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Essays on Economic Volatility and Financial Frictions

by

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Abstract

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This dissertation consists of three essays in macroeconomics. The first one essay discusses the reasons of Chinese huge foreign reserves holdings. It contributes to the literature of sudden stops, precautionary saving and foreign assets holdings. In the second essay, I study the price volatility of commodities and manufactured goods. I measure the price volatility of each individual goods but not on the aggregated level and therefore the results complete the related study. The third essay explores the correlation between the relative volatility of output to money stock and financial development. It extends the application of financial accelerator model.

In the first essay, I address the question of China's extraordinary economic growth during the last decade and huge magnitude of foreign reserves holdings. The coexistence of fast economic growth and net capital outflow presents a puzzle to the conventional wisdom that developing countries should borrow from abroad. This paper develops a two-sector DSGE model to quantify the contribution of precautionary saving motivation against economic sudden stops. The risk of sudden stops comes from the lagged financial reforms in China, in which banks continue to support inefficient state-owned enterprises, while the more productive private firms are subject to strong discrimination in credit market, and face the endogenous collateral constraints. When the private sector is small, the impact on aggregate output of binding credit constraints is limited. However, as the output share of private sector increases, the negative effect of financial frictions on private firms grows, and it is more likely to trigger a nation-wide economic sudden stop. Thus, the precautionary savings rise and the demand for foreign assets also increases. Our calibration exercise based on Chinese macro data shows that 25 percent of foreign reserves can be accounted for by the rising probability of sudden stops.

The second essay studies the relative volatility of commodity prices with a large dataset of monthly prices observed in international trade data from the United States over the period 2002 to 2011. The conventional wisdom in academia and policy circles is that primary commodity prices are more volatile than those of manufactured products, although most

existing studies do not measure the relative volatility of prices of individual goods or commodities. The literature tends to focus on trends in the evolution and volatility of ratios of price indexes composed of multiple commodities and products. This approach can be misleading. The evidence presented here suggests that, on average, prices of individual primary commodities are less volatile than those of individual manufactured goods. Furthermore, robustness tests suggest that these results are not likely to be due to alternative product classification choices, differences in product exit rates, measurement errors in the trade data, or the level of aggregation of the trade data. Hence the explanation must be found in the realm of economics, rather than measurement. However, the challenges of managing terms of trade volatility in developing countries with concentrated export baskets remain.

The third essay tries to understand why the relative volatility of nominal output to money stock is negatively related to countries' financial development level from cross-country evidence. In the paper I modify Bernanke et al. (1999)'s financial accelerator model by introducing the classic money demand function. The calibration to US data shows that the model is able to replicate this empirical pattern quite well. Given the same monetary shocks, countries with poorer financial system have larger output volatility due to the stronger effect of financial accelerator mechanism.

To my family, who made it possible,
and to my dearest Liugang, who made it happen.

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Chapter 1

Capital Misallocation, Sudden Stop and Foreign Reserves in China

1.1 Introduction

The rising stocks of foreign reserves in emerging economies in the last decade have stimulated a considerable debate both in policy institutions and academic circle, because it has been considered as a major force of global imbalance and housing price bubble. The reserves to GDP ratio has increased from about 4.7 percent in 1995 to 14.7 percent in 2011, and the surge of reserves in the emerging and developing economies is even more striking. The reserves to GDP ratio in those countries has risen from about 8 percent to 27 percent. Initially Dooley et al. (2003, 2004a,b) take the view of modern mercantilism-the accumulation of reserves is part of the development strategy for developing countries that pursue an export-led growth supported by undervalued exchange rates and capital controls. Recently economists are leaning toward the precautionary view of reserves accumulation-emerging economies treat reserves as a war chest against uninsured risks associated with financial frictions and sudden stops (Aizenman and Lee, 2007; Durdu et al., 2009; Obstfeld et al., 2010).

Undoubtedly China has been the focus of this debate because the country has held the largest amount of foreign reserves in the world; one single country has contributed more than 30 percent of total world reserves by 2011. As a result of market oriented reform, China has achieved miraculous economic growth in the last three decades. Meanwhile, the reserves to GDP ratio has increased dramatically to about 48 percent by the end of 2010 (Figure 1.1), which is very high even among those emerging and developing countries. Most of studies on China attribute this feature to the high saving rates (Song et al., 2011), however, no systematic exercise has been carried out to quantify the precautionary motivation of reserve assets except Wen (2011).[1] Our paper develops a quantitative framework where China is

[1] Wen (2011) argues that if entrepreneurs face constant uninsured income risk despite long-run growth,

facing an increasing likelihood of sudden stop due to financial frictions, and thus holding more foreign assets can hedge against the risk of domestic output drop. The rising risk of sudden stop comes from the lagged financial reform in China, in which the state-owned banking system continues to be the channel of transferring household savings into the funds for low-productive state-owned enterprises (SOEs), while the more productive private-owned firms that have been growing rapidly in the last two decades are subject to strong discrimination in credit market.

Figure 1.1 shows the growth of the private firms in China during 1980 and 2010. The gross industrial output share of private-owned firms has increased from 0.1 percent in 1980 to 72 percent in 2010. The rising share of private sector is largely due to its advantage in productivity, compared to SOEs. Based on the three-sector growth accounting framework, Brandt and Zhu (2010) show that the productivity growth of private firms in industrial sector is the driving force of China's economic growth. Moreover, many researches have also shown that SOEs are less profitable and productive (Hsieh and Klenow, 2009; Song et al., 2011). However, capital misallocation is still significant since the low productive SOEs still absorb more than half of the fixed investment. Figure 1.2 presents the liability-to-asset ratio for SOEs and private firms for different firm sizes, based on the firm level Annual Survey of Industrial Production (ASIP) data at 2000. The liability-to-asset ratio is much higher for SOEs than private firms, irrespective of firm sizes, indicating that private firms have less access to external credits.[2]

This paper develops a two-sector DSGE model where the probability of sudden stop is endogenous due to the stochastic binding of credit constraints on private firms. SOEs do not have credit constraints, however, exogenous shocks from productivity, imported goods prices, and borrowing cost may trigger the credit constraints on private firms, and make these firms invest and produce less. If these firms save more, then credit constraints are less likely to binding in future, and savings in foreign assets can hedge the risk of sudden drop in domestic outputs. When the private sector is small, the impact on aggregate output of binding credit constraints is limited. However, as the private sector grows, the negative impact of financial frictions on private firms becomes worse, and it is more likely to lead to a nation-wide economic sudden stop. Thus, the precautionary savings rise and the demand for foreign assets also increases. Our calibration exercise based on Chinese macro data shows that 25 percent of foreign reserves can be accounted for by the rising probability of sudden

then their marginal propensity to saving will increase as their incomes grow. The intuition is simple since a constant income risk implies that the volatility of absolute income level is increasing over time.

[2]The pattern is robust to other years as well. Note the ASIP data includes all SOEs and private firms with revenues above 5 million RMB. Since small firms are less likely to get bank loans, thus we underestimate the liability-to-asset ratio for SOEs for the group of small firm size. Moreover, we also notice that for the same type firms, the liability-to-asset ratio has an inverse U shape with their sizes. As firms grow, it becomes easier to get loans. But when their sizes reach a certain level, their external finance demand seems to decline perhaps because they have sufficient internal funds.

stop.

Our study also shows that improvement of financial constraints on private firms will reduce the risk of sudden stop significantly, as well as the precautionary saving in foreign reserves. This finding has important policy implication for the Chinese government. To ease the external imbalance of Chinese economy, the government needs to remove the barriers to credit market for private firms in future.

Our paper is close to Mendoza (2010) and Durdu et al. (2009) where they also argue that the high stocks of foreign reserves held by emerging economies act as a war chest against the risks of sudden stop. However, their models do not have two sectors in which they have different access to credit market, thus there is no capital misallocation across sectors or composition effect of production and probability of sudden stop. In this sense, our research is also complementary to the literature of capital misallocation (Hsieh and Klenow, 2009; Song et al., 2011), in which most of current studies focus on the impact of capital misallocation on aggregate productivity. However, this paper shows that capital misallocation also has implications on economic fluctuations.

We discuss the related literature in section 1.2 and China's foreign debts, capital flows and foreign exchange reserves in section 1.3. Section 1.4 discusses the model set up and how to solve it. Section 1.5 summarizes the parameters' estimation and introduces the exogenous shocks to the model. Section 1.6 presents the simulation results for China's case and in section 1.7 we conclude.

1.2 Literature Review

The rising stocks of foreign reserves in emerging economies in the last decade have prompted a considerable debate. Among these explanations, Dooley et al. (2003, 2004a,b) take the view of modern mercantilism-the accumulation of reserves is part of the development strategy for developing countries that pursue an export-led growth supported by undervalued exchange rates and capital controls. They also claim that official capital outflows in the form of accumulation of reserve asset are not only a necessary policy to maintain the undervalued exchange rates, but also serve as a "collateral" for encouraging foreign direct investment.

However, this explanation may not hold for the case of China. First, it is unlikely to maintain undervalued exchange rates for a median run or long run by using monetary policy, as shown in many studies that monetary policies usually do not have long run effect on exchange rates and outputs (Aizenman and Lee, 2008). Moreover, Cheung et al. (2007) have not found statistical significant evidence showing that China's currency is undervalued, in terms of the deviation of the price level from the international trend, based on a detailed examination of the price level data for a panel of more than 100 countries over the period of 1975-2004. Second, the impact of undervalued exchange rates on trade surplus is not uncontroversial. The extant literature studying the price and income elasticities of Chinese trade flows are relatively small, if there was a consensus among researchers (Cheung et al., 2010; Xing, 2012). In fact, previous research has indicated a mixed evidence of the effect of an appreciation of the Renminbi on Chinese trade flow, and sometimes researchers even find a wrong sign of the exchange rate elasticity on imports (e.g. see the discussion in Thorbecke and Smith (2012)). One important reason is that processing trade in China contributes about a half to Chinese total trade volume, so a large portion of Chinese imports is for re-export. An appreciation of the RMB that reduces exports will also reduce imports that are used to produce products for re-export. Thus, the impact of exchange rates on trade balance is ambiguous. Third, a systematic comparison of precautionary versus mercantilist views of foreign reserves requires a detailed econometric analysis. Based on a panel of 49 developing countries including China over the period 1908-2000, Aizenman and Lee (2007) have found supporting evidence for precautionary motives, while the role of mercantilism is quantitatively limited.

The second possible explanation of rising reserves in China is international portfolio diversification. In the last three decades, China has grown from a neglectable player in the world market to the largest exporter in the world. However, residential Chinese still have limited access to foreign assets, due to the government capital control. Thus, as an alternative way to diversify the country's portfolio, it might be optimal for the government to increase the holdings of foreign reserves. However, this portfolio diversification view cannot stand after a careful examination. The objective of portfolio diversification is to maximize the expected return of asset holdings; however, the dramatic accumulation of reserves by the Chinese government was accompanied by a significant depreciation of the U.S. dollar in the last decade. Because the majority of reserve assets are in U.S. dollar and highly liquid government bonds with low returns, the capital loss due to the depreciation of the dollar is tremendous.[3] Moreover, this capital loss is even foreseeable because in early 2004 the president of Federal Reserves, Alan Greenspan delivered a warning message that China was facing an increasing US dollar "concentration risk" as its reserves increased quickly. It is difficult to reconcile the low return of the dollar assets and the fast accumulation of reserves, if precautionary incentive does not play a significant role.

The third popular explanation is the "saving glut" hypothesis (Caballero et al., 2008a). Our model also follows this line to explain the rising saving rate and foreign reserves, and we also note that there is no shortage of theories of savings behavior in the literature.

China's national saving rates have been increasing from 38 percent in 2000 to 53 percent in 2007 (Yang et al., 2011). We observe the similar pattern in the experiences of the East Asian economies, such as Japan in the 1970s and Korea and Taiwan in the 1980s, as well

[3] A back-of-the-envelope calculation suggests that the capital loss of Chinese reserves due to the dollar depreciation since 2005, can easily exceed 5 percent of its annual GDP: $830 * 0.7 * (1 - 6.3/8.1)/2400 = 5.3$ percent, where 830 billion dollars were the reserves by the end of 2005, 70 percent is the proportion of the U.S. dollar assets in the reserves (Sheng, 2011), 8.1 was the RMB/dollar rate at the end of 2005, 6.3 is the current exchange rate of RMB, and 2400 billion dollars was China's nominal GDP in 2005.

as other BRIC countries (Brazil, Russia, India, and China) in recent years. Thus, the co-movement of high economic growth and high saving rate is not new to China. This presents a puzzle to the classical Life Cycle Hypothesis (Modigliani, 1970; Modigliani and Cao, 2004), because it predicts that households tend to save less when they expect high income growth in future. Thus, Chamon and Prasad (2010) argue that because Chinese government did not provide systematic health insurance and unemployment insurance, household expenditure on health care, education and housing is rising as well. This uninsured income risk and unexpected expenditures render the Chinese households to save more even though their incomes increase.[4] Wen (2011) develops a quantitative model showing that this precautionary saving motivation can account for the rising trade surplus and foreign reserves in China as well.

Moreover, Wei and Zhang (2011) provide a novel and interesting theory to account for the rising saving rates in China. They argue that as the sex ratio (the number of men per woman in the premarital cohort) rises, families with sons raise their saving rate to promote their sons' standing on marriage market. They show that this unbalanced sexual bias can account for about half of the actual increase in the household savings rate during 1990 and 2007. Based on this idea, Du and Wei (2010) develop a quantitative OLG model of open economies, and their calibration exercise show that the cross country difference in sex ratio can account for more than 1/2 of the actual current account imbalances observed in the international data.

Our explanation relies on precautionary saving incentive, but emphasizes on the role of financial friction. In this sense our research is close to Durdu et al. (2009), which argue that emerging economies are practicing a New Mercantilism that takes foreign reserves as a war chest against future economic sudden stops due to debt limit constraint in a more financial integrated world. Because reserves accumulation will decrease the probability of sudden stops in the long run, emerging economies prefer to hold more foreign assets although the return might be very low. The authors find that financial globalization and risk of sudden stop may account for the rising reserves in emerging economies; however, output volatility is not the driving force of precautionary saving since the data for countries experienced with sudden stops in history shows that their output volatility did not increase substantially before sudden stops.

Jeanne and Ranciere (2011) develop a tractable model of the optimal level of foreign reserves for a small open economy hedging against sudden stops in capital inflows. However, different from our model where the probability of sudden stop is endogenous, they treat foreign reserves as a state-contingent insurance contract that helps consumers to smooth

[4] Recently, Song and Yang (2010) develop an explanation to reconcile the co-movement of saving rates and economic growth with the Life Cycle theory. They argued that in fast-growing economies, the younger cohorts earn much more than the elders as they enter labor market, but their income growth rates are lower than the elders'. This flatten life-time income profile encourages the younger cohorts to save more, thus the aggregate household saving rate also increases as the aggregate income increases.

their consumptions between their sudden stop state and normal state with pre-specified probabilities. They find that the reserves accumulation in emerging market Asia can be explained only if these countries have a high level of risk aversion or a large anticipated output drop of sudden stops. Their calibration implies an optimal level of reserves of 9.1 percent of GDP.

Obstfeld et al. (2010) extend this precautionary saving motivation and focus on the role of foreign reserves in hedging the risk of domestic financial instability and exchange rates in a world of rising financial globalization. The central banks of emerging economics attempt to ease domestic illiquidity by acting as lenders of last resort, in the case of dramatic and vast capital flight due to various reasons including economic sudden stops and large devaluation of exchange rates. This explanation is one of possible reasons for China's huge reserves, but quantitatively it is not sufficient as the authors admitted that their empirical model left a substantial fraction of China's reserves unexplained in 2003-2004, however, it is the time that China's reserves accumulation started to accelerate.

Our research is also related to Song et al. (2011) where financial frictions play a central role in misallocation of capital between state-owned firms and private firms. In their model, more productive private firms have more severe credit constraints and the banking system in China prefers state-owned firms. However, saving in foreign assets in their model is mechanical as state-owned firms shrink and their demand for bank loans decreases, thus banks can only hold foreign reserves as their assets. In our model, foreign reserves are used to hedge domestic production risk of sudden stop, thus this paper is complementary to their studies.

1.3 External Sector in China

The risk of sudden stop is certainly associated with the country's exposure to foreign capital market, especially short term capital flows. Moreover, if the governments plan to use foreign reserves to hedge against the risk of massive capital outflow and economic sudden stops, then the majority of reserves must be highly liquid assets. This section provides a careful examination of China's external sector including the foreign debts, capital flows, and composition of foreign reserves. As a result, we find that the private sector in China essentially involved significantly in the foreign capital inflow, both in terms of foreign direct investment and short term foreign debts, and the main component of reserves is highly liquid government bonds.

1.3.1 Foreign Debts

China has been very cautious about taking on external debt. There has been little sovereign borrowing and enterprises have been discouraged from taking on external debt except for foreign owned enterprises. As a result, although the stocks of external debt significantly increased, the ratio of external debt stock over GDP has never exceeded 20 percent since 1981 (Table 1.1 and Figure 1.3). Since GDP includes a large portion of nontradeable goods, sometimes people prefer to use the ratio of external debt to export goods and services (tradeable goods) as a measure of countries' debt-paying ability. The third row in Table 1.1 presents this index indicating a decline of the relative size of external debts since 2001, and the index of China was below the average of emerging economies. However, since processing exports contribute about a half of aggregated trade in China, and their value added is small. Thus, we also compute the ratio of external debt to ordinary export, and this index is much higher; however, it declined over time as well. The common declining pattern in these three indices implies that the Chinese government aimed to control the size of external debt, particularly after the East Asian financial crisis. Given the limited size of external debt, it seems that one does not need to worry about China's external debt; however, a close examination hints that this might not be true.

First, it is not just the level of external debt but also the maturity structure and types of debts that have been shown to be associated with currency and financial crisis. Countries that have more short-term debt relative to long-term debt tend to be more susceptible to such crisis. At this point, one significant change is that the share of short-term debt in China's total external debt has risen dramatically, from 9 percent in 2000 to an unprecedented level 63 percent in 2011. Moreover, a significant part of this rising in the relative importance of short-term debt since 2001 can be accounted for by the surge in trade credits.[5] Trade credits contributed 27 percent of total external debt in 2001, and the share of trade credits has increased up to 36 percent. In addition, many external debt borrowed by financial institutions are also related to trade, such as Usance Credit. According to a recent report by the State Administration of Foreign Exchange, trade credit contributed about 84 percent of the rising short-term debt during 2001 and 2010 (SAFE, 2010, p.47.).

One important feature of the rising external debt inflow is that it is mainly driven by the private sector. The external debts taken by the Chinese government have been kept at a stable level and thus its share in debt stocks decreased from about a quarter in 2001 to only 5 percent. Even if the Chinese-funded financial institutions are considered as a part of government sector, the private sector still contributed more than 60 percent of total external debts in recent years because trade credits are also mainly driven by private firms. In particular, within the private sector, foreign funded enterprises play a significant and active role in taking on registered external debts, partly because they have better access to global financial market, partly because the Chinese government has more restrictive policies for Chinese-funded firms to borrow overseas. Chinese owned private firms are more likely to use trade credits to finance their liquidity because the government regulation on trade credit

[5] The statistics of short-term debts are not comparable before and after 2001, because trade credits within 3 months were not counted in the short term debts until 2001. Thus, the short term debts before 2001 were underreported.

is relatively limited, compared with those restrictions on registered debt.

Overall, the stock of external debt itself may not be the source of concern. However, the maturity structure of external debt and its concentration on trade credits and private sector require particular attention. Because the Chinese currency RMB is not convertible, the majority of foreign debts are in foreign currency, particularly in US dollar. If there occurred a short-term liquid shock on external debts, it would certainly hurt China's exports in short run, and further on foreign direct investment in the long run as well. This feature is very similar to developing countries that have experienced sudden stops, such as Malaysia and Korea in 1997. Given the important role of export and FDI in promoting economic growth in China, it might not be groundless to suspect a financial or currency crisis. In fact, the worrisome about a hard-landing of China's economy never ends in newspapers and media.

1.3.2 Capital Flows and Reserve Asset

The Chinese government took a conservative approach to the capital flow liberalization. In the last two decades the country was successful in encouraging foreign capital inflows in the form of direct investment, as it has emerged as the largest FDI receipting country among developing countries. Table 1.2 shows that inward FDI has contributed about 60 percent of total stocks of capital inflow during 2004 and 2011. A longer period covering 1982-2011 in Figure 1.4 shows that the annual FDI inflow is more important in 1990s than in 2000s, and other investments including trade credits, bank loans and currency and deposits were catching up in recent years, but the share of portfolio investment kept stable. This implies that the Chinese government was gradually lifting the capital controls in financial sector, but took a prudential step in liberalizing the restrictions on portfolio investment.

