Credit Market Frictions and Sudden Stops

Yuko Imura*

Bank of Canada

February 2015

Abstract

Financial crises in emerging economies in the 1980s and 1990s often entailed abrupt declines in foreign capital inflows, improvements in trade balance, and large declines in output and total factor productivity (TFP). This paper develops a two-sector small open economy model wherein heterogeneous firms face collateralized credit constraints for investment loans. The model is calibrated using Mexican data, and explains the economic downturn and subsequent recoveries following financial crises.

In response to a sudden tightening of credit availability, the model generates a large decline in external debt, an improvement in trade balance, and declines in output and TFP, consistent with the stylized facts of sudden stop episodes. Tighter borrowing constraints lead firms to reduce investment and production, which in turn results in some firms holding capital stock disproportionate to their productivity levels. This disrupts the optimal allocation of capital across firms, and generates an endogenous fall in measured TFP. Furthermore, the subsequent recovery is driven by the traded sector, since the credit crunch is more persistent among domestic financing sources relative to foreign financing sources. This is consistent with the experience of Mexico, where the relatively fast recovery from the 1994-95 crisis was driven mainly by the traded sector, which had access to international financial markets.

I would like to thank Julia Thomas, Aubhik Khan and Garima Vasishtha for helpful comments and suggestions, seminar participants at the Bank of Canada and Ohio State University, and conference participants at the 2014 North American Summer Meeting of the Econometric Society, Canadian Economic Association Annual Meetings, the 2013 Midwest Macro Meetings, and Eastern Economic Association Annual Meetings. The views expressed in this paper are my own and do not reflect those of the Bank of Canada. Any remaining errors are my own.

*Email: yimura@bankofcanada.ca

1 Introduction

Financial crises in emerging economies in the 1980s and 1990s had severe effects on real economic activity in these countries. In particular, these crises entailed abrupt declines in foreign capital inflows, commonly known as sudden stops, and resulted in large declines in output and total factor productivity (TFP). In the case of the Mexican crisis of 1994-95, studies have found that the traded sector experienced a smaller fall in output and TFP, and recovered at a much faster rate relative to the non-traded sector (Kehoe and Ruhl, 2009; Pratap and Urrutia, 2007, 2012). Krueger and Tornell (1999) argue that these asymmetric sectoral responses are a result of different degrees of severity of credit crunch in the two sectors. In particular, domestic bank lending continued to shrink substantially for a number of years following the crisis, and this affected firms in the non-traded sector, which relied mostly on domestic financial sources. On the other hand, firms in the traded sector had access to international financial markets, and were able to obtain credit from foreign sources.

Financial constraints can be a major challenge for firms' business decisions, especially in emerging economies. According to the World Bank Enterprise Survey of Business Managers, 30 percent of the surveyed firms in Latin America and the Caribbean identified access to credit as a major obstacle for their operations. These firms also required large collateral in order to borrow from banks, averaging at 198 percent of a loan value. Reliance on external finance and large collateral requirements are not limited to small firms. Using investment data for the manufacturing sector in Mexico from 1984 to 1994, Gelos and Werner (2002) report that 72 percent of loans over 20 million pesos were still backed by collaterizable assets. These observations suggest that credit market (in)efficiencies have significant influences over firms' investment and production decisions, and can play a crucial role in propagating the effects of financial crises.

This paper introduces the misallocation of capital across heterogeneous firms arising from borrowing constraints as a new channel of transmission of financial shocks in small open economies. I develop a two-sector small open economy model wherein heterogeneous producers face collateralized borrowing constraints for their investment loans. I extend the financial frictions model of Khan and Thomas (2013) to a small open economy environment with traded and non-traded sectors, and allow for borrowing from international credit markets for firms in the traded sector. Two key features of my model are collateralized credit constraints and firm heterogeneity in productivity, capital stock and debt. Borrowing constraints limit the amount of loans firms can take on and hence hinder their investment decisions and capital accumulation. In addition, firms face persistent individual productivity shocks every period that directly affect their cash on hand and endogenously alter the tightness of the credit constraint.

I calibrate the model using data for Mexico, and show that, in response to financial shocks, the model can generate an improvement in trade balance and declines in output and TFP, qualitatively consistent with the above-mentioned stylized facts of sudden stops. As credit availability is suddenly tightened, firms in both sectors reduce borrowing and investment. The falls in borrowing by households and firms in the traded sector together reduce foreign financial inflows into the country and therefore improve trade balance. On the production side, the decline in investment reduces production and hence firms' cash on hand. As some firms are not able to take on sufficient loans to finance their optimal levels of investment, credit shocks disrupt the allocation of capital across firms that is consistent with the distribution of their productivity. For example, credit constraints may limit investment undertaken by firms with small cash on hand but relatively higher productivity. As a result, their capital stock is disproportionate to their productivity levels, and the resulting misallocation of capital in turn causes an endogenous decline in the measured TFP. Furthermore, because firms' cash on hand serves as collateral for their borrowing, the decline in cash on hand further tightens credit constraints, thereby generating endogenous, persistent effects of financial shocks on the aggregate economy.

Accounting for the observed declines in output and TFP following sudden declines in foreign capital inflows has been a challenge for a large class of macroeconomic models. Chari, Kehoe and McGrattan (2005) show that, in standard equilibrium models, sudden stops and the resulting improvement in trade balance lead to an increase, rather than a decrease, in output because a reversal of the current account balance induces households to increase labor. Therefore, in order to generate a net decline in output, a model must have some frictions that generate negative effects on output large enough to outweigh its positive responses to a reduction in foreign credit.

Existing studies have introduced a number of mechanisms to explain the declines in output and TFP following financial crises in small open economies, such as working capital, variable capital utilization and exogenous shocks to productivity or import prices.[1] The misallocation of capital arising from collateralized borrowing constraints and firm heterogeneity in my model is a new transmission channel of sudden stops in small open economies.

I also show that, when the credit crunch is more persistent in the domestic financial market relative to the international financial market, large financial shocks lead to disproportionately larger declines in output and measured TFP and a more sluggish recovery of output in the non-traded sector relative to the traded sector. This is consistent with the evidence from the 1994-95 crisis in Mexico. Importantly, these differing sectoral responses are not a direct result of the assumed difference in the persistence of shocks in the two sectors. Even when the two sectors are hit by a large financial shock of the same size and persistence, the non-traded sector still experiences a larger, more persistent fall in output and a larger initial fall in measured TFP, relative to the traded sector.

Arguably, the magnitude of financial shocks calibrated to match the 1994-95 crisis is significantly larger than what an economy may experience over the course of business cycles. When shocks are relatively small, responses of measured TFP in the two sectors become almost identical even when the shock is more persistent in the non-traded sector relative to the traded sector. This non-linearity of my model due to occasionally binding borrowing constraints has an important implication for analyzing financial crises in small open economies, because financial shocks of different magnitudes can have disproportionate effects on the aggregate economy, or countries with different levels of financial market (in)efficiencies may exhibit asymmetric responses to financial shocks. I show that, in an otherwise-identical economy with less tight credit constraints, a credit shock of the same size generates larger declines in output and measured TFP in the non-traded sector but leaves output and TFP in the traded sector relatively unchanged.

Finally, I recalibrate the model to an advanced small open economy using Canadian data, and examine the economy's dynamic responses to credit shocks. I find that the responses of ag-

[1] See, for example, Kehoe and Ruhl (2009), Mendoza (2010), and Pratap and Urrutia (2007, 2012).

gregate output, foreign debt and net exports are all smaller in this case relative to those for the emerging-economy calibration. This finding suggests that emerging economies are more vulnerable to financial crises relative to advanced economies, and highlights the importance of financial development for promoting stable real economic activity.

The remainder of the paper is organized as follows. Section 2 reviews the literature. Section 3 provides some empirical findings from the 1994-95 sudden stop episode in Mexico. Section 4 describes the model. Section 5 explains the functional forms and parameter values used for model calibration. Results are reported in section 6, and section 7 concludes.

2 Related literature

There is a vast literature on quantitative analysis of sudden stops using small open economy frameworks. This paper contributes to the growing literature that focuses on the role of financial frictions as a transmission channel of financial crises in small open economies.[2] As mentioned above, Chari, Kehoe and McGrattan (2005) show that standard equilibrium models with a collateral constraint on foreign borrowing cannot generate a recession in response to sudden stops of foreign capital inflows, because an abrupt increase in net exports leads households to cut leisure. Recent studies have developed a number of other mechanisms that can potentially generate the observed declines in output and TFP following financial crises in small open economies. For example, Meza and Quintin (2007) examine various versions of a small open economy model, and conclude that capital utilization and labor hoarding can account for a large fraction of the fall in measured productivity during Mexico's 1994-95 crisis. Kehoe and Ruhl (2009) develop a multi-sector growth model, and examine the role of sectoral reallocations from the non-traded sector to the traded sector. They show that, in the presence of labor adjustment costs and variable capital utilization, the model can produce a decline in output and TFP, though at the cost of losing its ability to account for fluctuations in prices.

Given my focus on the role of financial frictions in propagating the effects of financial

[2] See, for example, Auernheimer and Garcia-Saltos (2000), Caballero and Krishnamurthy (2004), Gopinath (2004), Pratap and Urrutia (2004), Chari, Kehoe and McGrattan (2005), Gertler, Gilchrist and Natalucci (2007), Meza and Quintin (2007), Kehoe and Ruhl (2009), Mendoza (2010), and Pratap and Urrutia (2012).

crises in a quantitative model, my work is closely related to Mendoza (2010), Pratap and Urrutia (2007) and Pratap and Urrutia (2012). Mendoza (2010) develops a dynamic stochastic general equilibrium model with working capital and a collateral constraint, and explains the observed declines of output and TFP by giving exogenous shocks to TFP, the foreign interest rate, and the price of imported intermediate goods. In his model, working capital loans require collateral so that when the collateral constraint binds, the reduction in working capital loans amplifies the responses of output and production inputs to these shocks. In contrast, my model is able to generate an improvement in trade balance and endogenous falls in output and TFP solely by an exogenous shock to credit availability, and does not require any other exogenous shocks as used in Mendoza (2010). Pratap and Urrutia (2012) explore the role of financial frictions for generating the sectoral misallocation of production resources when firms face a working capital requirement on the purchase of intermediate goods. In their model, an exogenous increase in interest rates disrupts allocative efficiency due to the working capital requirement, and generates an endogenous fall in TFP and output.

The key mechanism in both Mendoza (2010) and Pratap and Urrutia (2012) is that output and measured TFP fall because the presence of working capital requirements creates a wedge between the producer and user prices of production inputs. In contrast to their approach, my model generates a fall in measured TFP through a misallocation of capital because of credit constraints on investment loans and firm-level heterogeneity in productivity that propagate the effects of financial shocks.

Pratap and Urrutia (2007) develop a two-sector small open economy model with working capital, borrowing constraints and firm-level productivity shocks, and explain the larger and more persistent falls in output and TFP in the non-traded sector relative to the traded sector in response to a temporary halt of foreign capital inflows. My model differs from theirs in that they assume that the household supply of labor is inelastic, and all firms face a working capital requirement to purchase intermediate goods as production input, borrow from abroad (in units of traded goods) and cannot save. Because firms in the non-traded sector hold debt denominated in units of traded goods while their revenues are in units of non-traded goods, this mismatch of the denomination on their balance sheet leads traded and non-traded sectors to respond to shocks differently. In contrast, my model assumes that only firms in the traded sector have access to foreign financing while those in the non-traded sector borrow domestically. In my model, the effects of financial shocks are more severe and persistent in the non-traded sector as domestic lenders face a fall in returns on their savings and lifetime wealth, and hence reduce savings.

