Chapter 3

MEASURING CONTAGION:
Conceptual and Empirical Issues*

Kristin Forbes
Massachusetts Institute of Technology and NBER

Roberto Rigobon
Massachusetts Institute of Technology and NBER

1. INTRODUCTION

The 1990's has been punctuated by a series of severe financial and currency crises: the Exchange Rate Mechanism (ERM) attacks of 1992; the Mexican peso collapse of 1994; the East Asian crisis of 1997; the Russian collapse of 1998; and the Brazilian devaluation of 1999. One striking characteristic of several of these crises was how an initial country-specific shock was rapidly transmitted to markets of very different sizes and structures around the globe. This has prompted a surge of interest in "contagion".

But what is contagion? Despite the fact that the term is widespread, there is little agreement on what exactly it entails. Many people assume that contagion occurred during the East Asian and Russian crises, but few agree on exactly which countries were subject to contagion. Numerous theoretical papers have described the various channels by which contagion could occur, but empirical work sharply disagrees on whether or not contagion actually occurred during recent financial crises.

This chapter addresses this ambiguity and establishes a concrete working definition of contagion. In order to differentiate this precise definition from pre-existing conceptions (or misconceptions), we propose utilizing the phrase "shift-contagion" instead of simply "contagion." The chapter then uses this definition and framework to survey and evaluate the theoretical and empirical work on this subject. More specifically, Section 2 begins with a discussion of what does and does not constitute shift-contagion, and why this seemingly esoteric discussion is of critical importance in: portfolio investment strategy; justifying multilateral intervention; and understanding how shocks are propagated internationally. Section 3 briefly

S. Claessens et al. (eds.), *International Financial Contagion*

surveys the theoretical literature on contagion, and Section 4 summarizes the econometric strategies traditionally used to test for its existence. Despite the variety of strategies utilized, virtually all of this work concludes that contagion occurred during recent financial crises. Section 5, however, discusses several problems with this empirical work, namely heteroscedasticity, endogeneity, and omitted variable bias. Tests for contagion that address these problems actually find little evidence of shift-contagion during recent financial crises. Instead, these papers argue that many countries are highly interdependent in all states of the world, and these strong cross-country linkages do not change significantly during periods of crisis. The final section of this chapter discusses the implications of these findings and suggests several directions for future research.

2. DEFINITIONS AND MISCONCEPTIONS

In the month following 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. But when the Russian ruble crashed and the Polish zloty depreciated by 11 percent in the same month, did this constitute contagion? Or if the U.S. stock market crashes and this has a significant impact on the Canadian market, is this considered contagion?

These sorts of examples show the difficulty in defining contagion. Most people would agree that the propagation of the 1998 crisis from Russia to Brazil was contagion. These two economies are located in separate geographic regions, have very different structures, and have virtually no direct linkages through channels such as trade. During more tranquil periods, shocks to the Russian economy have no significant impact on Brazil. On the other hand, the U.S. and Canada 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, and therefore it is not surprising that a large negative shock, such as a crash in the U.S. stock market, is quickly passed on to Canada. If this transmission of a large shock from the U.S. to Canada is a continuation of the same cross-market linkages that exist during more tranquil periods, then this should not be considered contagion.

More specifically, this chapter defines contagion as a significant increase in cross-market linkages after a shock to an individual country (or group of countries). In order to differentiate this precise definition from pre-existing conceptions (or misconceptions), we propose utilizing the phrase "shift-contagion" instead of simply "contagion." The term shift-contagion is sensible because it not only clarifies that contagion arises from a shift in cross-market linkages, but it also avoids taking a stance on how this shift occurs. 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, or the transmission of shocks or volatility. Therefore, in the above example, the impact of the ruble devaluation on the Polish zloty would only constitute shift-contagion if the correlation between these two currencies increased significantly during the Russian crisis. This definition of contagion is intuitively appealing based on the above examples and preconceptions of what constitutes contagion. This definition is also empirically useful since it easily translates into a simple test for contagion (by testing if cross-market linkages change significantly after a shock.)

It is important to note, however, that this definition of contagion is not universally accepted. Some economists argue that if a shock to one country is transmitted to another country, even if there is no significant change in cross-market relationships, this transmission constitutes contagion. In the above example, the impact of a U.S. stock market crash on the Canadian market would 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 – no matter what the magnitude – constitute contagion.

Although these arguments may appear esoteric and rest largely on different personal beliefs, there are three reasons why this chapter focuses on the specific definition of shift-contagion explained above. First, a critical tenet of investment strategy is that most economic disturbances are country specific, so stock markets in different countries should display relatively low correlations. International diversification should therefore substantially reduce portfolio risk and increase expected returns. If market correlations increase after a negative shock, however, this would undermine much of the rationale for international diversification. The test for contagion, as defined in this chapter, is therefore a clear test of the effectiveness of international diversification in reducing portfolio risk during a crisis. A less stringent definition of contagion that focuses on the magnitude of cross-market relationships, instead of changes in these relationships, would not address this issue. A more stringent definition of contagion that focuses on how the shocks are transmitted across markets would provide additional (albeit interesting) information, but this is not necessary to evaluate this rationale for international diversification.

