Contagion: Recent Models in International Finance Literature

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Abstract
Due to intensified economic globalization, cross-country linkages have become the channel through which country-specific shocks may affect financial conditions and macroeconomic variables across borders. Since financial crises of 1990s, crisis propagation has become a contentious issue. Especially after the recent global financial crisis, contagion has attracted considerable attention both from the academia and policymakers. This survey investigates recent model-based approaches on contagion in international finance literature.

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I. Contagion: A More Recent Concept

Cross-country linkages have a potential to play a role in channeling and amplifying country-specific shocks, due to increasing degrees of economic and financial globalization. To what extent can these cross-country effects be named as contagion? Empirically, Forbes and Rigobon (2002) were first to distinguish between contagion and interdependence. They define contagion as "a significant increase in the cross-market correlation during the period of turmoil". Based on their approach, contagion is captured by the increase in cross-market linkages (i.e. correlation) after a shock hits one country. On the other side, after a country-specific shock, if there is no fundamental change in cross-country relationships, this event constitutes interdependence.[1] The definition of contagion matters, especially in quantitative research, since the way one defines contagion affects how she measures it. Some early theories are worth mentioning. Bikhchandani, Hirshleifer and Welch (1992) model the mass behavior as a result of informational cascades. The model in Banerjee (1992) investigates the consequences of decisions that are affected by behaviors of others. Another approach, as in Gerlach and Smets (1996), is kind of voluntary contagion for devaluation of currencies in line with the idea of competitive devaluations. A strand of literature has focused on the role of financial links. One of the earlier papers, Kaminsky and Reinhart (2000), investigate the role of commercial banks in transmitting the initial shock. Another early study Van Rijckeghem and Weder (2001) test the significance of a common lender channel of contagion for the Asian, Mexican and Russian crises in 1990s, and find that contagion through common lenders is important. Calvo and Mendoza (2000) focus on financial links with imperfect information. In this paper, I will cover very recent model-based studies in contagion. Small open economy (SOE) and 2-country symmetric general equilibrium (GE) models are 2 strands that are covered in this study. They mainly focus on financial and/or trade links as channels of contagion. Next section illustrates driving forces, main results, distinct features and key components of these models. Section 3 concludes.

II. Recent Models of Contagion

Lizarazo (2009) is the earliest approach this paper investigates. Using risk-averse international investor, Lizarazo (2009) proposes a model of debt, default, and contagion of financial crises for SOEs with endogenous default risk, similar to Arellano (2008). She defines contagion as "transmission of negative productivity shocks that cannot be explained by a common shock to several economies". In a world with stochastic endowment, SOEs have access to international funds supplied by international borrowers. International borrowers exhibit decreasing absolute risk aversion (DARA) in wealth. The friction comes from limited enforcement. Lenders cannot enforce SOEs to repay the debt, and SOEs decide whether repay or not depending upon cost and benefit of default. The cost of default is exclusion from world asset market. Hence, the investor would consider SOE's default risk whenever they lend. Default risk of a SOE would be determined endogenously by the country's own fundamentals and the states of other countries (since the investor would reallocate investment across countries according to those). There are J SOE's in the model. A country specific shock to one of these SOEs would give rise to 2 channels of contagion: Wealth and portfolio recompositions channels. First, if a SOE faces with an income shock and defaults, the tolerance of investor for risk will decrease due to loss in wealth. She would switch her assets from risky (other $J-1$ countries) to riskless (T-Bill).[2] Hence wealth channel implies a decline in funds for other SOEs which have not faced with shocks initially. Second is portfolio recomposition channel. There can be positive correlation for defaults risk across countries (due to possible contagion, or correlated income processes). Hence, following an increase in risk of default in a SOE, overall risk of investor's portfolio would increase. As a result, she would reallocate her portfolio. There are 2 competing forces in the mechanism. First possibility is "flight to safe" (substitution between countries and T-Bill). Second, depending upon her degree of risk aversion, the investor can invest more in some countries if their risk is not increased significantly. If substitution effect dominates the latter, SOEs that have not faced with income shocks would lose funds, and hence contagion occurs. I note that both wealth and recompostion channels are arising from risk attitude of the common lender. Finally, the results are consistent with emerging market data.[3]

[1] According to their definition, if any 2 markets have strong co-movements in periods of stability, even if markets continue to show similar co-movements after a shock to one market, this may not mean a contagion. Contagion occurs, only if market co-movements increase significantly after a crisis. Based on Forbes and Rigobon (2002), Moser (2003) proposes an intuitive econometric model to measure degree of interdependence and contagion.