This paper is also related to a large literature on the quantitative significance of financial frictions for business cycle fluctuations.[3] In a seminal paper, Kiyotaki and Moore (1997) develop a model in which durable assets serve as collateral for loans, and examine how credit constraints interact with aggregate economic activity over the business cycle. They show that the interdependence of credit limits and the prices of collateralized assets plays an important role in amplifying and transmitting shocks to firms' net worth.

The interaction of firm heterogeneity and borrowing constraints in my model is based on recent developments in the literature, in particular by Buera and Moll (2012) and Khan and Thomas (2013). Buera and Moll (2012) examine the implications of financial shocks for aggregate efficiency, investment and labor wedges in the presence of firm heterogeneity in productivity levels. In their benchmark model, entrepreneurs draw a new productivity that is i.i.d. across firms and time, and face a borrowing constraint that limits firms' borrowing only up to a certain fraction of their capital stock next period. The authors show that, in this environment, a credit crunch generates an efficiency wedge and its effect is entirely absorbed by a decrease in TFP.

The model I develop in this paper is an open economy extension of the credit frictions model of Khan and Thomas (2013) in which firms face persistent idiosyncratic productivity shocks, collateralized borrowing constraints and partial investment irreversibilities. Khan and Thomas (2013) show that, when borrowing constraints are tightened, these two frictions together result in a subset of firms carrying a share of the aggregate capital stock disproportionate to their productivity, which in turn reduces aggregate TFP endogenously. The credit constraint in my model is different from theirs in that it hinges on cash on hand instead of capital stock.

[3] See, for example, Bernanke and Gertler (1989), Kiyotaki and Moore (1997), Aiyagari and Gertler (1999), Bernanke, Gertler and Gilchrist (1999), Kocherlakota (2000), Cooley, Marimon and Quadrini (2004), Jermann and Quadrini (2012), and Boz and Mendoza (2014).

3 The 1994-95 sudden stop in Mexico

This section documents key macroeconomic effects of financial crises in small open economies, focusing on the episode of the 1994-95 crisis in Mexico. Figure 1 shows detrended series of main macroeconomic variables from 1988 to 2002 for Mexico. All series are seasonally adjusted where appropriate, and, except for the trade balance as a percentage of GDP, are in logs and detrended using the Hodrick-Prescott (HP) filter.[4] We see that, prior to the crisis, Mexico's external liabilities accumulated rapidly following financial liberalization reforms in 1988-89. However, with the beginning of the crisis in 1994, external liabilities fell significantly and below the trend level. With the fall in external liabilities, Mexico experienced a sharp improvement in the trade balance, from a deficit of about 5 percent of GDP in 1994 to a surplus of over 2 percent in 1995. Real GDP, investment, hours worked and TFP all fell significantly. Interestingly, investment and hours worked recovered fairly quickly, exceeding their trend levels only two years following the beginning of the crisis. These macroeconomic effects of financial crises in emerging economies are not limited to Mexico. Mendoza (2010) examines 33 sudden stop episodes in the 1980s and 1990s, and finds that the median sudden stop causes a reversal of net exports (as a share of GDP) by about 3 percentage points and a fall in GDP of about 4 percentage points below trend.[5]

Following the initial sharp falls in real economic activity, growth rebounded by 1995Q4. GDP in absolute terms grew by 5 percent in 1996 and 7 percent in 1997. The severe economic downturn and the subsequent recovery, however, were not observed evenly across different sectors in the economy. Pratap and Urrutia (2012) find that the declines in output and TFP were smaller and the subsequent recovery was faster in the traded sector relative to the non-traded sector. Figure 2 shows growth rates of sectoral output in the traded and non-traded sectors in Mexico between 1990 and 2000. While output in the non-traded sector fell by 7.3 percent from 1994 to 1995, the traded-sector's output fell by only 3.5 percent. Furthermore, the traded sector started to recover

[4] TFP is computed as $TFP_t = Y_t/(K_t^{\alpha} N_t^{\nu})$, where Y_t is real GDP, K_t is physical capital and N_t is labor. I set $\alpha = 0.33$ so that the capital-to-output ratio is 1.7 in a one-sector version of my model to be in line with the observed ratio. The share of labor in production is set to $\nu = 0.63$ following the average of the estimates in García-Verdú (2005).

[5] Mendoza (2010) classifies sudden stops based on Calvo, Izquierdo and Talvi (2006), who define systemic sudden stop events as episodes with mild and large output collapses that coincide with large spikes in the Emerging Markets Bond Index (EMBI) spread and large reversals in capital flows.

immediately after the crisis, with output growing by 9 percent in 1996, and growth rates remaining well above the average pre-crisis level in subsequent years. On the other hand, the growth rate of output in the non-traded sector remained below the average pre-crisis level until 1997, and was almost half of the growth rate in the traded sector for the first few years following the crisis.

A larger decline in the non-traded sector and a faster recovery and subsequent growth in the traded sector is not only seen in output but also in sectoral TFP. Pratap and Urrutia (2012) find that, while aggregate TFP fell by 6.7 percent between 1994 and 1995, sectoral TFP fell by 4.4 percent in the traded sector and 7.2 percent in the non-traded sector. Furthermore, while TFP in the non-traded sector remained below the pre-crisis level until 2000, TFP in the traded sector exceeded the pre-crisis level by 1996, and was almost 10 percent above the pre-crisis level by 2000.

These asymmetric responses of the tradable and non-tradable sectors may be linked to differences in the two sectors' financing sources. Krueger and Tornell (1999) argue that, while firms in the non-traded sector were severely affected by a lack of access to credit following the crisis, those in the traded sector were able to obtain credit from international capital markets or receive financing from upstream firms. In fact, firms in the non-traded sector relied mostly on domestic financing, whereas those in the traded sector had a larger share of their debt from foreign sources. Figure 3 shows the fraction of foreign debt in short-term debt held by Mexican exporters and non-exporters between 1990 and 2000. We see that, while non-exporters held, on average, 15 percent of their short-term debt in foreign debt, exporters held nearly half of their short-term debt in foreign debt. Krueger and Tornell (1999) also report that, for the top 20 non-financial firms with the highest shares of liabilities denominated in foreign currencies, foreign liabilities accounted for, on average, 73 percent of their total liabilities in 1997.

Data on financial flows in Mexico reveal that, while non-exporting firms continued to have difficulties obtaining loans in domestic financial markets, exporting firms had better access to finance from foreign sources soon after the crisis. Despite a remarkable growth of the financial sector in the early 1990s, the crisis triggered a severe and persistent credit crunch in Mexico.[6]

[6] Hernández-Murillo (2007) reports that, from December 1988 to November 1994, commercial bank credit to the private sector rose in real terms by 277 percent. Gelos and Werner (2002) report that the credit of the consolidated banking system to the private sector increased from about 10 percent of GDP in 1983 to over 40 percent of GDP in 1994.

As shown in Figure 4, domestic commercial bank credit to the private industry declined from 20 percent of GDP in 1994Q4 to less than 5 percent by 2000. Because many firms in the non-traded sector relied on domestic financing, this large decline in credit suggests that they had limited access to loans following the crisis. On the other hand, after a large fall in 1995, foreign funds began to return to Mexico soon after the crisis. Foreign capital inflows in debt and equity returned to the near pre-crisis level by 1996, as shown in Figure 5.[7] In the model I develop in the next section, I account for these asymmetric financial conditions for the traded and non-traded sectors, and allow for access to international financial markets by firms in the traded sector while restricting the non-traded sector only to domestic finance.

4 Model

In this section, I develop a small open economy model with firm heterogeneity and collateralized borrowing constraints by extending the credit frictions model of Khan and Thomas (2013) to a small open economy setting with traded and non-traded sectors. There is a continuum of infinitely lived identical households, each with access to international credit markets. I assume that all markets are perfectly competitive and prices are flexible. Final goods are produced by a perfectly competitive representative final-good producer in two stages. First, domestically produced homogeneous intermediate traded goods and non-traded goods are combined to produce a composite of domestic goods. In the second stage, these domestic goods are combined with homogeneous imported intermediate goods to produce final goods. These final goods are used for consumption by households, and investment by intermediate-good producing firms.

There is a unit measure of intermediate-good firms in each of the traded and non-traded sectors. They own and manage their capital stocks, hire labor from domestic households, and produce intermediate goods using a decreasing-returns-to-scale technology. Each intermediate-good producer faces persistent individual productivity shocks every period. A part of the traded-goods production is consumed domestically, and the remainder is exported abroad. Because there are

[7]Because foreign direct investment (FDI) often entails long-term commitments that cannot be reversed without large costs, it tends to be less responsive to financial crises relative to other types of investment. This is why FDI inflows remained relatively stable during the 1994-95 Mexican crisis, as shown in Figure 5.

no frictions arising from trade costs, the law of one price holds. I assume that intermediate-good producers can borrow in order to finance their investment in physical capital. Firms in the traded sector have access to international financial markets, and can borrow at the world interest rate. Firms in the non-traded sector can only borrow from domestic households. However, regardless of their financial sources, all intermediate-good firms face collateralized borrowing limits that depend on the current level of their cash on hand.

I assume that a fixed fraction of intermediate-good firms are liquidated just after production but prior to investment each period, and replaced by new entrants. This assumption captures the entry and exit of firms in the economy, and also precludes the possibility that firms ultimately accumulate enough cash on hand so that they never face binding credit constraints. This is a standard assumption in models with credit constraints (see, for example, Kiyotaki and Moore, 1997; Khan and Thomas, 2013).

To facilitate the description of the economy, I summarize the aggregate state of the economy by $A \equiv [S, Z]$. S is the endogenous aggregate state, $S = [\mu^T(k^T, b^T, \varepsilon), \mu^N(k^N, b^N, \varepsilon)]$, where $\mu^i(k^i, b^i, \varepsilon)$ is the distribution of firms over capital stock k^i, debt b^i and firm-level productivity ε in the traded sector ($i = T$) or the non-traded sector ($i = N$). Z is the exogenous aggregate state, $Z = [z_T, z_N, \theta_T, \theta_N, r^*]$, where z_i is sectoral productivity, θ_i is the borrowing constraint parameter and r^* is the world interest rate. All agents in the economy take as given the evolution of the endogenous state according to an equilibrium mapping $S' = \Gamma(A)$.

4.1 Households

The representative household is endowed with one unit of time in each period, and it values consumption and leisure according to a period utility function $u(C, N)$, where C denotes consumption and N is labor. It discounts future utility by the subjective discount factor $\beta \in (0, 1)$, and provides labor service to domestic intermediate-good producers at real wage $w(A)$. The household has access to the world credit market. In the current period, it can borrow the amount d' and pay off any outstanding debt from the previous period plus the interest, r^*d. Given its wealth and equilibrium prices, the household chooses its current consumption C, the level of labor to supply to intermediate-good firms N, and the amount of borrowing d'. The household's optimization problem may be expressed as

$$\max_{C,N,d'} u(C,N)$$

subject to a period budget constraint

$$C + r^* d + q^N(A)B^{N'} + \frac{\kappa}{2}(d' - \bar{d})^2 \leq w(A)N + d' + B^N,$$

where κ is a debt-holding cost parameter and the term $\frac{\kappa}{2}(d' - \bar{d})^2$ is the debt-holding cost. Firms in the non-traded sector borrow $q^N(A)B^{N'}$ from the household in the current period and repay $B^{N'}$ in the next period, where $B^{N'} \equiv \int b^{N'} \mu^N \left(d[k^N \times b^N \times \varepsilon]\right)$.