People do not worry about the current pattern of Chinese capital inflows, given its strong regulations and controls on financial capital. The problem is how to liberalize the capital and financial account and its embedded risk of changes of international investment position after financial liberalization.[6]

Table 1.2 also shows that the majority of China's foreign assets are reserve asset, which on average contributed about 67.5 percent to total asset during 2004 and 2011. Direct investment abroad, porfolio and other investments play a minor role in its asset portfolio. Most of reserve assets are foreign exchange reserves held by the central bank. This is partly because the Chinese government had regulation on the holdings in foreign assets of residential households and domestic firms, partly because investors expected the RMB would appreciate in the long run, thus the central bank had to buy foreign assets at the given exchange rate.

Although the Chinese government does not provide information of currency composition and portfolio of its official foreign reserves, researchers have shown China held about two-thirds of its foreign exchange reserves in the U.S. dollar and more than one fifth in the

[6]See He et al. (2012) for a detailed discussion of the impact of capital account liberalization on China's capital flows, international investment position and the value of the Chinese RMB.

euro in 2007. These investments earned an average 3 percent annual rate of return (Sheng and Zhao, 2007; Sheng, 2011). Moreover, according to the report by U.S. Department of the Treasury on foreign portfolio holdings of U.S. Securities, China has been the largest investing country in holding U.S. securities by the end of June 30, 2011. The total Chinese holdings are 1,726 billion dollars, accounting for 54 percent of the Chinese foreign reserves (Table 1.3). Moreover, there are 90.5 percent of long-term debt, 0.3 percent of short-term debt, and 9.2 percent of equity. Overall 75.7 percent of U.S. securities holdings are government treasury bonds. This is consistent with Setser and Pandey (2009) that treasury bonds are the most important asset in the basket of Chinese reserves. The portfolio of reserves in other currencies is also similar. Thus, the Chinese reserves are high liquid asset with low return.

The discussion above presents an interesting pattern of China's capital flow. China has received massive physical foreign capitals and those foreign direct investments are usually long term investments, but yield considerable higher return to foreign investors. Moreover, the majority of foreign debts are short term debts to finance the export and foreign owned firms. Given the vital role of FDI and export in promoting Chinese economic growth, capital inflows seems to play an important role for China to maintain its high economic growth rate. Meanwhile, China has invested tremendous low return but high-liquid assets such as government bonds, implying that the Chinese government may use reserves asset as an insurance to against economic sudden stops, for instance, the output drop due to capital outflow.

1.4 Model

1.4.1 Preference

This section develops a two-sector DSGE model of a small open economy based on Mendoza (2010), in which the more productive private sector faces endogenous collateral constraints while the state-owned sector does not. We start with the basic set up of household preference. As in a basic business cycle model, households choose consumption and saving, labor supply and labor allocation between two sectors. The utility is based on stochastic sequences of consumption c_t and labor input $l_{s,t}$ and $l_{p,t}$. The subscript "s" stands for state-owned firms, while subscript "p" indicates private firms. The utility function is Stationary Cardinal Utility function from Epstein (1983) as follows:

$$\begin{aligned} max \quad & E_0[\sum_{t=0}^{\infty} exp\{-\sum_{\tau=0}^{t-1} \rho(c_\tau - N(l_{s,\tau}+l_{p,\tau}))\} u(c_t - N(l_{s,t}+l_{p,t}))] \\ s.t. \quad & B_t + c_t = (1+R_t^d)B_{t-1} + w_t(l_{s,t}+l_{p,t}) \\ & lim_{t\to+\infty}(\Pi_{l=1}^{t}(1+R_l^d))B_t = 0 \end{aligned}$$

where w_t is wages, B_t is household savings, and R_t^d is the return on domestic assets. By this setting, we assume that households only hold domestic assets. This assumption is reasonable for the case of China since most of foreign assets are in the hand of Chinese government. This assumption can be easily relaxed as we allow households to hold foreign assets as well.

Here the functional forms of time preference $\rho(\cdot)$ and utility function $u(\cdot)$are:

$$\begin{aligned}\rho(c_t - N(l_t)) &= \gamma[Ln(1 + c_t - \frac{l_t^\omega}{\omega}]\\ u(c_t - N(l_t)) &= \frac{[c_t - \frac{l_t^\omega}{\omega}]^{1-\sigma}}{1-\sigma}\end{aligned}$$

where $l_t = l_{s,t} + l_{p,t}$.

The Lagrangian of this maximization problem is:

$$\begin{aligned}L &= E_0 \sum_{t=0}^{\infty} exp\{-\sum_{\tau=0}^{t-1} \rho(c_\tau - N(l_{s,\tau} + l_{p,\tau}))\}(u(c_t - N(l_{s,t} + l_{p,t}))\\ &+ \lambda_t(-B_t - c_t + (1 + R_t^d)B_{t-1} + w_t(l_{s,t} + l_{p,t})))\end{aligned}$$

λ_t is the Lagrange multiplier of the budget constraint. The first order conditions (FOCs) are:

$$\begin{aligned}\frac{\partial L}{\partial c_t} &= u^{'}(\cdot) - \lambda_t = 0\\ \frac{\partial L}{\partial l_{s,t}} &= u^{'}(\cdot)(-\frac{\partial N}{\partial l_{s,t}}) + \lambda_t w_t = 0\\ \frac{\partial L}{\partial l_{p,t}} &= u^{'}(\cdot)(-\frac{\partial N}{\partial l_{p,t}}) + \lambda_t w_t = 0\\ \frac{\partial L}{\partial B_t} &= -\lambda_t + exp\{\rho(c_t - N(l_t))\}(1 + R_{t+1}^d)\lambda_{t+1} = 0\end{aligned}$$

Eliminate λ_t from the first two equations, we get $w_t = (l_{s,t} + l_{p,t})^{\omega-1}$. Thus, the labor supply elasticity is given by $\frac{1}{\omega-1}$.

1.4.2 Production

There are two sectors in the economy, private sector and stated-owned sector, both of them produce the same tradable goods. We assume homogeneous firms within each sector, and for each sector, the production requires capital k_t, labor and imported inputs v_t to produce the same tradable goods. The production functions are both constant return to scale, and the price of the tradable goods is normalized to 1. The difference in productions between state-owned and private firms is the technologies. Their production functions are the following:

$$F_{s,t}(k,l,v) = \bar{A}\epsilon_t^A k_{s,t}^{\beta} l_{s,t}^{\alpha} v_{s,t}^{\eta} \tag{1.1}$$

$$F_{p,t}(k,l,v) = \zeta\bar{A}\epsilon_t^A k_{p,t}^{\beta} l_{p,t}^{\alpha} v_{p,t}^{\eta} \tag{1.2}$$

Because ϵ_t^A is the random exogenous technology shocks with mean zero, the mean values of technologies are $\bar{A}$ and $\zeta\bar{A}$ for SOEs and the private firms respectively. If ζ is larger than 1, then it implies that private firms are more productive than the state-owned firms.

There are adjustment costs of capital for firms. For simplicity we assume both sectors have the same convex adjustment costs. Thus, the gross investment functions are:

$$\begin{aligned}
I_{s,t} &= i_{s,t} + \Phi(i_{s,t}, k_{s,t}) = k_{s,t+1} - (1-\delta)k_{s,t} + \frac{a}{2}\frac{(k_{s,t+1} - k_{s,t})^2}{k_{s,t}} \\
&= k_{s,t+1} - (1-\delta)k_{s,t} + \frac{a}{2}\frac{(i_{s,t} - \delta k_{s,t})^2}{k_{s,t}} \\
I_{p,t} &= i_{p,t} + \Phi(i_{p,t}, k_{p,t}) = k_{p,t+1} - (1-\delta)k_{p,t} + \frac{a}{2}\frac{(k_{p,t+1} - k_{p,t})^2}{k_{p,t}} \\
&= k_{p,t+1} - (1-\delta)k_{p,t} + \frac{a}{2}\frac{(i_{p,t} - \delta k_{p,t})^2}{k_{p,t}}
\end{aligned}$$

where $i_{s,t}$ is the net investment and the $\Phi(i_{s,t}, k_{s,t})$ is the adjustment costs.

For the state-owned firms, they borrow the capital from the households and borrow working capital loans from foreign lenders which is a fixed ratio (ϕ) of the sum of the labor and imported input cost. At the end of each period, the firms pay household the domestic interest rate R_t^d and foreign lenders the world real interest rate R_t. It has a random shock around the steady value, $R_t = \bar{R}\epsilon_t^R$. As for the imported input, the price is $p_t = \bar{p}\epsilon_t^p$. $\bar{p}$ is the steady value and ϵ_t^p represents the exogenous shocks to the imported input price. State-owned firms maximize the present value of the cash flow:

$$max \quad \sum_t (\Pi_{l=1}^t (1+R_l^d)^{-1})(F_{s,t} - w_t l_{s,t} - p_t v_{s,t} - \phi R_t(w_t l_{s,t} + p_t v_{s,t}) - I_{s,t})$$

subject to the capital accumulation constraint

$$k_{s,t+1} = (1-\delta)k_{s,t} + i_{s,t}$$

The Lagrangian of the problem is:

$$\begin{aligned} L &= \sum_t (\Pi_{l=1}^t (1+R_l^d)^{-1})(F_{s,t} - w_t l_{s,t} - p_t v_{s,t} - \phi R_t (w_t l_{s,t} + p_t v_{s,t}) \\ &\quad - i_{s,t} - \frac{a}{2}\frac{(i_{s,t} - \delta k_{s,t})^2}{k_{s,t}} + q_t(i_{s,t} + (1-\delta)k_{s,t} - k_{s,t+1})) \end{aligned}$$

The q_t is Tobin's Q, or the shadow value of capital. The FOCs are:

$$\frac{\partial L}{\partial l_{s,t}} = \alpha\frac{F_{s,t}}{l_{s,t}} - w_t - \phi R_t w_t = 0 \tag{1.3}$$

$$\frac{\partial L}{\partial v_{s,t}} = \eta\frac{F_{s,t}}{v_{s,t}} - p_t - \phi R_t p_t = 0 \tag{1.4}$$

$$\frac{\partial L}{\partial i_{s,t}} = -1 - a\frac{(i_{s,t} - \delta k_{s,t})}{k_{s,t}} + q_t = 0 \tag{1.5}$$

$$\begin{aligned} \frac{\partial L}{\partial k_{s,t+1}} &= -q_t + \frac{1}{(1+R_{t+1}^d)}(\beta\frac{F_{s,t+1}}{k_{s,t+1}} + a\delta\frac{(i_{t+1} - \delta k_{s,t+1})}{k_{s,t+1}} \\ &\quad + \frac{a}{2}(\frac{i_{t+1} - \delta k_{s,t+1}}{k_{s,t+1}})^2 + q_{t+1}(1-\delta)) \end{aligned} \tag{1.6}$$

By equations (1.3), (1.4), (1.5) and (1.6), we get

$$\alpha\frac{F_{s,t}}{l_{s,t}} = w_t(1+\phi R_t) \tag{1.7}$$

$$\eta\frac{F_{s,t}}{v_{s,t}} = p_t(1+\phi R_t) \tag{1.8}$$

$$\beta\frac{F_{s,t+1}}{k_{s,t+1}} = \delta - q_{t+1} - \frac{a}{2}(\frac{i_{t+1} - \delta k_{s,t+1}}{k_{s,t+1}})^2 + (1+R_{t+1}^d)q_t \tag{1.9}$$

For the private-owned firms, they borrow the working capital loans for not only the cost of labor and imported input, but also for the capital input. The ratio is also ϕ and the interest rate paying back is also R_t. In addition to the regular capital accumulation constraint, the private firms face collateral constraint. The debt they hold cannot exceed a certain portion κ of the capital value. The total debt is composed of the debt in one-period real international bonds b_t and the working capital loans.

$$-q_t^b b_{t+1} + \phi R_t(w_t l_{p,t} + p_t v_{p,t} + q_t k_{p,t}) \leq \kappa q_t k_{p,t+1} \tag{1.10}$$

In this constraint function, q_t^b is the price of bonds and it satisfies $q_t^b = 1/R_t$. If b_t is negative, then the country borrows from abroad.

The maximizing problem is:

$$\begin{aligned} max \quad & \sum_t (\Pi_{l=1}^t (1+R_l^d)^{-1})(F_{p,t} - w_t l_{p,t} - p_t v_{p,t} - q_t k_{p,t} \\ & -\phi R_t (w_t l_{p,t} + p_t v_{p,t} + q_t k_{p,t}) - I_{s,t} - q_t^b b_{t+1} + b_t) \end{aligned}$$

subject to equation (1.10) and the one below

$$k_{p,t+1} = (1-\delta)k_{p,t} + i_{p,t}$$

The Lagrangian of the problem is:

$$\begin{aligned} L \;=\; & \sum_t (\Pi_{l=1}^t (1+R_l^d)^{-1})(F_{p,t} - w_t l_{p,t} - p_t v_{p,t} - q_t k_{p,t} - \phi R_t (w_t l_{p,t} + p_t v_{p,t} + q_t k_{p,t}) \\ & -i_{p,t} - \frac{a}{2}\frac{(i_{p,t} - \delta k_{p,t})^2}{k_{p,t}} - q_t^b b_{t+1} + b_t + q_t(i_{p,t} + (1-\delta)k_{p,t} - k_{p,t+1}) \\ & +\mu_t(\kappa q_t k_{p,t+1} + q_t^b b_{t+1} - \phi R_t (w_t l_{p,t} + p_t v_{p,t} + q_t k_{p,t}))) \end{aligned}$$

The μ_t is the Lagrange multiplier of the collateral constraint. The FOCs are:

$$\frac{\partial L}{\partial l_{p,t}} = \alpha \frac{F_{p,t}}{l_{p,t}} - w_t - \phi R_t w_t - \mu_t \phi R_t w_t = 0 \tag{1.11}$$

$$\frac{\partial L}{\partial v_{p,t}} = \eta \frac{F_{p,t}}{v_{p,t}} - p_t - \phi R_t p_t - \mu_t \phi R_t p_t = 0 = 0 \tag{1.12}$$

$$\frac{\partial L}{\partial i_{p,t}} = -1 - a\frac{(i_{p,t} - \delta k_{p,t})}{k_{p,t}} + q_t = 0 \tag{1.13}$$

$$\begin{aligned} \frac{\partial L}{\partial k_{p,t+1}} = & -q_t + \mu_t \kappa q_t + \frac{1}{(1+R_{t+1}^d)}(\beta \frac{F_{p,t+1}}{k_{p,t+1}} - q_{t+1} - \phi R_{t+1} q_{t+1} + a\delta \frac{(i_{t+1} - \delta k_{p,t+1})}{k_{p,t+1}} \\ & + \frac{a}{2}(\frac{i_{t+1} - \delta k_{p,t+1}}{k_{p,t+1}})^2 + q_{t+1}(1-\delta) - \mu_{t+1}\phi R_{t+1} q_{t+1}) \end{aligned} \tag{1.14}$$

By equations (1.11), (1.12), (1.13) and (1.14), we get

$$\alpha\frac{F_{p,t}}{l_{p,t}} = w_t(1+\phi R_t+\mu_t\phi R_t) \tag{1.15}$$

$$\eta\frac{F_{p,t}}{v_{p,t}} = p_t(1+\phi R_t+\mu_t\phi R_t) \tag{1.16}$$

$$\begin{aligned}\beta\frac{F_{p,t+1}}{k_{p,t+1}} &= \delta - q_{t+1} - \frac{a}{2}(\frac{i_{t+1}-\delta k_{p,t+1}}{k_{p,t+1}})^2 + (1+R^d_{t+1})q_t \\ &\quad -\mu_t\kappa q_t(1+R^d_{t+1}+q_{t+1}(1+\phi R_{t+1}+\mu_{t+1}\phi R_{t+1})\end{aligned} \tag{1.17}$$

1.4.3 Solutions

The collateral constraint sometimes binds, and sometimes doesn't bind. Under such a case, we follow Mendoza and Smith (2006)'s nonlinear global solution method to solve it. The endogenous state variables are k_p, k_s and b. We give an evenly spaced distribute grids for those three variables, defined as K_p, K_s, and B. The number of grid points is $NK_p = 30$, $NK_s = 30$ and $NB = 40$. Also we have three random variables to represent different exogenous shocks: import input price shock ϵ^p, international real interest rate shock ϵ^R and technology shock ϵ^A. The shocks follow a joint discrete Markov process. Each shock has two realizations: high and low. Then each state is a combination of realizations of the three shocks $s = (\epsilon^p, \epsilon^R, \epsilon^A)$ and thus we have $NS = 2\times2\times2 = 8$ states, defined as S. Therefore, the model has $NK_p\times NK_s\times NB\times NS$ coordinates, each one is $(k_p, k_s, b, s) \in K_p\times K_s\times B\times S$.

Given the values of $(k_{p,t}, k_{s,t}, b_t, s_t)$, we can solve the values of $l_{p,t}$, $l_{s,t}$, $v_{p,t}$ and $v_{s,t}$. If the collateral constraint (1.10) doesn't bind, then they are decided by the first-order conditions.

$$\alpha\bar{A}\epsilon^A_t k^\beta_{s,t} l^{\alpha-1}_{s,t} v^\eta_{s,t} = (l_{s,t}+l_{p,t})^{\omega-1}(1+\phi R_t) \tag{1.18}$$

$$\eta\bar{A}\epsilon^A_t k^\beta_{s,t} l^{\alpha}_{s,t} v^{\eta-1}_{s,t} = p_t(1+\phi R_t) \tag{1.19}$$

$$\alpha\bar{A}\zeta\epsilon^A_t k^\beta_{p,t} l^{\alpha-1}_{p,t} v^\eta_{p,t} = (l_{s,t}+l_{p,t})^{\omega-1}(1+\phi R_t) \tag{1.20}$$

$$\eta\bar{A}\zeta\epsilon^A_t k^\beta_{p,t} l^{\alpha}_{p,t} v^{\eta-1}_{p,t} = p_t(1+\phi R_t) \tag{1.21}$$

If the collateral constraint (1.10) binds, then

$$-q^b_t b_{t+1} + \phi R_t(w_t l_{p,t} + p_t v_{p,t} + q_t k_{p,t}) = \kappa q_t k_{p,t+1}$$

The equations used to solve for $L_{p,t}$, $v_{p,t}$, $L_{s,t}$ and $v_{s,t}$ are the below two equations and equation (1.18) and (1.19):

$$\alpha\frac{q_t^b b_{t+1}+\kappa q_t k_{p,t+1}}{\phi R} = w_t l_{p,t} = (l_{s,t}+l_{p,t})^{\omega-1} l_{p,t} \tag{1.22}$$

$$\eta\frac{q_t^b b_{t+1}+\kappa q_t k_{p,t+1}}{\phi R} = p_t v_{p,t} \tag{1.23}$$

The private firms cannot get their optimal choice. The labor $l_{p,t}$ and import input $v_{p,t}$ are less than the case without collateral constraint. By comparing the value functions in different combinations of $k_{p,t+1}$, $k_{s,t+1}$ and b_{t+1}, we find the optimal choice which achieves the expected maximum with the transition matrix in eight states. After getting the decision rules under the two cases with and without collateral constraint, we iterate the next period choices to get the convergence of the long-run probability. That is, we will know the probability of observing each coordinate (k_p, k_s, b, s) at any give date t. Based on that, we do the later analysis.

1.5 Calibration

1.5.1 Parameters Estimation

To get the imported input share (η) to total output, we divide the import value by the sum of import value and GDP. The data is from Chinese statistical yearbook 1991-2009 (sheets 6-3 and 2-1). We use the ratio of compensation for workers to the difference of total value added and net taxes on production as the labor share. Then the capital share is just one minus labor share. The data are from flow of funds accounts (physical transaction) in the statistical yearbook from 2004-2008 (sheets 2-30). The labor and capital share (α and β) to total output should be those shares to GDP times the share of GDP to total output (which is just $1-\eta$).

The tax rate (τ) is got by the average ratio of government expenditure to household consumption from 1991 to 2009. The average household consumption share to GDP (c/GDP) is 0.4265 from 1991 to 2009. Here, GDP is in the form of expenditure but not in the form of production.[7]

For the depreciation rate (δ), we estimate it by looking into different parts of capital. The fixed assets are composed of three parts: construction and installation, equipment and instruments and others. The relative ratio of those three parts is 6:3:1.[8] Generally

[7]The values of GDP in the form of production and GDP in the form of expenditure are not consistent in China, but it has no effect here.

[8]We calculate each component's share by the data of investment in fixed assets of 1952-1978, see China statistical yearbook 1984.

constructions last 40 years, and equipments last 20 years.[9] The salvage values are 5%. Thus by $S = (1-\delta)^T$, the depreciation rates for constructions and equipments are 7.2% and 13.9% individually, where S is salvage value, δ is depreciation rate, and T is the magnitude of their life. We assume the depreciation rate of other fixed assets 10%, then the depreciation rate for the whole fixed assets is about 9.5%.[10]

We adopt Perpetual Inventory System to get the total capital stock at constant price. Then we use GDP at current price and GDP index to calculate the GDP values at constant price. Dividing those two items, we can get the ratio of capital stock to GDP which is 2.4587.

