THREE ESSAYS ON MONETARY POLICY IN ECONOMIES WITH FINANCIAL

FRICTIONS

A Dissertation

Presented to the Faculty of the Graduate School

of Cornell University

In Partial Fulfillment of the Requirements for the Degree of

Doctor of Philosophy

by

Rahul Anand

May 2010

THREE ESSAYS ON MONETARY POLICY IN ECONOMIES WITH FINANCIAL FRICTIONS

Rahul Anand, Ph. D.

Cornell University 2010

The objective of this dissertation is to understand the role of financial frictions in the transmission of shocks and their effect on the monetary policy transmission mechanism. To accomplish the task, we develop Dynamic Stochastic General equilibrium models with financial frictions.

In the first chapter, we develop a model to analytically determine the appropriate price index to target in the presence of financial frictions (where a fraction of households are constrained to consume their wage income each period). The analysis suggests that in the presence of financial frictions, a welfare-maximizing central bank should adopt flexible headline inflation targeting—i.e. a headline inflation target but with some weight on the output gap. These results are particularly relevant for emerging markets, where the share of food expenditures in total consumption expenditures is high and a large proportion of consumers are credit constrained.

In the second chapter, we develop a small open economy model with macro-financial linkages. The model includes a financial accelerator - entrepreneurs are assumed to partially finance investment using domestic and foreign currency debt - to assess the importance of financial frictions in the amplification and propagation of the effects of transitory shocks to productivity, interest rates and net worth of firms. We use Bayesian estimation techniques to estimate the model using India data. The model is used to assess the importance of the financial accelerator in India and to assess the

optimality of the current monetary policy rule.

   In the third chapter, we develop a small open economy New Keynesian model with financial frictions and an active banking sector for India. We find that the presence of a monopolistic banking sector with sticky interest rate setting attenuates the shocks. However, if the interest rates are flexible it results in the amplification of shocks. We also find that an unexpected reduction in bank capital can have a substantial impact on the real economy and particularly on investment. Use of non-monetary policy tools result in greater volatility as compared to when central banks use traditional monetary tightening.

BIOGRAPHICAL SKETCH

Son of Shobha Sinha and Birendra P. Sinha, Rahul Anand grew up in Patna, state of Bihar, India. He graduated from St. Xaviers' High School, Patna in 1988. He received his Bachelors' degree in Chemical Engineering from the Indian Institute of Technology, Kanpur, India. Being motivated by public service, he joined the prestigious Indian Administrative Service in 1996. He held various senior positions in the Government of Himachal Pradesh responsible for implementing the policies and programs of the Government for socio-economic development. He has also led donor funded projects in the fields of education, health and agriculture, and has a deep understanding of the working of social, legal, economic and political systems in India. Before deciding to take up academics again, he was a senior administrator of a district with 4 million people. He has received many accolades for his work in the field of e-governance and public administration. He was awarded the Catherine B. Reynolds Fellowship by Harvard University for his social entrepreneurial work to pursue a masters' program at the Kennedy School of Government in 2005. He is also a recipient of the Aga Khan International Scholarship. He started his PhD program at Cornell in 2006 as a Nandlal P. Tolani Fellow in the Applied Economics department. He has also worked at the World Bank and the International Monetary Fund. He has been offered a mid-career economist job at the International Monetary Fund. He is married to Kavita and is blessed with two lovely children, Shraddha and Yash.

To Baba and my family

ACKNOWLEDGMENTS

Whatever I have achieved in my life till date is due to the inspiration and teachings of my grandparents, Bhola Prasad Singh and Vidyawati Sinha. I thank my parents, Birendra Prasad Sinha and Shobha Sinha for believing in me and constantly urging me to take up new challenges. Their word of encouragement and faith in my abilities, gave me the vigor and strength for sustaining this work.

I would also like to thank Safiya Aftab for being a great friend and support from the day I decided to do the PhD.