4.2 Final-good producers

The perfectly competitive representative final-good producer first combines domestically produced non-traded goods (y^N) and traded goods (y^D) according to the constant elasticity of substitution (CES) aggregator to produce Y:

$$Y = \left[\omega_1 (y^D)^{\frac{\rho_1 - 1}{\rho_1}} + (1 - \omega_1)(y^N)^{\frac{\rho_1 - 1}{\rho_1}}\right]^{\frac{\rho_1}{\rho_1 - 1}}, \tag{1}$$

where ω_1 is the weight on traded goods and ρ_1 is the elasticity of substitution between traded and non-traded goods.

Taking as given the price of its output, $p^Y(A)$, and the prices of its inputs, $p^D(A)$ and $p^N(A)$, the final-good producer solves the following static profit maximization problem each period:

$$\max_{y^D, y^N} p^Y(A)Y - p^D(A)y^D - p^N(A)y^N$$

subject to the production technology (1).

The resulting first-order conditions yield the following conditional factor demands for y^D

and y^N:

$$y^D = (\omega_1)^{\rho_1} \left(\frac{p^D(A)}{p^Y(A)}\right)^{-\rho_1} Y \tag{2}$$

$$y^N = (1-\omega_1)^{\rho_1} \left(\frac{p^N(A)}{p^Y(A)}\right)^{-\rho_1} Y. \tag{3}$$

Next, the final-good producer combines the composite of domestically produced intermediate goods (Y) and imported intermediate goods (y^M) to produce final goods H using the CES production function

$$H = \left[\omega_2(Y)^{\frac{\rho_2-1}{\rho_2}} + (1-\omega_2)(y^M)^{\frac{\rho_2-1}{\rho_2}}\right]^{\frac{\rho_2}{\rho_2-1}}, \tag{4}$$

where ρ_2 is the elasticity of substitution between domestic goods and imports (Armington elasticity) and ω_2 is the relative weight on home-produced goods (home bias).

Let $P(A)$ denote the aggregate price level. The final-good producer sells its output H to households (for consumption and debt-holding costs) and to domestic intermediate-good producers (for investment) at price $P(A)$. Let $p^Y(A)$ denote the price index for domestically-produced composite goods, and $p^M(A)$ denote the price index for imported intermediate goods.[8] Taking as given the price of its output, $P(A)$, and the prices of its inputs, $p^Y(A)$ and $p^M(A)$, the final-good producer solves the following static profit maximization problem each period:

$$\max_{Y, y^M} P(A)H - p^Y(A)Y - p^M(A)y^M$$

subject to the production technology (4).

The resulting first-order conditions yield the following conditional factor demands for Y and y^M:

$$Y = (\omega_2)^{\rho_2} \left(\frac{p^Y(A)}{P(A)}\right)^{-\rho_2} H \tag{5}$$

$$y^M = (1-\omega_2)^{\rho_2} \left(\frac{p^M(A)}{P(A)}\right)^{-\rho_2} H. \tag{6}$$

[8] $p^M(A)/P(A)$ is normalized to 1.

4.3 Price indices

Given the conditional factor demands obtained above, we can retrieve the price indices for the domestically produced goods $p^Y(A)$ and the final goods $P(A)$. Using equations (2) and (3), we have the following:

$$p^Y(A) = \left[(\omega_1)^{\rho_1}(p^D(A))^{1-\rho_1} + (1-\omega_1)^{\rho_1}(p^N(A))^{1-\rho_1}\right]^{\frac{1}{1-\rho_1}}.$$

Similarly, we can retrieve the price index (or aggregate price level) using the conditional factor demands obtained above. Using equations (5) and (6), the aggregate price index can be written as

$$P(A) = \left[(\omega_2)^{\rho_2}(p^Y(A))^{1-\rho_2} + (1-\omega_2)^{\rho_2}(p^M(A))^{1-\rho_2}\right]^{\frac{1}{1-\rho_2}}.$$

4.4 Intermediate-good firms

Intermediate-good firms can be in either the traded or the non-traded sector, $i = T, N$, respectively. An intermediate-good firm in sector i is identified by (k^i, b^i, ε) for $i = T, N$, where k^i is the capital stock the firm selected at the end of last period, b^i is the level of debt it took on in the last period, and $\varepsilon \in \{\varepsilon_1, \ldots, \varepsilon_{N_\varepsilon}\}$ is its current firm-level productivity which follows a Markov chain with transition probabilities $\varphi_{hj} = pr(\varepsilon' = \varepsilon_j | \varepsilon = \varepsilon_h)$. The start-of-period distribution of firms in each period is summarized by $\mu^i(k^i, b^i, \varepsilon)$ for $i = T, N$.

4.4.1 Production and static profit flows

Non-traded intermediate-good producers produce y^N. Traded intermediate-good producers produce $y^T = y^D + y^X$, where y^D is domestically consumed and y^X is exported abroad. Each firm produces its intermediate good through the production function

$$y^i = z^i \varepsilon (k^i)^{\alpha_i} (n^i)^{\nu_i}, \tag{7}$$

where z^i is the sector-specific productivity level, ε its firm-specific productivity, k^i its capital input and n^i the labor it hires at real wage $w(A)$. Any such firm chooses n^i to solve

$$\max_{n^i} \left[\left(\frac{p^i(A)}{P(A)} \right) y^i - wn^i \right],$$

subject to the production function (7).

4.4.2 Cash on hand and a collateralized borrowing constraint

Define cash on hand x^i as the real value of a firm's static profits and non-depreciated capital net of outstanding debt:

$$x^i \equiv \pi^i + (1 - \delta_i)k^i - b^i,$$

where π^i is static profit flows defined as

$$\pi^i \equiv \left(\frac{p^i(A)}{P(A)} \right) y^i - w(A)n^i.$$

For each unit of debt a firm incurs for the next period, it obtains $q^i(A)$ units of domestic final output in the current period. Thus, a debt with face value $b^{i'}$ incurred for the next period yields $q^i(A)b^{i'}$ units of domestic goods now. The firm's budget constraint is

$$x^i + q^i(A)b^{i'} \geq D^i + k^{i'}, \tag{8}$$

where $D^i \geq 0$ is dividend payments and $k^{i'}$ is future capital stock. I assume that each such firm faces a collateral-based borrowing constraint, which is a function of its cash on hand:

$$b^{i'} \leq \theta_i x^i,$$

where $\theta_i > 0$.

4.4.3 Firm's problem

Let $\chi \in (0,1)$ be the probability that a firm is liquidated just after production, prior to investment. In this event, $k^{i'} = b^{i'} = 0$. Let $\Lambda(A)$ be the valuation that a firm assigns to its current real profit flows given its current aggregate state A.

The expected value of a firm at the beginning of the period, prior to its χ draw, is

$$V_0^i(x^i, \varepsilon, A) = \chi\Lambda(A)x^i + (1-\chi)V^i(x^i, \varepsilon, A).$$

A firm in sector i with current debt level x^i and firm-level productivity ε_h that survives to produce in the next period chooses future capital stock $k^{i'}$ and borrowing $b^{i'}$ in order to maximize its expected discount value:

$$V^i(x^i, \varepsilon_h, A) = \max_{k^{i'}, b^{i'}} \left[\Lambda(A) \left[x^i + q^i(A)b^{i'} - k^{i'} \right] + \beta \sum_{j=1}^{N_\varepsilon} \varphi_{hj}^{\varepsilon} V_0^i(x_j^{i'}, \varepsilon_j, A') \right],$$

subject to its future cash on hand

$$x_j^{i'} = \pi^i(k^{i'}, \varepsilon_j, z^i, A') + (1-\delta_i)k^{i'} - b^{i'}$$

and a collateralized borrowing constraint

$$b^{i'} \leq \theta_i x^i.$$

4.5 International financial intermediary

Firms in the traded-goods sector have access to international financial markets. These firms borrow $q^T(A)b^{T'}$ today, and pay back $b^{T'}$ in the next period. Let $B^{T'}$ denote the total borrowing by firms in the traded sector:

$$B^{T'} \equiv \int b^{T'} \mu^T \left(d[k^T \times b^T \times \varepsilon] \right).$$

Competitive financial intermediaries borrow $q^T(A)B^{T'}$ today at the international interest rate r^*, and pay back $r^*q^T(A)B^{T'}$ in the next period.

The zero profit condition for the intermediary implies that their costs of funds $r^*q^T(A)B^{T'}$ must equal the amount received from the firms $B^{T'}$:

$$r^*q^T(A)B^{T'} = B^{T'},$$

which gives

$$r^* = \frac{1}{q^T(A)}.$$

4.6 Real GDP and net exports

Real GDP is the total production of intermediate goods in the economy, evaluated at the price of final goods:

$$RGDP = \frac{p^N(A)}{P(A)}y^N + \frac{p^T(A)}{P(A)}y^T.$$

Net exports, evaluated at the price of final goods, is defined as

$$NX = \frac{p^X(A)}{P(A)}y^X - \frac{p^M(A)}{P(A)}y^M.$$

4.7 Equilibrium conditions

The final-goods market clears when

$$H = C + I + \frac{\kappa}{2}\left(d' - \bar{d}\right)^2,$$

where the total demand for investment goods is given by

$$\begin{aligned} I(A) \;\; &\equiv \;\; \int \left[g^T\left(k^T, b^T, \varepsilon; A\right) - (1-\delta_T)k^T\right] \mu^T\left(d[k^T \times b^T \times \varepsilon]\right) \\ &+ \;\; \int \left[g^N\left(k^N, b^N, \varepsilon; A\right) - (1-\delta_N)k^N\right] \mu^N\left(d[k^N \times b^N \times \varepsilon]\right), \end{aligned}$$

and g^i is the capital policy function for solving firms' problems.

Equilibrium in the market for firm shares requires that each firm value its dividends by the marginal utility of the household that owns it:

$$\Lambda(A) = \lambda(A) = D_1 u(C(A), N(A)),$$

where $\lambda(A)$ is the Lagrange multiplier on the household period budget constraint.

Equilibrium in the labor market is achieved when total labor demand is exactly satisfied by the labor supply of the representative household:

$$N(A) = \int n^T \left(k^T, b^T, \varepsilon; A\right) \mu^T \left(d[k^T \times b^T \times \varepsilon]\right) + \int n^N \left(k^N, b^N, \varepsilon; A\right) \mu^N \left(d[k^N \times b^N \times \varepsilon]\right).$$

This condition will be satisfied by the following equilibrium wages:

$$w(A) = \frac{D_2 u(C(A), N(A))}{\lambda(A)}.$$

Finally, equilibrium in the debt market is achieved when the real price that a firm pays to borrow one unit in the current period, q^{-1}, is equated to the expected gross real interest rate. This implies the following additional price restriction:

$$q^N(A) = \beta \frac{D_1 u(C(A'), N(A'))}{D_1 u(C(A), N(A))}.$$

5 Functional forms and parameter values

I assume that the period utility function takes the form

$$u(C, N) = \log C - \psi N.$$

The model is calibrated to annual data with the parameters of the model set to match the Mexican data. The household discount factor β is 0.925, to match the annual interest rate of 8.15 percent generated by the EMBI+ spread for Mexico between 1994Q1 and 2005Q4. The weight on leisure in the household utility function ψ is 2.4, so that households work about 30 percent of the total time to match the average ratio of hours worked to total non-sleeping hours of the working-age population in OECD Annual Hours and Productivity data (2002) for Mexico.