A second advantage of this chapter's approach to measuring contagion is its use in evaluating the role and potential effectiveness of international institutions and bailout funds. Policy makers worry that a negative shock to one country can reduce financial flows to another country, even if the fundamentals of the second economy are strong and there are few real linkages between the two countries. Even if this effect is temporary, it could lead to a financial crisis in the second country – a crisis completely unwarranted by the country's fundamentals and policies. According to this chapter's definition, this transmission of a shock would constitute contagion. If this sort of shift-contagion exists, it could justify I.M.F. intervention and the dedication of large sums of money to bailout funds. A short-term loan could prevent the second economy from experiencing a financial crisis. On the other hand, if two countries (such as the U.S. and Canada) are closely linked through economic fundamentals, then a crisis in the U.S. would be expected to have a strong, real impact on the Canadian economy. For example, Canadian export revenues could decrease. According to this chapter's definition, this transmission would not constitute contagion. Canada's economy would need to adjust to this shock, and although a bailout fund might reduce the initial negative impact, it would only prolong the necessary adjustment. Unless other inefficiencies exist, a bailout under these conditions would be sub-optimal. Therefore, when contagion is defined as an increase in cross-market linkages, evidence of contagion could justify multilateral intervention. If there were no evidence of contagion, multilateral intervention would be less effective and harder to justify. Less stringent definitions of contagion would not make this differentiation.

A final advantage of this chapter's definition of contagion is that it provides a useful method of distinguishing between explanations of how shocks are transmitted across markets. As discussed in the next section, there is an extensive theoretical literature on the international propagation of shocks. Some models are based on individual behavior and assume that investors react differently after a large negative shock. Other models argue that most shocks are propagated through "fundamentals" such as trade. Many of these transmission mechanisms are difficult, if not impossible, to test directly. By defining contagion as a significant increase in cross-market linkages, this chapter avoids having to directly measure and differentiate between these various propagation mechanisms. Moreover, tests based on this definition provide a useful method of classifying theories as those that entail either a change in propagation mechanisms after a shock versus those which are a continuation of existing mechanisms. Identifying if this type of contagion exists could therefore provide evidence for or against certain theories of transmission. Although this set of tests is clearly only a first-pass at explaining how shocks are transmitted across countries, it does indicate which propagation mechanisms are most important and which should be the focus of future work.

To summarize, this chapter defines contagion as a significant increase in cross-market linkages after a shock. Cross-market linkages can be measured by anything from the correlation in asset returns, to the probability of a speculative attack, to the transmission of shocks or volatility. This definition implies that if two markets are highly correlated after a shock, this 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 our intuitive understanding of contagion, as well as provide a straightforward method of testing for the existence of contagion. Moreover, this definition is useful in: evaluating the effectiveness of international diversification; justifying multilateral intervention; and differentiating between various transmission mechanisms.

3. THEORETICAL LITERATURE

The theoretical literature on how shocks are propagated internationally is extensive. This work is well summarized in chapter 2 by Claessens, Dornbusch and Park.[1] For the purpose of this chapter, 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, and therefore cross-market linkages do not increase after a shock. As a result, 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.

3.1 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. For example, Masson (1998) 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 cause a crash in the second economy. Mullainathan (1998) argues that investors imperfectly recall past events. 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 co-movement in prices would occur because memories (instead of fundamentals) are correlated. In both of these models, the shift from a good to bad equilibrium, and the transmission of the initial shock, is therefore driven by a change in investor 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 to be fundamentally sound.[2] 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, after the crisis in the first economy, investors change their expectations and therefore 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 (1996) develops a model where a crisis in one country can reduce the liquidity of market participants. This could force investors to recompose their portfolios 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 (1999) develops a different model of endogenous liquidity. In Calvo's model, there is asymmetric information among investors. Informed investors receive signals about the fundamentals of a country and are hit by liquidity shocks (margin calls) that force the informed investors to sell their holdings. Uninformed investors cannot distinguish between a liquidity shock and a bad signal, and 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 and only occurs after the initial shock.

A final transmission mechanism which can be categorized as a crisis-contingent theory is political contagion. Drazen (1998) studies the European devaluations of 1992 and 1993 and develops a model that assumes that central bank presidents are under political pressure to maintain their countries' fixed exchange rates. 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 of these countries switching exchange rate regimes. As a result, exchange rate crises may be bunched together, and once again, transmission of the initial shock occurs through a mechanism that did not exist before the initial crisis.

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 causing 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 than that before the shock. The crisis causes a structural shift, so that shocks are propagated via a channel that does not exist in stable periods. Therefore, each of these theories could explain the existence of contagion as defined in Section 2.

3.2 Non-Crisis-Contingent Theories

On the other hand, the remainder of the theories explaining how shocks could be propagated internationally do not generate shift-contagion. These theories assume that transmission mechanisms after an initial shock are not significantly different than 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.[3] If one country devalues its currency, this would have the direct effect of increasing the relative competitiveness of that country's goods. Exports to a second country could increase, thereby hurting 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 not only have a direct impact on a country's sales and output, but if the loss in competitiveness is severe enough, it could increase expectations of an exchange rate devaluation and/or lead to an attack on another country's currency.

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

The third propagation mechanism, country reevaluation or learning, argues that investors may apply the lessons learned after a shock in one country to other countries with similar macroeconomic structures and policies.[4] For example, if a country with a weak banking system is discovered to be susceptible to a currency crisis, investors could reevaluate the strength of the banking system 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), so that directly after the shock, cross-market correlations between affected countries could increase.

