Contagion in Latin America:

Definitions, Measurement, and Policy Implications[1]

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Abstract

This paper analyzes bond and stock markets in Latin America and uses these patterns to investigate whether contagion occurred in the 1990's. It defines "shift-contagion" as a significant increase in cross-market linkages after a shock to one country or region. Several coin-toss examples and a simple model show that the standard tests for contagion are biased due to the presence of heteroscedasticity, endogeneity, and omitted-variable bias. Recent empirical work which addresses these problems finds little evidence of shift-contagion during a range of crisis periods. Instead, this work argues that many countries are highly "interdependent" in all states of the world and the strong cross-country linkages which exist after a crisis are not significantly different than those during more stable periods. These findings have a number of implications for Latin America.

1 Introduction

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. No wonder insurance for the region is costly!

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 (such as Latin America). 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 to that which can be explained by *fundamentals*.[1]

A simple example shows the practical difficulties in 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%. Is this contagion? Can this impact of Russia on Brazil be explained by any fundamental linkages? A preliminary analysis would suggest no. Russia and Brazil have virtually no direct trade links; the two countries do not export similar goods which compete on 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 IMF would respond and what sort of rescue package it would implement during the next currency crisis. This learning process may have conveyed valuable information about potential rescue packages for the next countries which devalued their currencies and/or defaulted on their international debt.

A close look at stock performance and public debt prices for countries in Latin America supports this interpretation. For example, Figure 1 graphs aggregate stock market indices for Argentina,

[1] For example, if a negative shock to Mexico leads to a depreciation of the peso and reduces the earnings and dividends of firms in Argentina (because the Argentine firms compete with the Mexican firms in third markets), this shock to Mexico could affect stock prices in Argentina. Since the transmission of the initial shock can be explained by fundamentals (competitiveness effects in third markets), this would not constitute contagion.

Brazil, Chile, Colombia, Mexico and Venezuela during the Russian crisis[2]. Brazil and Venezuela, which were the two countries generally believed to be most vulnerable to a currency crisis or debt default, were the countries 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 crisis.

This example shows one practical problem with a fundamentals-based definition of contagion. How can we measure these fundamentals, especially in the short run? Potentially even more problematic, there is no agreement on which cross-country linkages constitute fundamentals. Does learning based on IMF behavior in Russia qualify as fundamentals? Given these rather 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 "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 co-move. This paper focuses on the first of these three definitions (for reasons discussed in Section 3), although it frequently provides analysis and discussion based on the broader definitions. Moreover, to clarify terms and avoid any misunderstanding, this paper uses the phrase "shift-contagion" when referring to this first 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. Section 2 motivates the paper by examining recent patterns and correlations in bond markets and stock markets in Latin America. It finds a high degree of co-movement within Latin America and across emerging markets in general, especially in bond markets, during both crisis and non-crisis periods. Section 3 uses these trends in Latin America to discuss how contagion ought to be defined and what are the advantages and disadvantages of alternate definitions. Section 4 briefly surveys the theoretical literature on contagion and Section 5 summarizes the econometric strategies traditionally used to test for its existence. Despite the range of strategies utilized, virtually all of this work concludes that

[2]Stock market indices reported by Datastream. Indices based on rolling average ten-day returns. Holidays and weekends are excluded. Indices normalized to 100 on August 3, 1998.