My special thanks to my children, Shraddha and Yash. Even at this tender age they fully understood the constraints on my time and in their own small little way helped me as much as they could. They have been a source of immense joy and made this sometimes trying process entirely bearable. I thank my wife, Kavita, for going through all the ups and downs with me and extending her unflinching support and love at each stage. Without the support of my kids and wife, I would not have been able to finish this onerous task.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1
OPTIMAL PRICE INDICES FOR TARGETING INFLATION UNDER INCOMPLETE MARKETS

1.1 Introduction

The global financial crisis has led to a vigorous debate about the appropriate objectives for monetary policy. For instance, it has been posited that a narrow version of inflation targeting (IT) could pose risks if it implies that potential asset bubbles are ignored by central banks. The emerging consensus appears to be that the IT framework has delivered price stability and should be retained but that central banks should use prudential regulation and other policy tools to counteract asset price bubbles. Whether or not IT is the chosen framework, central banks around the world view low and stable inflation as a primary, if not dominant, objective of monetary policy.

What is the right price index that should be the focus of the inflation objective? This is a central operational issue in implementing not just IT but any version of monetary policy. Two key issues about the choice of price index are--determining the level of inflation that is consistent with the notion of price stability and determining the appropriate price index. In this paper, we focus on the task of analytically determining the appropriate price index for markets with financial frictions in general and emerging markets in particular.

In the literature, the choice of price index has been guided by the idea that inflation is a monetary phenomenon. It has been suggested that core inflation (excluding food, energy and other volatile components from headline CPI) is the most appropriate measure of inflation (Wynne, 1999). The logic is that fluctuations in food and energy prices represent supply shocks and are non-monetary in nature. Since these shocks are

transitory and volatile and do not reflect changes in the underlying rate of inflation, they should not be a part of the inflation targeting price index (Mishkin, 2007, 2008).

Previous authors have used models with price and/or wage stickiness to show that the choice of this price index is consistent with a welfare maximization objective. Existing models have looked at complete market settings where price stickiness is the only source of distortion (besides monopoly power). Infrequent price adjustments cause mark-ups to fluctuate and also distort relative prices. In order to restore the flexible price equilibrium, central banks should try to minimize these fluctuations by targeting sticky prices (Goodfriend and King, 1997, 2001). Using a variant of a New Keynesian model, Aoki (2001) has shown that under complete markets targeting inflation in the sticky price sector leads to welfare maximization and macroeconomic stability. Targeting core inflation is equivalent to stabilizing the aggregate output gap as output and inflation move in the same direction under complete markets.

Appropriateness of the core price index in these models relies heavily on the assumption that markets are complete (allowing households to fully insure against idiosyncratic risks) so that the central bank only needs to tackle the distortions created by price stickiness. However, there is compelling evidence that not all agents in the economy may be able to smooth their consumption (Campbell and Mankiw, 1989, 1990, 1991).[1] This observation is also consistent with the findings of a myriad of papers rejecting the permanent income hypothesis. It has been shown that, in the presence of credit-constrained consumers, policymakers' welfare objectives are altered and the Taylor rule becomes too weak a criterion for stability (Amato and Laubach, 2003; and Gali, Lopez-Salido and Valles, 2004) .

---

[1] Campbell and Mankiw estimate that in the U.S. nearly 50 percent of income accrues to consumers who do not smooth their consumption. Muscatelli, Tirelli and Trecroci (2003) find that about 37 percent of consumers are rule-of-thumb consumers and they account for 59 percent of total employment. For further evidence on the proportion of credit-constrained consumers in the U.S., see Jappelli (1990), Shea (1995), Parker (1999), Souleles (1999), Fuhrer (2000), and Fuhrer and Rudebusch (2003).

Our main objective in this paper is to develop a model to study the welfare implications of targeting different price indices in an incomplete markets setting and to analytically determine the appropriate price index to target. A major contribution of this paper is to study the implication of financial frictions (modeled by the presence of credit constrained consumers) on the choice of optimal price index.

Financial frictions that result in credit-constrained consumers have not received much attention in models of inflation targeting. To examine the significance of financial frictions, we develop a model with heterogeneous agents, where a fraction of consumers can not smooth their consumption—that is, they simply consume their current labor income.[2] When markets are not complete and agents differ in their ability to smooth consumption, their welfare depends on the nature of idiosyncratic shocks. Thus, this modeling choice also allows us to look at the welfare distribution under alternative choices of the price index.

Under complete markets, the income distribution following a sector-specific shock does not matter for the choice of consumption and, hence, welfare. However, under incomplete markets, household income, which depends on the nature of shocks and the price elasticity of demand for goods, matters for the consumption choice.[3] Price elasticity of the demand for food, which has not attracted much attention in complete market settings, becomes important under incomplete markets. We show that, through its impact on household's income and expenditure, the low price elasticity of the demand for food is an important determinant of the optimal choice of price index under incomplete markets.[4]

---

[2] We introduce this friction in a manner similar to that of Gali, Lopez-Salido and Valles (2004).