With the values of the depreciation rate and the share of capital stock to GDP, we can calculate the world interest rate $\bar{R} = 1 - \delta + \beta Y/K$. The value of $barR$ is 1.073. If we use the values as the paper of Bai et al. (2006) ($\delta = 0.1$ and $K/GDP = 1.67$), then the interest rate is 1.148, which is quite high.

We measure the fraction of working capital loans (ϕ) as the share of total working liabilities to the gross industrial output value. For state-owned firms it is usually 0.5, but it is about 0.3 for private firms.

Although we allow the two sectors can pay different wages to their works, for simplicity we assume the labor elasticity ϕ is the same. Since $\frac{\partial N(l_t)}{\partial l_t} = l_t^{\omega-1} = w_t$, and $w_t = F_{l,t}(k,l,v) = \alpha \frac{F_t}{l_t}$, we can get $l_t^{\omega} = \alpha F_t$, and $lnl_t = \frac{1}{\omega} ln\alpha + \frac{1}{\omega} lnF_t$. By regressing the logarithm of employment on the logarithm of output, we have the labor supply elasticity. The data of total number of employed persons (sheet 1-4) and wages (sheet 1-5) are from China compendium of statistics 1949-2008 (NBS, 2010), and we revise recent years values by statistical yearbook 2011. GDP at constant price is calculated by GDP current value in 1978 and GDP index (1978=100). The calculated labor elasticity is about 4.

We have time series of GDP deflator and import price indices.[11] To get the relative imported input price ($\bar{p}$), we divide import price indices by GDP deflator indices and then compute its average value among different years. But there is one problem. If the base year for the two time series change, then the result will change accordingly. For example, if we use 1993 as the base year, then the average relative import price is 0.95. However, if the base year is 1995 instead, then the result is 1.12. The reason lies in that price indices only give us the relative price change among different years, but cannot be used to do horizontal comparison. Therefore, we adopt an average value of different base years.[12]

The values of capital adjustment coefficient a and CRRA coefficient in utility function σ are just followed the literature, like Mendoza (2010), and others.

The values for the parameter are listed in the Table 3.3. Among those parameters, ϕ, a,

[9] According to the Rule of Fixed Assets Depreciation of State-owned Firms released in 1985 by China's State Council, the life expectancy is about 40 years for constructions and 20 years for equipments.

[10] Our assumption is quite common in literature, see Bai et al. (2006).

[11] GDP deflator is calculated by GDP at current prices and GDP index which is treated as GDP at constant prices.

[12] Here, it is an average of 1993- 2009 since China's customs releases import price data only after 1993.

σ can be used to do parameters robust check. $\bar{A}$ and ζ are adjusted to simulate the model to the real China's economy.

1.5.2 Shocks and Estimation

The shocks are from import input price, real international interest rate and productivity. We let the positive and negative shocks are both one standard deviation from the steady state level.[13]

To calibrate the transition matrix, we also need to get the first order autocorrelations and correlations among shocks for the above three variables. Price indices of imported goods are released by General Administration of Customs of the People's Republic of China. There are two types of import price index. One is the index over the same period of the previous year, and the other is the one which sets last year average 100. Based on those two series we can calculate the import price index which uses the average of a certain year as base (100). Here we use the year 2004 as the base year. As one of the tools to implement monetary policies, the interest rate is controlled by the People's Bank of China (PBoC). The official interest rates of deposits and loans of financial institutions doesn't fluctuate frequently and they are only adjusted when the central bank decides to use monetary policy to manage money flow or just send a signal to the market. Here we find the data of official interest rates of deposits of financial institutions (1 year) and the date when it was adjusted in the monetary policy department of PBoC. We use the yearly average deposit interest rate level as nominal interest rate. Then it is deflated by GDP deflator to get the real interest rate. We use the common methods to decompose the GDP growth rate and calculate the Total Factor Productivity (TFP).[14] We find the correlations among the three variables are small (the absolute value less than 0.12), thus we assume the shocks are independent. Table 1.5 list their standard deviations and first order correlations.

1.6 Results

1.6.1 Long Run Moments of Major Variables

First, let's look at the performance of our model under two cases: without and with collateral constraint. No matter under which cases, they can match the long-run business cycles moments pretty well, which is also the result of the paper Mendoza (2010). Table 1.6 shows the moments for the major economic variables, including GDP, private consumption, investment, net export to GDP ratio and foreign assets to GDP ratio in the real data and

[13]The real interest rate is too volatile, and thus we only apply one tenth of its standard deviation.

[14]The source of data of GDP at constant price, labor, capital stock and shares of capital and labor are the same as previously mentioned.

calibrated models. The real data is from Chinese Statistical Yearbook 2011 and China Compendium of Statistics 1949-2008 (NBS, 2010). The moments here include standard deviation (in percent), standard deviation relative to GDP, correlation with GDP and first-order autocorrelation. In the real data, private consumption is less volatile than GDP and investment is more volatile. The consumption, investment and next exports to GDP ratio all correlated with GDP tightly. But the net export is not counter-cyclical like the analysis in Mendoza (2010). By several countries evidence, Backus and Kehoe (1992) show that in two-thirds of the cases, the correlation with GDP is negative, and in the other cases, the correlation is generally small. Thus the pro-cyclicity of net export in China is not a special thing. In the calibrated models, there is no big difference between the one without collateral constraint and the one with it. They both display the same moments as the empirical evidence. Only for the first-order autocorrelation, the calibrated models have smaller magnitude.

1.6.2 Sudden Stop Event Simulation

In literature, three main empirical regularities define sudden stop: reversals of international capital flows, reflected in sudden increases in net exports and the current account; declines in production and absorption; and corrections in asset prices. Mendoza (2010) and Calvo et al. (2006) use net exports-GDP ratio as 2 percentage points above the mean as the definition of sudden stop states. However, this criterion seems to be not feasible for the case of China given the fact that China's export/GDP ratio increased significantly. Meanwhile, there is no sudden stop event in the past three decades which demonstrates the above three features at the same time in China. China also has current account surplus since 1994, and the surplus is more than 200 billion U.S. dollars in 2011. Thus, it already has significant capital outflow. Thus, in the sense of reversals from capital inflow to outflow, it is unlikely to have sudden stop in China. But it doesn't mean we have no need to worry about. China's output has experienced fast growth in the past thirty years. We all care about its prospect. If it has a dramatic decline, then clearly it will cause many other problems like unemployment, stock market crash and even social instability. Therefore we want to predict the behaviors of other variables when the output declines significantly. Thus in the case of China, we define sudden stop states as those in which the collateral constraint binds with positive long-run probability and the GDP is at least 2 percentage points below its mean.

To see the dynamics of the simulated sudden stop event, we conduct a 10,000 time periods stochastic simulation and then construct a five-year event windows around the sudden stop event.[15] Figure 1.5 shows the dynamics for GDP, private consumption, investment, net exports to GDP ratio, Tobin Q and the three exogenous variables (technology, international interest and import price). For the first four variables, we take logarithm. Then HP filters

[15] The calibrated parameters are based on the yearly data, thus here the time periods are represented by years.

are used to get the deviations from the trends. Among the simulated 10,000 time series, we identify the sudden stop events as the situation in which the collateral constraint binds and GDP is at least one standard deviation below the trend. Unlike the papers in Mendoza (2010) and Calvo et al. (2006), we don't use the net export to GDP ratio (at least one standard deviation above trend) as an identification because China's real situations are quite different from Mexico as we explain in the above paragraph. We depict the median deviation from the trend for each variable around the sudden stop event.

The model predicts that two periods before Sudden Stops GDP and private consumption begin to decline and after that they increase quickly. On the second periods before and after sudden stop, output and consumption are above the trend. But for the investment although it is above trend before the sudden stop event, it cannot recover after two periods. Net export to GDP ratio has the same dynamics as output and consumption. It is still pro-cyclical which is far different from other capital inflow countries. The Tobin's Q's path also has no recovery which might not be a good implication of the calibrated model.

1.6.3 Effects of Relative Productivity

In order to simulate the high growth path in China, we have two choices: increase A or ζ. The increase of A means there is technology improvement in both two sectors, but the relative efficiency doesn't change. The increase of ζ means there is an improvement in relative productivity of the private firms and the technology level of the state-owned firms keeps constant. The combination of these two parameters change is more suitable to the real economy path. But here we want to show the effect of relative productivity. If the parameter ζ increases from 0.9 to 1.6, then the output share of private firms changes from 42% to 73%. It is close to the development path of Chinese private firms in the past two decades (see Figure 1.1). With the increase of productivity of private firms, the corresponding Sudden Stops probability and the international bonds holding both increase (Figure 1.6).

By Figure 1.7, we are confirmed that higher productivity will lead to bigger shares in the total output. Currently the private firms contribute about 70% to the whole production (year 2010). In our calibrated model it links to the productivity coefficient $\zeta = 1.5$. We depict it as a point in Figure 1.7. Also by that figure we can tell higher output share is positively related to the foreign reserve holdings and Sudden Stops probability. Corresponding to the private firms' share, the ratio of foreign reserve holdings to GDP would be 12.4% in 2010. In reality there were 2,847 billion U.S. dollars reserves in China in 2010 and it was 48% of GDP. Our calibration result can explain a quarter of the foreign reserves accumulation. For the unexplained part, the reason may lay in the governments' behavior. Figure 1.8 shows that savings of general governments are more than 40 percent of the total domestic savings from 1992 to 2008. And in some years it exceeds 50 percent. Thus government's behavior plays an important role in explaining foreign reserves. In the future work, it would be helpful to include government into our model.

1.6.4 Effects of Financial Development

To see the effect of financial improvement, we increase the value of κ. κ is the ratio of firms' maximum debt holding to its total capital wealth. Thus when it increases, it means the collateral constraint for the private firms loosens. Figure 1.9 shows with the decreasing financial constraint or better financial environment, the ratio of sudden stop probability and foreign reserve holdings to GDP decrease too. It confirms our hypothesis that financial constraint is one of the reasons that private firms hold foreign reserves. With the improvement in financial restrictions, private firms can get the loans easily from domestic lenders, the capital allocation will be more efficient and the precautionary saving part of firms will decrease.

1.7 Conclusions

In this paper we discuss the puzzle that China has very large growth rates and huge magnitude of foreign reserves accumulation. We use a two-sector DSGE model to explain the private firms' incentive of precautionary savings. Then by calibration the major parameters from Chinese real data, we simulate the model and get some useful results. As the relative productivity of private firms to state-owned firms increases, the private firms' share in total output rises. They become the driving force of economic growth. And given that private firms have collateral constraint and capital allocation is less efficient, the probability of Sudden Stops increases and foreign reserves holding increases too. In the real case of China's macro economy the private firms contribute about 70% of industry output.[16] Using the calibrated value of relative productivity of private firms corresponding to their output share, the Sudden Stops probability is 3.8%, and the share of foreign reserves holdings to GDP is 12.4%. Our model can explain about 25% of China's reserves holding. To interpret such a result, one way is that there must be other reasons that contribute a lot to such a huge amount of foreign reserves and the other one is that China's reserves holding is quite excessive.

In our model, we let the relative price of import to output is an exogenous shock. But given China is a big country in terms of total output and trade volume, the import and export price will be changed accordingly by China's import and export volume. Thus a small open economy hypothesis may need to be revised to fit China's real case.

[16] Here it is only the industry output, and it doesn't include other sectors.

Table 1.1: China's External Debt, 2001-2011

Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Total											
In billions of U.S. dollars	203.3	202.6	219.4	263.0	296.5	338.6	389.2	390.2	428.6	548.9	695.0
In % of GDP	15.3	13.9	13.4	13.6	13.1	12.5	11.1	8.6	8.6	9.3	9.5
In % of export of goods and service	67.9	55.5	45.2	40.1	35.4	31.9	29.0	24.7	32.1	31.3	30.3
In % of ordinary export	171.0	139.1	111.6	99.1	85.8	73.8	64.8	51.8	69.9	65.7	65.5
By maturity (in % of total debt)											
Short_term	41.2	43.0	46.9	52.7	57.9	58.8	60.6	58.0	60.5	68.4	72.1
Median and Long_term	58.8	57.0	53.2	47.3	42.1	41.2	39.5	42.0	39.5	31.6	27.9
By type (in % of total debt)											
Trade Credits	27.0	28.4	28.4	30.8	35.8	35.3	38.2	33.2	37.7	38.5	35.9
Registered external debt	73.0	71.6	71.6	69.2	64.2	64.7	61.8	66.8	62.3	61.5	64.1
Registered external debt by debtor (in % of total debt)											
Ministries under the State Council	24.5	24.9	24.1	12.8	11.1	10.1	9.0	8.5	8.6	7.1	5.4
Chinese-funded Financial Institutions	16.9	17.9	17.2	25.1	20.6	20.8	20.6	21.2	21.9	24.7	30.5
Foreign-funded Financial Institutions	8.4	7.4	9.5	12.0	13.8	14.7	11.9	11.2	8.9	8.8	7.8
Foreign-funded Enterprises	17.3	16.4	17.2	17.0	17.0	18.0	19.0	24.6	21.7	20.0	19.6
Chinese-funded Enterprises	5.5	4.9	3.5	2.3	1.5	1.0	1.2	1.1	1.0	1.1	0.9
Others	0.4	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0

Source: China State Administration of Foreign Exchange and author's calculation. The trade credit is from survey data, so it may not match with the trade credit in the Balance of Payment.

Table 1.2: Structure of China International Investment Position

Year	2004	2005	2006	2007	2008	2009	2010	2011
Net Asset (Billion $)	276	408	640	1188	1494	1491	1688	1775
Asset (Billion $)	929	1223	1690	2416	2957	3437	4119	4718
Direct Investment Abroad (%)	5.7	5.3	5.4	4.8	6.3	7.2	7.7	7.7
Portfolio Investments (%)	9.9	9.5	15.7	11.8	8.5	7.1	6.2	5.5
Other Investments (%)	17.8	17.7	15.0	19.4	18.7	14.4	15.3	17.8
Reserve Asset (%)	66.6	67.5	63.9	64.0	66.5	71.4	70.8	69.0
Liability (Billion $)	653	816	1050	1228	1463	1946	2431	2943
Direct Investment in China (%)	56.5	57.8	58.5	57.3	62.6	67.5	64.6	61.3
Portfolio Investments (%)	8.7	9.4	11.5	11.9	11.5	9.8	9.2	8.4
Other Investments (%)	34.8	32.8	30.0	30.8	25.9	22.7	26.2	30.3

Source: China State Administration of Foreign Exchange and author's calculation.

Table 1.3: Chinese Holdings of U.S. Securities

Year	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Total	181.5	255.5	341.0	527.3	698.9	922.0	1205.1	1464.0	1610.7	1726.6
Equity	4.0	1.9	2.5	2.5	3.8	28.5	99.5	77.7	126.5	158.8
Long-term debt	164.7	250.1	320.3	485.0	677.9	870.5	1075.3	1226.4	1479.3	1562.9
Short-term debt	12.7	3.5	18.2	39.7	17.2	23.0	30.3	159.9	4.9	4.9
China foreign reserve	286.4	403.3	609.9	818.9	1066.3	1528.2	1946.0	2399.2	2847.3	3181.1
Share of US securities (%)	63.4	63.4	55.9	64.4	65.5	60.3	61.9	61.0	56.6	54.3

Source: U.S. Department of the Treasury and author's calculation.

Table 1.4: Values of Parameters

Parameters	Values	Explanations
η	0.17044	imported input share to total output
α	$0.5865 * (1 - \eta)$	labor share to total output
β	$0.4135 * (1 - \eta)$	capital share to total output
τ	0.34256	tax rate
c/GDP	0.42974	household consumption share to GDP
δ	0.095	depreciation rate
$\bar{R}$	1.073	world interest rate
ϕ	0.5	fraction of working capital loans
ω	4	labor supply elasticity
$\bar{p}$	1.01	imported input price
a	1	capital adjustment coefficient
σ	2	CRRA coefficient in utility function

Table 1.5: Moments for Exogenous Variables

Variable	Standard deviation	First-order autocorrelation
Import goods price	0.054	0.961
Real interest rate	0.234	0.869
Total factor productivity	0.070	0.316

Source: General Administration of Customs of the People's Republic of China, People's Bank of China, National Bureau of Statistics of China and author's calculation.

Table 1.6: Comparison of Business Cycle Moments in the Model and Data

Variable	Standard deviation	Standard dev. Relative to GDP	Correlation with GDP	First-order autocorrelation
I. In the Data				
GDP	0.08	1.00	1.00	0.90
Private consumption	0.08	0.96	0.96	0.90
Investment	0.11	1.39	0.90	0.89
Net exports-GDP ratio	0.02	0.22	0.76	0.79
Fixed capital investment	0.12	1.46	0.84	0.89
II. In the Calibrated Model without Collateral Constraint				
GDP	0.10	1.00	1.00	0.38
Private consumption	0.07	0.68	0.91	0.61
Investment	0.13	1.23	0.19	0.19
Net exports-GDP ratio	0.06	0.56	0.65	0.09
b/GDP	0.07	0.70	-0.10	0.74
III. In the Calibrated Model with Collateral Constraint ($\kappa = 0.2$)				
GDP	0.10	1.00	1.00	0.40
Private consumption	0.07	0.67	0.91	0.62
Investment	0.14	1.40	0.21	0.26
Net exports-GDP ratio	0.06	0.56	0.62	0.09
b/GDP	0.07	0.70	-0.09	0.74

Note: The source of real data is Chinese Statistical Yearbook 2011 and China Compendium of Statistics 1949-2008 (NBS, 2010). We take logarithm for all the variables except for the net export to GDP ratio and foreign assets to GDP ratio. Then HP filters are used to get the standard deviation.

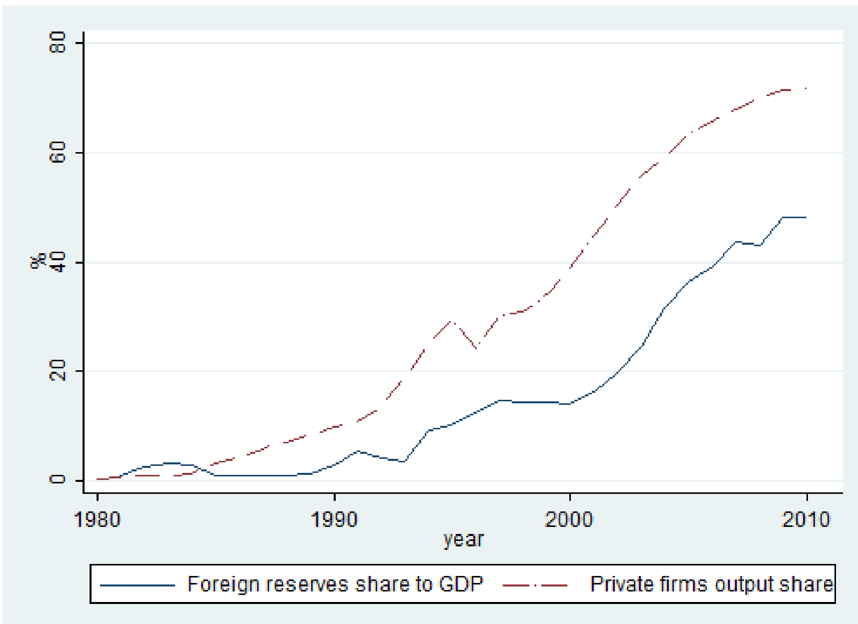

Figure 1.1: Foreign Reserves Ratio to GDP and Private Firms Output Share in China (1980-2010)

Source: Foreign reserve data is from the State Administration of Foreign Exchange. GDP data is from Statistical Yearbook 2001. Industrial output data are from China Compendium of Statistics 1949-2008 (NBS, 2010) and Statistical Yearbook 2010 and 2011.

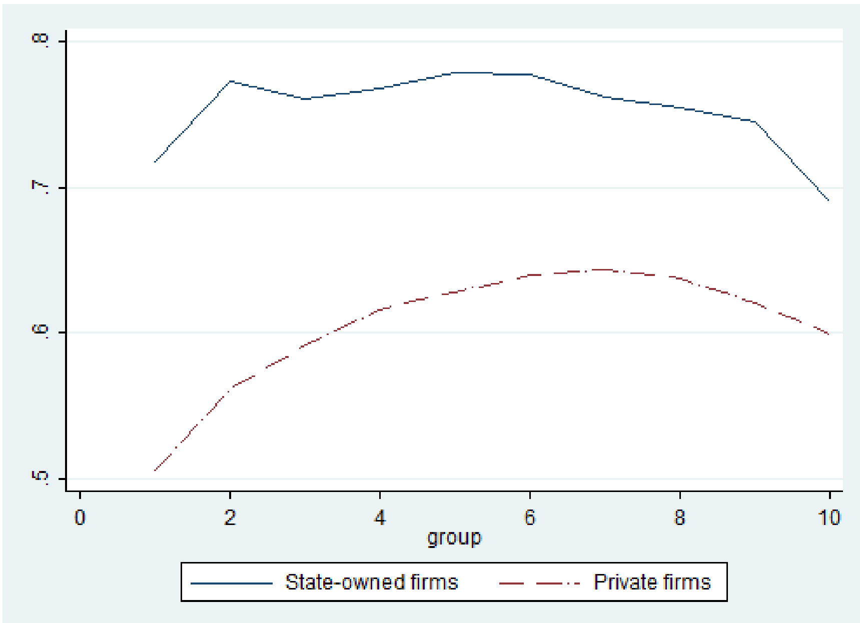

Figure 1.2: Liabilities-to-Assets Ratio of Industrial Firms (2000)

Source: Chinese Annual Survey of Industrial Production 2000.
Note: Groups are categorized by the size of firms' assets. From Group 1 to Group 10, firms' assets increase.