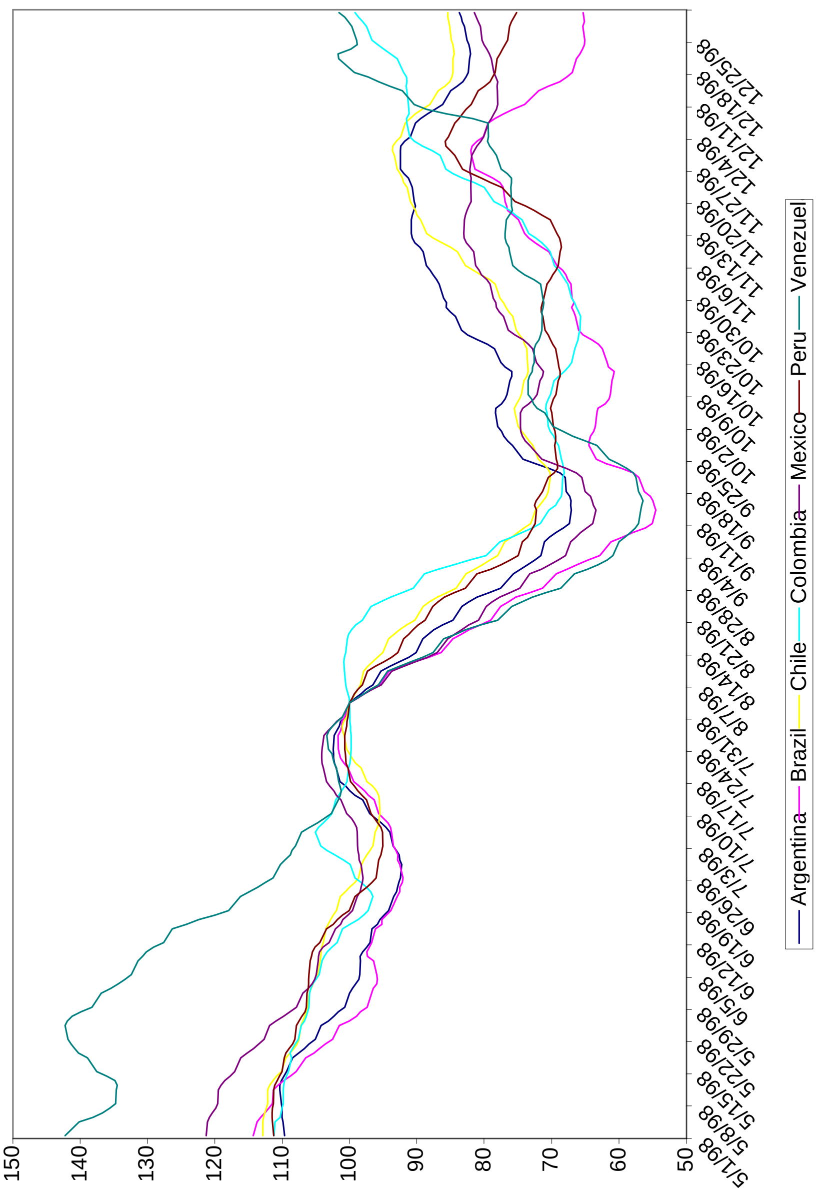

Figure 1: Stock Market Indices During the Russian Crisis

contagion occurred during recent financial crises. Section 6, however, discusses several problems with this empirical work, namely heteroscedasticity, endogeneity, and omitted variable bias. Tests for contagion which 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 highly interdependent (with each other as well as the rest of the world) at all times, and these strong cross-country linkages do not change significantly during periods of crisis. Finally, section 7 concludes and discusses several policy implications for Latin America.

2 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 1990's and measures the degree of co-movement between Latin American markets and between emerging markets in general. These comparisons provide a preliminary test for contagion and raise a number of intriguing questions.

2.1 Bond Markets in Latin America

To examine trends in Latin American bond markets, this section begins by focusing on the interest rate yield between Latin Eurobonds and the international interest rate. 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 of 1994 to July of 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 period in the third quarter of 1994, to about 1600 basis points less than one quarter 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. Then why did shocks to Hong Kong and Russia have any impact on the default risk of countries in Latin America? Aren't the interrelationships between Latin American and Hong Kong or Russia small? In order to answer this question, as well as to have a better understanding of how different Latin American countries are affected by crises which

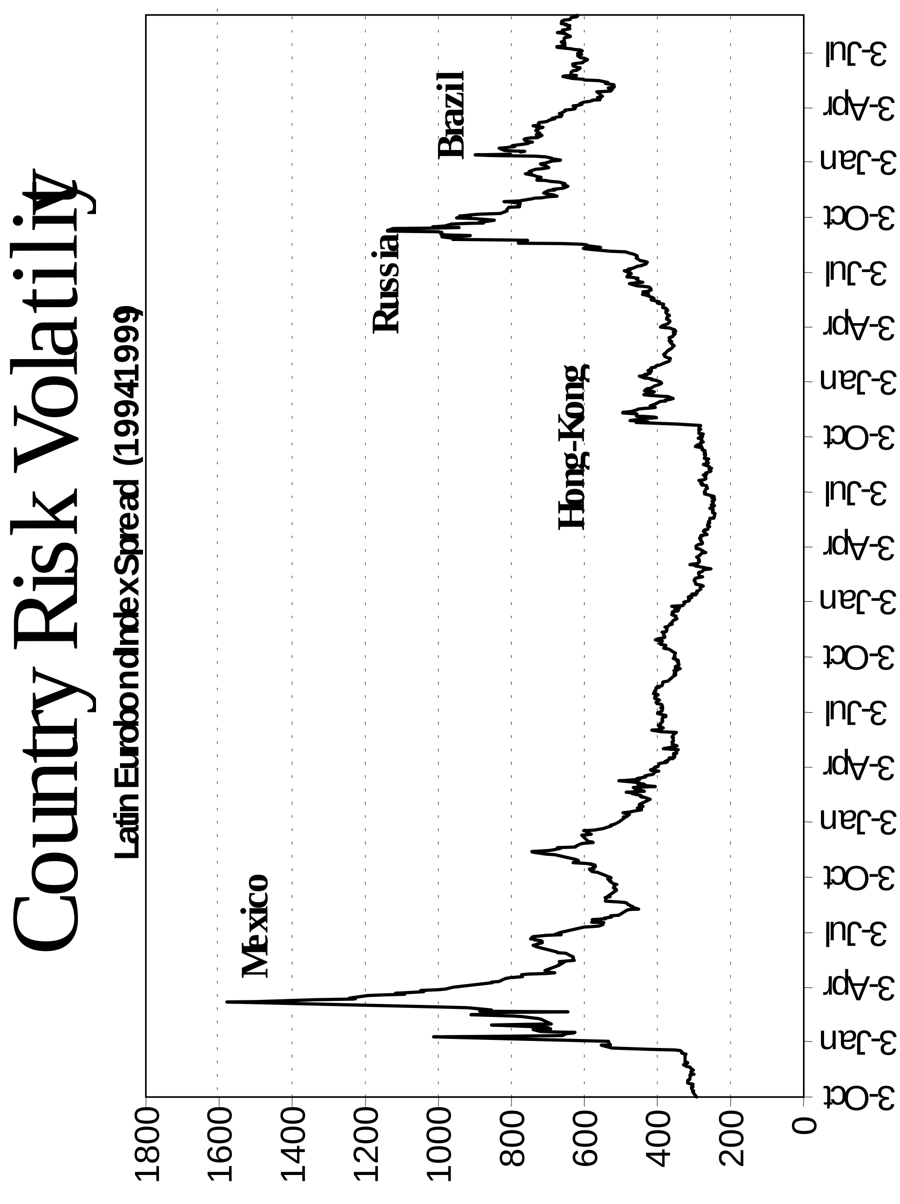

Figure 2: Source: JP Morgan.

occur within the region (such as the 1999 Brazilian crisis) it is useful to examine the impact of each of these crises on specific bonds instead of the aggregate index.