The labor share in production is 0.52 in the traded-good sector (ν_T) and 0.64 in the non-traded-good sector (ν_N), to match the worker compensation in each sector in Mexico (Pratap and Urrutia, 2012). In both sectors, the share of capital in production α_i, $i = T, N$, is 0.33, so that the capital-to-output ratio is 1.7, which is in line with the empirical value of 1.8. The depreciation rate of capital δ_i, $i = T, N$, is set to 0.10. This matches the average investment-to-capital ratio between 1950 and 2003 of 0.10 using the data set from Kehoe and Ruhl (2009). In both sectors, the borrowing constraint parameter θ_i, $i = T, N$, is set equal to 0.5. This matches the value of collateral needed for a loan as a percentage of the loan amount of 208.9 percent for Mexico, according to the Enterprise Surveys by the International Corporation and the World Bank.[9]

The share of traded goods in the domestic-good composite ω_1 is 0.23, so that the ratio of traded goods to non-traded goods used in the production of domestic composites is 0.54 as reported in Pratap and Urrutia (2012). The elasticity of substitution between traded and non-traded goods is 0.5, as used in Stockman and Tesar (1995), Kehoe and Ruhl (2009) and Pratap and Urrutia (2012). The home bias in the final-good composite ω is set to 0.72. This implies that the weight on imported goods is 0.2, which is in line with the average imports-to-GDP ratio for Mexico in the pre-crisis period (1986-94) based on the World Bank's World Development Indicators. I chose this period because Mexico joined the General Agreement on Tariffs and Trade (GATT) in 1986. Following the literature, I set the Armington elasticity, ρ, to 1.5, as used in open-economy business cycle models, such as Backus, Kehoe and Kydland (1993) and Chari, Kehoe and McGrattan (2002).

The steady-state foreign debt level $\bar{d}$ is 0.02, so that the debt-to-GDP ratio is 0.33 in the steady state, as in Lane and Milesi-Ferretti (2007). The debt-holding cost parameter κ is set equal to 0.1. The probability of firm liquidity χ is set to 0.1, so that 10 percent of firms exit the market each year. Table 1 summarizes the parameter values.

[9] This is based on a survey of business owners and top managers of 1,480 firms in Mexico, interviewed from August 2009 through June 2010.

6 Results

6.1 Credit shocks

In this section, I examine the implications of credit market frictions for macroeconomic dynamics in response to a sudden tightening of credit availability. Figure 6 shows the model's impulse responses to a persistent credit shock in both sectors. The magnitude of the initial shock in each sector is calibrated so that sectoral output falls by 3.5 percent and 7.3 percent in the traded sector and the non-traded sector, respectively, as observed in the data. These shocks are equivalent to a fall in the credit constraint parameters θ_T from 0.5 to 0.31, and θ_N from 0.5 to 0.28. I assume that the persistence of the shock is 0.3 in the traded sector, and 0.6 in the non-traded sector. This is to reflect the empirical observation that domestic bank loans in Mexico continued to decline persistently in the years following the 1994-95 crisis, while foreign capital inflows recovered sooner, as discussed in section 3.

Upon the impact of the shock, as the economy experiences limited access to credit, foreign debt immediately falls by 28 percent from its steady-state level. The debt level remains below its steady-state value for three periods following the shock, and slightly exceeds the steady-state level in subsequent periods. With the large fall in foreign debt, the economy experiences a temporary but sizable improvement in trade balance, from a 7 percent deficit (as a percentage of GDP) in the steady state to a 1 percent deficit upon the impact of the shock. It falls below the steady-state level in the following few periods as debt begins to increase, and slowly converges to its steady-state level subsequently.

Because firms' current capital stock is determined in the previous period, the financial shock has real effects on production with a lag of one period. Sectoral output falls in both sectors, as calibrated to match the magnitude of the observed fall in each sector. Together, aggregate output falls by almost 6 percent on impact. This fall in aggregate GDP closely matches the observed fall in total output of 6.4 percent in Mexico from 1994 to 1995. In the non-traded sector, we see that the fall in sectoral output is very persistent, and production remains far below its steady-state level even after the shock itself dies out. Even after 15 periods, output in the non-traded sector is still below the steady-state level. On the other hand, output in the traded sector recovers relatively quickly, and returns to the near steady-state level only two periods after the initial fall. Despite the sluggish recovery in the non-traded sector, this fast recovery in the traded sector helps the recovery of aggregate output, especially in the earlier periods following the shock. Only two periods following the large initial fall, the magnitude of the fall in aggregate output is reduced to less than half of the initial fall.

The relative declines in output and speed of recovery in the non-traded and the traded sectors are reflected in the impulse responses of labor and investment in each sector and at the aggregate level. Labor in the non-traded sector falls substantially (7.2 percent) upon the impact of the shock, and recovers sluggishly in subsequent periods. In the traded sector, labor falls by about 3.5 percent upon the impact of the shock, but recovers to the near steady-state level by only one period after the initial fall. At the aggregate level, the large fall in the non-traded sector's labor is dampened by the smaller fall in the traded sector, leading aggregate labor to fall by about 6 percent. The recovery of aggregate labor is sluggish, but less so than in the non-traded sector. We see that the credit shock has very persistent effects on the economy, especially on real GDP, consumption, and sectoral output and labor in the non-traded sector, all lasting well beyond when the shock itself has dissipated.

In both sectors, we see that investment falls substantially as the credit constraints are tightened. Again, the fall is much larger in the non-traded sector relative to the traded sector. However, investment in both sectors recovers fairly quickly, and, in fact, it exceeds the respective steady-state levels only one period after the shock, before starting to revert to the steady state subsequently. The significant recovery of investment in both sectors contributes to a quick recovery of aggregate investment, consistent with the pattern seen in Figure 1.

In the presence of credit market frictions in my model, financial shocks lead to declines in sectoral output not only because of falling sectoral employment and investment, but also because of endogenous declines in sectoral measured TFP. Measured TFP falls by 0.11 percent in the traded sector, and by 0.17 percent in the non-traded sector. The declines in measured TFP and hence output are a result of the misallocation of capital stock across firms caused by the limited availability of credit. When access to credit is limited, we see that firms cut investment. In the presence of heterogeneity across firms, the decline in investment leads to capital stock holdings that may be disproportionate to firms' individual productivity levels. For example, some firms with relatively smaller cash on hand but higher productivity may not be able to borrow enough to finance their optimal levels of investment. Therefore, as relatively productive firms hold less than their respective optimal level of capital, measured TFP declines endogenously, thereby persistently reducing the economy's aggregate production capacity.

The disruption to the optimal allocation of capital across firms is shown in Figures 7 and 8. These figures compare the distributions of firms over capital and productivity at $t = 1$ (upon the impact of the shock) and $t = 2$, in the traded sector (Figure 7) and the non-traded sector (Figure 8). Since capital stock is a state variable, the distribution at $t = 1$ is the steady-state distribution, and the effects of the credit shock are reflected on the distribution at $t = 2$. In both sectors, we see that, moving from $t = 1$ to $t = 2$, the distribution of firms shifts toward lower levels of capital stock once the effects of the shocks on firms' investment decisions are reflected in their capital stocks. This shows that the shocks generate more small- to medium-sized firms in the economy, and hinder the growth of larger firms.

It is important to note that the larger decline in measured TFP and the sluggish recovery of output in the non-traded sector relative to the traded sector shown in Figure 6 is not a result of the assumed higher persistence of the credit shock in the non-traded sector. Figure 9 shows the responses of sectoral output and measured TFP in response to a 100 percent increase in the collateral requirement, with the same persistence of the shock in both sectors. These shocks are equivalent to the borrowing constraint parameter θ_i, $i = T, N$, falling from 0.5 to 0.25. I assume the persistence of 0.3 for both sectors, as used for the traded sector in Figure 6. In Figure 9, we see that, even in this case, the non-traded sector still experiences a larger fall and a more sluggish recovery of sectoral output and a larger initial fall in measured TFP. Recall that firms in the non-traded sector borrow from domestic households. Therefore, the cost of their loans is endogenously determined by the household's intertemporal marginal utility of consumption. As the credit shock reduces aggregate production and hence consumption, it increases the cost of borrowing for firms in the non-traded sector. This in turn reduces the firms' investment and hence future aggregate production and consumption. This creates an endogenous cycle of high borrowing costs and lower production, and generates more persistent effects on firms in the non-traded sector.

A key feature of my model is that the credit constraints are occasionally binding, and therefore the dynamics of the economy are non-linear. This has an important implication for analyzing the effects of financial shocks, since sudden stops or financial crises of a similar magnitude are historically rare events, and an economy may respond differently to financial shocks of a smaller scale. In Figure 10, I compare the dynamic responses of sectoral GDP and measured TFP to different sizes of credit shocks. Figure 10a shows the responses of sectoral output and measured TFP to a 50 percent increase in the collateral constraint. This is equivalent to a drop in the credit constraint parameter θ_i, $i = T, N$, from 0.5 to 0.33. Figure 10b shows the responses of these variables to a 100 percent increase in the collateral requirement, which is equivalent to a drop in the credit constraint parameter θ_i, $i = T, N$, from 0.5 to 0.25. I find that the effects of financial shocks on sectoral output and measured TFP are disproportionate to the size of the shocks. First, looking at the responses of sectoral output, we see that a 50 percent increase in the collateral requirement (Figure 10a) leads to falls in sectoral output by 2.7 percent in the traded sector and 6 percent in the non-traded sector. When the size of the shock is increased to a 100 percent increase in the collateral requirement (Figure 10b), the fall in output of the traded sector is almost doubled (-5 percent). On the other hand, the fall in output of the non-traded sector is -8 percent, much larger than the response to the 50 percent increase in the collateral requirement. Similarly, the effects of credit shocks on sectoral measured TFP are also disproportional to the size of the shocks. We see in Figure 10a that, despite the difference in the persistence of the shocks, a 50 percent increase in the collateral requirement has almost identical effects on sectoral TFP in the traded and non-traded sectors. Measured TFP declines by 0.11 percent in both sectors. However, when the shock is sufficiently large (Figure 10b), it has disproportionately larger effects on measured TFP in the non-traded sector relative to the traded sector. While measured TFP in the traded sector falls by 0.15 percent, the non-traded sector TFP falls by about 0.2 percent. These results suggest that, as the magnitude of credit shocks increases, the non-traded sector is affected more relative to the traded sector.