Although this impact of a global shock appears to be straightforward, one point merits further clarification. A contraction in the international supply of capital (i.e. an exogenous liquidity shock) is classified as a non-crisis-contingent theory, while in Section 3.1 an endogenous liquidity shock (which occurred as a result of a country-specific shock) was classified as a crisis-contingent theory. A brief example comparing these two types of liquidity shocks clarifies the major difference between these crisis- and non-crisis-contingent theories. Assume two stock markets are related as follows:

$$\begin{aligned} y_t &= \beta x_t + \gamma z_t + \varepsilon_t \\ x_t &= z_t + \eta_t \end{aligned} \tag{1}$$

where x_t and y_t are two stock market indices, z_t is a liquidity shock, and ε_t and η_t are idiosyncratic and independent shocks. This model assumes that shocks are transmitted from country x_t to country y_t through the variable β, and that the liquidity shock has different effects on the two countries. Also assume that z_t is independent of ε_t and η_t. A liquidity shock, which could be either a negative realization of z_t or an increase in its variance, would have a negative impact on both x_t and y_t, but would not change how shocks are propagated across markets. It is important to mention that z_t can have any distribution (truncated or not) and that as long as z_t is independent of x_t, y_t, ε_t, and η_t, the transmission mechanism is independent of the realizations of z_t. This is a typical example of an exogenous liquidity shock.

On the other hand, a model of an endogenous liquidity shock could express z_t as:

$$z_t = \begin{cases} \alpha x_t & x_t < 0 \\ 0 & x_t > 0 \end{cases} \tag{2}$$

In this case, there are two regimes. When the realization of x_t is positive, the propagation of shocks from x_t to y_t is β, but when the realization is negative, then the propagation of shocks is $\beta+\alpha\gamma$. The process described in these equations is identical to that of a margin call. When there is a negative realization, the shock is proportional to the realization (i.e. a margin call which forces investors to sell a share of their other assets), and when there is a positive realization, there is no shock (i.e. no margin call or forced asset sales.) This endogenous liquidity shock would continue to increase the variance of both markets (as seen for an exogenous liquidity shock), but now the propagation mechanism changes and is based on the realization of x_t. [5]

Therefore, these two types of liquidity shocks are fundamentally different. Exogenous liquidity shocks do not change how shocks are transmitted across markets and are an example of a non-crisis-contingent theory. Endogenous liquidity shocks fundamentally change how shocks are propagated across countries and are an example of a crisis-contingent theory.

Since shift-contagion is defined as a change in cross-market linkages, exogenous liquidity shocks do not generate shift-contagion, while the endogenous liquidity shocks do.

4. EMPIRICAL EVIDENCE: CONTAGION EXISTS

The empirical literature testing if contagion exists is even more extensive than the theoretical literature explaining how shocks can be transmitted across markets. Much of this empirical literature uses the same definition of contagion as specified in Section 2, although some of the more recent work has used a broader or less well-specified definition. Four different approaches have been utilized to measure the transmission of shocks and test for contagion: analysis of cross-market correlation coefficients; GARCH frameworks; cointegration; and probit models. Virtually all of these papers conclude that contagion – no matter how it is defined – occurred during the crisis under investigation.

Tests based on cross-market correlation coefficients are the most straightforward. 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 contagion occurred. The majority of these papers test for contagion directly after the U.S. stock market crash of 1987. In the first major paper on this subject, King and Wadhwani (1990) test for an increase in cross-market correlations between the U.S., U.K. and Japan and find that correlations increase significantly after the U.S. crash. Lee and Kim (1993) extend this analysis to twelve major markets and find further evidence of contagion: that average weekly cross-market correlations increased from 0.23 before the 1987 crash to 0.39 afterward. Calvo and Reinhart (1995) use this approach to test for contagion after the 1994 Mexican peso crisis and find that the correlation in stock prices and Brady bonds between Asian and Latin American emerging markets increased significantly. Baig and Goldfajn (1998) present the most thorough analysis using this framework and test for contagion in stock indices, currency prices, interest rates, and sovereign spreads in emerging markets during the 1997-98 East Asian crisis. They find that cross-market correlations increased during the crisis for many of the countries. To summarize, each of these tests based on cross-market correlation coefficients reaches the same general conclusion: correlations usually increase significantly after the relevant crisis and therefore, contagion occurred during the period under investigation.[6]

A second approach to test for contagion is to use an ARCH or GARCH framework to estimate the variance-covariance transmission mechanism across countries. Chou et al. (1994) and Hamao et al. (1990) use this procedure and find evidence of significant spillovers across markets after the 1987 U.S. stock market crash. They also conclude that contagion does not occur evenly across countries and is fairly stable through time. Edwards (1998) examines the propagation across bond markets after the Mexican peso crisis by focusing on how capital controls affect the transmission of shocks. He estimates an augmented GARCH model and shows that there were significant spillovers from Mexico to Argentina, but not from Mexico to Chile. His tests indicate that volatility was transmitted from one country to the other, but they do not indicate if this propagation changed during the crisis.