Figure 3 performs this analysis. It graphs the long-term sovereign spread from January of 1997 through December of 1999 for six Latin American countries: Argentina; Brazil; Colombia; Mexico; Venezuela; and Uruguay. More specifically, these are the stripped yields on the EMBI+ index constructed by JPMorgan. These indices 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 premia between countries, (i.e. the differences in the risk premium 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 during the Russian crisis. The risk premium on Argentine debt rose from about 400 to 1000 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 themselves.

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 premia in all Latin American countries. Even the Brazilian crisis in 1999 affected risk premia throughout Latin America and not just in Brazil. Moreover, since each of these risk premiums is stripped, this co-movement can not be explained by movements in international interest rates. Then why is there such a high degree of co-movement in risk premiums for countries which are so different? Could this be caused by a common shock to the region? To answer this question, it is useful to perform one final analysis of bond markets in Latin America: examine the correlations between bond yields in Latin American countries with those in other emerging markets.

Table 1 performs this analysis. It reports the cross-country correlation of stripped yields for Brady bonds from January of 1994 to December of 1999. The Latin American countries included in the table are: Argentina; Brazil; Ecuador; Mexico; Panama; Peru; and Venezuela. The other emerging markets are: Bulgaria; Morocco; Nigeria; the Philippines; Poland; and Russia.

This table clearly shows that the co-movements in risk premia, as measured by stripped interest

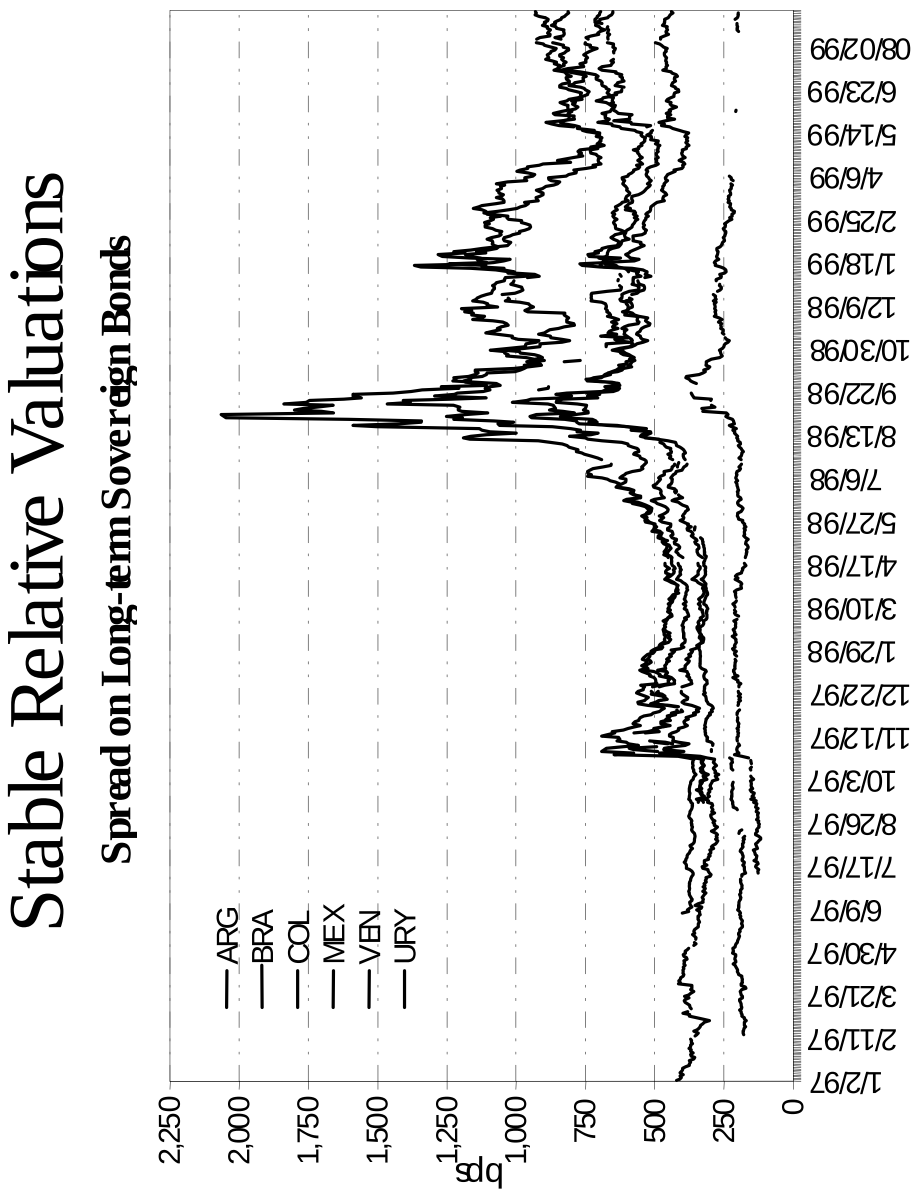

Figure 3: Source: JP Morgan.