As discussed in section 1, one of the major obstacles for business operations in emerging economies is access to credit, and the value of collateral needed for a loan is substantially large (200 percent of the loan amount for Mexico). This is less of an issue for more-advanced small open economies. For example, according to the same survey, the collateral requirement is 128 percent of the loan amount for Spain and 133 percent for South Korea (both from the 2005 survey). It is therefore of interest to examine how the sectoral responses of output and measured TFP would change if a country with less tight credit constraints were to be subjected to financial shocks. To this end, I increased the borrowing constraint parameter θ_i, $i = T, N$, from 0.5 to 0.75, so that in the steady state the value of collateral is about 130 percent of the loan amount, while keeping all other parameter values unchanged from the benchmark calibration. Figure 11 shows the impulse responses of sectoral output and measured TFP to a 100 percent increase in the collateral requirement in each sector, with a persistence of 0.3 in the traded sector and 0.6 in the non-traded sector as considered earlier. Relative to Figure 10b, we see that the effect of the shocks on sectoral output is larger in an otherwise-identical economy with less restricting credit constraints. Sectoral output falls by 6.8 percent in the traded sector and 9 percent in the non-traded sector, compared to 5 percent and 8 percent, respectively, under the previous calibration with $\theta_i = 0.5$. The responses of measured TFP are somewhat mixed. While the fall in TFP becomes larger in the non-traded sector, from -0.2 percent to -0.28 percent, the response in the traded sector shrinks slightly, from -0.14 percent to -0.12 percent. This may be because of the less constraining borrowing limit assumed in the steady state and hence less disruption in the capital allocation of the traded sector following the shocks.

6.2 Financial shocks in an advanced small open economy

In this subsection, I calibrate the model to an advanced small open economy using Canadian data, and examine the model economy's responses to financial shocks.

In order to match the Canadian data, the following parameters were recalibrated. The discount factor β is set to 0.96 so that the annual interest rate is 4 percent. The weight on labor in the household's utility function (ψ) is 2.20, so that the households supply one-third of their time for labor. In specifying the firms' production functions, I closely follow de Resende, Dib and Kichian (2009). The labor share in production ν_i, $i = T, N$, is 0.63 in the traded sector and 0.66 in the non-traded sector. The share of capital in production α_i, $i = T, N$, is 0.24 in the traded sector and 0.20 in the non-traded sector. The latter is chosen so that the capital-to-GDP ratio is 1.4 in the steady state. The share of traded goods in domestic production is 0.5, and the home bias is 0.7 to match the average imports-to-GDP ratio of 30 percent for Canada. The foreign debt level $\bar{d}$ is 0.009, so that the debt-to-GDP ratio is 0.11 in steady state, as observed for Canada between 1999 and 2011. I chose this time period because Canada's net foreign asset position has significantly improved since the late 1990s, as shown in Figure 12. The borrowing constraint parameter θ is set equal to 0.77, implying that the value of collateral as a percentage of a loan is 130 percent. While the collateral requirement data are not available for Canada in the Enterprise Surveys by the International Corporation and the World Bank, this value is close to those for other small open economies such as South Korea (133 percent), Spain (128 percent) and Ireland (144 percent). The new parameter values are summarized in Table 2.

Figure 13 shows the economy's impulse responses to the same credit shocks as considered in the Mexican calibration in Figure 6. That is, the collateral requirement increases by 60 percent in the traded sector and 80 percent in the non-traded sector. In response to the shock, foreign debt falls by 18 percent, and, with the decline in foreign borrowing, net exports improve from a deficit of 2 percent of GDP in steady state to a surplus of 2.5 percent of GDP upon the impact of the shock. Sectoral output falls by 4.5 percent in the traded sector and 3.2 percent in the non-traded sector. Together, aggregate output falls by 3.8 percent following the shock and gradually reverts to the steady-state level in the subsequent periods. Measured TFP falls by 0.14 percent in the non-traded sector and 0.2 percent in the traded sector. Overall, the responses of the aggregate variables (real GDP, labor, investment, consumption and foreign debt) are smaller than the predictions under the Mexican calibration, as shown in Figure 6.

At the sectoral level, I find that the responses are larger for the traded sector than for the non-traded sector. This is in contrast to the results for the emerging-economy case, where the non-traded sector was affected more by financial shocks compared to the traded sector. Since the traded sector in Canada is larger than in Mexico, and more capital intensive than the non-traded sector, the misallocation of capital across firms in the traded sector following financial shocks is more pronounced than in the non-traded sector.

7 Conclusions

In this paper, I studied the implications of credit market (in)efficiencies as a transmission mechanism of financial crises in small open economies. I developed a two-sector small open economy model wherein firms face persistent idiosyncratic productivity shocks and their investment decisions are constrained by collateralized borrowing limits. The model developed here is a small open economy extension of the financial frictions model of Khan and Thomas (2013), with the introduction of traded and non-traded sectors as additional features. I calibrated the model to the Mexican economy, and studied the economy's responses to financial shocks.

In response to a sudden tightening of credit availability, my model generates a large decline in capital inflows, an improvement in trade balance, and declines in output and measured TFP, consistent with the stylized facts of financial crises in emerging economies in the 1980s and 1990s. Importantly, the model is able to generate these results without resorting to frictions such as working capital and variable capital utilization, or exogenous shocks to productivity, typically used in existing studies of sudden stops. In the model, as the borrowing constraint is tightened, firms cut investment, thereby reducing capital accumulation and production. These falls in capital stock and production lower firms' cash on hand and further tighten the borrowing constraints. This in turn disrupts the optimal allocation of capital across firms and creates endogenous, persistent effects on output and measured TFP.

Further, with a more persistent credit crunch in the non-traded sector, which relies solely on the domestic financial market, the model generates larger declines in sectoral output and TFP and a more sluggish recovery in the non-traded sector relative to the traded sector. This is consistent with macroeconomic developments in Mexico following the 1994-95 crisis, where a relatively quick recovery from a sharp fall in output was driven mainly by growth in the traded sector, which had access to international financial markets. These results suggest that the loss of access to credit plays a crucial role in exacerbating the economic downturn and delaying the subsequent recovery following financial crises in emerging economies.

I also showed that, when the model is calibrated to an advanced small open economy using Canadian data, the adverse effects of financial shocks on aggregate variables are significantly smaller relative to the emerging-economy calibration. Given that firms in advanced small open economies have better access to credit and face lower interest rates, my results highlight the importance of credit market (in)efficiencies as a transmission channel of financial shocks.

The model and analyses described in this paper can be extended in several directions. One extension may be to introduce international portfolio choices and allow for time variation in portfolio allocation following shocks in both traded and non-traded sectors. This modification would introduce a rich financial structure that may amplify the transmission channel of credit frictions during financial crises, and may be more relevant for analyzing recent financial crises. For example, Tille and van Wincoop (2010) show that international capital flows are driven by portfolio growth, portfolio reallocation associated with time-varying expected returns, and portfolio reallocation associated with time-varying second moments. My model with heterogeneity at sectoral and firm levels offers flexibility in accommodating large cross-country differences, and thus it is an ideal candidate environment in which to undertake such an analysis.

References

[1] Aiyagari, S. Rao, and Mark Gertler, "'Overreaction' of Asset Prices in General Equilibrium," *Review of Economic Dynamics* 2 (1999), 3-35.

[2] Auernheimer, Leonardo, and Roberto Garcia-Saltos, "International Debt and the Price of Domestic Assets," IMF Working Paper, No. 00/177 (2000).

[3] Backus, David, Patrick J. Kehoe, and Finn E. Kydland, "International Business Cycles: Theory and Evidence," NBER Working Paper No. 4493 (1993).

[4] Bernanke, Ben, and Mark Gertler, "Agency Costs, Net Worth and Business Fluctuations," *American Economic Review* 79 (1989), 14-31.

[5] Bernanke, Ben, Mark Gertler, and Simon Gilchrist, "The Financial Accelerator in a Quantitative Business Cycle Framework," in John B. Taylor and Michael Woodford (ed.), *Handbook of Macroeconomics* Volume 1 (1999), chapter 21, 1341-1393.

[6] Boz, Emine, and Enrique Mendoza, "Financial Innovation, the Discovery of Risk, and the U.S. Credit Crisis," *Journal of Monetary Economics* 62 (2014), 1-22.

[7] Buera, Francisco J., and Benjamin Moll, "Aggregate Implications of a Credit Crunch," NBER Working Paper No. 17775 (2012).

[8] Caballero, Ricardo J., and Arvind Krishnamurthy, "Smoothing Sudden Stops," *Journal of Economic Theory* 119 (2004), 104-127.

[9] Calvo, Guillermo A., Alejandro Izquierdo, and Ernesto Talvi, "Phoenix Miracles in Emerging Markets: Recovering without Credit from Systemic Financial Crises," NBER Working Paper No. 12101 (2006).

[10] Chari, V.V., Patrick Kehoe, and Ellen R. McGrattan, "Can Sticky Price Models Generate Volatile and Persistent Real Exchange Rates?," *Review of Economic Studies* 69 (2002), 533-563.

[11] Chari, V.V., Patrick Kehoe, and Ellen R. McGrattan, "Sudden Stops and Output Drops," *American Economic Review* 95 (2005), 381-387.

[12] Cooley, Thomas, Ramon Marimon, and Vincenzo Quadrini, "Aggregate Consequences of Limited Contract Enforceability," *Journal of Political Economy* 112 (2004), 817-847.

[13] de Resende, Carlos, Ali Dib, and Maral Kichian "Optimal Monetary Policy in Multi-Sector Small Open Economy Models: Conventional Wisdom?," mimeo (2009).

[14] García-Verdú, Rodrigo, "Factor Shares from Household Survey Data," Banco de Mexico Working Paper (2005).

[15] Gelos, R. Gaston, and Alejandro M. Werner, "Financial Liberalization, Credit Constraints, and Collateral: Investment in the Mexican Manufacturing Sector," *Journal of Development Economics* 67 (2002), 1-27.

[16] Gertler, Mark, Simon Gilchrist, and Fabio M. Natalucci, "External Constraints on Monetary Policy and the Financial Accelerator," *Journal of Money, Credit and Banking* 39 (2007), 295-330.

[17] Gopinath, Gita, "Lending Booms, Sharp Reversals and Real Exchange Rate Dynamics," *Journal of International Economics* 62 (2004), 1-23.

[18] Hernández-Murillo, Rubén, "Experiments in Financial Liberalization: The Mexican Banking Sector," *Federal Reserve Bank of St. Louis Review*, September/October 2007, 415-432.

[19] Jermann, Urban, and Vincenzo Quadrini, "Macroeconomic Effects of Financial Shocks," *American Economic Review* 102 (2012), 238-271.

[20] Kehoe, Timothy J., and Kim J. Ruhl, "Sudden Stops, Sectoral Reallocations, and the Real Exchange Rate," *Journal of Development Economics* 89 (2009), 235-249.

[21] Khan, Aubhik, and Julia K. Thomas, "Credit Shocks and Aggregate Fluctuations in an Economy with Production Heterogeneity,"*Journal of Political Economy* 121 (2013), 1055-1107.

[22] Kiyotaki, Nobuhiro, and John Moore, "Credit Cycles," *Journal of Political Economy* 105 (1997), 211-248.

[23] Kocherlakota, Narayana R., "Creating Business Cycles through Credit Constraints," *Federal Reserve Bank of Minneapolis Quarterly Review* 24 (2000), 2-10.

[24] Krueger, Anne, and Aaron Tornell, "The Role of Bank Restructuring in Recovering from Crises: Mexico 1995-98," NBER Working Paper No. 7042 (1999).

[25] Lane, Philip R., and Gian Maria Milesi-Ferretti, "The External Wealth of Nations Mark II: Revised and Extended Estimates of Foreign Assets and Liabilities, 1970-2004," *Journal of International Economics* 73 (2007), 223-250.

[26] Lobato, Ignacio, Sangeeta Pratap, and Alejandro Somuano, "Debt Composition and Balance Sheet Effects of Exchange Rate and Interest Rate Volatility in Mexico: A Firm Level Analysis," Working paper (2003).

[27] Mendoza, Enrique G., "Sudden Stops, Financial Crises, and Leverage," *American Economic Review* 100 (2010), 1941-1966.