A third series of tests for contagion focus 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 test for changes in the co-integrating vector between stock markets instead of in the variance-covariance matrix. For example, Longin and Solnik (1995) consider seven OECD countries from 1960 to 1990 and report that average correlations in stock market returns between the U.S. and other countries rose by about 0.36 over this period.[7] This approach is not an accurate test for contagion, however, since it assumes that real linkages between markets (i.e. the non-crisis-contingent theories such as trade flows) remain constant over the entire period. If tests show that the co-integrating relationship increased over time, this could be a permanent shift in cross-market linkages instead of contagion. Moreover, by focusing on such long time periods, this set of tests could miss brief periods of contagion (such as after the Russian collapse of 1998).

Instead of testing for changes in correlation coefficients, variance matrices, or cointegrating relationships, the final approach to testing for contagion uses simplifying assumptions and exogenous events to identify a model and directly measure changes in the propagation mechanism. Baig and Goldfajn (1998) study the impact of daily news (the exogenous event) in one country's stock market on other countries markets during the 1997-98 East Asian crisis. They find that a substantial proportion of a country's news impacts neighboring economies. Forbes (2000b) estimates the impact of the Asian and Russian crises on stock returns for individual companies around the world. She finds that trade (which she divides into competitiveness and income effects) is the most important transmission mechanism. Eichengreen, Rose and Wyplosz (1996) and Kaminsky and Reinhart (1998) estimate probit models to test how a crisis in one country (the exogenous event) affects the probability of a crisis occurring in other countries. Eichengreen, Rose and Wyplosz examine the ERM countries in 1992-3 and find that the probability of a country suffering a speculative attack increases when another country in the ERM is under attack. They also argue that the initial shock is propagated primarily through trade.[8] Kaminsky and Reinhart (1998) estimate the conditional probability that a crisis will occur in a given country and find that this probability increases when more crises are occurring in other countries (especially in the same region).

To summarize, a variety of different econometric techniques have been used to test if contagion occurred during a number of financial and currency crises. The transmission of shocks has been measured by: simple cross-market correlation coefficients; GARCH models; cointegration techniques; and probit models. The cointegration analysis is not an accurate test for contagion due to the long time periods under consideration. Results based on the other techniques, however, all arrive at the same general conclusion: some contagion occurred. Although some of these papers use very different definitions of contagion, the consistency of this finding is remarkable given the range of techniques utilized and periods investigated.

5. CONTAGION REINTERPRETED AS INTERDEPENDENCE

Although the above tests for contagion 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 the 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 (i.e. shift-contagion.)

5.1 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 approach to test for changes in cross-country transmission mechanisms after a crisis. Suppose that there are two related games. In the first game you flip one coin. If it is heads, you win, and if it is tails, you lose. The game can be played with either a penny or a special 100-dollar coin. In the second game, you also flip a coin and win with heads and lose with tails. Now, however, the coin is always a quarter and the payoff after both games depends on both outcomes. For simplicity, assume that the payoff is always ten percent of the outcome of the first game plus the outcome of the second game.

Therefore, if the first game is played with a penny, the possible scenarios (in cents) after both games have been played are:

Table 1. Coin Scenario 1

GAME 1 (penny)	GAME 2 (quarter)	PAYOFF (in cents)
Heads (+1)	Heads (+25)	+25.1
Heads (+1)	Tails (-25)	-24.9
Tails (-1)	Heads (+25)	+24.9
Tails (-1)	Tails (-25)	-25.1

Payoff is (10% x outcome of game 1) + outcome of game 2

Since the 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.

On the other hand, when the first game is played with a 100-dollar coin instead of a penny, the possible scenarios are (again in cents):

Table 2. Coin Scenario 2

GAME 1 ($100 coin)	GAME 2 (quarter)	PAYOFF (in cents)
Heads (+10,000)	Heads (+25)	+1025
Heads (+10,000)	Tails (-25)	-975
Tails (-10,000)	Heads (+25)	+975
Tails (-10,000)	Tails (-25)	-1025

Payoff is (10% x outcome of game 1) + outcome of game 2

The 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).

The critical point of this exercise is that in both the 1-cent and the 100-dollar scenario, the propagation of shocks from the first game to the second is always ten percent. The correlation coefficient, however, increases from almost zero in the 1-cent scenario to almost one in the 100-dollar scenario.[9] Moreover, 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 the volatility is low. This is the scenario when the first game is played with a penny. When the economy becomes more vulnerable to a crisis, volatility increases, and this is the scenario when the first game is played with the 100-dollar coin. The crisis actually occurs when the outcome of the 100-dollar 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 states, the cross-market correlation in returns increases significantly after the crisis. As a result, tests for contagion based on correlation coefficients would suggest 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 of these types of tests, this inaccurate finding of contagion results from the heteroscedasticity in returns across the two different states (i.e. the two different coins for the first toss.)