	Arg	Bra	Bul	Ecu	Mex	Mor	Nig	Pan	Per	Phi	Pol	Rus	Ven
Arg	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
Bra		1.00	0.93	0.98	0.97	0.99	0.99	0.98	0.99	0.97	0.95	0.92	0.99
Bul			1.00	0.95	0.96	0.95	0.94	0.92	0.94	0.87	0.89	0.81	0.92
Ecu				1.00	0.97	0.98	0.97	0.97	0.98	0.94	0.92	0.93	0.98
Mex					1.00	0.97	0.97	0.97	0.98	0.93	0.96	0.84	0.95
Mor						1.00	0.98	0.99	0.99	0.94	0.94	0.90	0.97
Nig							1.00	0.98	0.99	0.97	0.97	0.89	0.98
Pan								1.00	0.99	0.96	0.96	0.89	0.97
Per									1.00	0.96	0.96	0.91	0.98
Phi										1.00	0.97	0.89	0.96
Pol											1.00	0.80	0.93
Rus												1.00	0.95
Ven													1.00

Table 1: Correlations in Stripped Yields on Brady Bonds for select Emerging Markets

rates on Brady bonds, is extremely high for all emerging markets–not just for Brady bonds within 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! The same number for Brazil and Bulgaria is 93 percent and for Peru and the Philippines 96 percent! Other than the fact that the names of the countries in these pairs start with the same letter of the alphabet, what else do these pairs have in common? Intuition suggests that these countries have few similarities. Then why are these markets so highly correlated over such a long period of time?

2.2 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 also show a similar set of relationships, although in most cases they are not as extreme as those for bond markets. For comparison, this section repeats the bond market analysis in Section 2.1 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 indices in US dollars reported by DataStream.[3]. 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 graphing the spread between the Latin Eurobond index and international interest rates. Both Latin American indices are highly volatile

[3]More specifically, these indices are ten-day rolling average, demeaned returns. Weights for each country are calculated as the standard deviation for that country relative to the average standard deviation for the sample.

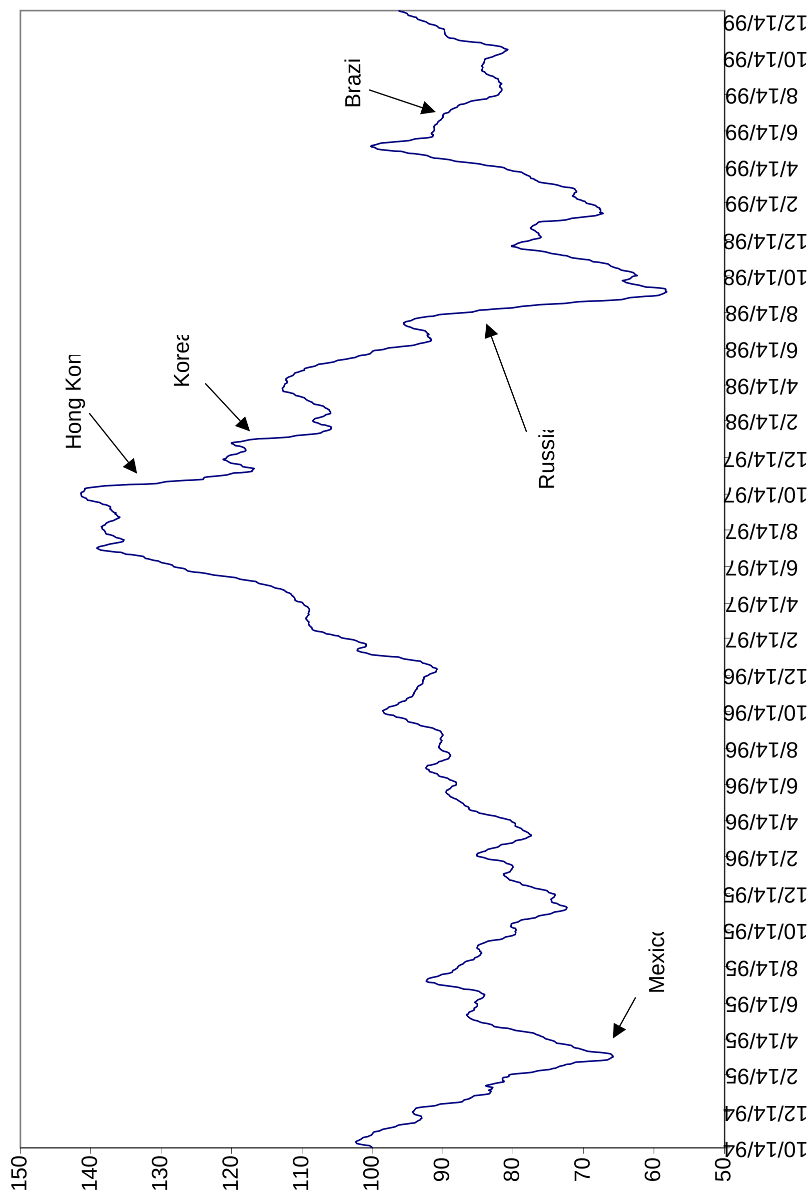

Figure 4: Aggregate Latin American Stock Market Index

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 which originate within the region as to shocks external to the region. For example, the index only falls 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 in Figure 4.[4]

Figure 5 shows that stock markets in most Latin American countries are highly volatile, and that during recent currency crises, the stock markets in this region have tended to move together.[5] Although this co-movement is not as extreme as seen in Figure 3 for Brady bonds, these patterns are still intriguing. Why is there such a high correlation between such different countries in Latin America?

The final step in this analysis of Latin American markets is to calculate this correlation between Latin American stock markets and those in other emerging markets. Table 2 calculates these correlations from January of 1994 through December of 1999 for seven Latin American countries (Argentina, Brazil, Chile, Ecuador, Mexico, Peru, and Venezuela) and six other emerging markets (Egypt, Hungary, Morocco, the Philippines, Poland, and Russia.)[6]

This table shows that co-movements 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%. This is not surprising since these two markets are closely linked through channels such as trade. More surprising, however, is the cross-market correlation between Argentina and Hungary–which is also 78%. What do these two markets have in common? Similarly, why are stock markets in Peru and Russia correlated by 75%? And in Brazil and Egypt by 80%? Intuition suggests that these countries have few similarities.