[2] She does not model T-Bill market in which investors are price-takers, and there is full enforcement.

[3] Sovereign bond prices and capital flows are positively correlated. There is domestic impact of fundamentals of other emerging markets on sovereign bond prices and capital flows, increase in probability of default when financial links are taken into account and finally, deterioration of average financial condition when others have defaulted.

One of the key elements in financial crisis literature is occasionally binding constraint in borrowing activities. Mendoza (2010), the pioneering study on the amplifying effects of the borrowing constraint, investigates sudden stop events in a SOE model. Even if he does not propose his study as a contagion model, the basics he proposed have been exploited in the contagion literature. Key components of the model are working capital constraint,[4] endogenous collateral constrained borrowing and imported goods in production. He uses endogenous collateral constraint to explain amplification and business cycle asymmetries. There are only self-employed households with working capital constraint, and production uses imported good as an input. Therefore, there are exogenous price, productivity and interest shocks to the economy. He doesn't investigate shocks arising from financial system. Price of bonds (hence interest rates) is exogenous. He introduces an occasionally binding collateral constraint which is endogenous in 2 dimensions.[5] This constraint helps to explain business cycle asymmetries during sudden stops events. It requires that the value of asset holdings net of borrowing due to working capital must be greater than or equal to (marked-to-market) value of the capital scaled by a constant.[6] Debt-deflation mechanism occurs when constraint binds. When it binds, agents will reduce demand for equity (fire sale), hence, price of equity will fall.[7] Moreover, imported goods are crucial for production, and the amount that firms borrow for working capital also enters into collateral constraint. I also note that marginal product of capital increases in labor and the imported input. With these in hand, when constraint binds, firms cannot purchase enough input for production, and production decreases. Second, since marginal production of capital decreases, there would be further decline in price of capital. As a result, debt-deflation is even stronger in this setup. He shows that sudden stops can occur due to small shocks arising from rest of the world,[8] even if there are only indirect links. Since the initial one can be a small shock with a world component, his model can explain contagion as sudden stop events that hit several countries in response to the trigger shock, even if the countries are not directly linked with each other.

Ozkan and Unsal (2012) propose a 2-country DSGE model to investigate the contagion from the point-view of a SOE. One important feature of the model is that there are 2 countries that differ in population sizes, hence potential interaction between 2 countries is innovative in contrast to existing SOE and fully symmetric models of contagion. Contagion arises from financial frictions in the rest of the world. They argue effects of recent crisis on emerging markets. First effect has been a slowdown in financial flows to emerging markets. Second, there has been a significant fall in their exports due to contractions in other economies. Hence, they have been unable to export even though some emerging countries have experienced devaluations in their currencies. The model has 3 important features. First, a large share of domestic investment is financed by foreign investors (high leverage). Second, borrowing by emerging markets is in foreign currency terms (foreign currency denominated debt). Third, it gives a room to investigate exchange rate pass-trough. The model allows to investigate the effects of trade openness and financial integration on contagion with Rotemberg (1982) price stickiness.[9] Re-pricing of credit risk increases cost of external borrowing, and gives rise to decline in inflation and output in domestic economy with depreciation of currency. As a reaction, firms reduce borrowing in order to reduce leverage. On the other side, fall in inflation and currency depreciation give rise to an increase in real debt burden, which leads to a decrease in consumption. When crisis is originated in domestic country, depreciation offsets some of the decline in consumption and investment. In contrast, if shock is transmitted from outside, export channel works in opposite direction, and creates a further decline in investment and consumption. There are several papers that illustrate empirical evidence for the role of trade channel in contagion. Among others, one of the early studies, Eichengreen et al. (1996) estimate a probit model for 20 developed countries. They define contagion as a "crisis in one country increasing the probability of a crisis occurring in other countries". They discriminate between different channels of transmission, and find the trade weighted measure to be significant in crisis propagation. Ozkan and Unsal (2012) also find that greater trade integration gives rise to higher reponse of macroeconomic variables to sudden stops of capital inflows, since the impact of changes in export is greater for these countries. They conduct monetary policy experiments and conclude

[4] See Neumeyer and Perri (2005). Firms have to borrow in order to pay for some fraction of inputs in advance.
[5] With endogenous price and amount of capital
[6] Maximum value of loan to value ratio. It is inverse of leverage when constraint binds.
[7] This mechanism is weaker for extreme values of the scale parameter in the constraint. See the article for more detailed explanation.
[8] Shocks to interest rate or terms of trade
[9] They impose convex costs of changing price. It gives rise to incomplete exchange rate pass-through.

that the effectiveness of 2 types [10]of policies depends upon degrees of contagion, trade opennes and foreign currency denominated debt.