[3] If demand of one good is very low, following a negative shock its demand will not go down by much and the income of net seller of that good will go up. Consequently, the expenditure on that good will go up substantially for net buyers.

[4] A survey by the U.S. Department of Agriculture suggests that the average price elasticity of food is -0.34 in a sample of 114 countries; this estimate is much lower than the elasticity normally used in other models.

We also incorporate other important features relevant to emerging markets into the model. The share of food in total household expenditures is much higher in emerging markets, where it constitutes nearly 40-50 percent of household expenditures compared to 10-15 percent in advanced economies. Low price and income elasticities of food, and low income levels make the welfare of agents in emerging markets more sensitive to fluctuations in food prices. Since expenditure on food in total household expenditure is high and demand for food is relatively inelastic, agents may factor in food price inflation while bargaining over wages. Through this channel, food price inflation feeds into inflation expectations. Thus, in emerging markets even inflation expectation targeting central banks have to be concerned about food price inflation.

The key finding of the paper is that in the presence of financial frictions targeting core inflation (i.e., inflation in the sticky price sector) may not be optimal. Lack of access to financial markets makes the demand of credit-constrained consumers insensitive to fluctuations in interest rates. Since their demand depends only on real wages, a link is established between aggregate demand and real wages. Thus, in the presence of financial frictions, the relative price of the good produced in the flexible price sector not only affects aggregate supply but, through its effects on real wages, also influences aggregate demand.

This result is at variance with the prior literature based on complete markets settings. For instance, in Aoki's (2001) model, relative prices of the flexible price sector only appear as a shift parameter of inflation in the sticky price sector. Thus, under incomplete markets, the central bank cannot ignore fluctuations in the price of the good produced in the flexible price sector if it wants to affect aggregate demand. Financial frictions break the comovement of inflation and output (as inflation and output may now move in opposite directions). Stabilizing core inflation is no longer sufficient to stabilize output. Thus, in the presence of financial frictions targeting

4

flexible headline inflation is a better policy choice.

Since our model exhibits monetary super-neutrality, we limit our analysis to non-inflationary steady states (long-run price stability) and do not have anything to say about the optimal level of inflation. We also do not attempt to define optimal policy rules but focus on evaluating welfare outcomes from different policy rules using alternative measures of inflation.

The paper is organized in six sections. In the next section of the paper, we present some empirical facts to further motivate the analysis. In Section 3, we develop a two sector, two goods model with heterogeneous agents, which forms the basis of further analysis. In Section 4 we discuss the main results and in Section 5 we conduct various sensitivity experiments to check the robustness of our baseline results and also present some extensions of the basic model. Section 6 concludes the paper.

1.2 Basic Stylized Facts

We begin by presenting some stylized facts about the share of household consumption expenditures on food and also various measures of the elasticity of food expenditures. In a cross country comparison, emerging markets and advanced countries differ markedly on these measures. Next, we present data on credit constraints in emerging markets. We also look at the features of core and headline CPI inflation measures in some emerging and advanced economies.

Engel's law states that as average household income increases, the average share of food expenditure in total household expenditure declines. When this idea is extended to countries, we expect poor countries to have a high average share of food expenditure in total household expenditure. Figure 1.1 plots the expenditure on food (as a percentage of total expenditure) against log real per capital income for the year