[4] Indices continue to be ten-day rolling average, demeaned, daily, dollar returns as reported by Datastream. The indices are normalized to 100 on October 1, 1994.

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

[6] More specifically, this table reports the cross-market correlations in weekly US$ stock market indices as calculated by Datastream. The countries in this table are slightly different than those in the table for bond markets because several countries used in the previous table do not have data for stock markets.

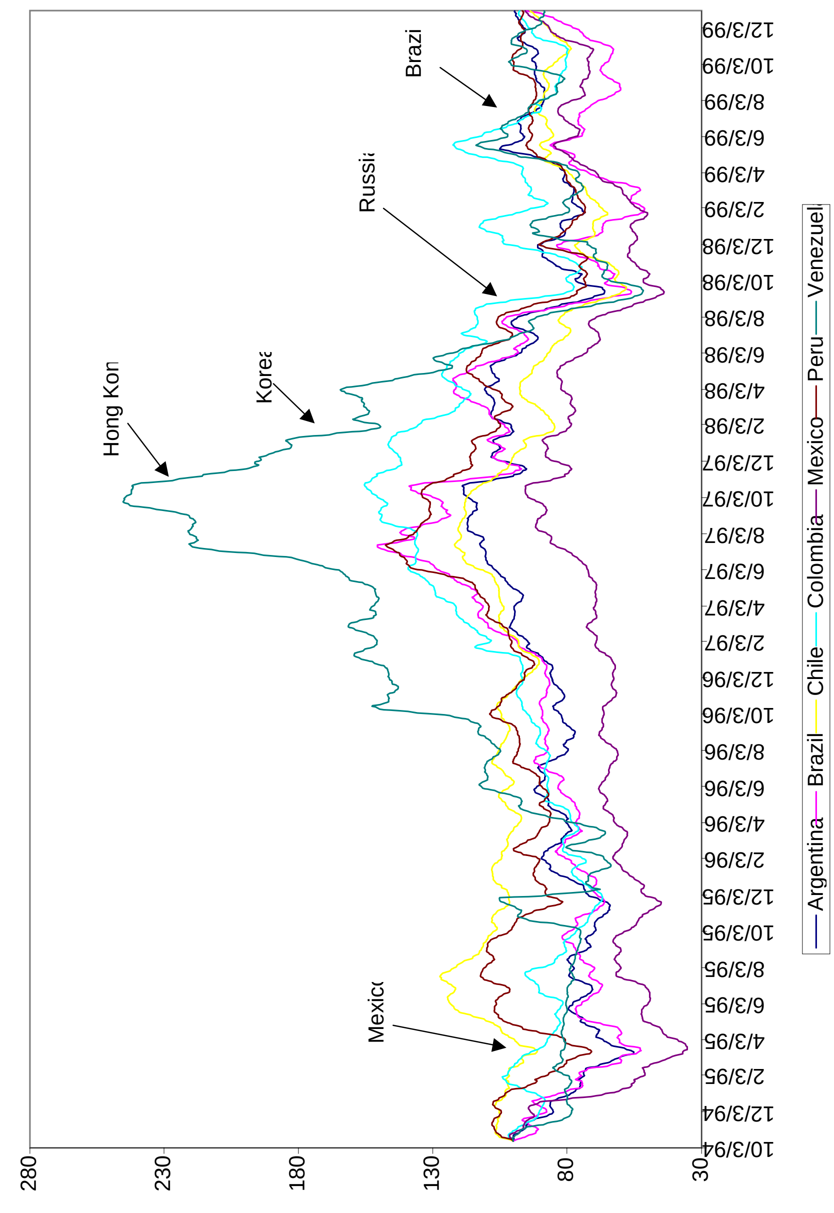

Figure 5: Stock Market Indices for Select Latin American Countries

	Arg	Bra	Chl	Ecu	Egy	Hun	Mex	Mor	Per	Phi	Pol	Rus	Ven
Arg	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
Bra		1.00	0.08	-0.12	0.80	0.88	0.27	0.53	0.62	-0.20	0.43	0.87	0.52
Chl			1.00	0.63	0.04	-0.28	-0.06	-0.59	0.73	0.70	-0.22	0.31	0.43
Ecu				1.00	-0.17	-0.42	-0.07	-0.60	0.43	0.45	-0.30	0.14	0.36
Egy					1.00	0.78	-0.08	0.66	0.43	-0.23	0.20	0.74	0.29
Hun						1.00	0.24	0.75	0.31	-0.47	0.51	0.70	0.34
Mex							1.00	-0.16	0.25	-0.02	0.45	0.56	0.48
Mor								1.00	-0.13	-0.73	0.14	0.13	-0.24
Per									1.00	0.32	0.12	0.75	0.69
Phi										1.00	0.07	0.02	0.25
Pol											1.00	0.50	0.38
Rus												1.00	0.90
Ven													1.00

Table 2: Correlations in Stock Market Returns for select Emerging Markets

2.3 Conclusions: Bond and Stock Markets in Latin America

This examination of Latin American bond and stock markets has generated a number of patterns and questions. Each of these patterns is strongest in bond markets, but is also 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 events outside of this region–such as by the Asian and Russian crises. Second, this volatility is not driven 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 or relative stock returns between countries are fairly stable. Third and finally, this co-movement in risk premiums and stock returns is high between many emerging markets, not just between countries in Latin America. This series of patterns has generated a number of questions. First, why are risk premiums and returns in Latin America so significantly affected by events outside of the region? Second, why do risk premiums and stock returns across such diverse countries in Latin America show such a high degree of co-movement? Third and closely related, why are movements in bond and stock markets so highly correlated in emerging markets around the world?