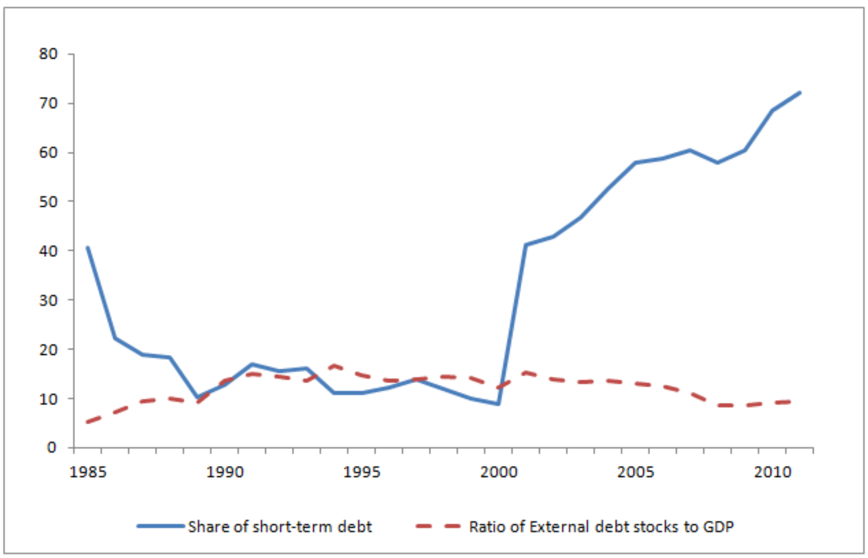

Figure 1.3: External Debt in China (1985-2011)

Source: China State Administration of Foreign Exchange.

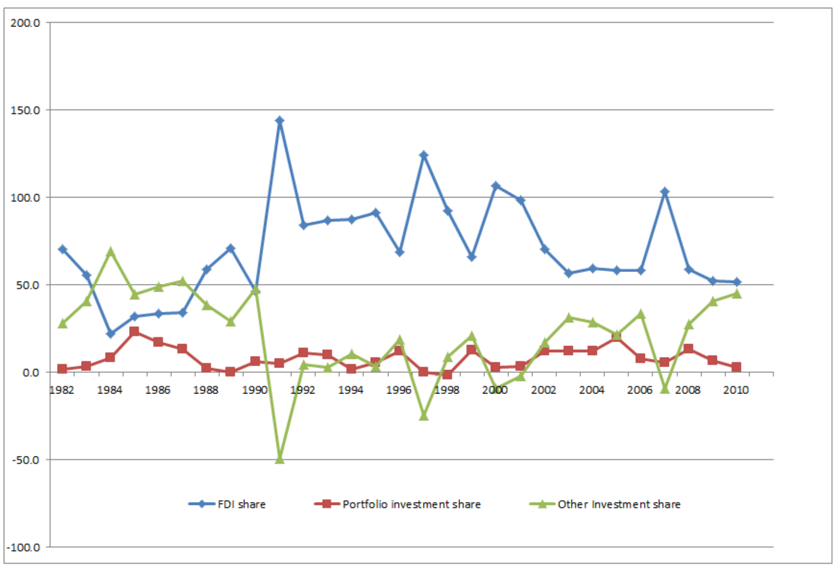

Figure 1.4: The Compostion of Annual Capital Inflows in China 1982-2011 (%)

Source: China State Administration of Foreign Exchange and author's calculation.

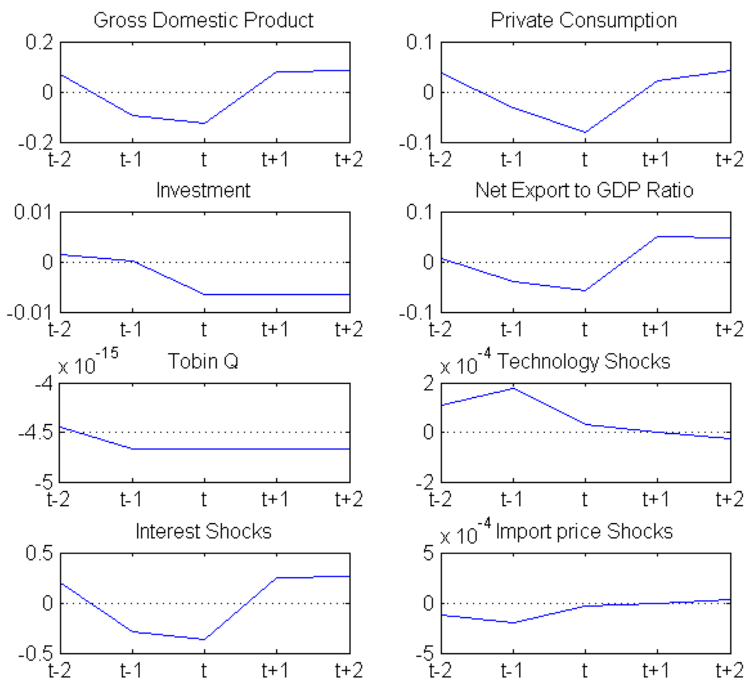

Figure 1.5: Simulated Sudden Stop Events Dynamics

Source: Foreign reserve data is from the State Administration of Foreign Exchange. GDP data is from Statistical Yearbook 2001. Industrial output data are from China Compendium of Statistics 1949-2008 (NBS, 2010) and Statistical Yearbook 2010 and 2011.

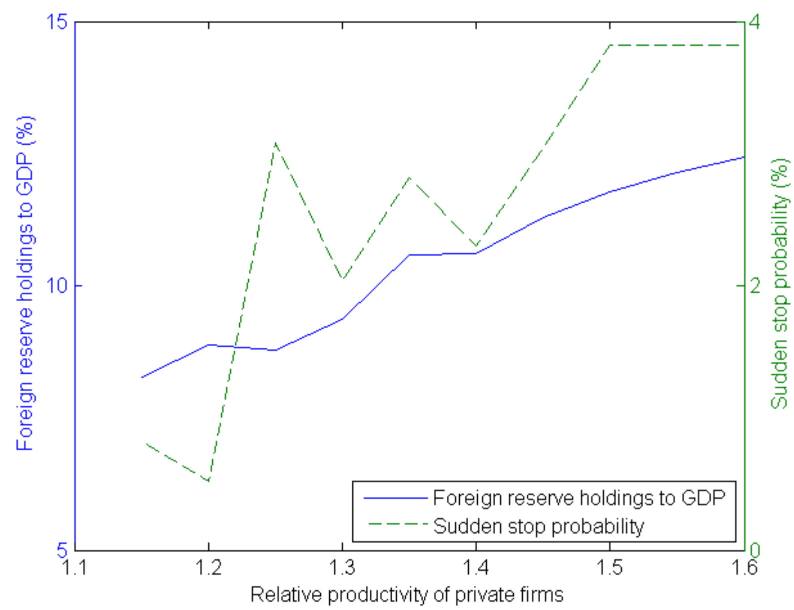

Figure 1.6: Sudden Stops Probability and Foreign Reserves Holdings

Note: We use the parameter ζ in production function to represent the relative productivity of private firms. The calibrated value changes from 0.9 to 1.6 which means the private firms are much more productive than the state-owned firms.

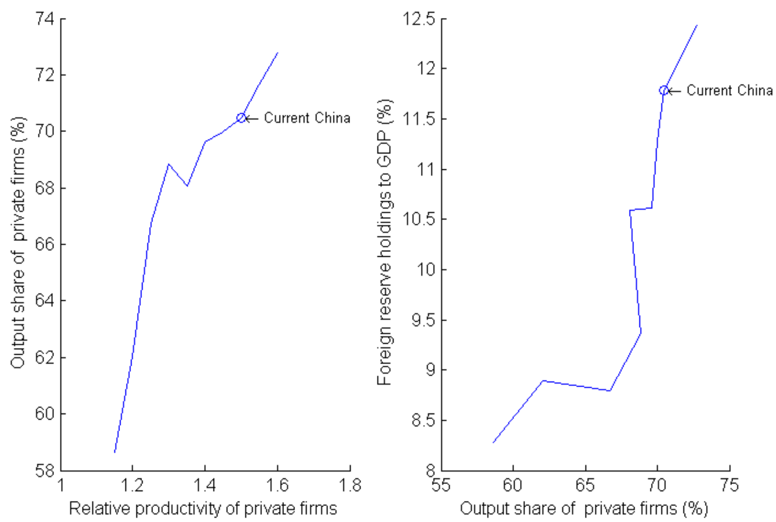

Figure 1.7: Current China's Position in the Calibrated Model

Note: We use the parameter ζ in production function to represent the relative productivity of private firms. By matching the output share of the private firms in the calibration model to the real one in China, we get the estimated parameter ζ. And then the Sudden Stops probability and foreign reserve ratio to GDP can be calibrated.

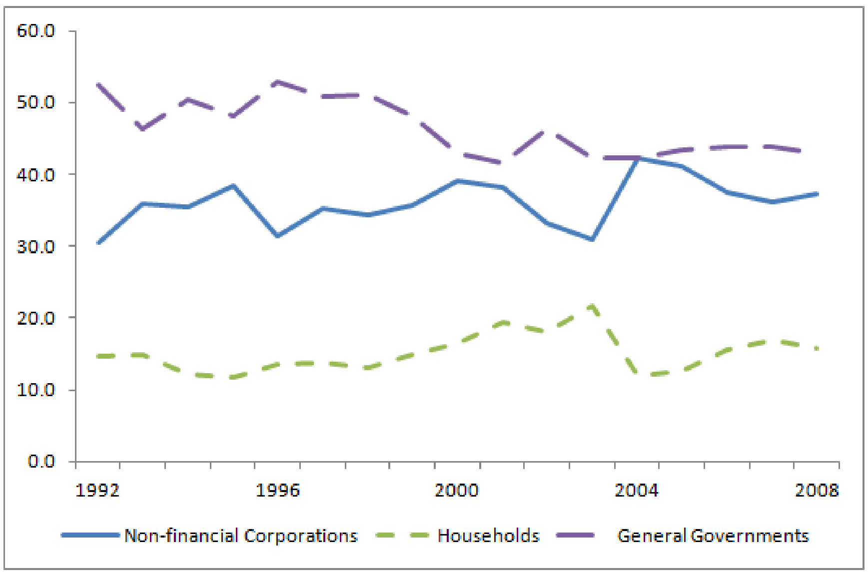

Figure 1.8: Savings by Sectors (%)

Source: Data is from Flow of Funds Accounts (Physical Transaction) in Statistical Yearbook 1996-2011. We haven't depicted the financial institutions' saving in the figure which only attributes to 4% at the most.

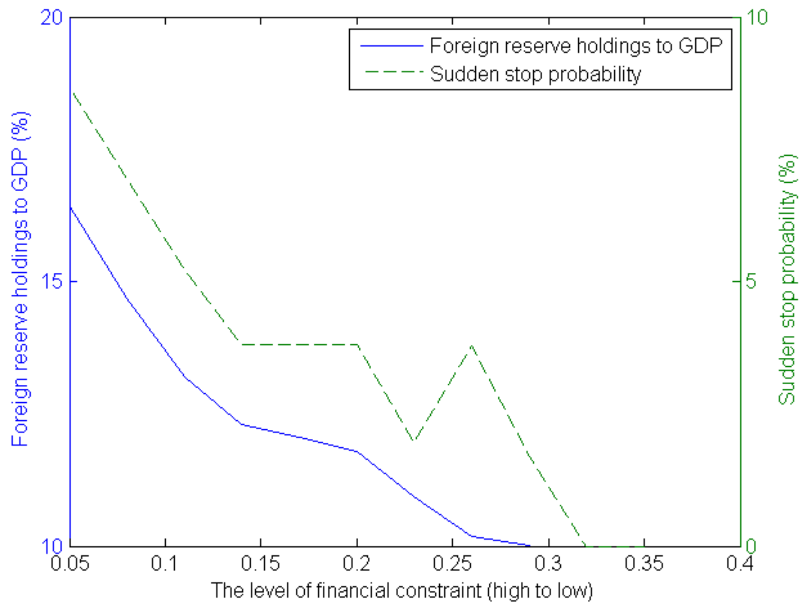

Figure 1.9: The Effect of Financial Constraint

Note: The level of financial constraint is represented by the parameter κ. It measures the maximum proportion of debt to the capital value. If κ increases, then the maximum debt which private firms can hold also increases. The financial constraint loosens.

Chapter 2

The Relative Volatility of Commodity Prices: A Reappraisal[1]

2.1 Introduction

Are the international prices of primary commodities more volatile than those of manufactured goods? This question has important implications for macroeconomic and development policies, and the conventional wisdom expressed in academic and policy circles is that they are. The policy literature is replete with prescriptions for economies to cope with the volatility of commodity prices, ranging from prescribed investments in financial hedging instruments such as commodity futures to fiscal stabilization rules to help reduce the pass through of commodity price volatility into domestic economies. A recent example is the World Bank's 4 billion dollar contribution to a joint fund launched in June 21, 2011 with J.P. Morgan to help developing countries invest in commodity-price hedging instruments.[2] In fact, the concern over the impact of commodity price volatility on developing countries has also led the World Bank to argue that economic diversification away from commodities should be a priority for these countries even if this requires industrial policies. These policy prescriptions and concerns are valid, regardless of the relative volatility of commodity prices. Such policies are justified even if the prices of commodities are less volatile than those of manufactured goods, for example, because many developing countries tend to have highly concentrated export baskets that are associated with volatile terms of trade and thus macroeconomic uncertainty, which itself can lead to social unrest (Brückner and Ciccone (2010)). In addition, the volatility of some commodities linked to food staples can result even in social unrest (see Arezki and Bruckner (2011)).

Indeed, there are good reasons to expect that commodity prices are relatively volatile.

[1] This paper is coauthored with Rabah Arezki and Daniel Lederman.

[2] World Bank, Press Release No:2011/559/EXT, Washington, DC.

One is that commodities, by definition, are goods that retain their qualities over time, which allows economic agents to use them as financial assets. This might be the case, for example, of gold and other commodities whose prices tend to rise amidst global financial uncertainty. Caballero et al. (2008b), for example, argued that the volatility of commodity prices could be due to the lack of a global safe asset (besides the U.S. Treasury bills). An earlier literature argued that commodity price volatility was fueled by stockpiling policies to secure access to food or fuel during times of relative scarcity (Deaton and Laroque (1992)). These mechanisms add price volatility because of unavoidable asymmetric stockpiling rules; that is, the stockpile of commodities cannot be negative. Yet another potential explanation is the lumpiness of exploration investments in mining, which results in inelastic supply in the short run (Deaton and Laroque (2003)). Finally, more traditional economic analysis of the effects of random demand shocks on homogeneous (i.e., commodities) and differentiated goods (i.e., manufactured products) also suggests that the resulting price volatility of the latter would tend to be lower as producers of differentiated products could maximize profits by reducing supply in response to negative demand shocks.

However, there are also good reasons to expect a higher volatility of differentiated manufactured goods. Product innovation and differentiation itself might contribute to price volatility by producing frequent shifts in residual demand for existing varieties. Indeed, the trade literature has acknowledged the wide dispersion in unit values of within narrowly defined product categories in the United States import data at the 10-digit level of the Harmonized System (HS) (Schott (2004)). Also, the demand for differentiated products might be more unstable with respect to household and aggregate income shocks than that for basic commodities. For instance, the demand for fuel and food might decline proportionately less than the demand for automobiles or electronics when incomes fall.

In spite of these contradictory predictions, there are few analyses that systematically compare the volatility of commodity and manufactured goods prices. An important exception is the historical study by Jacks et al. (2011), who examined the volatility of domestic prices since 1700 in several countries; however, it covered only few commodities due to data constraints. In contrast, analyses of the evolution and volatility of the average price of baskets of commodities relative to the average price of a basket of manufactured goods-usually the manufacturing unit value index (MUV) constructed by the International Monetary Fund-are omnipresent in the literature and policy documents (e.g. Cashin and McDermott (2002); Calvo-Gonzalez et al. (2010)).

Figures 2.1 and 2.2 show the time series of aggregate price indices for various definitions of primary commodities. These series seem to corroborate the conventional wisdom as commodity prices appear to be more volatile than non-commodity prices. The present paper challenges this conventional wisdom by providing a new stylized fact on the relative volatility of primary commodity prices using data from U.S. imports data at the 10-digit level of aggregation in the Harmonized System (HS) nomenclature.

This paper contributes to several strands of the literature. First, it contributes more directly to the literature studying the behavior of commodity prices. This literature does not necessarily compare commodity prices to non commodity prices but focuses on the former. For instance, Deaton and Laroque (1992) used coefficients of variation of aggregated price indexes as a measure of volatility to analyze the volatility of 13 commodities. They argue that "commodity prices are extremely volatile" but do not provide an explicit comparison with non-commodity price volatility.[3] As far as we know, this paper is the first to compare the volatility of individual primary commodity prices not with aggregate indexes but rather with disaggregated monthly data.

Second, our paper contributes to the literature on trends in commodity prices relative to manufactured products (e.g., Harvey et al. (2010)). Our paper instead focuses on the differences in the second moments of commodity prices compared to those of non-commodity prices.

Third, this paper also contributes to the literature on the so-called "resource curse" that has focused on the adverse effect of resource endowments on economic growth (e.g., Lederman and Maloney (2007); Van der Ploeg (2011); Frankel (2010)). If commodity prices are intrinsically more volatile than the prices of manufactured goods, a higher natural resource endowments could result in higher macroeconomic volatility.

The rest of this paper is organized as follows. Section 2.2 discusses the monthly data from the United States international trade records over the period from 2002 to 2011 covering more than 18 thousand goods. Section 2.3 presents the main results. Section 2.4 provides an array of robustness tests. Section 2.5 concludes.

2.2 Data

Our data come from trade records of the United States, classified at the 10-digit level of the Harmonized System (HS) of trade classification. We use monthly frequency import data from January 2002 to April 2011. The data was obtained from the Foreign Trade Division of the U.S. Census Bureau. From these data, prices were computed as the ratio of import values to quantities. These unit values are used as our proxy for goods prices.

In total, the dataset covers 26,459 product categories. However, not all categories have price information; 7,976 products do not. Also, the analysis of volatility requires data for extended periods of time, and we dropped products that do not have price data for at least 36 consecutive months. The final data set thus covers 12,955 products.[4] Our benchmark

[3] More recently, Deaton and Laroque (2003) have focused on the longer-run determinants of commodity prices. They developed a Lewis model where commodity supply is infinitely elastic in the long run and the rate of growth of supply responds to the excess of the current price over the long-run supply price. They find that commodity prices are stationary around its supply price and are driven in the short run by fluctuations in world income.

[4] The results reported below are unaffected by alternative choices of datasets such as keeping products with price data available throughout the whole sample period.

analysis focuses on U.S. imports data rather than on exports data for two reasons. First, the reporting of imports data is generally less subject to measurement errors than exports data, as imports are more subject to tariffs and inspections than exports. Second, U.S. imported products are more numerous and diverse than exports. In fact, the U.S. reports twice as many imported as exported goods. Also, 17 percent of imports are commodities compared to only 4 percent for exports. While studying the pattern of US exports may be relevant for a U.S. specific analysis, it is essential for our general analysis to use imports data.[5]

It is noteworthy that this sample period covers years of historically high volatility of real commodity prices, perhaps only surpassed by the early 1970s (see, e.g., Calvo-Gonzalez et al. (2010)). Consequently, if there is a period selection bias in the data, it would probably bias commodity price volatility upwards. But, again, such historical analyses focus on commodity prices relative to an aggregate price index of non-commodity goods, which might be misleading.

As a starting point, the analysis focuses on aggregate price indexes-see Figures 2.1 and 2.2. A relevant issue in this type of analysis concerns the definition of commodities. The International Monetary Fund has one such classification, which includes non-fuel, energy and all primary commodities. The United Nations Conference on Trade and Development (UNCTAD) also has a definition, which includes some commodities that are not in the IMF, such as cottonseed oil and manganese ore. Appendix A.1 lists the commodities included under both definitions. In addition, it is easy to tell which goods are manufactured in the North American Industry Classification System (NAICS). At the two digit level, chapters 31-39 of the NAICS are classified as manufactured goods.