1996.[5] It shows that countries with lower per capita income levels have a higher share of expenditure on food in total household expenditure. In order to examine how emerging markets differ from advanced countries, in Table 1.1 we present recent data on shares of food expenditure in total expenditure for selected emerging and advanced economies.[6] As expected, expenditure on food is a much larger share of total household expenditure in emerging markets relative to advanced economies.
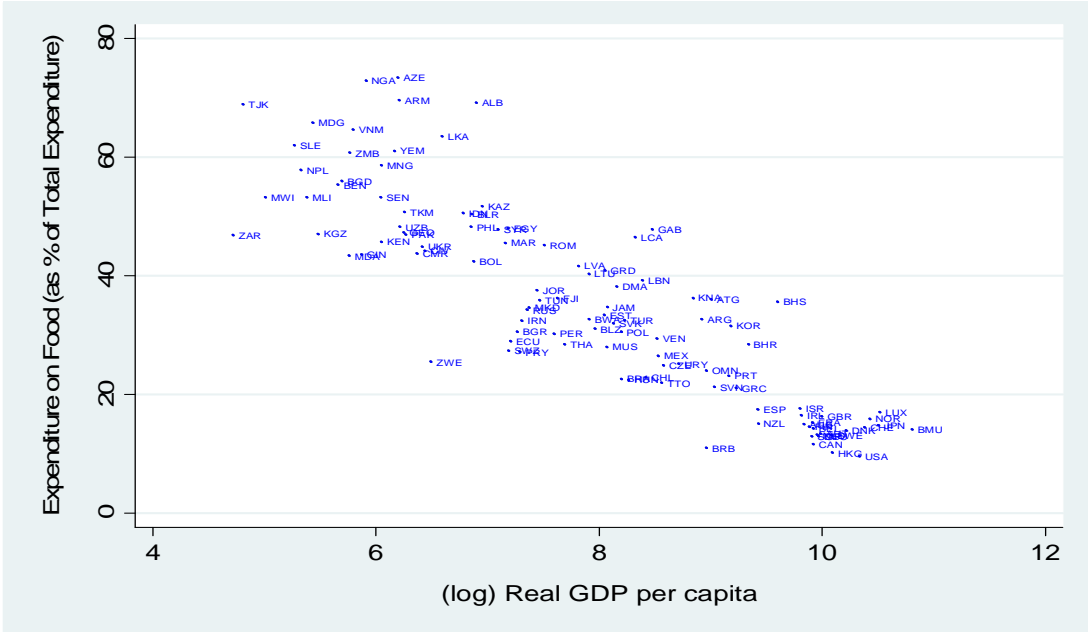
Figure 1.1: Share of Expenditure on Food ((as percent of total household expenditure), 1996. Expenditure on food includes expenditure on food prepared at home and consumed plus beverages and tobacco. Source: WDI and International Food Consumption Patterns Dataset, Economic Research Service, USDA.

---

[5] We use data for 1996 for illustrative purposes since data for a large number of countries were available for that year.

[6] We looked at household surveys for each country in this table rather than the weight of food in each country's CPI index since those weights are changed only occasionally. However, data from household surveys are available for only a few emerging markets. These data typically cover expenditure on food consumed at home and don't include expenditures on beverages and tobacco.

Table 1.1: Share of Food Expenditure in Total Household Expenditure

Emerging Markets		Advanced Economies	
Indonesia	53.0	Japan	14.7
Vietnam	49.8	Germany	11.5
India	48.8	Australia	10.8
China	36.7	Canada	9.3
Russia	33.2	United Kingdom	8.8
Malaysia	28.0	USA	5.7
Average	41.6	**Average**	**10.1**

Data for emerging markets are for 2005 while for advanced economies it is for 2006. Expenditure on food includes expenditure on food consumed at home only and does not include expenditure on beverages and tobacco. Source: Household Surveys, CEIC, International Food Consumption Patterns Dataset, Economic Research Service, USDA and authors' calculations.

Income and price elasticities of the demand for food are important for our analysis. Figure 1.2 plots the income elasticity of food against real per capita GDP for the year 1996. The income elasticity of food is low, suggesting that food is a necessary good. Since expenditure on food is not a major share of household expenditure in rich countries, the income elasticity of food is much lower.[7] We present the income elasticity of food for selected emerging market and advanced economies in Table 1.2. The income elasticity of food in emerging markets is on average twice as large as in advanced economies.