Another 2-country model, Mendoza and Quadrini (2010), adopt several features from Mendoza et al. (2009) which is on global imbalances and financial development. Using data facts, they conclude that financial globalization played a significant role in recent crisis. Main motivation of this paper is to explain several aspects in US data. They introduce heterogeneous financial development across countries to explain asset positions of countries, effects of price shocks with contagion dynamics. They propose a model in which financial integration gives rise to increase in credit in the most financially developed country, and results in large asset price spillovers of country specific shocks to bank capital. The effects of these shocks are further amplified by bank capital requirements based on mark to market. Different from Mendoza et al. (2009), they focus on unanticipated shocks hitting net worth of financial intermediary. They model market incompleteness with limited enforcement. The countries better enforcement systems would have lower propensity to save (due to better insurance against idiosyncratic risk with state contingent claims), and hence have negative net foreign asset. A relatively small shock hitting equity of financial intermediation would give rise to large fluctuations in asset prices, and it would take a long time to recover. The change in asset prices is the source of contagion. The policy experiment about capital requirement is crucial. If capital requirement rule is changed from marked-to-market to a new system based on historical prices, the effect of shock on asset prices is found to be smaller, since this policy shuts down Fisherian-deflation channel.

Dedola and Lombardo (2012) is another 2-country model to study the effect of levered international investors on the transmission of shocks. One discussion about recent crisis is international exposure of balance sheet of highly levered investors to toxic US assets.[11] The empirical evidence is mixed though. Direct exposures being inadequate to explain contagion in recent crisis[12] is the motivation. Instead of balance sheet exposure channel, the propogation of crisis occurs through price equalization (i.e. no-arbitrage mechanism). In a world with integration and financial frictions, following an asymmetric shock (i.e. credit spread shock to a country), the model yields a synchronization of credit spread and borrowing costs across countries. Based on the model, since the degree of contagion is not strongly related to exposure of foreign assets in balance sheets of highly levered investors, they suggest caution on discussion relating contagion to cross-border balance sheet exposures. In the model environment, investors can invest in production capital domestically and abroad, but they limit investors to borrow only from domestic financial market with a spread over risk free rate. With this financial friction (i.e. cost of borrowing) and financial integration, no arbitrage condition implies that credit spread is equalized across countries. This mechanism works independent of degree of balance sheet exposures. When this mechanism is incorporated to a DSGE model of 2 country, it yields strong comovements of spreads, and weak comovements of GDP across countries after country specific productivity shocks. On the other side, financial shocks create strong comovements in both of those. The important policy question is about the optimal degree of integration when domestic financial market has frictions. Integration is found to be welfare improving, and they argue the role of integration as an insurance against idiosyncratic risks. This latter in line with the finding in Devereux and Yu (2014) that financial integration brings less severe crisis.[13] Key components of the model are Calvo (1983) price rigidity for producers, endogenous portfolio choice for investors, and Mendoza (2010) type collateral constraint. To sum up, a high degree of financial integration gives rise to a pressure towards the cross-country equalization of external finance premia faced by levered investors, and hence global flight to quality mechanism occurs. This explains linkages in macroeconomic variables, and leverages across countries in the model.

Kalemli-Ozcan et al. (2013) use working capital constraint as the channel of contagion in a 2-country GE setup. Using empirical findings, they conclude that financial crises induce comovements across countries. Moreover, their finding that countries having stronger financial linkages to US experienced more synchronized cycles with US during the recent financial crisis. To explain these, they propose a DSGE model with international banking, and investigate both productivity and financial shocks. They also investigate how exogenous changes in financial

[10] Targeting exchange rate or inflation

[11] These assets have been bought by international investors, and when value of these started to decline, these investors have been affected, and started to deleveraging, contracting lending and investment across borders. This is related to "international financial multiplier" by Krugman (2008).

[12] See Kamin and Pounder DeMarco (2010 for an example.