Since the data on import prices from the U.S. are classified according to the Harmonized System, we used concordance tables between the HS and the NAICS.[6] To match the HS data classification to the IMF and UNCTAD commodity classifications, we used the names of the commodities as keywords to find matching product descriptions in the trade data.

To assess the volatility of individual goods prices it is important to de-trend the price series. We report results based on the Hodrick-Prescott filtered series, but all results reported herein hold with alternative filters, including the Baxter-King band-pass filter and first differences.[7] In all three cases, we measure volatility with the standard deviation of de-trended price series. After calculating the standard deviations for each 10-digit product, we compare the distribution of volatilities across groups of goods, namely commodities versus manufactured goods.

[5]Nevertheless, the main result presented in this paper holds when using US exports data rather than imports.

[6]Robert Feenstra's web site provides the concordance for data from 1989-2006: http://cid.econ.ucdavis.edu/. The U.S. Census Bureau provides concordance tables for 2010 and 2011: http://www.cnesus.gov/foreign-trade/reference/codes/index.html.

[7]There is thus no concern that the main result presented in this paper is driven by the choice of filtering method.

2.3 Main Results

2.3.1 Product "Re-Classification"

For starters, in the HS classification, the goods classified as machinery and electrical equipment have the highest average volatility see Table 2.1. Table 2.2 provides summary statistics for the goods classified as primary commodities and manufactured goods, based on the NAICS-IMF classification, after finding the best concordance between the two classifications. It is noteworthy that over 92 percent of products are classified as manufactured goods and have, on average, higher volatilities than the primary commodities. Furthermore, the cumulative distribution functions (CDFs) in Figure 2.3 show that the price volatility of manufactured goods dominates both that of primary commodities and that of other (unmatched) goods.

For the sake of completeness, Figure 2.4 plots the volatility CDF of primary commodities based on the IMF commodity price table data, the previously defined group of manufactured products and primary commodities (based on the NAICS-IMF overlap sets) and a more narrow set of manufactured goods classified as "computers". The latter appear to have the highest volatility distribution, followed by the large group of all manufactured goods.

Thus, the data on price volatility at the level of individual products suggests that manufactured goods prices are more volatile than that of commodities. This result is at odds with Figure 2.1. We argue that the use of aggregate indices in comparing prices across classes of goods is subject to an aggregation bias. That is, some price swings in one direction cancel out swings in the other direction, which makes for an overall index that looks more stable than its components. Of course that same effect is also at play in commodity price indices, but there are far fewer commodities than manufactures, so fewer prices cancel each other out. According to NAICS, manufactures account for more than 90 percent of the goods in our data set.[8]

Nonetheless, since the analysis compares the whole distribution of volatilities within categories of goods, we next need to establish that the observed differences in the CDFs are statistically different.

2.3.2 Formal Tests of CDF Stochastic Dominance

Delgado et al. (2002) provide a non-parametric test for assessing the difference between cumulative distribution functions; it is a two-step test for first order stochastic dominance. The first step is a one-sided test of the null hypothesis that the difference between the two

[8] More formally, it can easily be shown that using a variance operator to compute measures of volatility for two different price indices will bias the measure of volatility upward for the index which comprises more sub-components compared to the one with less.

cumulative distribution functions is equal to or less than zero. The second step is a two-sided test of the null hypothesis that the two CDFs are equal. If the one-sided test is not rejected, then this is interpreted as evidence of weakly stochastic dominance. A rejection of the equality of the two CDFs in the two-sided test indicates strict stochastic dominance.

More formally, the test statistic, the Kolmogorov-Smirnov test statistic, for the null hypotheses of the one-sided first-step test can be written as follows:

$$T^1_{N,M} = \sqrt{\frac{N*M}{N+M}} * max(\widehat{F_m(z)} - \widehat{F_c(z)}) \tag{2.1}$$

where T is the test statistic; superscript 1 is the identifier of the first, one sided test; N and M are the number of observations included in each product group, subscript m stands for manufactures; subscript c stands for commodities; and z is the standard deviation (our proxy for price volatility) of each good ranked from the lowest to the highest volatility. $\hat{F}$ denotes the empirical cumulative distribution function. The test statistic for the two sided test examines the distribution of the absolute value of the differences (as opposed to the differences) between the two empirical distributions:

$$T^2_{N,M} = \sqrt{\frac{N*M}{N+M}} * max|\widehat{F_m(z)} - \widehat{F_c(z)}| \tag{2.2}$$

We now discuss the results of the stochastic dominance tests performed on the CDF of the volatility of manufactured and commodity import prices shown in Figure 2.3. For the one-sided test, the statistic is 0.034. It is smaller than the 1.073 critical value for the 10% level of significance.[9] Thus we cannot reject the null hypothesis that the CDF of manufactured goods is smaller or equal than that of commodities. The CDF of manufactured goods weakly dominates that of commodities. For the two-sided test, the corrected combined p-value is 0, so we can reject the null hypothesis that the two distributions are equal at 1% significance level. Overall, the results of the stochastic dominance test suggest that the CDF of the standard deviations of prices of manufactured goods strictly stochastically dominates that of commodity prices.

2.4 Robustness

This section tests the robustness of our surprising finding that prices of commodities are less volatile than those of manufactured goods. This finding could be misleading for at least five reasons. First, some products tend to disappear from the sample. If most product exits are observed within the group of manufactured goods, then it is possible that the observed

[9] Critical values of the one-sided test are 1.073, 1.2239, and 1.5174 for the 10%, 5%, and 1% levels of significance respectively (Barrett and Donald (2003), page 78).

volatility of manufactures might be biased upward, driven by product destruction rather than by within-product price fluctuations. Second, the trade data on unit values comes from ratios of reported values over reported quantities. Hence it is worth examining the volatility of quantities. Third, the key distinguishing feature of commodities is their relative lack of product differentiation over time, and this characteristic might not be neatly identified in the ad hoc categorizations used by the IMF, UNCTAD or in the NAICS. Fourth, measurement errors in unit values may be an important explanation for our main results. Fifth, even at the ten digit level of aggregation in the HS nomenclature, each product code might include multiple varieties of products. Thus the level of aggregation might affect the estimates of price volatilities. We address these concerns below.[10]

2.4.1 Product Destruction

An easy way to examine the influence of product destruction on the previous results is to limit the analysis to a constant sample of products. For this constant sample, we chose goods that have price information for the whole time period from January 2002 to April 2011. Thus, our sample is reduced to 7,842 goods, which is about 60% of the total number of goods (12,955) in the benchmark sample. Indeed, Table 2.3 shows that there is quite a bit of product exit in manufactured products. It is also noteworthy that there is a notable increase in the number of entering and exiting products in 2007, which is very likely due to changes in the trade classification and reporting systems. However, Figure 2.5 shows that even when considering a constant sample of products, our main result remains intact: commodities appear to be less volatile than manufactured goods.

2.4.2 Volatility of Quantities

So far, we have used unit values to compute measures of price volatility. It is important to keep in mind that quantities may adjust to prices, and it is worth exploring whether the difference in volatilities between primary commodity and non-primary goods prices is evident in quantities. We thus re-computed the volatility for quantities both for individual commodities and manufactures. Figure 2.6 shows that our main result, that individual commodity prices are less volatile than those of manufactures, holds for import quantities as well.

[10]The results from stochastic dominance tests indicate that we failed to reject the null hypothesis in the first step but reject the null hypothesis in the second steps for all the robustness cases presented hereafter. For the sake of conciseness, the test statistics and associated critical values are not reported but are available from the authors upon request.

2.4.3 Homogeneous versus Differentiated Products

Rauch (1999) provided an intuitive classification of homogeneous and differentiated goods which goes to the heart of the economic distinction. Homogeneous goods are those which are traded globally in organized exchanges, whereas differentiated goods are those that are not. An intermediate category in Rauch (1999) is composed of goods for which no formal exchanges (organized markets) exist, but for which there are "reference prices". Rauch provided a concordance between the Standard International Trade Classification (SITC) and his three categories. We used the SITC-HS concordance table in order to then classify our sample of products into Rauch's three groups. In our sample, 95 percent of manufactured goods appear in the bin of differentiated goods, whereas only 35 percent of commodities were classified as differentiated products. Thus there was a notable overlap, albeit not enough to overturn the main findings: Figure 2.7 indicates that the most volatile products are differentiated manufactured goods.

2.4.4 Measurement Errors

One potential caveat to our results is that measurement errors in the unit values may be an important driver of the difference in the observed -as opposed to the true- price volatility between commodity and manufactured goods.[11] One potential source of measurement error is that goods which have smaller import values may be disproportionately more subject to measurement error. Following Hummels and Klenow (2005) and Feenstra et al. (2002), we re-computed the price volatility CDFs for various groups of products by dropping goods whose monthly import value was less than a given cut-off from our sample. Specifically, we dropped goods below US $50,000 import value, which resulted in a drop of 6 percent (805 goods) of the total number of products. Interestingly, the dropped goods were evenly distributed across commodity and manufactured goods. Our main results regarding the higher volatility of manufactured goods unit values were confirmed after dropping goods with low import values.

Another potential source of concern is that using the standard deviation as a measure of dispersion may give disproportionate importance to outliers, which in turn may lead to over or underestimation of the relative volatility of commodity prices. Indeed, a standard deviation, being a sum of square distances to the trend, implicitly gives more weight to outliers. To address that issue we used alternative measures of dispersion, namely the inter-deciles range: the difference between the first and the ninth deciles, or the inter-quartile range, the difference between the upper and lower quartiles. Once again, when re-computing the price volatility CDFs, our main results regarding the higher volatility of manufactured goods unit values were confirmed using these alternative measures of dispersion. While it is impossible to argue with absolute certainty that measurement error is not driving our

[11] The results discussed in this sub-section are not reported but available from the authors upon request.

main results, this evidence suggests that measurement errors that disproportionately affect unit values of manufactured goods are unlikely to be the main source of the difference in volatilities with respect to commodities.

2.4.5 Level of Aggregation and Product Varieties in the Trade Nomenclature

Lastly, we explore the role of the level of aggregation in the trade classification system to ascertain whether our results might be due to the existence of multiple product varieties and even various types of products, especially among manufactured products, within the narrowly defined product categories even at the 10-digit level of the HS. Hence it is plausible that the CDFs of product-price volatilities might reflect price fluctuations of many products. The results might thus be biased in either direction. If the product categories include many products and their underlying unit values do not co-move, then the observed volatilities of the manufactured products might be under-estimated. If the underlying prices co-move then the price volatilities might be either over-stated or unbiased, depending on the nature of the co-movement of the underlying prices. To assess whether this product bundling within product aggregates biases the estimated volatilities, we examined the relationship between the level of aggregation of the trade nomenclature and the differences in the CDF of volatilities between commodities and manufactured products. The idea is to assess whether the level of aggregation affects the estimated differences in the CDFs of price volatilities between commodities and manufactured goods. If the difference becomes attenuated at higher (than 10 digits) then we can expect the differences to become more pronounced if we were to find even more disaggregated price data at the product level. This seems to be a practical way to proceed, because we do not have access to data at higher levels of disaggregation than the data at 10 digits.

The results for the stochastic dominance tests with the data at different levels of aggregation are shown in Table 2.4. At all levels of aggregation, we can reject the null that commodity prices are more volatile than those of manufactured goods (again, using the NAICS-IMF classification of products as manufactured or commodities). In contrast, we cannot reject the null that manufactured goods prices are more volatile than those of commodities at the 10- and 8-digit levels of aggregation, but the significance disappears at higher levels of aggregation. Likewise, we can reject the null of the two-sided test that the two CDFs are equal only at the 10- and 8-digit level of aggregation. That is, it seems that the differences in the CDFs of price volatilities become more pronounced with the number of digits in the product code of the HS nomenclature. Thus we conclude that our estimates of the differences using the 10-digit level data are a floor rather than a ceiling, and commodity prices are likely to become relatively more stable than those of manufactured goods if we were able to get a more precise product classification system.

2.5 Conclusions

Conventional wisdom holds that commodity prices are much more volatile than prices of differentiated manufactured products are. However, there are economic arguments that both support and counter this perception. Our empirical results challenge the conventional wisdom. In fact, the evidence presented in this paper suggests that on average the prices of individual primary commodities might be less volatile than those of individual manufactured goods. Furthermore, robustness tests suggest that these results are not likely to be due to alternative product classification choices, differences in product exit rates, measurement errors in the trade data, or the level of aggregation of the trade data. Indeed, our estimates with the U.S. trade data at the 10-digit level of aggregation in the HS nomenclature are likely to be a floor estimate of the difference between the volatilities of commodities and manufactured (or differentiated) goods. Hence the explanation must be found in the realm of economics, rather than measurement.

The literature has thus far focused on trends in the evolution and volatility of ratios of price indexes composed of multiple commodities and products. This approach can be misleading as the use of aggregate indices in comparing prices across classes of goods is subject to aggregation bias. More research is needed to explore the theoretical explanations behind these new findings. As mentioned in the introduction, one likely candidate to explain why differentiated manufactured goods prices would be more volatile that commodities is that product differentiation itself might contribute to price volatility by producing frequent shifts in residual demand for existing varieties. The wide dispersion in unit values of within narrowly defined product categories in the United States import data at the 10-digit level of the Harmonized System (HS) (Schott (2004)) certainly supports that view.

Our empirical results also have potentially important implications for the macroeconomics literature and perhaps for development policy. For instance, our evidence suggests that specialization in the manufacturing sector does not necessarily yield less volatility. On the contrary, specializing in manufacturing activity could increase an economy's exposure to price volatility. Moreover, manufacturing may prove more challenging than commodity specialization, perhaps because it requires constant upgrading of the production process to meet international competition through product upgrading and quality differentiation. Thus, while specializing in manufactures should still be considered an objective of policy options, authorities should keep in mind that manufacturing requires a strong capacity to innovate and adapt to withstand international competition.

That said, developing countries tend to be smaller, poorer and more dependent on primary commodity exports than high-income economies, all of which result in higher export concentration dominated by basic commodities. This concentration of their export baskets is, in turn, associated with volatile terms of trade. Hence managing external volatility and economic diversification in the long run remain important policy challenges for developing countries, but this is not because commodity prices per se are more volatile. Similarly, developing financial hedging instruments to help countries to dampen the consequences of commodity-price volatility are also worth pursuing, but this is so because it is plausible to develop such instruments for goods that are homogeneous over time rather than because the prices of commodities are (supposedly) relatively more volatile than those of differentiated manufactured goods.

Table 2.1: Price Volatility by Harmonized System Groups

HS	Descriptions	Num. of goods	Mean	Minimum	Maximum
01-05	Animal & Animal Products	505	0.223	0.023	1.499
06-15	Vegetable Products	592	0.271	0.027	1.736
16-24	Foodstuffs	662	0.219	0.013	1.131
25-27	Mineral Products	201	0.376	0.033	1.435
28-38	Chemicals & Allied Industries	1564	0.425	0.038	2.543
39-40	Plastics / Rubbers	420	0.280	0.026	1.551
41-43	Raw Hides, Skins, Leather, & Furs	220	0.444	0.071	1.528
44-49	Wood & Wood Products	808	0.293	0.028	2.206
50-63	Textiles	2630	0.410	0.028	1.583
64-67	Footwear / Headgear	341	0.301	0.016	1.163
68-71	Stone / Glass	385	0.415	0.019	2.750
72-83	Metals	1448	0.271	0.044	1.678
84-85	Machinery / Electrical	2021	0.526	0.034	3.310
86-89	Transportation	384	0.382	0.028	2.370
90-97	Miscellaneous	773	0.502	0.033	2.326
98-99	Service	1	0.406	0.406	0.406
	Total	12955	0.382	0.013	3.310

Source: Authors' calculations, based on data from the Foreign Trade Division of the U.S. Census Bureau.

Table 2.2: Price Volatility Using Alternate Goods Classification

Descriptions	Num. of goods	Mean	Minimum	Maximum
Primary commodities	110	0.257	0.031	1.736
Manufactured goods	12006	0.387	0.013	3.310
Others	839	0.316	0.023	1.897
Total	12955	0.382	0.013	3.310

Source: Authors' calculations, based on data from the Foreign Trade Division of the U.S. Census Bureau.

Table 2.3: Goods Entry and Exit

	Number of exiting goods				Number of entering goods			
year	commodities	manufactured	others	total	commodities	manufactured	others	total
2003	1	90	8	99	0	115	10	125
2004	1	81	5	87	0	97	0	97
2005	3	70	9	82	0	94	7	101
2006	0	57	6	63	0	113	2	115
2007	19	1510	225	1754	20	1320	216	1556
2008	0	37	5	42	1	73	6	80
2009	1	40	11	52	2	63	12	77
2010	3	55	5	63	3	33	2	38
2011	3	307	67	377	10	108	16	134

Source: Authors' calculations, based on data from the Foreign Trade Division of the U.S. Census Bureau.

Table 2.4: CDFs of Price Volatilities and the Level of Aggregation of Trade Data

Stochastic Dominance Test: Null Hypothesis		HS Level of Aggregation 10	8	6	4	2
Commodity Price Volatility Dominates Manufactured Price Volatility	K-S test statistic	0.034	0.255	0.227	0.697	0.563
	p-value	0.998	0.878	0.902	0.379	0.531
Manufactures Price Volatility Dominates Commodity Price Volatility	K-S test statistic	2.404	1.312	0.656	0.826	0.366
	p-value	0.000	0.032	0.423	0.256	0.765
CDFs of Price Volatilities are Equal	Two-Sided Test p-value	0.000	0.042	0.699	0.376	0.670
	No. of manufactured	12006	5788	3598	983	77
	No. of commodities	110	33	26	10	5

Source: Authors' calculations, based on data from the Foreign Trade Division of the U.S. Census Bureau – see text for details. Here the test means Kolmogorov-Smirnov test.

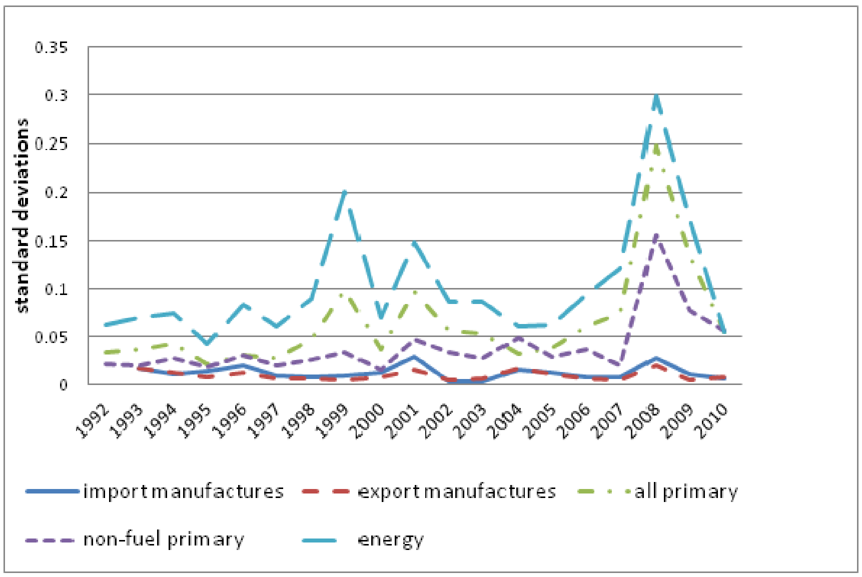

Figure 2.1: Volatility of Aggregate Price Indices Using IMF Commodity Indices

Note: The figure shows the evolution of the annualized standard deviations of Hodrick-Prescott filtered price series. The aggregate price indices for all primary, non-fuel primary and energy goods are from IMF Primary Commodity Price Tables (2005=100). The aggregate price indices for import and export manufactured goods are from the Bureau of Labor Statistics (2000=100). The latter data is available using the Standard International Trade Classification from 1993 to 2005 and available using North American Industry Classification System from 2005 to 2010. We constructed an extended series throughout the period 1993 to 2010 by setting the same index value for December 2005 in those two available series.