[28] Meza, Felipe, and Erwan Quintin, "Factor Utilization and the Real Impact of Financial Crises," *B.E. Journal of Macroeconomics* 7 (2007), 1-41.

[29] Pratap, Sangeeta, and Carlos Urrutia, "Firm Dynamics, Investment, and Debt Portfolio: Balance Sheet Effects of the Mexican Crisis of 1994," *Journal of Development Economics* 75 (2004), 535-563.

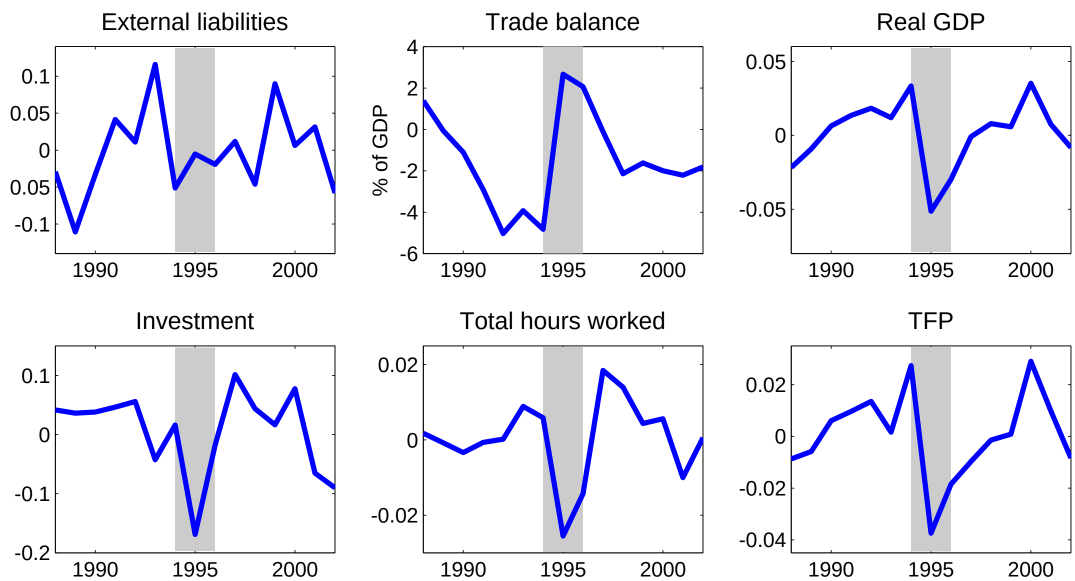
[30] Pratap, Sangeeta, and Carlos Urrutia, "Credit Constraints, Firm Dynamics, and the Transmission of External Financial Shocks," mimeo (2007).

[31] Pratap, Sangeeta, and Carlos Urrutia, "Financial Frictions and Total Factor Productivity: Accounting for the Real Effects of Financial Crises," *Review of Economic Dynamics* 15 (2012), 336-358.

[32] Stockman, Alan C., and Linda Tesar, "Tastes and Technology in a Two-Country Model of the Business Cycle: Explaining International Comovements," *American Economic Review* 85 (1995), 168-185.

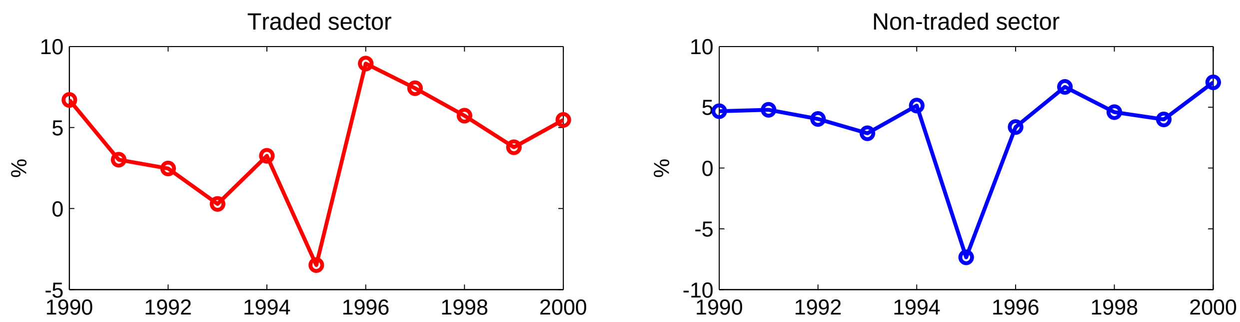
[33] Tille, Cédric, and Eric van Wincoop, "International Capital Flows," *Journal of International Economics* 80 (2010), 157-175.

Figure 1: Key macroeconomic variables in Mexico (1988-2002)



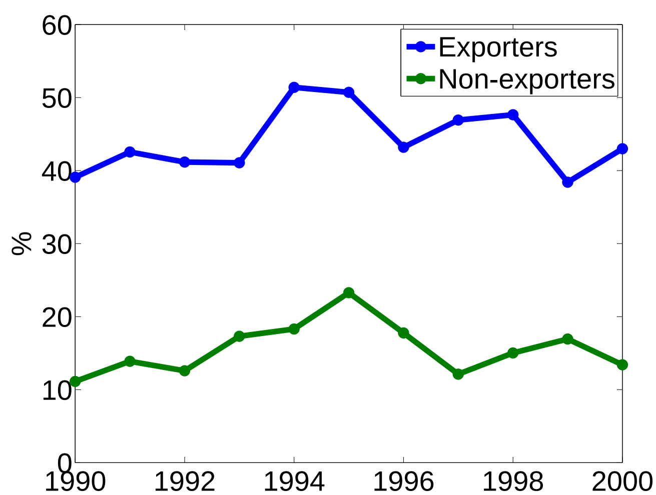
Notes: All data series are annual. The shaded areas indicate the crisis period. The data on external liabilities are from the data set constructed by Lane and Milesi-Ferretti (2007). The data on trade balance, real GDP, investment and total hours worked are from the data set used by Kehoe and Ruhl (2009). Total factor productivity is computed as $TFP_t = Y_t/(K_t^{\alpha} N_t^{\nu})$, where Y_t is real GDP, K_t is capital, N_t is labor hours, and α and ν are parameters. I set $\alpha = 0.33$ and $\nu = 0.63$.

Figure 2: Growth rates of sectoral output in Mexico



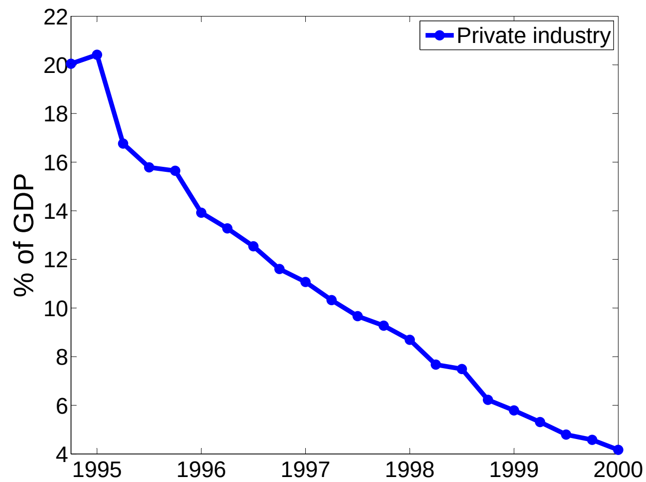
Note: Growth rates are in percentage.
Data source: Instituto Nacional de Estadística y Geografía

Figure 3: Shares of foreign debt in short-term debt held by exporters and non-exporters in Mexico



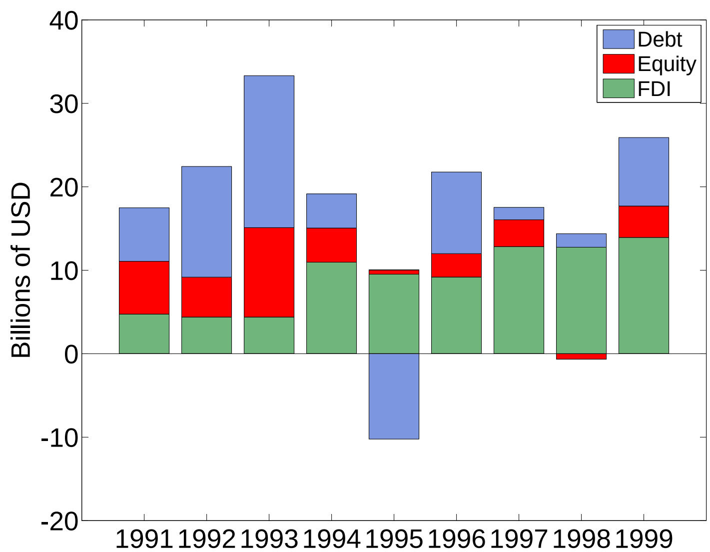
Data source: Lobato, Pratap and Somuano (2003)