[13] Whereas Devereux and Yu (2014) finds that welfare effects of integration depends upon the existing degree of risk.

integration affects business cycle comovements, and how this impact works under the presence of these shocks. Their model mimics empirical findings about the relationship between business cycle comovements and financial integration. That is, in normal times more integration brings less comovement, whereas they are positively correlated in times of crisis.[14] It is a 2-sector, one good world. The sectors are financially isolated and integrated[15] with exogenous fractions {1-lambda, lambda}. Parameter lambda introduces the degree of financial integration.[16] They also differentiate between lending and deposit rates of the banking sector. This wedge between 2 interests arises from that bank would gain/lose on investment on risky projects, even if its profit is zero. They assume that expected return of risky asset is high enough so that bank will always invest maximum allowed fraction of its capital in risky assets. Hence, they introduce a constant fraction for bank portfolio in risky assets.[17] As long as the policy parameter is positive, there are possible losses which create the wedge between lending/borrowing rates. Banks will increase interest charged on firms when there is a negative shock to risky assets, hence an idiosyncratic credit shock from one country[18] to the bank will be transmitted to real economies of both countries via working capital.[19]

Devereux and Yu (2014), adopting Mendoza (2010) type collateral constraint[20] as a key component, study tradeoff arising from financial integration in a 2-country symmetric GE model. They focus on 2 channels: Risk sharing (diversification of risk) and contagion (transmission of crises). They introduce a model in which world interest, asset prices, capital flows and portfolio choices are endogenous. There are investors (firms), savers (workers) in each countries and a global banker (in case of integration). They investigate the effects of 3 levels[21] of financial integration on risk taking, leverage levels, and probability, contagion and severity of crisis. Crisis in country j is defined as a state in which collateral constraint is binding in country j. Contagion is a state in which these constraints are binding in both countries.[22] The model yields a tradeoff arising from integration: Probability and severity of crises. Financial integration increases investors' leverage and risk taking, hence global credit availability, value of existing assets, collateral values of investors, hence borrowing capacity. Moreover integration decreases consumption risk, hence precautionary savings. The bottom line is more likely but less severe crises. The key in the calibration is rare disaster[23] introduced to AR(1) process of productivity shocks. Note that, similar to Mendoza (2010), collateral constraint is occasionally binding in a stochastic environment due to precautionary saving (i.e. self-insurance against future low realizations). Moreover, this is the key for Fisherian-deflation mechanism (fire sales), and to explain asymmetric effects of integration[24] depending upon financial situation of the country. They only investigate productivity shocks. I will summarize differences of this model from closely related ones. This model is different from Perri and Quadrini (2011) in 2 dimensions. First is endogenous portfolio choice, and second is imperfect risk sharing of investors across borders. In contrast, since they assume the objective function of global banker includes workers utility, there is a perfect risk sharing between workers of 2 countries in case of any level of integration. Moreover, this paper introduces fire sale mechanism, hence, as well as quantity channel of Perri and Quadrini (2011), there are also endogenous price adjustments in response to a shock. Kalemli-Ozcan et al. (2013)

[14] Note that this approach is in line with the definition of contagion in Forbes and Rigobon (2002)

[15] For consumers of each countries in this sector, interest rate is world interest since they have access to international financial market. Same for firms of this sector.

[16] They investigate effects of exogenous financial shocks and assume lambda is exogenous.

[17] This parameter, with lambda, is the key in this model, it determines the impact of credit shock on the real economy. They argue that it is related to banking regulation, and exogenous. They also assume a fixed intermediation cost, and specific asset returns in which bank can invest are independent across countries

[18] A shock to the return of a risky asset in a country. They don't model this side and simply say these are the ones whose returns held by banks such "as mortgages or stocks"

[19] Increase in the policy parameter will give rise to even higher lending rates and more burden on real economy in the model.

[20] In Devereux and Yetman (2010), without these kinds of leverage constraints on investors, financial integration has no impact on international macro co-movements. On the other side, diversified portfolio and binding constraints create a channel of transmission.

[21] Financial autarky (FA), bond market integration (BMI), and equity market integration (EMI)

[22] I note that this definition may overstate the degree of contagion. Since they investigate idiosyncratic productivity shocks to each country, they count situations in which both country faces with low productivity (by coincidence) and go into the crisis as contagion.