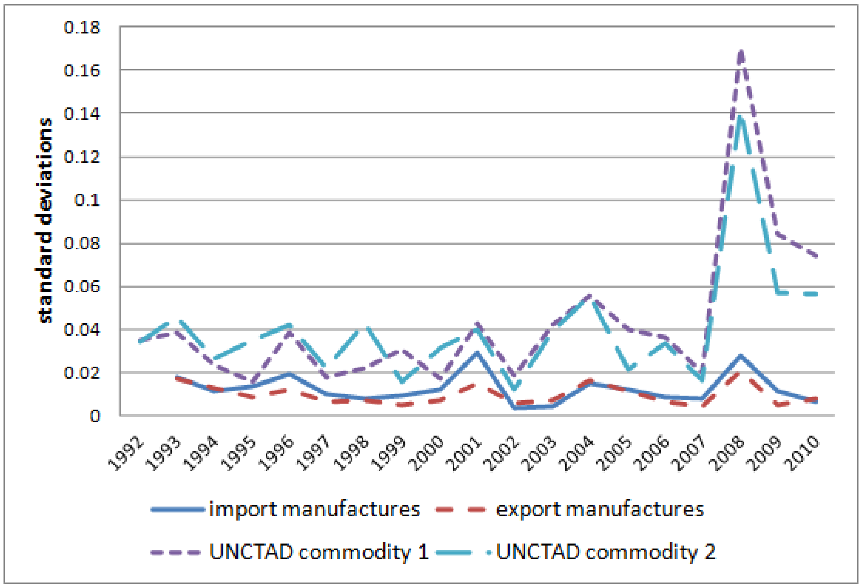

Figure 2.2: Volatility of Aggregate Price Indices using UNCTAD Commodity Indices

Note: The figure shows the evolution of the annualized standard deviations of Hodrick-Prescott filtered price series. Commodity price indices are from UNCTAD Stat (2000=100). The UNCTAD commodity 1 price index is originally in current dollars while UNCTAD Commodity 2 is in Special Drawing Rights. The aggregate price indices for import and export manufactured goods are from the Bureau of Labor Statistics (2000=100). The latter data is available using the Standard International Trade Classification from 1993 to 2005 and available using North American Industry Classification System from 2005 to 2010. We constructed an extended series throughout the period 1993 to 2010 by setting the same index value for December 2005 in those two available series.

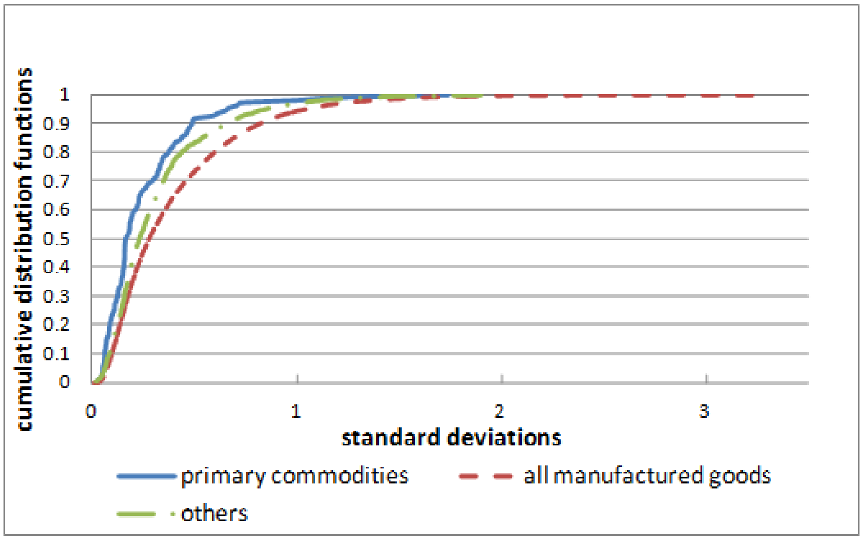

Figure 2.3: Cumulative Distribution Functions of Price Volatility for Goods with Uninterrupted Price Series

Note: The figure shows the cumulative distribution functions of the standard deviations of Hodrick-Prescott filtered series of individual goods prices. The goods represented are those which prices are available for at least 36 consecutive months. Data are from the Foreign Trade Division of the U.S. Census Bureau.

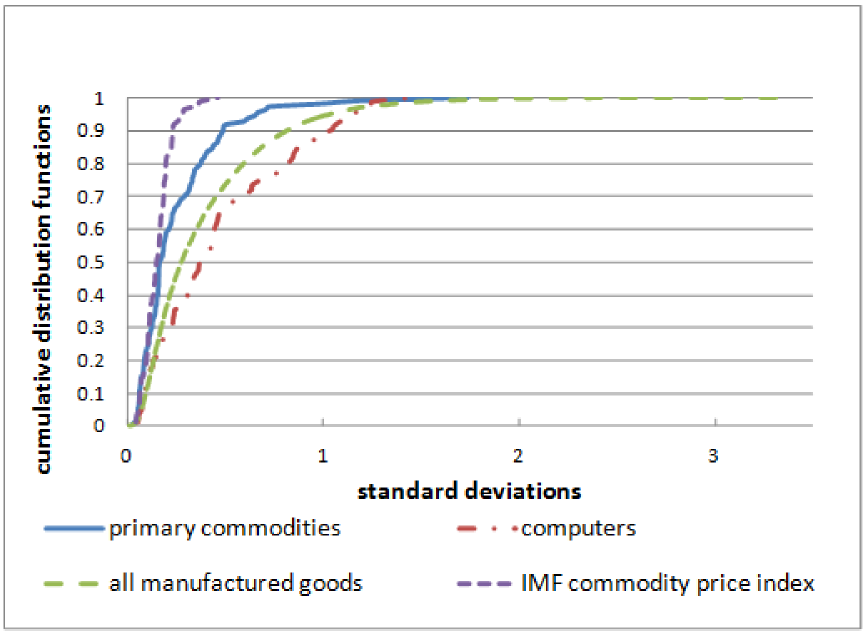

Figure 2.4: Cumulative Distribution Functions of Price Volatility for Selected Manufactured Products

Note: The figure shows the cumulative distribution functions of the standard deviations of Hodrick-Prescott filtered series of individual goods prices. Data are from the Foreign Trade Division of the U.S. Census Bureau.

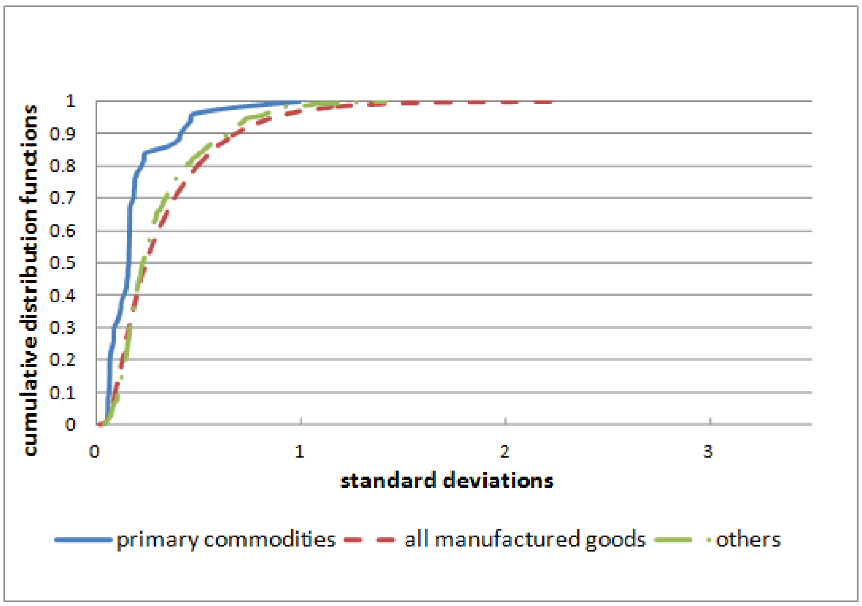

Figure 2.5: Cumulative Distribution Function of Price Volatility for Goods Available for the Whole Period

Note: The figure shows the cumulative distribution functions of the standard deviations of Hodrick-Prescott filtered series of individual goods prices. The goods represented are those which prices are available for the whole sample period. Data are from the Foreign Trade Division of the U.S. Census Bureau.

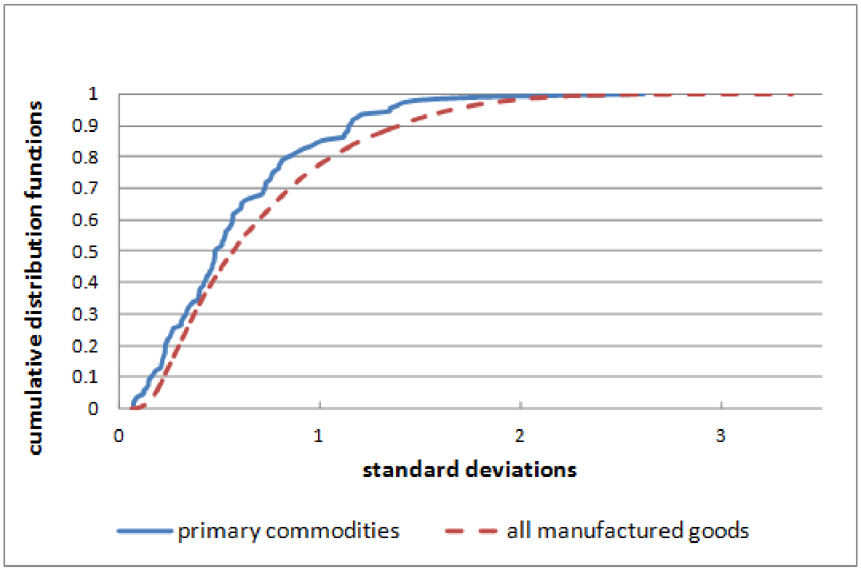

Figure 2.6: Cumulative Distribution Function of Volatility of Import Quantities

Note: The figure shows the cumulative distribution functions of the standard deviations of Hodrick-Prescott filtered series of individual goods quantities. Data are from the Foreign Trade Division of the U.S. Census Bureau.

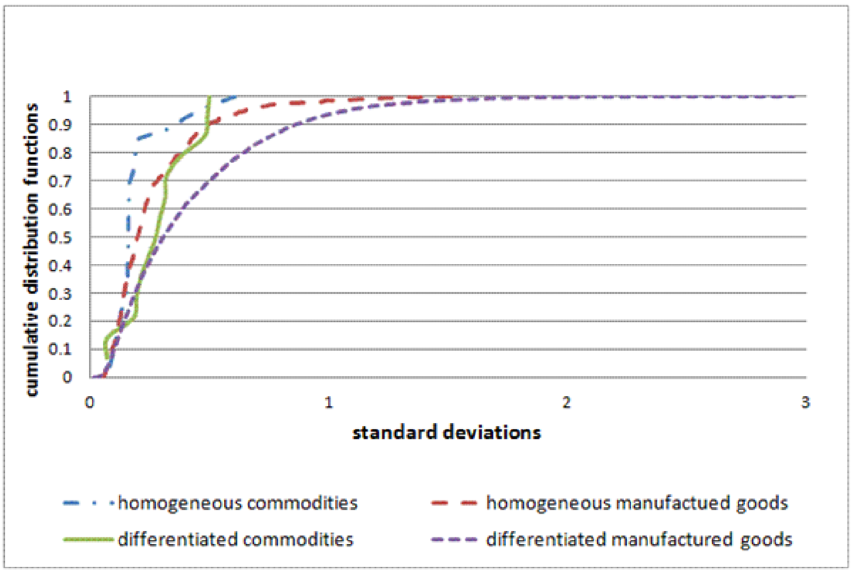

Figure 2.7: Cumulative Distribution Function of Price Volatility for Differentiated and Homogenous Goods

Note: The figure shows the cumulative distribution functions of the standard deviations of Hodrick-Prescott filtered series of individual goods prices. Data are from the Foreign Trade Division of the U.S. Census Bureau.

Chapter 3

The Relative Output Volatility and Financial Development

3.1 Introduction

Understanding the economic volatilities is one of the central topics in the literature of Business Cycles (Kydland and Prescott, 1982; Lucas, 1987). Macro economists have spent decades in understanding the source of frictions in investment, labor and financial market, and searching for the channels that amplify exogenous shocks (Bernanke et al., 1999; Chari et al., 2007). One noticeable channel is the financial accelerator, which has been received new attention with global perspective, due to the recent global financial crisis and economic recession. Mendoza (2010) shows that financial crash can lead to economic "sudden stop" through the mechanism of financial accelerator.

The essential spirit of Bernanke et al. (1999) is that the effect of Balance Sheet on firms' investment decision may amplify the impact of exogenous shocks such as interest rates changes, leading to the fluctuations of aggregate economy. Previous cross-country analyses focus on the relationship between the volatility of real output and financial friction, but ignore the difference in the magnitude of exogenous shocks. The current paper presents new cross-country evidence of the relative output volatility and financial development, in particular, we focus on the volatility ratio of nominal output to money stocks.[1] Cross-country evidence shows that there is a negative correlation between the relative output volatility and financial development, and we show that it is consistent with an extended

[1] We use the volatility of money stock, rather than the volatility of nominal interest rate, as a measure of the magnitude of monetary shocks. It is because the nominal interest rate instruments are likely to be manipulated by governments in many developing countries, which adopt inflation targeting monetary policy by controlling money supplies directly. Moreover, we find a weakly negative correlation between the real output volatility and financial development, but it makes more sense to use the relative volatility of output because the magnitude of monetary shocks can be different across countries.

model of financial accelerator based on Bernanke et al. (1999).

Our paper is firstly motivated by the observation of the volatilities of nominal GDP to money stock (M2) in the US and China.[2] Table 3.1 shows that the volatilities of money stock (g_M) and nominal output (g_{PY}) are both larger in China than in the US. [3] It is not surprising to see that the Chinese economy is more volatile than the US, because it is a fast-growing transitional economy. However, it is interesting to see that the volatility ratio of the output to money stock is much larger in China (more than 1) than in the U.S. (about one half).

Table 3.1 and Table 3.2 list the volatilities of money stock and nominal GDP's growth rates for 22 (annual data) and 18 (quarterly data) countries individually. First, we observe large variations in both the volatilities of money stocks and output, and there is a positive correlation between them. Basically, more volatile money stock is associated with more dramatic fluctuation of output. Second, we also observe a large variation of the relative volatility of output to money stock. Notice that Mexico and India, just like China, have a larger ratio than 1, while the relative volatility ratio is smaller in UK and Denmark.

Figure 3.1 shows that the relative volatility of output to money stock is negatively correlated with financial development level.[4] It implies that the relative volatility of output is smaller in countries with better financial systems. Figure 3.2 shows a similar pattern for a group of developed countries in which we use a different measure of financial index. [5] Our conjecture is that countries with poorer financial system have larger output volatility due to the stronger effect of financial accelerator mechanism, given the same monetary shocks.

We introduce the classic liquidity demand for money into the framework of Bernanke et al. (1999) model. This allows us to evaluate the relative volatility of output to money demand (in money market equilibrium it is equal to money stock). By doing so, we can evaluate the role of financial friction in the relative volatility of output. We calibrate the model to both the U.S. and China, simulation exercise shows that the model can catch the empirical evidence that financial development and relative output volatility is negatively correlated.

This paper is organized as follows. Section 3.2 describes the literature of financial accelerator. Section 3.3 describes the model. In section 3.4 we do simulation and show the results can replicate the empirical evidence. Section 3.5 presents concluding remarks.

[2] We use the standard deviation of de-trended time series data to assess the volatility. Here we report results based on the first difference filter, namely the growth rates, but all results reported herein also hold with alternative filters, including the Hodrick-Prescott and Baxter-King band-pass filter.

[3] The sample period is between 1985 and 2008 because China has begun to build the modern bank system and the central bank has started to release international comparable statistics since 1985.

[4] The sample size is small as we limit the countries which have consistent definition of money stock in IFS dataset.

[5] In Figure 3.1, the measure of financial development is FD score from world economic forum. In Figure 3.2, it is financial index scores from IMF, 4th chapter of World Economic Outlook, September 2006.

3.2 Literature Review

Most economists agree that monetary policy can significantly influence the real economy, at least in the short run (Friedman et al. (1989), Romer and Romer (1989),Christiano et al. (1996)). Conventional wisdom about how money influences real economy is that monetary policymakers use their leverage over short-term interest rate to influence the cost of capital, and consequently spending on fixed investment, housing, inventories and consumer durables. Changes in aggregate demand affect the level of production. But empirical studies show that the effect of cost-of-capital is weak. Also it is puzzling to see that monetary policy has large effects on purchase of long-term assets. Thus Bernanke and Gertler (1995) introduce financial friction, so called credit channel, to explain those puzzles. They emphasize two channels. One is balance sheet channel, stressing the potential impact of changes in monetary policy on borrowers' balance sheets and income statements, including variables such as borrowers' net worth, cash flow and liquid assets. Another is bank lending channel, focusing more narrowly on the possible effect of monetary policy actions on the supply of loans by depository institutions.

The procyclical nature of net worth leads the external finance premium, the wedge between the cost of external finance and internal funds, to fall during booms and to rise during recessions. Bernanke et al. (1999) and others, including Kiyotaki and Moore (1997) and Carlstrom and Fuerst (1997), demonstrate that these financial frictions may significantly amplify the magnitude and the persistence of fluctuations in economic activity.

Bernanke et al. (1999) develop a model in which there is a two-way link between the borrowing costs of firms and their net worth. In their model, entrepreneurs, who borrow funds to undertake investment projects, face an external finance premium that rises when their leverage increases. A tightening in monetary policy, for example, reduces the return on capital and then the net worth of firms. The declines in net worth raise external financing costs and reduce the demand for capital. The drop in demand for capital reinforces the decline in its value. This mechanism is often called an accelerator effect, because the lower price of capital has a feedback effect, further lowering the net worth of firms.

Carlstrom and Fuerst (1997) find that the financial friction allows the model to better match the key feature of the data: a hump-shaped output response to shocks in a standard real business cycle model, but it did not amplify the response of output. Using a sticky-price model calibrated to postwar US data, Bernanke et al. (1999) show that a different setup for the financial-accelerator mechanism both amplifies the impact of shocks and provides a quantitatively important mechanism that propagates shocks at business cycle frequencies.

Meier and Muller (2005) estimate their model with US data by matching impulse responses with the empirical ones to a monetary policy shock from a vector autoregression. Their findings attribute an important role to capital adjustment costs, but only a marginal role to the accelerator in explaining the transmission of monetary policy shocks. They argue that little is lost if DSGE models do not incorporate financial-accelerator effects. Christensen and Dib (2008) find that the accelerator mechanism plays an important role in the transmission of monetary policy shocks.

3.3 Model

We follow the financial accelerator model discussed in Bernanke et al. (1999). The financial friction is represented by "costly state verification". The lender must pay a cost if he or she wishes to observe a borrower's realized return on capital. The monitoring cost is assumed to be equal to a proportion (μ) of the realized gross payoff to the firm's capital. Thus, μ is a measure of financial development. It is smaller in a financially developed country and bigger in a less developed country. In order to control other differences between developed and developing countries, we will look at the effect of μ in a specified economy.

When μ increases, the lender must pay a larger proportion to know the real return of capital if the borrower defaults; thus the lender will ask for a bigger return premium. The borrower then will decrease its borrowings and accumulate more net worth, therefore the steady state capital-net worth ratio decreases. As money expands, values of net worth increase and firms only need to pay a smaller risk premium to get loans. It stimulates investment and therefore increases output. On the other side, if there is a negative shock to shrink money stock, the prices of goods and capital decrease which make the net worth of firms worthless. Risk premium will increase and prevent firms from buying a lot to do investment. Therefore the μ plays an important role in accelerating output to make it more volatile than money stock. In the following model we will see in detail how this parameter works. We add the money demand function into the basic model so that in general equilibrium we can identify the role of μ on volatility of money and output.

3.3.1 Financial Friction

Let's denote the profit per unit of capital as ωR^k, where ω is an idiosyncratic shock to a firm's return and R^k is the return to capital. Assume $E(\omega) = 1$, $F(x) = Pr(\omega < x)$ is the CDF and $f(\omega)$ is the pdf of ω. The initial net worth of a firm is N, and the price of capital is Q. In order to invest a project which needs capital K, the firm has to borrow QK-N. Before investment ω is unknown to both firms and lender. After making the investment decision, the firm knows ω, but the lender has to pay some monitoring cost to know it. The cost is proportional (μ) to the total return of that firm.

If ω is quite large, the firm will have enough return to pay the loan back to the lender, and then get the left. The non-default loan rate is Z. But if ω is very small, the firm will go to bankruptcy and receive nothing. After paying the monitoring cost the lender will then get the residual which is $1 - \mu$ times the total capital payoff. Thus the cut-off $\bar{\omega}$ is defined as $\bar{\omega} R^k QK = Z(QK - N)$. Let's define the total capital payoff of default firms as:

$G(\bar{\omega}) = \int_0^{\bar{\omega}} \omega f(\omega) d\omega$
Then the total gross share of the capital payoff going to the lender is
$\Gamma(\bar{\omega}) = G(\bar{\omega}) + \bar{\omega} \int_{\bar{\omega}}^{\infty} f(\omega) d\omega$.
The net share to the lender is $(1-\mu)G(\bar{\omega}) + \bar{\omega} \int_{\bar{\omega}}^{\infty} f(\omega) d\omega$.