3 Defining Contagion

The previous section documented the high degree of co-movement in bond and stock markets in Latin America. It also discussed the high correlation between very diverse emerging markets around the world. But is this high degree of co-movement evidence of contagion? And what are the policy implications of these strong cross-market relationships? Before attempting to answer these questions, 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%. Even without a precise definition, most people would agree that this transmission of a shock from Russia to Brazil was contagion. On January 13, 1999 the Brazilian stock market crashed by about 13 percent and the Argentine stock market fell by about 9 percent, and then 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? Or if the US stock market (ever) 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 contagion before the crises of the late 1990's. Since then a number of additional definitions have been created, although there is little consensus on which definition should be utilized. This paper uses the phrase "shift-contagion" instead of simply "contagion" in order to differentiate this precise definition from the numerous other definitions which currently exist. 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 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, or 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 which will be discussed in more detail in Section 7. Third and finally, this definition is appealing based on our intuition and preconceptions of what constitutes contagion. For example, the discussion above mentioned that the Argentine stock market fell and rose with the Brazilian market during the crisis of January 1999. When Brazil initially abandoned its peg during this period, what did we predict would happen to Argentina? 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, and therefore it is not surprising that a large negative shock to one country is quickly passed on to the other. If this transmission of the 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.

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 example above, the impact of a US stock market crash on the Mexican 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 (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. There are few fundamental linkages between these two nations. Therefore, according to these broader definitions of contagion, if a shock to Mexico had a significant impact on Morocco, this would qualify as contagion. In Section 2, however, we saw 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. Therefore, according to the stricter definition of contagion used in this paper, this transmission of a shock from Mexico to Morocco would not qualify as shift-contagion. Yet 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. In order to discuss this puzzle and differentiate it from the concept of shift-contagion, this paper uses the term "interdependence" to describe this type of scenario. In other words, interdependence describes situations when countries show a higher degree of co-movement in all states of the world than can be explained by fundamental linkages.

To summarize, this paper defines contagion as a significant increase in cross-market linkages after a shock. 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.

4 Theoretical Literature

The theoretical literature on how shocks are propagated internationally is extensive and has been well summarized in a number of other papers.[7] 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 which 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.

4.1 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.

[7] For example, see Claessens, Dornbusch and Park (2000) and Forbes (2000).

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 not only explain the bunching of crises, but also why speculative attacks occur in economies that appear to be fundamentally sound.[8] 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 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 [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) which 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 in 1992-3 and develops a model which assumes that central bank presidents are under political pressure to maintain their countries' fixed

[8] This point has been raised by Radelet and Sachs [1998], and Sachs, Tornell and Velasco [1996].

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 which 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 which does not exist in stable periods. Therefore, each of these theories could explain the existence of contagion as defined in Section 3.

4.2 Non Crisis-Contingent Theories

On the other hand, the remainder of the 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 than before the crisis. Instead, any large cross-market correlations after a shock are a continuation of linkages which 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.[9] If one country devalues its currency, this would have the direct effect of increasing the competitiveness of that country's goods, potentially increasing exports to a second country and hurting domestic sales within the second country. The initial devaluation could also have the indirect effect of reducing export sales from other countries which 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

[9] Gerlach and Smets [1995] first developed this theory with respect to bilateral trade and Corsetti et.al. [2000] used microfoundations to extend this to competition in third markets. For exmpirical tests of the importance of trade, see Eichengreen, Rose and Wypolsz [1996], Glick and Rose [2000], Forbes [2000a] and Forbes [2000b] .

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.[10] 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 transmission mechanism 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 4.1 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:

[10] This includes models based on pure learning, such as Rigobon [1998], as well as models of herding and informational cascades, such as Chari & Kehoe [1999] and Calvo & Mendoza [1998].

$$y_t = \beta x_t + \gamma z_t + \varepsilon_t$$
$$x_t = z_t + \eta_t$$

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 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:

$$z_t = \begin{cases} \alpha x_t & x_t < 0 \\ 0 & x_t > 0 \end{cases} \tag{1}$$

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 $\beta + \alpha\gamma$. This process described in equation (1) 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.[11]

[11] 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.

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 contagion, while the endogenous liquidity shocks do.

5 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. Since this literature is so extensive and has been well summarized elsewhere, this paper will not attempt to survey this work.[12] Instead, it will simply mention the four general strategies used to test for contagion and the essence of each strategy's findings. Much of this empirical literature uses the same definition of contagion as specified in Section 3, although some of the more recent work has used 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 contagion occurred. Virtually all papers using this testing strategy reach the same general conclusion: cross-market correlation coefficients usually increase significantly after a currency crisis and, therefore, contagion occurred during the period under investigation.

A second approach to testing for contagion is to use an ARCH or GARCH framework to estimate the variance-covariance transmission mechanism across countries. These tests generally indicate that volatility was transmitted from one country to the other. A third testing strategy uses

[12] For excellent surveys of empirical tests for contagion, see Forbes and Rigobon [2000], Baig and Goldfajn [1998], and Claessens, Dornbusch, and Park [2000].

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 (and especially in the same region).

A final 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 vectors between stock markets instead of in the variance-covariance matrices. 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) 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).