[23] large but unlikely downturns

[24] They find that financial integration has more effects on macroeconomic variables in bad times than good times

use working capital as the transmission channel, whereas in this model it is via balance sheet of investors. In Mendoza and Quadrini (2010), there is idiosyncratic uncertainty, Devereux and Yu (2014) incorporate aggregate uncertainty and explore how financial integration affects crisis probability. Mendoza and Smith (2006) is a small economy, in contrast, this model that is symmetric GE framework. The results of Devereux and Yu (2014) are in line with several strands of literature. There are some paper that find a positive relationship between financial liberalization and risk of crisis.[25] Some others find high leverage levels following financial integration.[26] There are findings for positive relationship between capital flows and credit build-up.[27] Finally, another strand of the literature finds more likely but less severe crises due to role of financial integration as buffer or insurer of last resort.[28]

The innovation of Garleanu et al. (2014) is to introduce costly participation to financial markets. Investors and firms are located on a circle, and access to credit requires a cost related to distance.[29] Under the presence of limited integration, they investigate asset price determination, optimal investment strategies (leverage, participation, risky asset position decision), and contagion. Despite the ex-ante identical investors, they differ expost with endogenous decisions. The capital in high leverage investments is highly sensitive even to small changes in access costs, as a result, there are discontinuous price drops, de-leveraging, and portfolio-flow reversals. Moreover, the shocks arising from a subset of location would change prices everywhere, and this is the channel for contagion. Limited market integration brings overexposure of investors to shocks near themselves, hence risk premia is higher than frictionless world. I note that participation decision is also important in the model. When an investor participates more markets, incentives to increase leverage increases. When there is a negative shock to a location in the market (e.g. participation cost increases), prices in every market goes down. The main difference of this model is that it is able to produce contagion even if there is no agent participating in all markets. The main result is that contagion occurs due to limited rather than excessive integration. Contagion from local shocks has larger effects when market integration is more limited. Small changes in participation costs can generate large fluctuations in leverage and prices due to collateral constraint.[30]

In contagion, cross-country linkages are crucial. In contrast to the majority of existing literature, Glover and Shubik (2012) develop a network model for international lending and borrowing in a SOE framework. They focus how sovereign default of a country affects the others, and find that it may have significant effects on borrowing costs and default probabilities of other countries in the network. The crucial feature of the model is that network is formed endogenously. They define default of a representative household of a country as debt being greater than revenue, since household is representative, this definition applies to the country. Loan choice of country depends on solvency probability of potential borrowers, as a result, lending-borrowing links are constructed endogenously. Using the cross-holdings of sovereign debt data, they estimate the network model, and observe a significant role for direct contagion effect resulting from a sovereign default

III. Conclusion and Future Directions

Contagion still has many open directions. Among others, policy questions are crucial. Banking regulation, trade policies, exchange rate regime, government borrowing decisions have effects on contagion. Negative externalities from investors' decisions are also significant. The leading indicators of contagion have not been investigated yet. Studies exploring signals of contagion may enhance the ability to foresee it. Financial intermediation is in reduced forms in the majority of the model-based approaches. Since it is considered as the main source of the recent crisis, more sophisticated and realistic modeling is required for intermediation sector. In addition, off-balance sheet items

[25] Reinhart and Rogoff (2009), Demirgüç-Kunt and Detragiache (1998), Imbs (2010), Lane (2013)

[26] Lane (2013), Borio and Disyatat (2011)

[27] Lane and McQuade (2014), Calderon and Kubota (2012)

[28] Lane (2013), Bordo et al. (2001)

[29] One empirical fact that motivates this modeling strategy is that bilateral capital flows and stocks decay with geographical distances. The second fact is that the level of market integration is varying, and it decreases in the periods of crises.

[30] They use haircut-the fraction of value of assets that is cut to compute capital requirement or collateral level- in collateral constraint which is equivalent to the constraint with maximum loan to value ratio.

must be incorporated into these kinds of models. We know that these items have played a role in recent crisis.[31] Another direction may be to incorporate collateral assets with different qualities, or quality shocks to these assets. Main channels considered as important in contagion are financial and trade linkages by recent literature. Asymmetric effects and amplification during the crisis are widely explained by collateral constraints in these models. Otherwise, these models need unusually high levels of shocks to get fluctuations in real macroeconomic variables. There is a growing literature on contagion, models are evolving in a way that more aspects are endogenous, and more questions are being addressed.

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[31] In a macroeconomic framework, He and Krishnamurthy (2014) conduct a stress testing experiment including "hidden leverage" arising from off-balance sheet activities, and quantitatively show the importance of these activities on systemic risk.

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