Heteroscedasticity will also bias 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 strategies. Assume that now you are only interested in knowing if the payoff from both games is positive (labeled as one) or negative (labeled as zero). The restated outcomes of the game are:

Table 3. Coin Scenario 3

		1st toss with a penny		**1st toss with a $100 coin**	
		Heads	Tails	Heads	Tails
2nd coin (quarter)	Heads	1	1	1	0
	Tails	0	0	1	0

A probit regression estimating how the outcome of the first game (or the state of the first country) affects the probability of the payoff after the second game (or outcome in the second country) could be written:

$$\Pr[y_t > 0] = \gamma \Pr[x_t > 0] \tag{3}$$

The table shows that $\gamma = 0$ when the first toss is done with a penny (i.e. the first economy is stable), but $\gamma = 1$ when the first toss is done with the $100 coin (i.e. the economy is more volatile).[10] As a result, tests for contagion would 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, so that 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 (i.e. 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 (i.e. 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 (i.e. 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 this 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. Therefore, tests for contagion after a crisis, which are conditional probabilities by definition, will 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 fictionary country moves from the stable to the volatile state (i.e. when we switch coins in the first coin toss.) Despite this simplification, however, 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 utilized, heteroscedasticity will bias the results toward finding contagion, even when the underlying propagation mechanism is constant and no shift-contagion actually occurs.

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

Beside 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 which are described by the following model:

$$
\begin{aligned}
&y_t = \beta x_t + \gamma z_t + \varepsilon_t \\
&x_t = \alpha y_t + z_t + \eta_t \\
&E[\eta_t'\varepsilon_t] = 0, \quad E[z_t'\varepsilon_t] = 0, \quad E[z_t'\eta_t] = 0, \\
&E[\varepsilon_t'\varepsilon_t] = \sigma_{\varepsilon_t}^2, \quad E[\eta_t'\eta_t] = \sigma_{\eta_t}^2, \quad E[z_t'z_t] = \sigma_{z_t}^2,
\end{aligned}
\tag{4}
$$

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 return has mean 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) and affect both countries. Note that z_t is assumed to be independent of x_t and y_t.[11] Since shocks are transmitted across countries through real linkages, the stock markets are expected to be endogenous variables (α, $\beta \neq 0$). Finally, it is worth noting that the variance of the idiosyncratic shocks changes through time to reflect the heteroscedasticity discussed above.

Tests for contagion estimate if the propagation mechanisms (α, β, or γ) change significantly during a crisis. Forbes and Rigobon (1999) present a proof that shows that heteroscedasticity in market returns can have a significant impact on estimates of cross-market correlations. For any distribution of the error terms, when market volatility increases after a crisis, the unadjusted correlation coefficient will be biased upward.[12] 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 of Section 5.1. If the variance of x_t goes to zero in the first line of equation 4, 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/signal ratio and biases 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. Moreover, since the correlation coefficient is biased upward after a shock, tests could incorrectly conclude that the propagation mechanism increased and contagion occurred.

In addition to heteroscedasticity, another problem with this simple model is endogeneity. The first two lines of equation 4 are clearly endogenous, and it is impossible to identify these equations and estimate the coefficients directly. For example, in tests based on correlation coefficients or GARCH models, there is no way to differentiate between shifts in the coefficients or shifts in the variances (i.e. 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. Since unobservable aggregate shocks, as well as the stock price in the other market, would both be omitted variables, this bias is likely to be large and can have a significant impact on tests for contagion.

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

Unfortunately, it is impossible to adjust for heteroscedasticity, endogeneity, and omitted variables in the model of equation 4 without making more restrictive assumptions or utilizing additional information. Nevertheless, several papers have tried to correct for one or more of these problems and explore how these corrections affect tests for contagion. Forbes and Rigobon (1999) focus on how heteroscedasticity affects tests for contagion using cross-market correlation coefficients. Lomakin and Paiz (1999) use a similar technique to examine the impact of heteroscedasticity on tests using probit models. Each of these papers makes simplifying assumptions so as to avoid the problems of endogeneity and omitted variables. Rigobon (1999) takes a slightly different approach and makes a more restrictive set of identifying assumptions in order to simultaneously correct for heteroscedasticity, endogeneity, and omitted variables.

In the first paper to address the problem of heteroscedasticity in tests for contagion, Forbes and Rigobon (1999) simplify the above model by assuming that there is no feedback from stock market y_t to x_t (i.e. that $\alpha = 0$). They also begin by assuming that there are no exogenous global shocks (i.e. that $z_t = 0$). Both of these assumptions are possible based on what the literature calls near-identification. In their paper, x_t is always the country under crisis, and the variance of returns in the crisis countries increases by more than 10 times during their respective collapses. As a result, it is realistic to assume that the entire shift in the variances is due to the change in the volatility of the idiosyncratic shock of country x_t. This means that, at least during the crisis, the contribution of the other two shocks (the aggregate shock z_t, and the other country shock η_t) is negligible. Therefore, during the period under examination, any bias from endogeneity and omitted variables should be insignificant.

After establishing this framework, Forbes and Rigobon (1999) extend the proof from Ronn (1998) for the case of a general distribution function for the error terms. They show why the unadjusted correlation coefficient is biased upward after a shock and describe a simple technique for adjusting for this bias.[13] Basically, they calculate both the conditional correlation, ρ^c_t, (i.e. the unadjusted correlation coefficient) and the relative increase in the conditional variance in the crisis country (δ). Then they use equation 5 to calculate the unconditional correlation coefficient, ρ_t, and compare it with the cross-market correlation in returns during the tranquil months prior to the crisis.[14]

$$\rho_t = \frac{\rho_t^c}{\sqrt{1+\delta_t\left[1-\left(\rho_t^c\right)^2\right]}} \qquad (5)$$

A simple graph clarifies the intuition behind this adjustment and why it can have a significant impact on tests for contagion. Figure 1 graphs the correlation in stock market returns between Hong Kong and the Philippines during 1997.[15] The dashed line is the unadjusted (or conditional) correlation in daily returns (ρ^c_t), and the solid line is the adjusted (or unconditional) correlation (ρ_t). While the two lines tend to move up and down together, the bias generated by changes in market volatility (i.e. 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. On the other hand, during the relatively tumultuous period of the fourth quarter, 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. On the other hand, the adjusted correlations do not increase by nearly as much, so a test based on these unconditional correlations might not indicate contagion.