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 cross-market correlation coefficients, GARCH models, probit models, and cointegration techniques. 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: contagion occurred. The consistency of this finding is remarkable given the range of techniques utilized and periods investigated.

6 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 the recent empirical work that has corrected for each of these problems and found that virtually no contagion occurred during recent financial crisis. These studies show that high cross-market linkages after a shock are simply a continuation of strong transmission mechanisms which exist in more stable periods. We refer to these strong transmission mechanisms which exist in all states of the world as interdependence, in order to contrast these linkages with new transmission mechanisms which occur only during crisis periods (i.e. shift-contagion.)

6.1 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 testing for changes in cross-country transmission mechanisms after a crisis.[13] Suppose that there are two related games. In the first game you flip one coin. If it is heads, you win the coin, and if it is tails, you lose the coin. The game can be played with either a penny or a special \$100 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 depends on the outcome of the first game. 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:

$$\text{second game}\begin{cases} \text{2nd. coin head} \quad +25 & \begin{matrix} +0.1 & \text{1st. coin head} & = +25.1 \\ -0.1 & \text{1st. coin tails} & = +24.9 \end{matrix} \\ \text{2nd. coin tails} \quad -25 & \begin{matrix} +0.1 & \text{1st. coin head} & = -24.9 \\ -0.1 & \text{1st. coin tails} & = -25.1 \end{matrix} \end{cases}$$

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 %, 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 coin instead of a penny, the possible scenarios are (again in cents):

[13] This coin example is an extension of that in Rigobon [1999b].

$$\text{second game}\begin{cases} \text{2nd. coin heads} \quad +25 & \begin{matrix} +1000 & \text{1st. coin heads} & = +1025 \\ -1000 & \text{1st. coin tails} & = -975 \end{matrix} \\ \text{2nd. coin tails} \quad -25 & \begin{matrix} +1000 & \text{1st. coin heads} & = +975 \\ -1000 & \text{1st. coin tails} & = -1025 \end{matrix} \end{cases}$$

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%) and the outcomes of the two games are clearly dependent on each other.

The critical point of this exercise is that in both the one 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 one-cent scenario to almost one in the $100 scenario.[14] Moreover, this coin example is directly applicable to measuring the transmission of shocks across countries. The first coin toss represents a country which is susceptible to a crisis. When the country is stable, volatility is low, which is the scenario 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 actually 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%) 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

[14] 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].

toss.)

Heteroscedasticity will also bias tests for contagion which 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 the previous game is positive (labelled as one) or negative (labelled as zero). The restated outcomes of the game are:

1st. Toss With Penny				**1st. Toss With $100 Coin**			
		1st. coin				**1st. coin**	
		Heads	**Tails**			**Heads**	**Tails**
2nd. coin	**Heads**	1	1	**2nd. coin**	**Heads**	1	0
	Tails	0	0		**Tails**	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 outcome in the second game (or payoffs in the second country) could be written:

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

The table shows that γ=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.)[15] 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% 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

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

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.

6.2 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 and which are described by the following model:

$$y_t = \beta x_t + \gamma z_t + \varepsilon_t \tag{2}$$

$$x_t = \alpha y_t + z_t + \eta_t \tag{3}$$

$$E\left[\eta_t' \varepsilon_t\right] = 0, \quad E\left[z_t' \varepsilon_t\right] = 0, \quad E\left[z_t' \eta_t\right] = 0 \tag{4}$$

$$E\left[\varepsilon_t' \varepsilon_t\right] = \sigma^2_{\varepsilon_t}, \quad E\left[\eta_t' \eta_t\right] = \sigma^2_{\eta_t}, \quad E\left[z_t' z_t\right] = \sigma^2_{z_t} \tag{5}$$

where ε_t and η_t are country-specific shocks which are assumed to be independent but are not necessarily identically distributed. Also, without loss of generality, assume that the returns have 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.[16] 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.

Tests for contagion estimate if the propagation mechanisms (α, β, or γ) change significantly during a crisis. Forbes and Rigobon [1999] present a proof which 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.[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 of Section 6.1. If the variance of x_t goes to zero in equation (2), 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 modifies 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. But, 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. Equations 2 and 3 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,

[16] It is possible to drop this assumption by interpreting equations (2) and (3) as reduced forms and expressing z_t as an innovation in a third equation.

[17] Ronn [1998] presents a proof for the special case in which the errors are distributed bivariate normal.

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.

6.3 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 Equations 3 through 5 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. This section summarizes a number of papers which have used a variety of different approaches, identification assumptions, and model specifications to adjust for one (or more) of these problems. Each paper finds 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 shift-contagion occurred during recent crises.

In the first paper to address this 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 crises, the contribution of the other two shocks (the aggregate shock z_t, and the other country shock η_t) are 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.[18] Basically, they calculate both the conditional correlation (ρ_t^c) (i.e. the unadjusted correlation coefficient) and the relative increase in the conditional variance in the crisis country (δ). Then they use equation 6 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.[19]

$$\rho_t = \frac{\rho_t^c}{\sqrt{1 + \delta_t \left[1 - (\rho_t^c)^2\right]}} \tag{6}$$

A simple graph clarifies the intuition behind this adjustment and why it can have a significant impact on tests for contagion. Figure 6 graphs the correlation in stock market returns between Hong Kong and the Philippines during 1997.[20] 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 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 suggest contagion.

Forbes and Rigobon then perform an extensive set of tests for shift-contagion based on both

[18] 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], chp. 13, which refers to this adjustment as the theorem on normal correlation.

[19] The derivation of equation (6) assumes that there is no endogeneity or omitted-variable bias.