---

[7] A low income elasticity of demand also means that, as family income increases, consumption of the commodity will not increase by much.
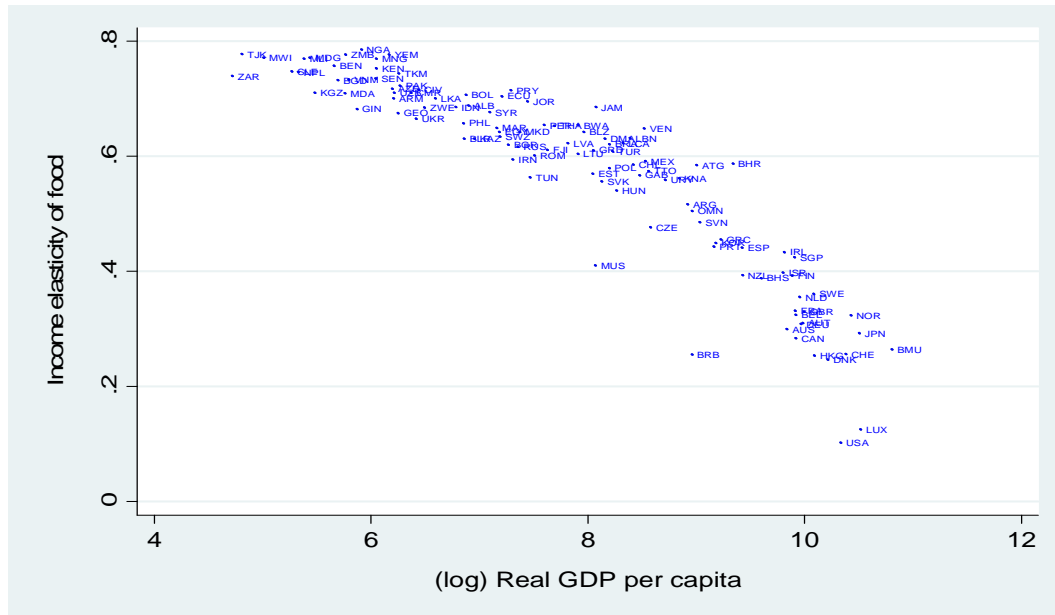
Figure 1.2: Income Elasticity of Demand for Food, 1996
These country-specific income-elasticity values represent the estimated percentage change in demand for food if total income increases by 1 percent. Food includes food prepared at home and consumed plus beverages and tobacco. Source: WDI and International Food Consumption Patterns Dataset, Economic Research Service, USDA.

Figure 1.3 plots, for a large sample of countries, the Slutsky own price elasticity of food against the real per capita GDP for the year 1996.[8] The price elasticity of food demand is nonlinear, decreasing at low income levels, and then increasing, with a range from -0.4 to -0.1. We also present data on the Slutsky own-price elasticity of food for selected countries in Table 1.2.[9]

---

[8] The Slutsky own price elasticity is estimated by keeping real income constant.
[9] Frisch elasticity values lie between Slutsky and Cournot values and can be considered as an average own price elasticity.
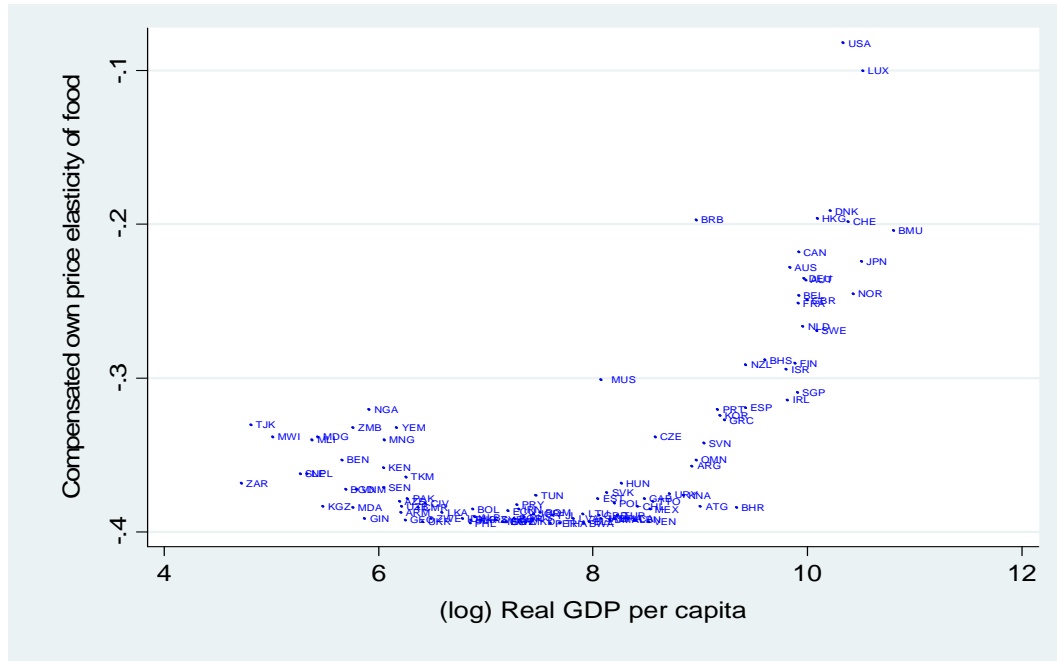
Figure 1.3: Slutsky Own-Price Elasticity of Demand for Food, 1996
Country-specific elasticity value represents a percentage change in demand for food if food prices increases by 1 percent (keeping real income constant). Food includes food prepared at home and consumed plus beverages and tobacco. Source: WDI and International Food Consumption Patterns Dataset, Economic Research Service, USDA.