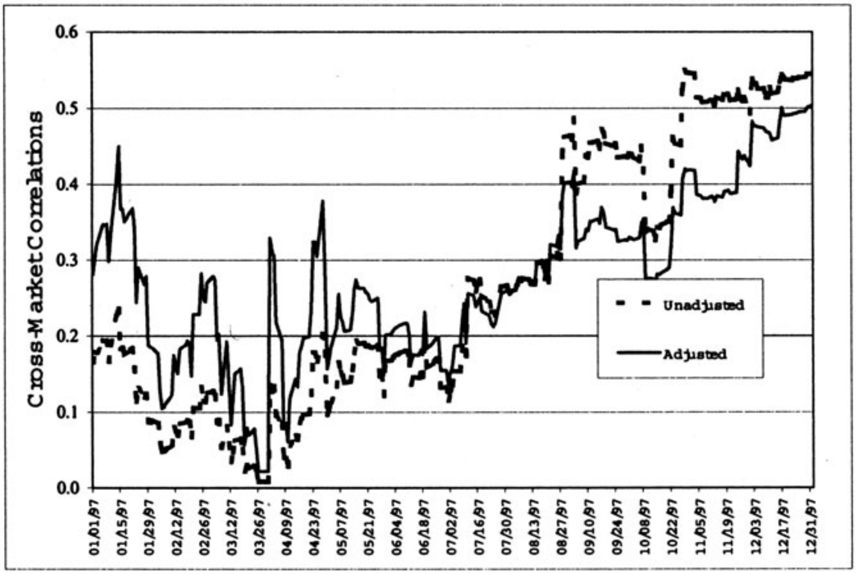

Figure 1. Cross-Market Correlations: Hong Kong and the Philippines

Forbes and Rigobon then perform an extensive set of tests for shift-contagion based on both the unadjusted and adjusted correlation coefficients. The use daily data for a variety of developed and emerging market stock indices (up to 28 countries) and test for contagion during three periods of market turmoil: the 1997 East Asian crisis, the 1994 Mexican peso collapse, and the 1987 U.S. stock market crash. In each case, they 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. They also control for a variety of other variables, such as lagged stock market returns and interest rates in the two relevant countries and the U.S.

Results are striking. Tests based on the unadjusted correlation coefficients find evidence of contagion in a significant number of countries – about 50 percent of the sample during the Asian crisis and U.S. crash and in about 20 percent of the sample after the Mexican collapse. When the same tests are based on the adjusted 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 utilizing 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 dependent on the specification estimated.) Forbes and Rigobon conclude that when contagion is defined as a significant increase in cross-market relationships and correlation coefficients are adjusted for heteroscedasticity, there was virtually no contagion during the East Asian crisis, Mexican peso collapse, and U.S. stock market crash.

Lomakin and Paiz (1999) make the same simplifying assumptions as Forbes and Rigobon (1999) to address this problem of heteroscedasticity in tests for contagion in bond markets. Instead of testing for a significant change in cross-market correlation coefficients, however, Lomakin and Paiz use a probit analysis to compute the likelihood that one country will have a crisis given that another country has already experienced one. They show that estimates of this probability 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 they use the adjustment proposed in Forbes and Rigobon to correct the variance-covariance matrices, the number of crises and the strength of cross-country linkages are both reduced significantly.

Rigobon (1999) makes a different set of simplifying assumptions in order to directly identify his model. Rigobon's identifying assumptions not only solve for endogeneity, but also are valid in the presence of heteroscedasticity and omitted variables. A significant advantage of identifying the model directly is that it is possible to directly estimate the size of the propagation mechanisms. More specifically, Rigobon's key assumption is that during a crisis the variance of the disturbances in only one market increases. Using this assumption, he develops a test where 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 (i.e. contagion occurs) or if the variances of two or more disturbances increase.

Rigobon (1999) then uses this methodology to test if 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 Forbes and Rigobon (1999) and tests for a significant change in transmission mechanisms between the stable period before each crisis and the tumultuous period directly after each crisis. 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 during the Mexican crisis.) 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.

5.4 No Contagion, Only Interdependence

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. As a result, tests for contagion that do not adjust for heteroscedasticity may suggest that contagion occurred, even when cross-market transmission mechanisms are stable and shift-contagion does not occur.

Second, each of the papers that has attempted to correct for heteroscedasticity, endogeneity and/or omitted variables has shown that the bias from these problems is not insignificant and will affect estimates of contagion during recent financial crises. These papers use a variety of different approaches, identification assumptions, and model specifications to adjust for one (or more) of these problems. They find that transmission mechanisms were fairly stable during recent financial crises, and since contagion is defined as a significant increase in cross-market linkages after a shock, this suggests that little contagion occurred during recent crises.