[20] 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].

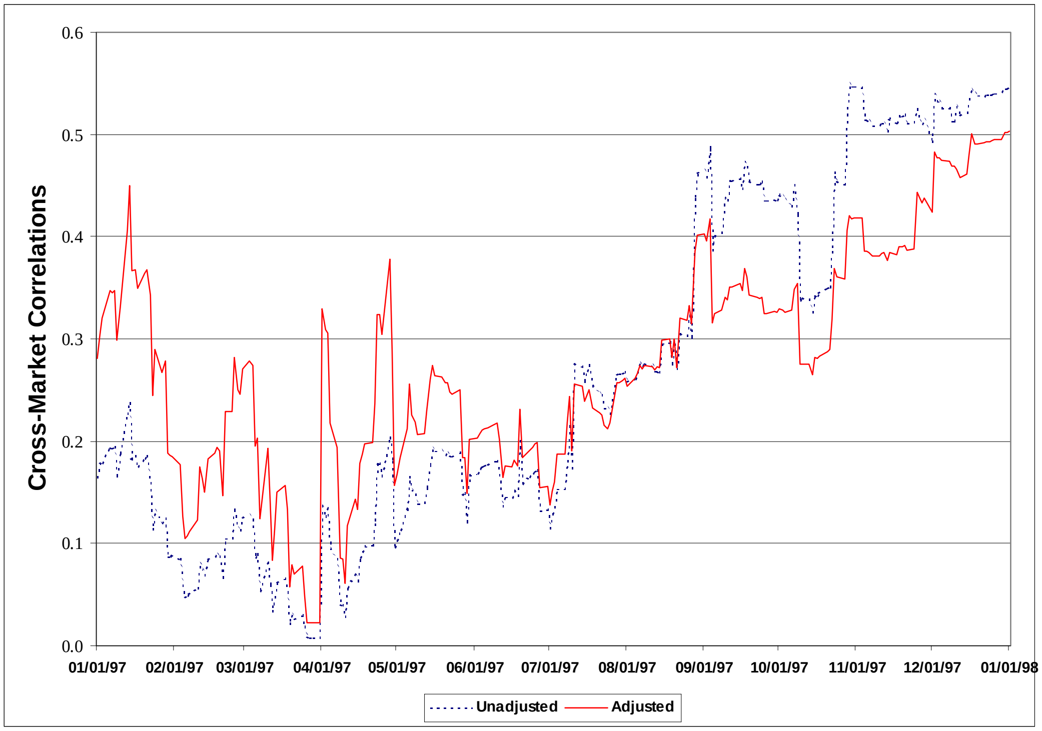

Figure 6: Cross-Market Correlations in Stock Returns: Hong Kong and the Philippines

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 crises, the 1994 Mexican peso collapse, and the 1987 US 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 a 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 US.

Results are striking. Tests based on the unadjusted correlation coefficients find evidence of contagion in a significant number of countries–about 50% of the sample during the Asian crisis and US crash and in about 20% 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 highly 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 US 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 identify his model directly. Rigobon's identifying assumptions not only solve for endogeneity, but are also 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. Arias, Hausmann and Rigobon [1999] extend this analysis to test for the existence of shift-contagion in sovereign bond markets. They find that cross-country relationships are stable during currency crises in Mexico, Thailand, Hong Kong and Korea, and only increase significantly between Argentina and Brazil during the Russian crisis.

Finally, Rigobon [2000] proposes a new methodology which uses heteroscedasticity to identify parameters when the model and data suffer from omitted variables and endogeneity. 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. 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 during this period between these two markets.

7 Conclusions and Policy Implications.

This survey of recent empirical work testing for contagion makes several critical points. First, tests for contagion which 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 which 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 which has attempted to correct for heteroscedasticity, endogeneity and/or omitted variables has shown that the bias from these problems is significant 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 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 which 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 which adjusts for heteroscedasticity, endogeneity, and/or omitted variables finds "no contagion, only interdependence."

These key results are not surprising in light of the analysis of Latin American bond and stock markets. Section 2 showed that the co-movement in risk premiums and stock returns was surprisingly high for countries within Latin America. These co-movements were also high for a number of emerging markets around the world. This high degree of co-movement over long periods of time reflects this empirical finding of "excess interdependence." Similarly, Section 2 presented two graphs which showed that although Latin American countries were extremely vulnerable to events outside of the region, relative risk premiums and relative stock returns between countries were fairly stable. In other words, cross-market relationships appeared fairly constant during crisis and non-crisis periods. This supports the empirical finding of "no contagion" when contagion is defined as a shift in cross-market linkages.

These central results also 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 which only exist after a crisis, then short-run isolation strategies, such as capital controls, could be highly effective in reducing the effect of a crisis elsewhere in the world. On the other hand, if crises are transmitted mainly through permanent channels which exist in all states of the world, then these short-run isolation strategies will only delay a country's adjustment to a shock and not prevent it from being affected by the crisis in the first place.

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 in Section 4, 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 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/or aggregate shocks. There is little support for crisis-contingent 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 can not prevent the necessary fundamental adjustment through these long-term linkages. As a result, short-run isolation strategies, such as capital controls, will only have a limited effectiveness in reducing a country's vulnerability to shocks elsewhere in the world.[21]

Moreover, not only does this paper imply that the benefits of short-run isolation strategies are limited, but an extensive literature has also documented that these strategies could be extremely costly. Since crises are transmitted largely 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.) Not only could implementing either of these policies be difficult, but it could be 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.

[21] This result is consistent with Edwards [1998] which finds that capital controls had little effect in the transmission of the "Tequila effect".

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