Figure 4: Bank credit to private sector in Mexico



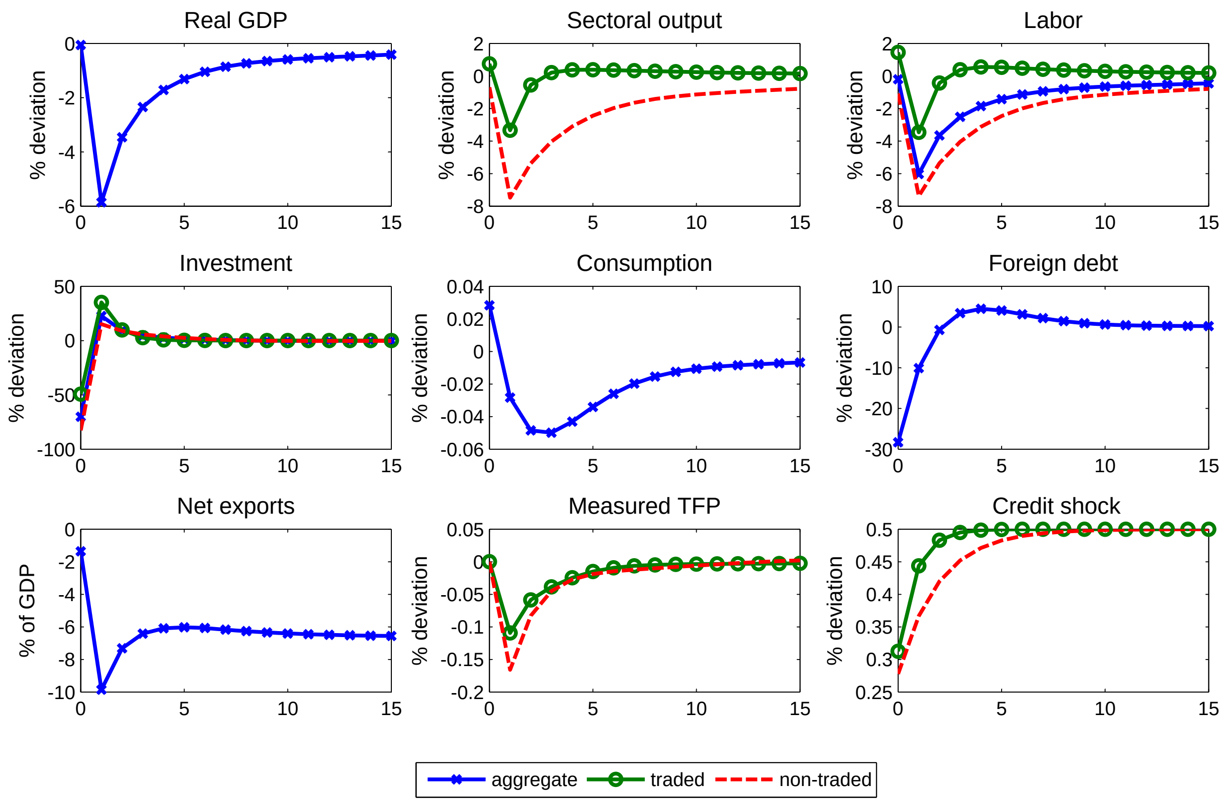
Data source: Banco de México

Figure 5: Foreign capital inflows to Mexico



Data source: IMF International Financial Statistics

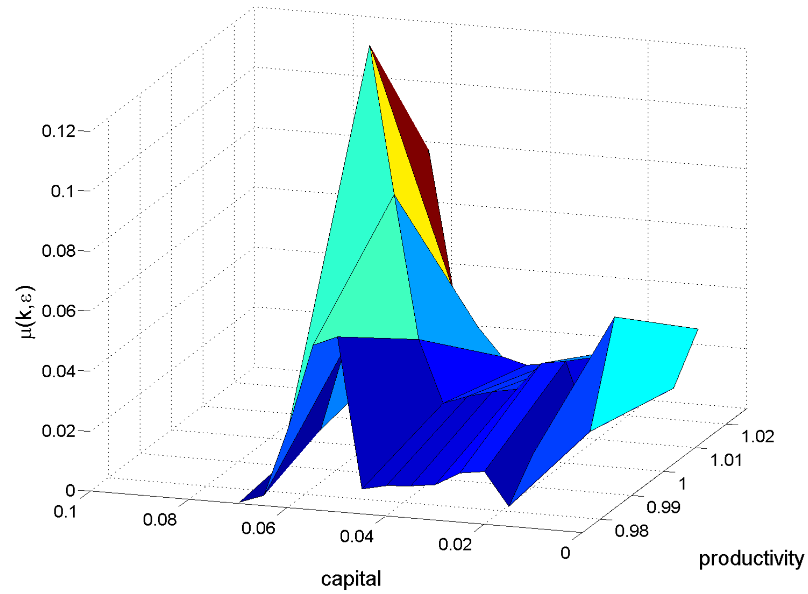
Figure 6: Impulse responses to persistent credit shocks



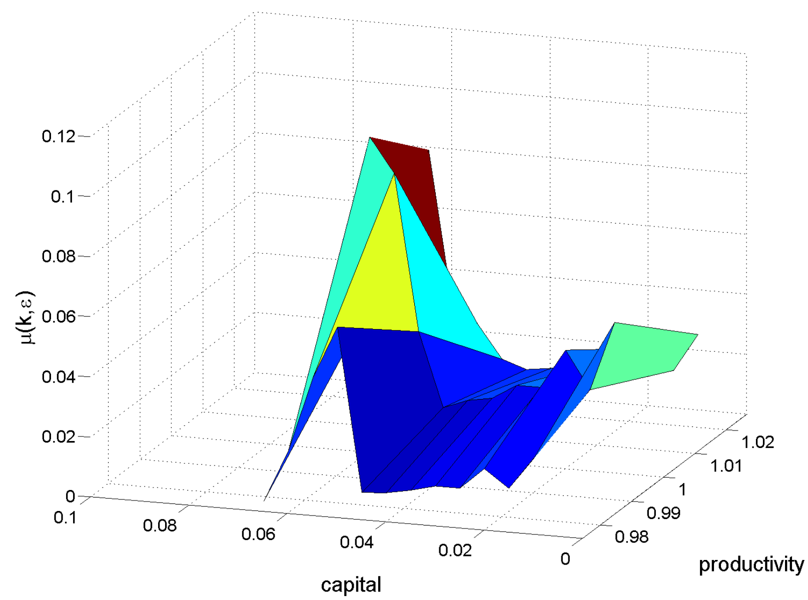
Note: Responses to a 60 percent increase in the collateral requirement, with 0.3 persistence, in the traded sector, and an 80 percent increase in the collateral requirement, with 0.6 persistence, in the non-traded sector.

Figure 7: Distribution of firms over capital and productivity (traded sector)

$t = 1$

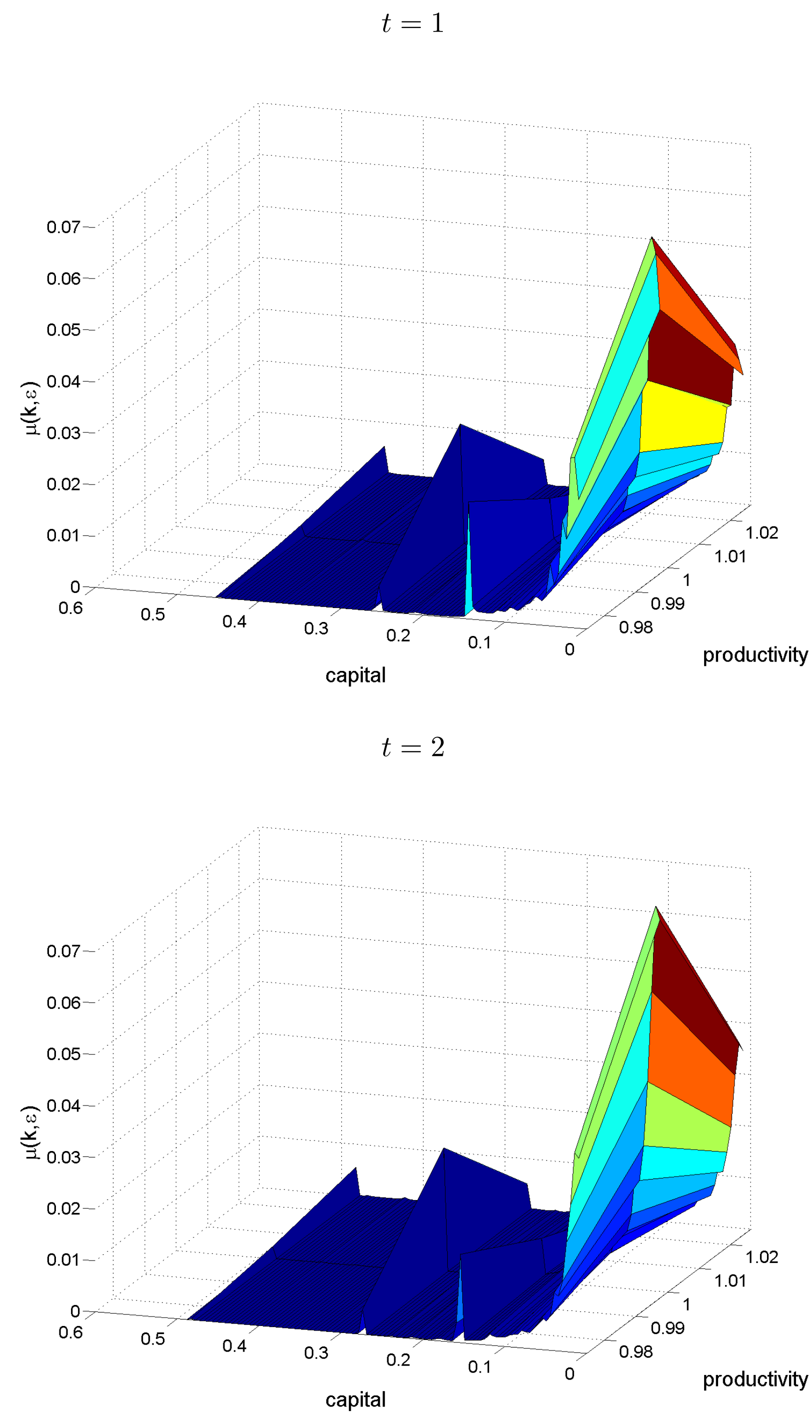


$t = 2$



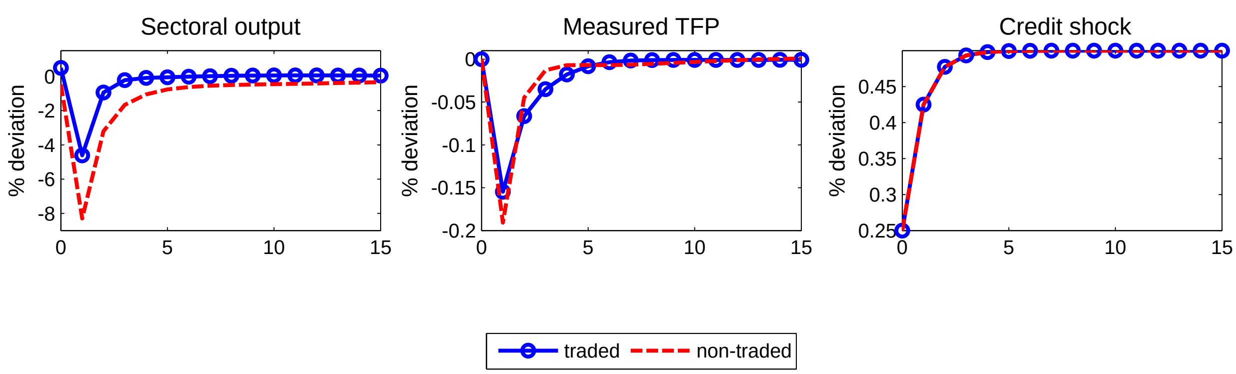
Notes: Distributions of firms in the traded sector over capital and productivity at $t = 1$ and 2 in response to increases in the collateral requirement in the traded and non-traded sectors. The shock for the traded sector is a 60 percent increase in the collateral requirement, with 0.3 persistence, and that for the non-traded sector is an 80 percent increase in the collateral requirement, with 0.6 persistence.

Figure 8: Distribution of firms over capital and productivity (non-traded sector)



Notes: Distributions of firms in the non-traded sector over capital and productivity at $t = 1$ and 2 in response to increases in the collateral requirement in the traded and non-traded sectors. The shock for the traded sector is a 60 percent increase in the collateral requirement, with 0.3 persistence, and that for the non-traded sector is an 80 percent increase in the collateral requirement, with 0.6 persistence.