Third, these results have strong implications for how shocks are transmitted across markets. As explained in Section 3, 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, and non-crisis-contingent channels imply that transmission mechanisms are stable during both crisis and tranquil periods. Since the empirical evidence discussed in this section 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. As a result, there is little support for crisis-contingent channels, such as those based on multiple equilibria, endogenous liquidity, or political economy.

Fourth and 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 order to differentiate this situation from shift-contagion, Forbes and Rigobon (1999) refer to the existence of strong transmission mechanisms in all states of the world as "excess interdependence". Therefore, recent empirical work that adjusts for heteroscedasticity, endogeneity, and/or omitted variables finds "no contagion, only interdependence."

6. FUTURE RESEARCH: EXPLAINING INTERDEPENDENCE

These results suggest a new direction for research on stock market co-movements. Focusing on how international propagation mechanisms change after a shock may not be the most productive approach. Instead, research should focus on why markets are so highly integrated during periods of relative stability, as well as during periods of crisis. Crisis periods could be used as windows to help identify these transmission mechanisms, instead of being interpreted as periods that generate new types of transmission mechanisms.

In other words, further empirical research should focus not on why some countries are so vulnerable during periods of crisis, but why countries are always so vulnerable to movements in other countries. Why do so many markets of such different sizes, structures, and geographic locations generally show such a high degree of co-movement? Does trade with third markets link these diverse countries? Or other economic fundamentals, such as common creditors, that we have been unable to measure? Or is there an "excess interdependence" across markets in all states of the world? And in this case, what theories could explain excess interdependence?

Notes

*The authors would like to thank Stijn Claessens, Rudiger Dornbusch, and Yung Chul Park for organizing the conference "International Financial Contagion: How it Spreads and How it Can Be Stopped" for which this paper was written. Further thanks to the rapporteur, Holger Wolf, and conference participants for useful comments and suggestions.

[1] Also see Forbes (2000b).

[2] This point has been raised in Radelet and Sachs (1998) and Sachs et al. (1996).

[3] Gerlach and Smets (1995) first developed this theory with respect to bilateral trade and Corsetti et al. (2000) used micro-foundations to extend this to competition in third markets.

[4] This includes models of pure learning, such as Rigobon (1998), as well as models of herding and informational cascades, such as Chari and Kehoe (1999) and Calvo and Mendoza (1998).

[5] Random margin calls (which do not depend on a particular realization of the stock markets), aggregate changes in the preference for risk, and changes in the international interest rate, are all liquidity shocks that will not change how shocks are transmitted across markets. A margin call that is generated because a bad return was realized in a particular asset, however, is by construction asymmetric and endogenous. Therefore, only in the case of a margin call does the transmission mechanism change as described in the second part of the example.

[6] For further applications of this procedure see: Bertero and Mayer (1990) for a study of why transmission of the U.S. crash differed across markets; Pindyck and Rotemberg (1990) for a test of co-movements in commodity prices; Pindyck and Rotemberg (1993) for a test of co-movements in individual stock prices; Karolyi and Stulz (1996) for a test of co-movements in U.S. and Japanese markets; and Masson (1998) for an application to speculative attacks.

[7] For further examples of cointegration tests, see Cashin et al. (1995) or Chou et al. (1994).

[8] Glick and Rose (1998) use a different framework to investigate five crisis periods and agree that trade linkages play an important role in the transmission of shocks. Forbes (2000a) finds strong evidence of trade linkages at the industry level in the international transmission of crises.

[9] This general result is known as the Normal Correlation Theorem. To the best of our knowledge, the first person to highlight this result was Rob Stambaugh in a discussion of Karolyi and Stulz (1996).

[10] This fact that heteroscedasticity biases coefficient estimates in non-linear regressions is well-known. See Horowitz (1992, 1993) and Manski (1975, 1985).

[11] It is possible to drop this assumption by interpreting the first two lines of equation 4 as reduced forms and expressing z_t as an innovation in a third equation.

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

[13] The basis for this adjustment was proposed by Rob Stambaugh in a discussion of Karolyi and Stulz (1995) at the May NBER Conference on Financial Risk Assessment and Management. In the mathematical literature, the oldest reference we have found is Liptser and Shiryayev (1978), chapter 13, which refers to this adjustment as the theorem on normal correlation.

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

[15] Correlations are calculated as quarterly moving averages. The procedure, definitions, and data source used to estimate this graph are described in Forbes and Rigobon (1999).

References

Baig, Taimur, and Ilan Goldfajn (1998). "Financial Market Contagion in the Asian Crises." IMF Working Paper No. 98/155.

Bertero, Elisabetta, and Colin Mayer (1990). "Structure and Performance: Global Interdependence of Stock Markets around the Crash of October 1987." *European Economic Review*, 34:1155-1180.

Calvo, Guillermo (1999). "Contagion in Emerging Markets: When Wall Street is a Carrier." University of Maryland Mimeo.

Calvo, Guillermo, and Enrique Mendoza (1998). "Rational Contagion and the Globalization of Security Markets." University of Maryland Mimeo.

Calvo, Sarah, and Carmen Reinhart (1995). "Capital Inflows to Latin America: Is There Evidence of Contagion Effects?" World Bank and International Monetary Fund, Mimeo.

Cashin, Paul, Manmohan Kumar, and C. John McDermott (1995). "International Integration of Equity Markets and Contagion Effects." IMF Working Paper 95/110.

