + \phi)(1 + \lambda + \alpha\phi)\sigma_\eta + \alpha\sigma_\varepsilon & \\ & & (\beta + \beta\lambda + \phi)(1 + \lambda + \alpha\phi)\sigma_\eta + \alpha\sigma_\varepsilon \\ & & & (1 + \lambda + \alpha\phi)^2\sigma_\eta + \alpha^2\sigma_\varepsilon \end{bmatrix}$$

for the more volatile period. The change in the covariance matrices is

$$\mathbf{\Omega}_2 - \mathbf{\Omega}_1 = \frac{\sigma_n}{(1 - \alpha\beta)^2} \begin{bmatrix} \theta_2^2 + 2\beta\theta_2 & \theta_1\theta_2 + \theta_2 + \beta\theta_1 \\ \theta_1\theta_2 + \theta_2 + \beta\theta_1 & \theta_1^2 + 2(\theta_1) \end{bmatrix},$$

where θ_1 and θ_2 are given by

$$\theta_1 \equiv \lambda + \alpha\phi \text{ and}$$

$$\theta_2 \equiv \beta\lambda + \phi.$$

Furthermore, the determinant of the change in the covariance matrix reduces to

$$\det|\mathbf{\Omega}_2 - \mathbf{\Omega}_1| = -(\theta_2 - \beta\theta_1)^2 = -(1 - \alpha\beta)^2\phi^2.$$

Therefore, under the assumption that the variables have finite variance ($|\alpha\beta| < 1$), the determinant is equal to zero if and only if $\phi = 0$.³¹

31. See Rigobon (2000b) for further information and an application to test for contagion.