For firms they want to get maximal payoff by choosing the quantity of capital K. For lenders the expected return should be equal to the opportunity cost of their funds which is the riskless rate R. Therefore the optimal contracting problem is:

$$\max_{K,\bar{\omega}} (1-\Gamma(\bar{\omega}))R^k QK$$
$$s.t. [\Gamma(\bar{\omega}) - \mu G(\bar{\omega})] R^k QK = R(QK - N)$$

Let's define the premium on external financing $s = R^k/R$, capital-wealth ratio $k = QK/N$, and λ as the Lagrange multiplier on the constraint. After rearranging the first order conditions to K, ω, λ, we can get three equations for s, k, λ.

$$\lambda(\bar{\omega}) = \frac{1-F(\bar{\omega})}{1-F(\bar{\omega}) - \mu\bar{\omega} f(\bar{\omega})}$$
$$s = \frac{\lambda(\bar{\omega})}{(1-\Gamma(\bar{\omega})) + \lambda(\Gamma(\bar{\omega}) - \mu G(\bar{\omega}))}$$
$$k = 1 + \frac{\lambda(\Gamma(\bar{\omega}) - \mu G(\bar{\omega}))}{1-\Gamma(\bar{\omega})}$$

By calculation, we get $\bar{\omega}'(s) > 0$, $k'(\bar{\omega}) > 0$ and thus $\frac{\partial s}{\partial k} > 0$. It is the most important result in our analysis. If a firm has relatively large ratio of net worth to the total capital required, then the risk premium the lender would like to charge is relatively small; thus in equilibrium the firm gets more capital and invest more.

Then, the supply of extern financing is defined by the below equation.

$$E(R_t^k) = s\left(\frac{N_t}{Q_{t-1}K_t}\right)R_t \tag{3.1}$$

3.3.2 Household

In the model, there is a continuum of households. Each household works, consumes, holds money, and deposits. Let's denote C_t as consumption, H_t as labor supply, D_t as deposit, M_t as money holdings, W_t as real wage, R_t as riskless interest rate, Π_t as dividends from ownership of retail firms, T_t as tax. Then the household problem is:

$$\max_{C_t,H_t,D_t,M_t} E_t\Sigma_{k=0}^{\infty}\beta^k[ln(C_{t+k}) + \varsigma ln(M_{t+k}/P_{t+k}) - \frac{H_{t+k}^{1+\frac{1}{\eta}}}{1+\frac{1}{\eta}}]$$
$$s.t. C_t = w_t H_t - \frac{T_t}{P_t} + \frac{\Pi_t}{P_t} + R_t D_t - D_{t+1} + \frac{M_{t-1} - M_t}{P_t}$$

Arranging the first order conditions, we can get the following equations.

$$\frac{1}{C_t} = \frac{\beta}{C_{t+1}} R_t \qquad (3.2)$$
$$H_t^{\frac{1}{\eta}} = \frac{W_t}{C_t} \qquad (3.3)$$
$$\frac{M_t}{P_t} = \varsigma C_t \frac{R_t \cdot \frac{P_{t+1}}{P_t} - 1}{R_t \cdot \frac{P_{t+1}}{P_t}} \qquad (3.4)$$

3.3.3 Enterprise Sector

First, we assume the labor input is composed of two parts: household labor H_t and entrepreneurial labor H_t^e. $L_t = H_t^{\Omega}(H_t^e)^{1-\Omega}$. For the enterprises which produce the wholesale goods, they hire house labor at wage rate W_t, give entrepreneurial labor wage rate W_t^e and rent capital at rate R_t^k to produce and sell at a relative price of $1/X_t$. Their optimal problem is:

$$\max_{H_t,H_t^e,K_t} \prod_t = \frac{1}{X_t} Y_t - W_t H_t - W_t^e H_t^e - R_t^k Q_{t-1} K_{t-1} + (1-\delta) Q_t K_{t-1}$$
$$s.t. Y_t = A_t K_{t-1}^{\alpha} H_t^{(1-\alpha)\Omega} (H_t^e)^{(1-\alpha)(1-\Omega)}$$

The first order conditions are:

$$W_t = \Omega(1-\alpha)\frac{Y_t}{X_t H_t} \qquad (3.5)$$
$$W_t^e = (1-\Omega)(1-\alpha)\frac{Y_t}{X_t H_t^e} \qquad (3.6)$$
$$R_t^k = \frac{\alpha\frac{Y_t}{X_t K_{t-1}} + (1-\delta) Q_t}{Q_{t-1}} \qquad (3.7)$$
$$Y_t = A_t K_{t-1}^{\alpha} H_t^{(1-\alpha)\Omega} (H_t^e)^{(1-\alpha)(1-\Omega)} \qquad (3.8)$$

By equation (3) and (5), we get labor market equilibrium conditions.

$$(1-\alpha)\Omega\frac{Y_t}{H_t X_t C_t} = H_t^{\frac{1}{\eta}} \tag{3.9}$$

By equation (7), the demand for external financing is defined by the below equation.

$$E(R_t^k) = E(\frac{\alpha\frac{Y_t}{X_t K_{t-1}} + (1-\delta)Q_t}{Q_{t-1}}) \tag{3.10}$$

Let's look at the problem of capital producing enterprises. Assume there is increasing marginal adjustment costs in the production of capital. The investment expenditures of I_t yields a gross output of new capital goods $\Phi(\frac{I_t}{K_{t-1}})K_{t-1}$, where $\Phi(\cdot)$ is increasing and concave and $\Phi(0) = 0$. Then the optimal problem is:

$$\max_{I_t} \Phi(\frac{I_t}{K_{t-1}})K_{t-1}Q_t - I_t$$

The first order condition gives the below equation:

$$Q_t = [\Phi'(\frac{I_t}{K_{t-1}})]^{-1} \tag{3.11}$$

The evolution of capital is $K_{t+1} = \Phi(\frac{I_t}{K_{t-1}})K_{t-1} + (1-\delta)K_{t-1}$.

The equity that enterprises have at time $t-1$ equals to $R_t^k Q_t K_t - (R_t + \frac{\mu G(\bar{\omega}) R_t^k Q_t K_t}{Q_t K_t - N_t})(Q_t K_t - N_t)]$. The part of $R_t + \frac{\mu G(\bar{\omega}) R_t^k Q_t K_t}{Q_t K_t - N_t}$ is just the premium enterprises pay for their external financing. We assume a proportion γ of the enterprises will run business at time period t, but $1-\gamma$ of the enterprises fail and they consume the left equity. That is, the consumption of enterprises is:

$$C_t^e = (1-\gamma)[R_t^k Q_t K_t - (R_t + \frac{\mu G(\bar{\omega}) R_t^k Q_t K_t}{Q_t K_t - N_t})(Q_t K_t - N_t)] \tag{3.12}$$

The net worth of enterprise sector is the sum of the equity of succeeding firms and the entrepreneurial labor earnings.

$$N_t = \gamma[R_t^k Q_t K_t - (R_t + \frac{\mu G(\bar{\omega}) R_t^k Q_t K_t}{Q_t K_t - N_t})(Q_t K_t - N_t)] + (1-\alpha)(1-\Omega)A_t K_{t-1}(H_t^e)^{(1-\alpha)(1-\omega)} \tag{3.13}$$

3.3.4 Log-linearized Equations

To complete the model, we add the equilibrium conditions. In equilibrium, the goods market is clear.

$$Y_t = C_t + I_t + G_t + Ce_t \tag{3.14}$$

The shocks that we consider here are exogenous disturbances to nominal interest rate, technology and government expenditure. They are autoregressive processes.

$$G_t = G_{t-1}^{\rho_g} * \epsilon_t^g \tag{3.15}$$
$$A_t = A_{t-1}^{\rho_a} * \epsilon_t^a \tag{3.16}$$
$$R_t^n = R_{t-1}^{n\rho_g} * \epsilon_t^{rn} \tag{3.17}$$

Also we introduce traditional money demand equation into the model. Real money demand is a function of real output and nominal interest rate. It increases with the increase of real output and (or) the decrease of nominal interest rate.

We use lower case to denote deviations from steady state. Then the whole log-linearized model is composed of the following equations.

$$
\begin{aligned}
y_t &= \frac{C}{Y}c_t + \frac{I}{Y}i_t + \frac{G}{Y}g_t + \frac{Ce}{Y}c_t^e \\
c_t &= -r_t + c_{t+1} \\
c_t^e &= n_t \\
r_{t+1}^k - r_t &= -v[n_t - (q_t + k_t)] \\
r_t^k &= (1-\epsilon)(y_t - k_{t-1} - x_t) + \epsilon q_t - q_{t-1} \\
q_t &= \psi(i_t - k_{t-1}) \\
y_t &= a_t + \alpha k_{t-1} + (1-\alpha)\Omega h_t \\
y_t - h_t - x_t - c_t &= \frac{1}{\eta}h_t \\
\pi_t &= \kappa x_t + \beta\pi_{t+1} \\
k_{t+1} &= \delta i_t + (1-\delta)k_{t-1} \\
n_t &= \frac{\gamma RK}{N}(r_t^k - r_{t-1}) + r_{t-1} + n_{t-1} \\
r_t^n &= \rho r_{t-1}^n + \zeta\pi_{t-1} + \varepsilon_t^{rn} \\
g_t &= \rho_g g_{t-1} + \varepsilon_t^g \\
a_t &= \rho_a a_{t-1} + \varepsilon_t^a \\
r_t^n &= r_t + \pi_{t+1} \\
m_t + x_t &= \phi_y y_t - \phi_r r_t^n
\end{aligned}
$$

3.4 Simulations

3.4.1 Parameters and Coefficients

To choose the values of parameters in the log-linearized equations, we followed the paper of Fisher (1999), Carlstrom and Fuerst (1997), Clarida et al. (2000), and Bernanke et al. (1999) (See Table 3.3).

In order to solve the model, we need to fix some steady state values. There are some coefficients which are strictly affected by the value and the distribution of μ, like R^k, K/N, X, and Y/K. If we change the value of μ, the return premium varies and thus the required return to the capital does. The steady state ratio of capital to net worth will change too. The leverage ratio decreases with higher financial friction.

In steady states, $\beta R = 1$, thus we know the value of $R = 1/\beta$. For the share of government expenditure to the total output, we use the historical average (0.2) like Bernanke et al. (1999).

The share of income to entrepreneurs' labor is 0.01 given $\Omega = 0.99$. We use the historical average data to estimate C/Y and then compute $I/Y = 1 - C/Y - G/Y - Ce/Y$. For the income and interest rate elasticity of money demand, we use the long-run estimators: 1 and -0.6. Different values of ϕ_y and ϕ_i change the absolute values of the variance ratio, but the negative correlations between μ and variance ratio still exist. This is what we want to get. Using the parameters in Table 3.3 and the steady states values, we can directly calculate ϵ and κ.

3.4.2 Simulation Results

Consider a positive monetary shock, nominal interest rate unanticipated decreases 0.25 points. Here the time period we use is in quarters. Following the regular assumption, $\mu = 0.12$, the impulse response functions are shown in Figure 3.3. The impulse response of output does not have humped shape like the VAR evidence, but this question will be solved by adding investment delay (See appendix A.2).[6]

Then let's look at the case of $\mu = 0.52$, which is a random value bigger than 0.12 that we choose. Comparing with the benchmark case, the larger the μ is, the larger the responses of major variables are (Figure 3.4).

Next we show the correlation between μ and the volatility ratio $(std(PY)/std(M))$. Choosing T=100, we see a downward sloping curve (Figure 3.5).[7] With the decrease of μ, which means the financial conditions get better, the relative volatility of output to money is smaller. This is exactly what we have seen in the empirical facts.

Also, Figure 3.6 shows the calibration of China's case, and it has a similar pattern like the benchmark case of US.[8]

3.4.3 Parameters Sensitivity Check

In the appendix A.4, we plot the figures of parameters robust check. ρ_a and ρ_g have no impact since we only consider the monetary shock. α should be bigger than 0.3, η is less than 0.5, δ is less than 0.1, θ is bigger than 0.2, γ is bigger than 0.4, $F(\omega)$ is less than 0.5, Variance of ω is bigger than 0.6, and ρ needs bigger than 0.89. As long as all the parameters take the above reasonable values, we can get the negative correlation between μ and volatility ratio $std(g_{PY})/std(g_M)$. The simulated results are not affected by the choice of parameters' values.

[6]The results reported herein hold if we add investment delay.

[7]Here one period is one quarter, thus 100 means 25 years. It is long enough to show the effect of shocks.

[8]To calibrate China, I modified the following parameters: depreciation rate for capital ($\delta = 0.025$), response of nominal interest rate to lagged inflation ($\zeta = 0.04$), serial correlation of nominal interest rate ($\rho = 0.96$), death rate ($1 - \gamma = 0.3$), entrepreneurial consumption share ($C_e/Y = 0.02$), steady-state share of government expenditures ($G/Y = 0.1437$), consumption share to GDP ($C/Y = 0.4517$)

3.4.4 Quantitative Analysis

Until now our simulation results are qualitatively similar as the empirical evidence. In order to see the model performance, let's do quantitative analysis. Since it is hard to define μ in reality, we need to turn to an intermediate statistics. In the model, the interest premium fluctuates more as μ increases. It not only leads to bigger variance ratio, but also a smaller ratio of credit to output. Credit is the total capital purchased and invested by entrepreneur minus the net worth it has. It is just what the entrepreneurs borrow. See Figure 3.7 for the correlation of μ and credit/(PY).

By Figure 3.5 and 3.7, we can infer there is a negative correlation between the ratio of credit to output and the variance ratio. Figure 3.8 is the simulated result of credit/(PY) and variance ratio $std(g_{PY})/std(g_M)$.

We would like to find a measure of credit, and then divide it by nominal GDP to get the ratio of credit/(PY) in real world. By adjusting parameters we can let the simulated ratio the same number as the real one.

In Flow of Funds Accounts of the United States, there is a measure of credit market debt outstanding.[9] It is a stock but not flow variable, just like the credit definition in our model. We add credit market debt outstanding of household sector, non-financial corporate business, nonfarm noncorporate business, and farm business together to get the domestic debts without government. It is consistent with our definition in the model. Dividing this variable by nominal GDP we get credit/(PY). Taking average for 1985-2005, the value is 1.36.

Slightly adjusting some parameters values, η decreases from 3 to 1 and $var(\omega)$ increases from 0.28^2 to 0.6^2. We can get simulated value of credit/PY, which is 1.36. We change ψ from 0.25 to 2 and then the simulated value of $std(PY)/std(M)$ approaches the real one 0.53.[10] Ideally if we have other countries credit data, we can compare it with the value got from calibration by US parameters. Then we can tell to what extent the output volatility difference among countries is caused by the difference of financial development. This is my future work.

3.5 Conclusions

In this paper, we reveal the correlation between relative output volatility and financial development using cross country data. Then we expand the financial accelerator model to explain such a correlation. With poorer financial conditions, the changes of asset prices lead to dramatic fluctuations of net worth, and thus the wedge between external and internal

[9]It is table L.1, end of period measurement. Unit is billions of dollars and the frequency is annually.

[10]King and Wolman (1996) also uses a value of 2 based on estimates from aggregate data by Chirinko (1993).

financing cost is bigger. The stronger effect of financial accelerator mechanism accounts for the larger volatility of output to money. The simulation results are also consistent with the empirical facts.

Table 3.1: Standard Deviations of Money and Nominal GDP Growth Rates (Annual Data)

Country	Stdev(g_{M2})	Stdev(g_{NGDP})	Stdev(g_{NGDP})/Stdev(g_{M2})	Sample
Australia	7.04	2.97	0.42	1985-2008
Canada	4.00	2.27	0.57	1985-2008
Chile	7.57	4.81	0.63	1998-2008
China	7.31	7.91	**1.08**	1985-2008[1]
	6.75	7.91	**1.17**	1985-2008[2]
	2.12	5.01	**2.37**	1999-2008[3]
Denmark	5.63	1.67	0.30	1992-2008
Egypt	3.52	4.63	**1.32**	1999-2007
France	3.18	2.10	0.66	1985-1998
Germany	6.35	4.05	0.64	1985-1998
Hungary	7.96	7.49	0.94	1991-2008
India	2.56	3.92	**1.53**	1985-2008
Indonesia	14.68	10.66	0.73	1996-2008
Italy	3.51	2.86	0.81	1985-1998
Japan	3.53	3.05	0.87	1985-2008
Kenya	5.55	4.59	0.83	2001-2008
Korea	8.45	5.84	0.69	1985-2008
Mexico	33.59	34.58	**1.03**	1986-2008
Poland	8.37	5.35	0.64	1997-2008
Singapore	7.26	6.24	0.86	1992-2008
Spain	5.19	3.26	0.63	1985-1998
UK	19.03	2.13	0.11	1985-2008
US	2.53	1.34	0.53	1985-2008
Vietnam	13.93	5.14	0.37	1996-2008

Data source is International Financial Statistics (IFS).
[1] The sum of money and quasi money from IFS.
[2] M2 with measurement change by author's revision.
[3] M2 from IFS.

Table 3.2: Standard Deviations of Money and Nominal GDP Growth Rates (Quarterly Data)

Country	Stdev(g_{M2})	Stdev(g_{NGDP})	Stdev(g_{NGDP})/Stdev(g_{M2})	Sample
Australia	7.18	3.27	0.46	1985q1-2009q3
Canada	4.00	3.23	0.81	1985q1-2009q3
Chile	7.30	5.98	0.82	1998q4-2009q3
China	3.66	9.06	**2.47**	2000q1-2009q3
	6.22	8.97	**1.44**	1993q1-2009q3[1]
Denmark	5.25	2.75	0.52	1992q1-2009q3
France	3.36	2.25	0.67	1984q1-1998q4
Germany	6.71	5.46	0.81	1984q1-1998q4
Hungary	4.28	7.33	**1.71**	1996q1-2009q3
India	3.63	6.40	**1.76**	2005q1-2009q3
Indonesia	15.26	10.99	0.72	1996q1-2009q3
Italy	4.14	3.20	0.77	1984q1-1998q4
Korea	8.28	5.95	0.72	1984q1-2008q4
Mexico	33.52	34.99	**1.04**	1986q4-2009q3
Poland	7.89	4.39	0.56	1997q4-2009q3
Singapore	5.47	6.96	**1.27**	2004q1-2009q2
Spain	5.15	3.25	0.63	1984q1-1998q4
UK	18.45	2.81	0.15	1984q1-2009q3
US	2.41	1.94	0.81	1984q1-2009q3

Data source is International Financial Statistics (IFS).
[1] we construct the quarterly GDP data from 1993Q1 to 1999Q4 by using yearly data.