Chari, V.V., and Patrick Kehoe (1999). "Herds of Hot Money." Federal Reserve Bank of Minneapolis Research Department, Mimeo.

Chou, Ray, Victor Ng, and Lynn Pi (1994). "Cointegration of International Stock Market Indices." IMF Working Paper 94/94.

Corsetti, Giancarlo, Paulo Pesenti, Nouriel Roubini, and Cédric Tille (2000). "Competitive Devaluations: Toward a Welfare-Based Approach." *Journal of International Economics*, 51:217-241.

Drazen, Allen (1998). "Political Contagion in Currency Crisis." University of Maryland Mimeo.

Edwards. Sebastian (1998). "Interest Rate Volatility, Capital Controls, and Contagion." NBER Working Paper 6756.

Eichengreen, Barry, Andrew Rose, and Charles Wyplosz (1996). "Contagious Currency Crises." NBER Working Paper 5681.

Forbes, Kristin (2000a). "How Important is Trade in the International Spread of Crises?" MIT mimeo. Paper prepared for NBER Conference on Currency Crises Prevention.

Forbes, Kristin (2000b). "The Asian Flu and Russian Virus: Firm-Level Evidence on How Crises Are Transmitted Internationally." NBER Working Paper 7807.

Forbes, Kristin, and Roberto Rigobon (1999). "No Contagion, Only Interdependence: Measuring Stock Market Co-Movements." NBER Working Paper 7267.

Gerlach, Stephan, and Frank Smets (1995). "Contagious Speculative Attacks." *European Journal of Political Economy*, 11:45-63.

Glick, Reuven, and Andrew Rose (1998). "Contagion and Trade: Why Are Currency Crisis Regional?" *Journal of International Money and Finance*, 18:603-617.

Hamao, Yasushi, Ronald Masulis, and Victor Ng (1990). "Correlations in Price Changes and Volatility Across International Stock Markets." *The Review of Financial Studies*, 3(2):281-307.

Horowitz, Joel (1993). "Semiparametric Estimation of a Work-Trip Mode Choice Model." *Journal of Econometrics*, 58:49-70.

Horowitz, Joel (1992). "A Smoothed Maximum Score Estimator For the Binary Response Model." *Econometrica*, 60:505-531.

Kaminsky, Graciela, and Carmen Reinhart (1998). "On Crises, Contagion, and Confusion." University of Maryland Mimeo.

Karolyi, Andrew, and René Stulz (1996). "Why Do Markets Move Together? An Investigation of U.S.-Japan Stock Return Comovements." *The Journal of Finance*, 51(3):951-986.

King, Mervyn, and Sushil Wadhwani (1990). "Transmission of Volatility Between Stock Markets." *Review of Financial Studies*, 3(1):5-33.

Lee, Sang Bin, and Kwang Jung Kim (1993). "Does the October 1987 Crash Strengthen the Co-Movements Among National Stock Markets?" *Review of Financial Economics*, 3(1):89-102.

Liptser, Robert, and Albert Shiryayev, (1978). *Statistics of Random Processes II: Applications*. New York: Springer-Verlag.

Lomakin, Alexandra, and Salvador Paiz (1999). "Measuring Contagion in the Face of Fluctuating Volatility." MIT-Sloan Project, 15.036.

Longin, François, and Bruno Solnik (1995). "Is the Correlation in International Equity Returns Constant: 1960-1990." *Journal of International Money and Finance*, 14(1):3-26.

Manski, Charles (1975). "Maximum Score Estimation of the Stochastic Utility Model of Choice." *Journal of Econometrics*, 3:205-228.

Manski, Charles (1985). "Semiparametric Analysis of Discrete Response: Asymptotic Properties of the Maximum Score Estimator." *Journal of Econometrics*, 27:313-334.

Masson, Paul (1998). "Contagion: Monsoonal Effects, Spillovers, and Jumps Between Multiple Equilibria." IMF Working Paper 98/142.

Mullainathan, Sendhil (1998). "A Memory Based Model of Bounded Rationality." Mimeo.

Pindyck, Robert, and Julio Rotemberg (1990). "The Excess Co-Movement of Commodity Prices." *The Economic Journal*, 100(403):1173-1189.

Pindyck, Robert, and Julio Rotemberg (1993). "The Comovement of Stock Prices." *Quarterly Journal of Economics*, 108(4):1073-1104.

Radelet, Steven, and Jeffrey Sachs (1998). "The East Asian Financial Crisis: Diagnosis, Remedies, Prospects." *Brookings Papers on Economic Activity* (1): 1-90.

Rigobon, Roberto (1998). "Informational Speculative Attacks: Good News is No News." MIT Mimeo.

Rigobon, Roberto (1999). "On the Measurement of the International Propagation of Shocks." NBER Working Paper 7354.

Ronn, Ehud (1998). "The Impact of Large Changes in Asset Prices on Intra-Market Correlations in the Stock and Bond Markets." Mimeo.

Sachs, Jeffrey, Aaron Tornell, and Andrés Velasco (1996). "Financial Crises in Emerging Markets: The Lessons from 1995." *Brookings Papers on Economic Activity.*

Valdés, Rodrigo (1996). "Emerging Market Contagion: Evidence and Theory." MIT Mimeo.