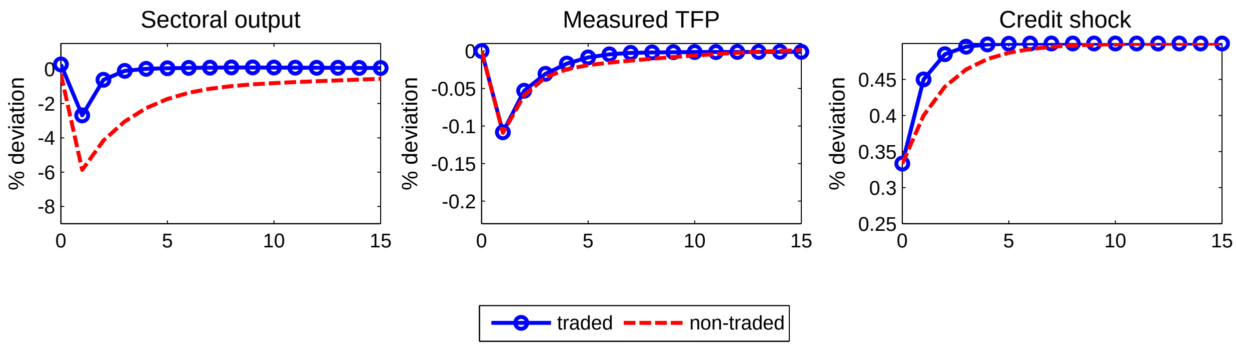
Figure 9: Responses to a 100% increase in collateral requirement: Equal persistence



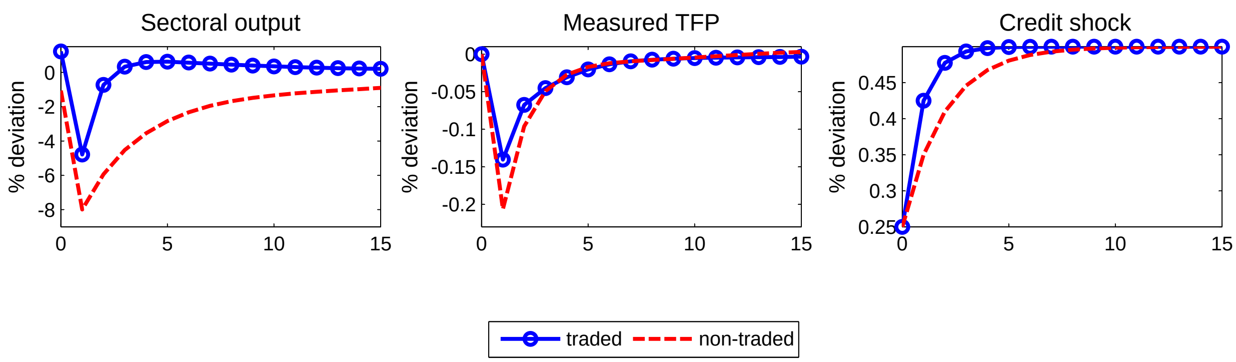
Note: Responses to a 100 percent increase in the collateral requirement, with 0.3 persistence, in the traded and non-traded sectors.

Figure 10: Impulse responses to persistent credit shocks

(a) 50% increase in collateral requirement

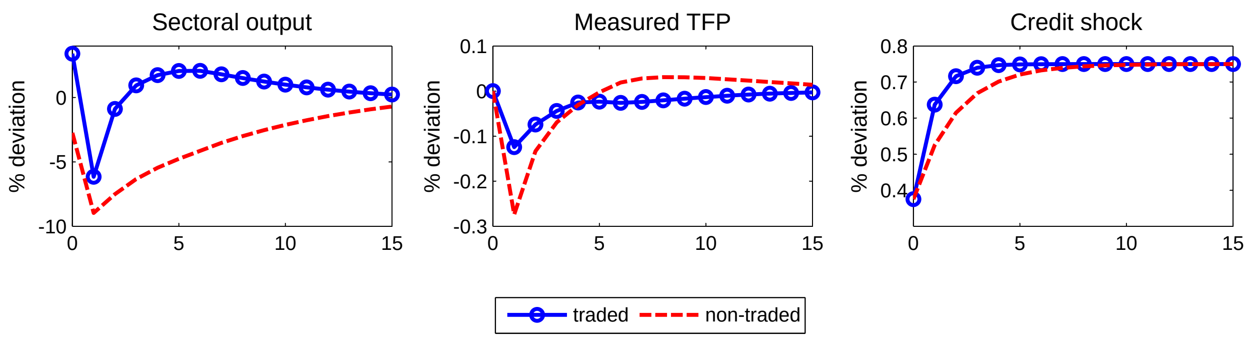


(b) 100% increase in collateral requirement



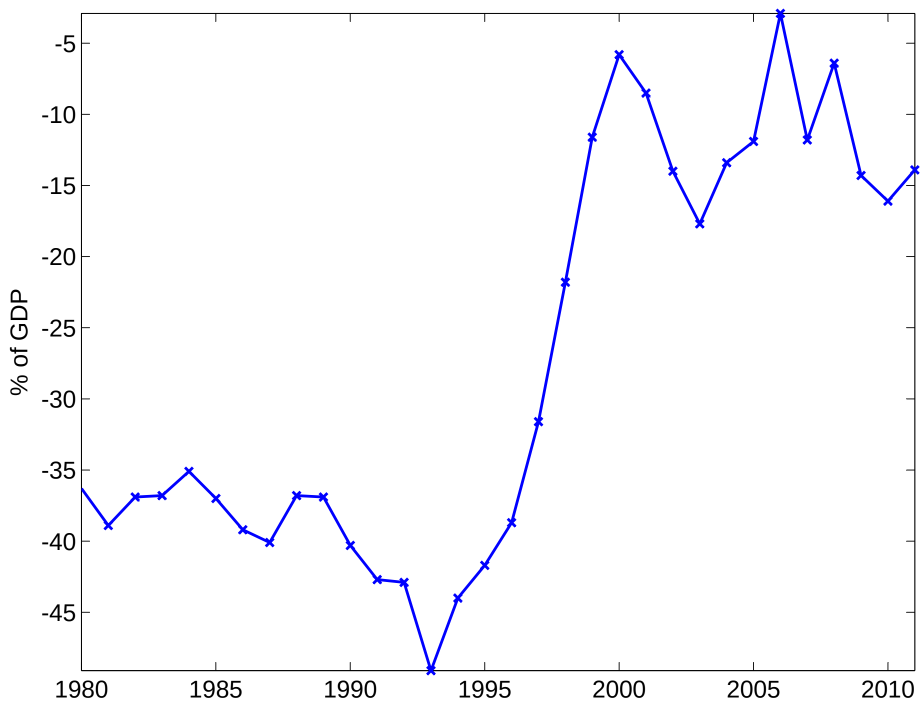
Notes: Panel (a): Responses to a 50 percent increase in the collateral requirement, with 0.3 persistence in the traded sector and 0.6 persistence in the non-traded sector. Panel (b): Responses to a 100 percent increase in the collateral requirement, with 0.3 persistence in the traded sector and 0.6 persistence in the non-traded sector.

Figure 11: Responses to a 100% increase in collateral requirement: $\theta = 0.75$



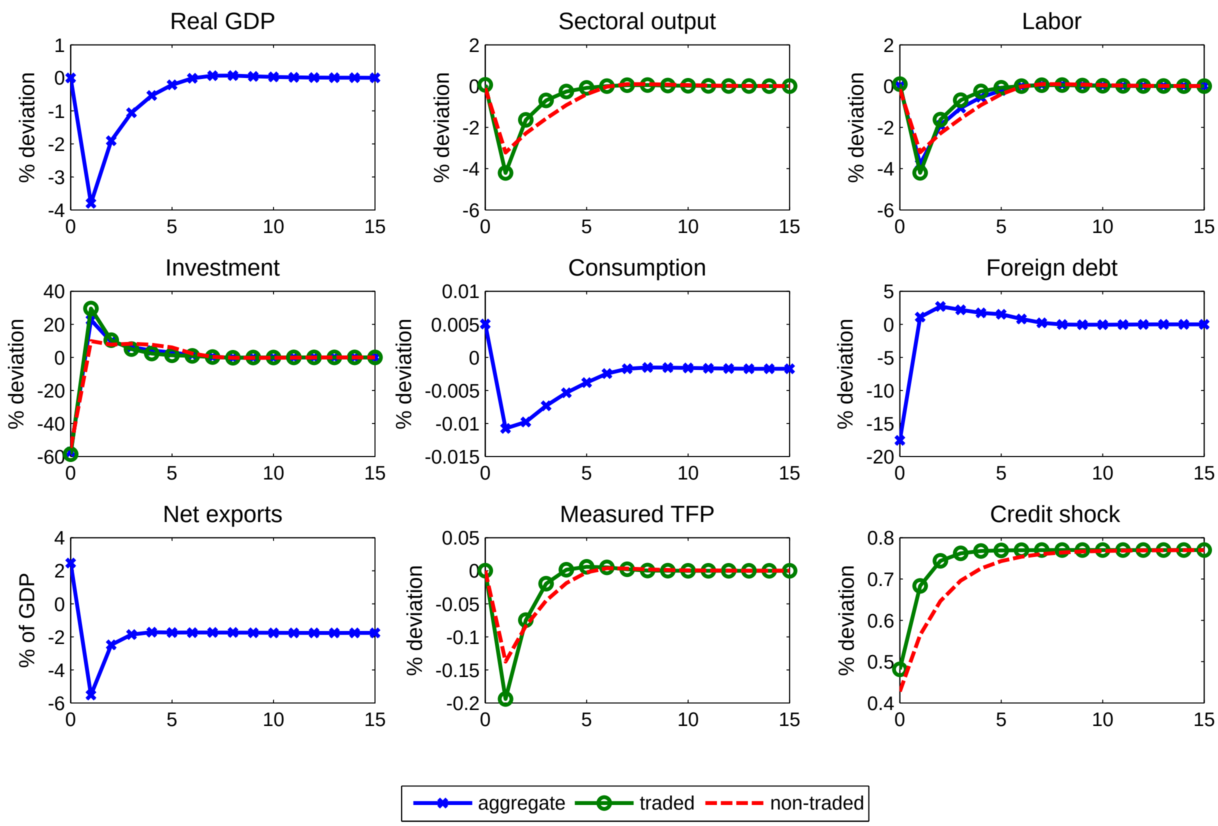
Note: Responses to a 100 percent increase in the collateral requirement, with 0.3 persistence in the traded sector and 0.6 persistence in the non-traded sector, in an otherwise-identical economy with $\theta_i = 0.75$, $i = T, N$, in the steady state.

Figure 12: Net foreign assets (Canada)



Data source: Updated and extended data set (1970-2011) of Lane and Milesi-Ferretti (2007)

Figure 13: Impulse responses to persistent credit shocks (Calibration based on Canadian data)



Note: Responses to a 60 percent increase in the collateral requirement, with 0.3 persistence, in the traded sector, and an 80 percent increase in the collateral requirement, with 0.6 persistence, in the non-traded sector.

Table 1: Parameter values for Mexico

Subjective discount factor	β	0.925
Weight on labor	ψ	2.4
Traded-good sector		
Labor share in production	ν_T	0.52
Capital share in production	α_T	0.33
Capital depreciation rate	δ_T	0.10
Borrowing constraint	θ_T	0.5
Non-traded-good sector		
Labor share in production	ν_N	0.64
Capital share in production	α_N	0.33
Capital depreciation rate	δ_N	0.10
Borrowing constraint	θ_N	0.5
Share of traded goods	ω_1	0.23
Home bias	ω_2	0.72
Elasticity of substitution between traded and non-traded goods	ρ_1	0.5
Armington elasticity	ρ_2	1.5
Firm liquidity probability	χ	0.10
Steady-state foreign debt level	$\bar{d}$	0.02
Debt-holding cost parameter	κ	0.1
Number of firm-level productivity	N_ε	3
Persistence	ρ_ε	0.653
Standard deviation	σ_ε	0.014

Table 2: Parameter values for Canada

Subjective discount factor	β	0.96
Weight on labor	ψ	2.20
Traded-good sector		
Labor share in production	ν_T	0.63
Capital share in production	α_T	0.24
Borrowing constraint	θ_T	0.77
Non-traded-good sector		
Labor share in production	ν_N	0.66
Capital share in production	α_N	0.20
Borrowing constraint	θ_N	0.77
Share of traded goods	ω_1	0.50
Home bias	ω_2	0.70
Steady-state foreign debt level	$\bar{d}$	0.009

Note: Remaining parameter values are the same as those in Table 1.