Table 3.3: Values of Parameters

Parameters	Value	Explanation
β	0.99	discount factor
α	0.35	capital share of production
η	3	labor supply elasticity
Ω	0.99	household labor share
δ	0.025	depreciation rate for capital
ρ_a	1	serial correlation for technology shock
ρ_g	0.95	serial correlation for government expenditure shock
ρ	0.90	serial correlation for nominal interest rate
ζ	0.11	response of nominal interest rate to lagged inflation
θ	0.75	probability a firm does not change its price within a given period
γ	1-0.0272	death rate is 1-γ=0.0272
ψ	0.25	elasticity of the price of capital with respect to the investment capital ratio

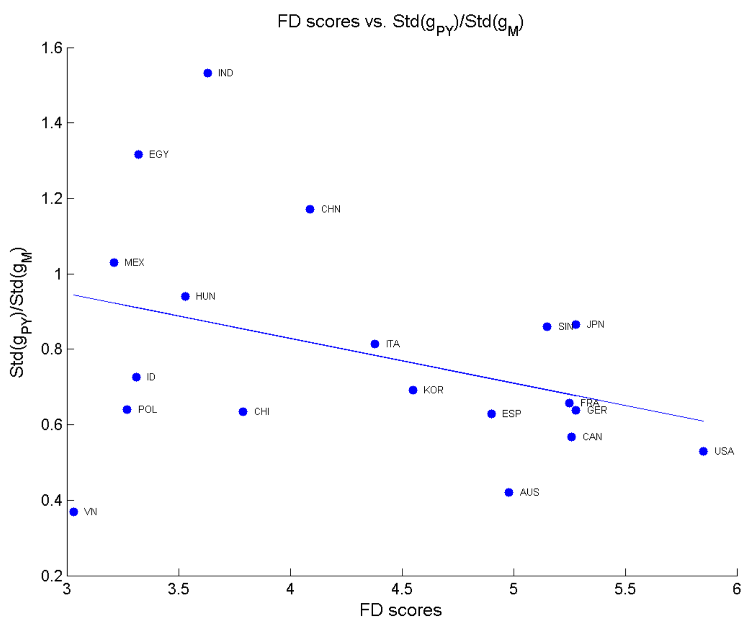

Figure 3.1: Financial Development and Volatility Ratio

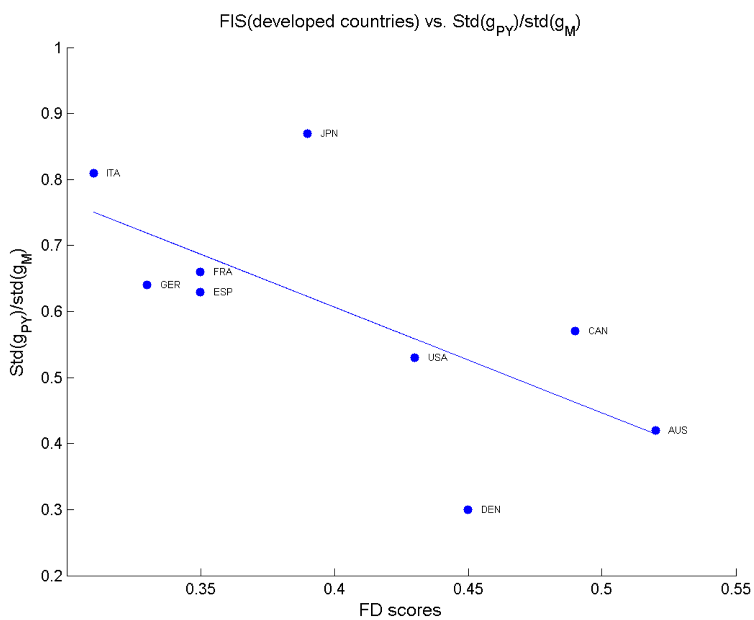

Figure 3.2: Financial Development and Volatility Ratio (Developed Countries)

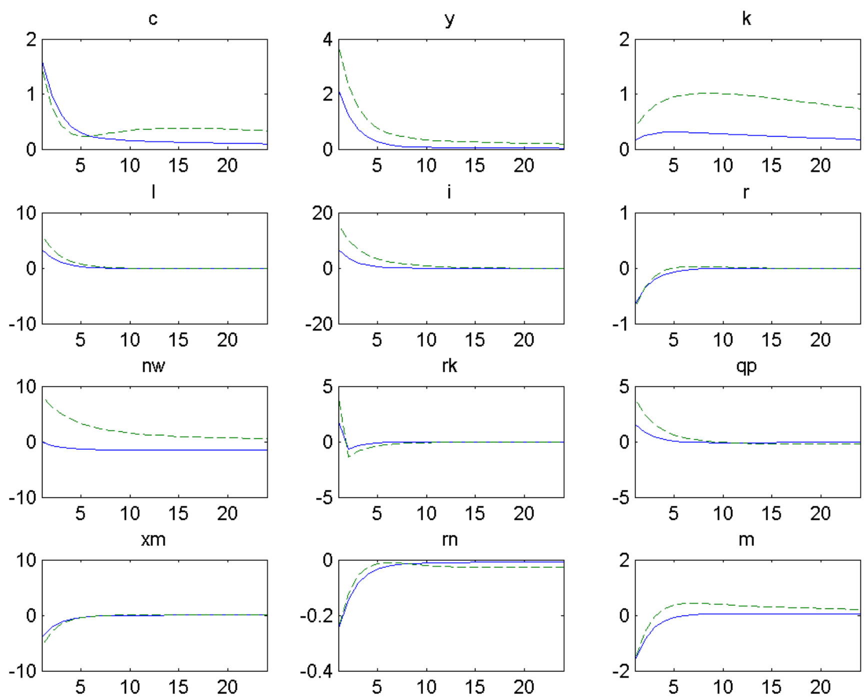

Figure 3.3: Impulse Response of Monetary Shock-Basic Case: $\mu = 0.12$

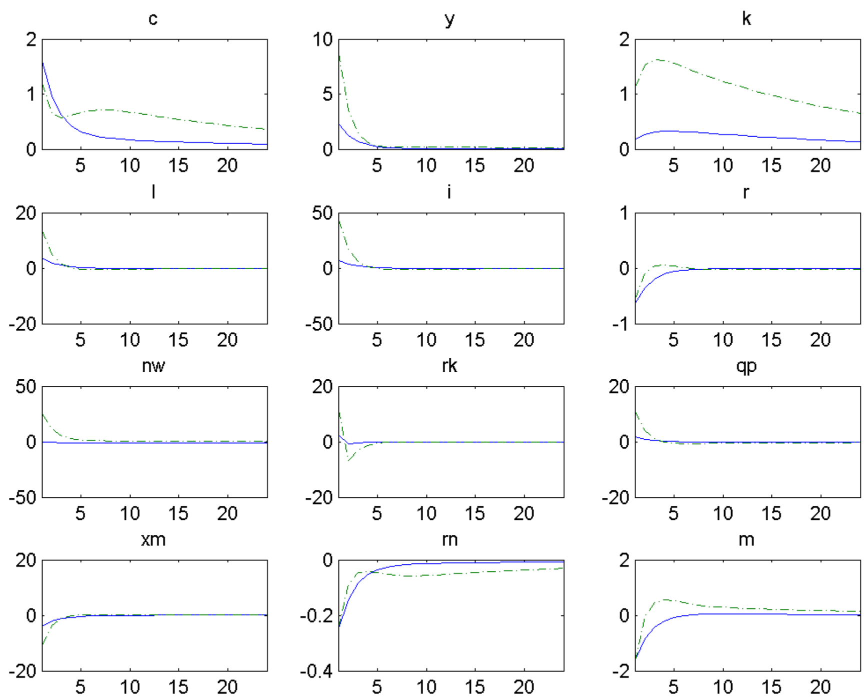

Figure 3.4: Impulse Response of Monetary Shock-Alternative Case: $\mu = 0.52$

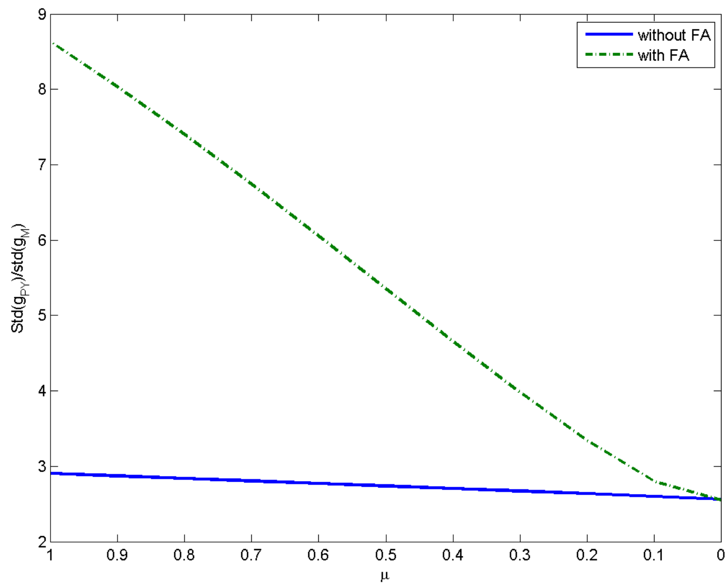

Figure 3.5: Simulated Financial Development Measure and Volatility Ratio

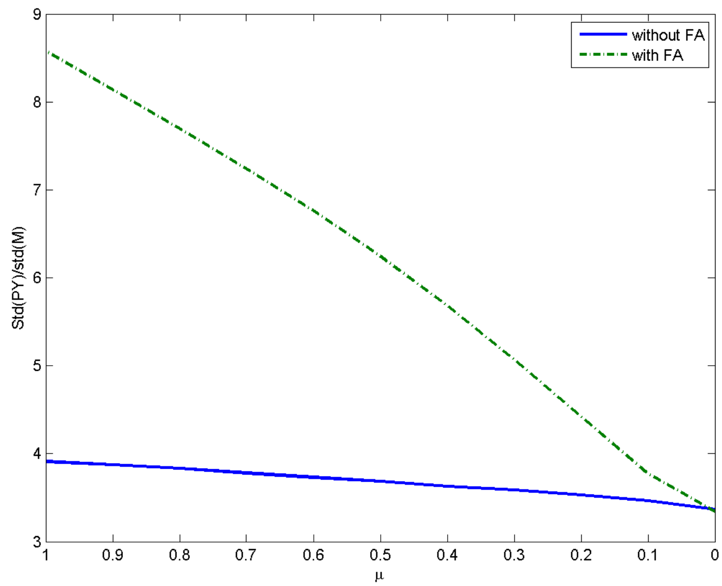

Figure 3.6: Simulated Financial Development Measure and Volatility Ratio in China

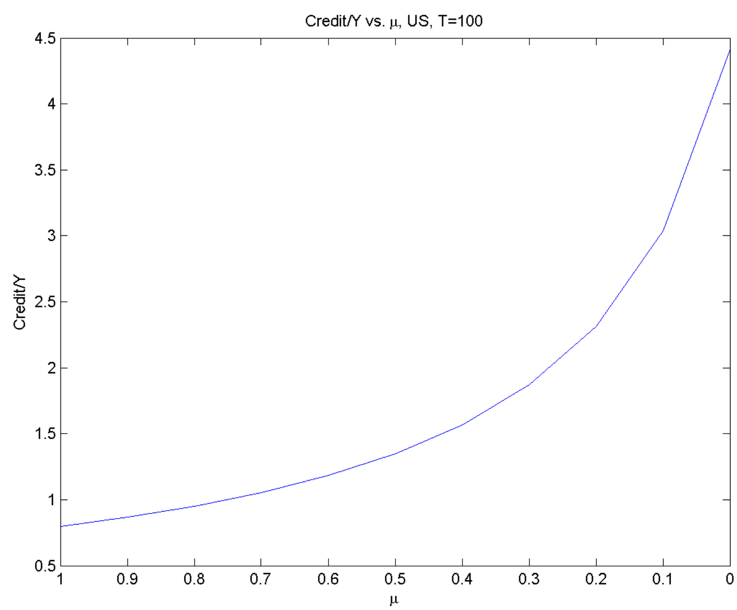

Figure 3.7: Simulated Financial Development Measure and Ratio of Credit to Output

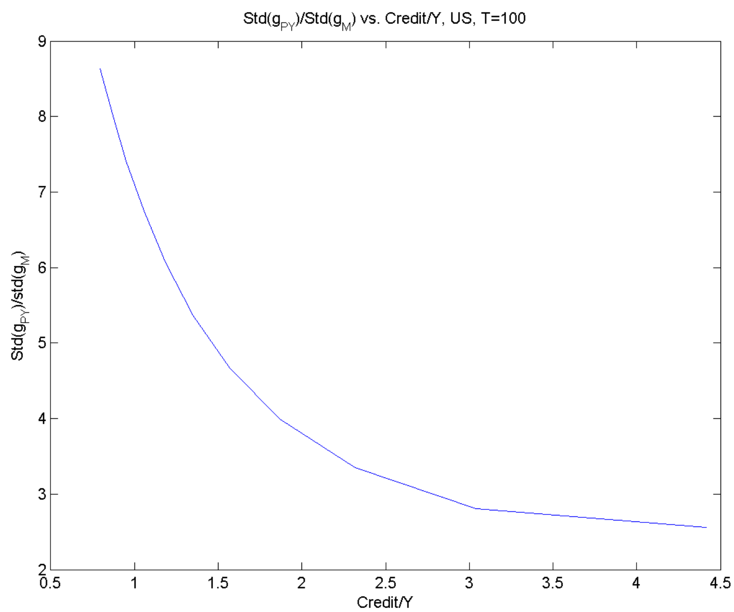

Figure 3.8: Simulated Ratio of Credit to Output and Volatility Ratio

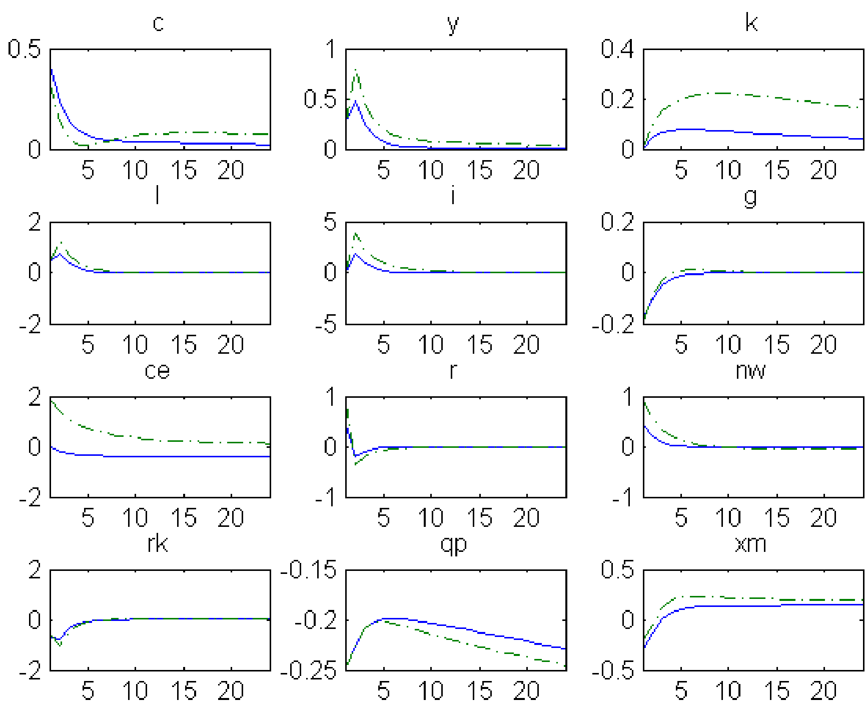

Figure 3.9: Impulse Responses of Monetary Shock with Investment delay: $\mu = 0.12$

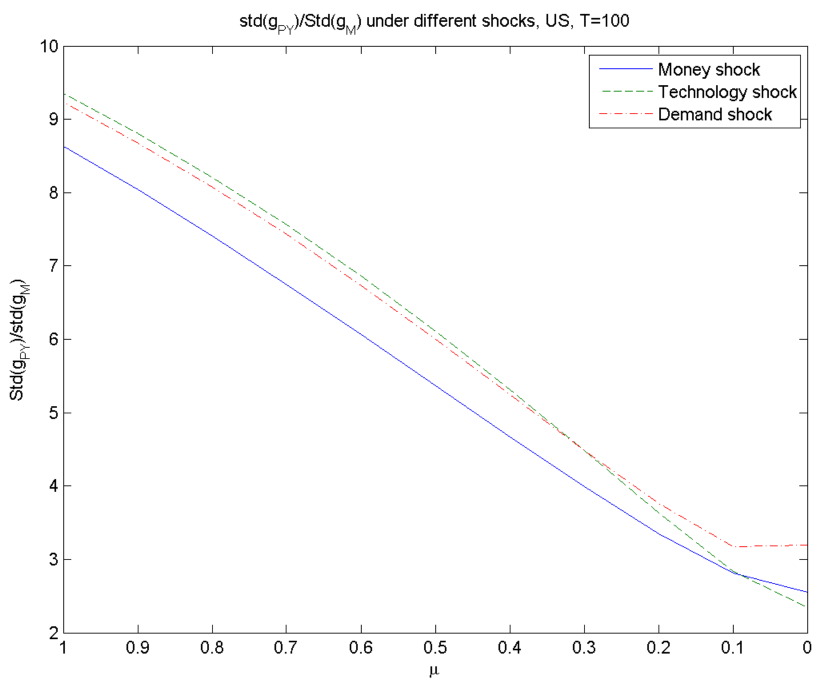

Figure 3.10: Comparison under Different Shocks

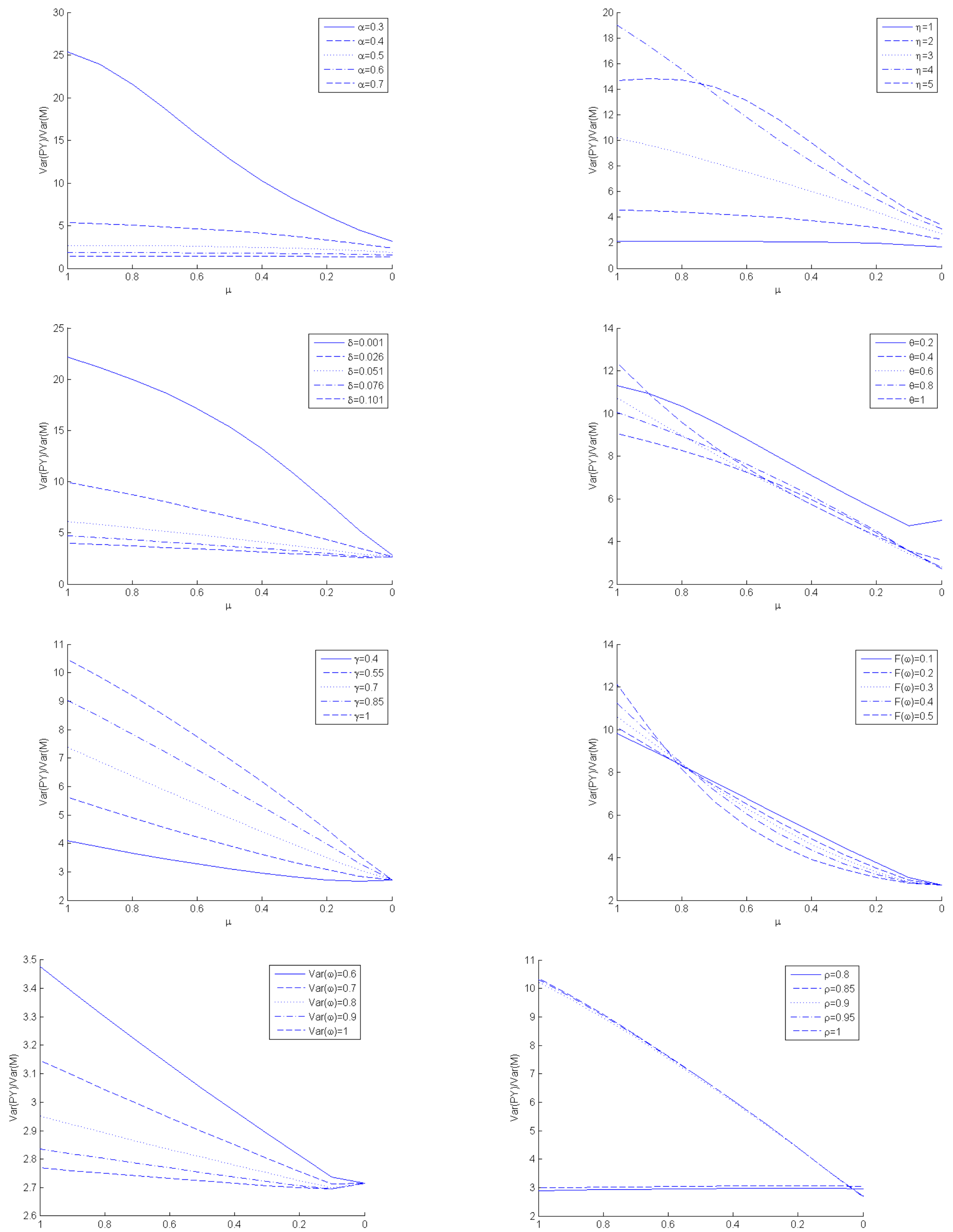

Figure 3.11: Parameters Sensitivity Check

Appendix A

A.1 Lists of Commodities under the IMF Primary Commodity Price Tables and UNCTAD Classifications

IMF Primary Commodity Price Tables: Aluminum, bananas, barley, beef, butter, coal, cocoa beans, coconut oil, coffee, copper, copra, cotton, DAP, fish, fish meal, gasoline, gold, groundnuts, groundnut oil, hides, iron ore, jute, lamb, lead, linseed oil, maize, natural gas, newsprint, nickel, olive oil, oranges, palm kernel oil, palm oil, pepper, petroleum, phosphate rock, potash, poultry, plywood, pulp, rice, rubber, shrimp, silver, sisal, sorghum, soybeans, soybean meal, soybean oil, sugar, sunflower oil, superphosphate, swine meat, tea, timber, hardwood logs, hardwood sawnwood, softwood logs, softwood sawnwood, tin, tobacco, uranium, urea, wheat, wool, zinc.

UNCTAD: Aluminum, bananas, beef, cattle hides, coarse wool, cocoa beans, coconut oil, coffee, copper, copra, cotton, cottonseed oil, crude petroleum, fine wool, fish meal, gold, groundnut oil, iron ore, jute, lead, linseed oil, maize, manganese ore, nickel, non-coniferous woods, palm kernel oil, palm oil, pepper, phosphate rock, plywood, rice, rubber, silver, sisal, soybean oil, soybeans, soybean meal, sugar, sunflower oil, tea, tin, tobacco, tropical logs, tropical sawnwood, tungsten ore, wheat, zinc.

A.2 The Case with Investment Delay

Different from the basic model in the text, we consider the case with investment delay. See Figure 3.9 of the impulse response functions for the same μ like Figure 3.3, output has humped shape like the VAR evidence.

A.3 Other Shocks

In the basic model, if the shocks are not from the changes of interest rate, but from the changes of technology or government expenditure, then we still get downward sloping curves (Figure 3.10).

A.4 Parameters Sensitivity Check

We do robust checks for main parameters: α, η, δ, θ, γ, $F(\omega)$, $Var(\omega)$ and ρ. See Figure 3.11 for the simulation results.

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