   The price elasticity of food is very low (suggesting that the demand for food is

inelastic). As the share of expenditure on food is high in emerging markets, the price

elasticity of food is higher in these economies. However, the overall value of price

elasticity of food is much lower than used in the literature on inflation targeting. Low

price and income elasticities of the demand for food have considerable significance for

the choice of price index.

Table 1.2: Income (Expenditure) Elasticity and Slutsky Own-Price Elasticity of Food, 1996

Emerging Economies	Income Elasticity	Price Elasticity	Advanced Economies	Income Elasticity	Price Elasticity
Vietnam	0.73	-0.37	New Zealand	0.39	-0.29
Pakistan	0.72	-0.38	Finland	0.39	-0.29
Jordan	0.70	-0.39	Sweden	0.36	-0.27
Indonesia	0.69	-0.39	Netherlands	0.36	-0.27
Philippines	0.66	-0.39	France	0.33	-0.25
Peru	0.66	-0.39	United Kingdom	0.33	-0.25
Thailand	0.65	-0.39	Belgium	0.33	-0.25
Egypt	0.64	-0.39	Norway	0.32	-0.24
Brazil	0.62	-0.39	Austria	0.31	-0.24
Russia	0.62	-0.39	Germany	0.31	-0.23
Turkey	0.61	-0.39	Australia	0.30	-0.23
Iran	0.60	-0.39	Japan	0.29	-0.22
Mexico	0.59	-0.38	Canada	0.28	-0.22
Chile	0.59	-0.38	Switzerland	0.26	-0.20
Poland	0.58	-0.38	Denmark	0.25	-0.19
Hungary	0.54	-0.37	Luxembourg	0.13	-0.10
Argentina	0.52	-0.36	United States	0.10	-0.08
Average	**0.63**	**-0.38**	**Average**	**0.63**	**-0.38**

These country-specific income-elasticity values represent the estimated percentage change in demand for food if total income increases by 1 percent. Country-specific price-elasticity value represents a percentage change in demand for food if food prices increases by 1 percent (keeping real income constant). Food includes food prepared at home and consumed plus beverages and tobacco. Source: WDI and International Food Consumption Patterns Dataset, Economic Research Service, USDA.

In order to examine the extent of credit constraints in emerging markets, in Table 1.3 we present data on the percentage of the adult population with access to formal finance (measured by the share of the population using financial services) in emerging

markets. As evident, on average more than half of the population in emerging markets does not have access to the formal financial system.

Table 1.3: Composite Measure of Access to Financial Services in Emerging Markets

	Percent with access		*Percent with access*
Argentina	28	Mexico	25
Brazil	43	Nigeria	15
Chile	60	Pakistan	12
China	42	Peru	26
Egypt	41	Philippines	26
India	48	Poland	66
Indonesia	40	Russia	69
Iran	31	South Africa	46
Korea	63	Thailand	59
Malaysia	60	Turkey	49
		Average	**42**

The composite indicator measures the percentage of the adult population with access to an account with a financial intermediary. Source: "Finance for All? Policies and Pitfalls in Expanding Access," World Bank, 2008.

Next, we examine the characteristics of core and headline inflation. We plot the levels and volatility of inflation for selected advanced and emerging market economies (Figure 1.4 – 1.5). Values of average inflation, average volatility and the persistence of inflation (for the period March 1991 – September 2009) are reported in Table 1.4. The two measures of inflation have very different characteristics in advanced and emerging market economies. Average inflation (both headline and core) has been higher in emerging market economies during the period. Headline inflation is more volatile than core inflation in both advanced and emerging market economies. However, the volatility of both inflation measures is much higher in emerging markets. Core

inflation has on average been twice as volatile in emerging market economies compared to advanced countries. The two measures of inflation exhibit a high degree of persistence in both sets of economies.
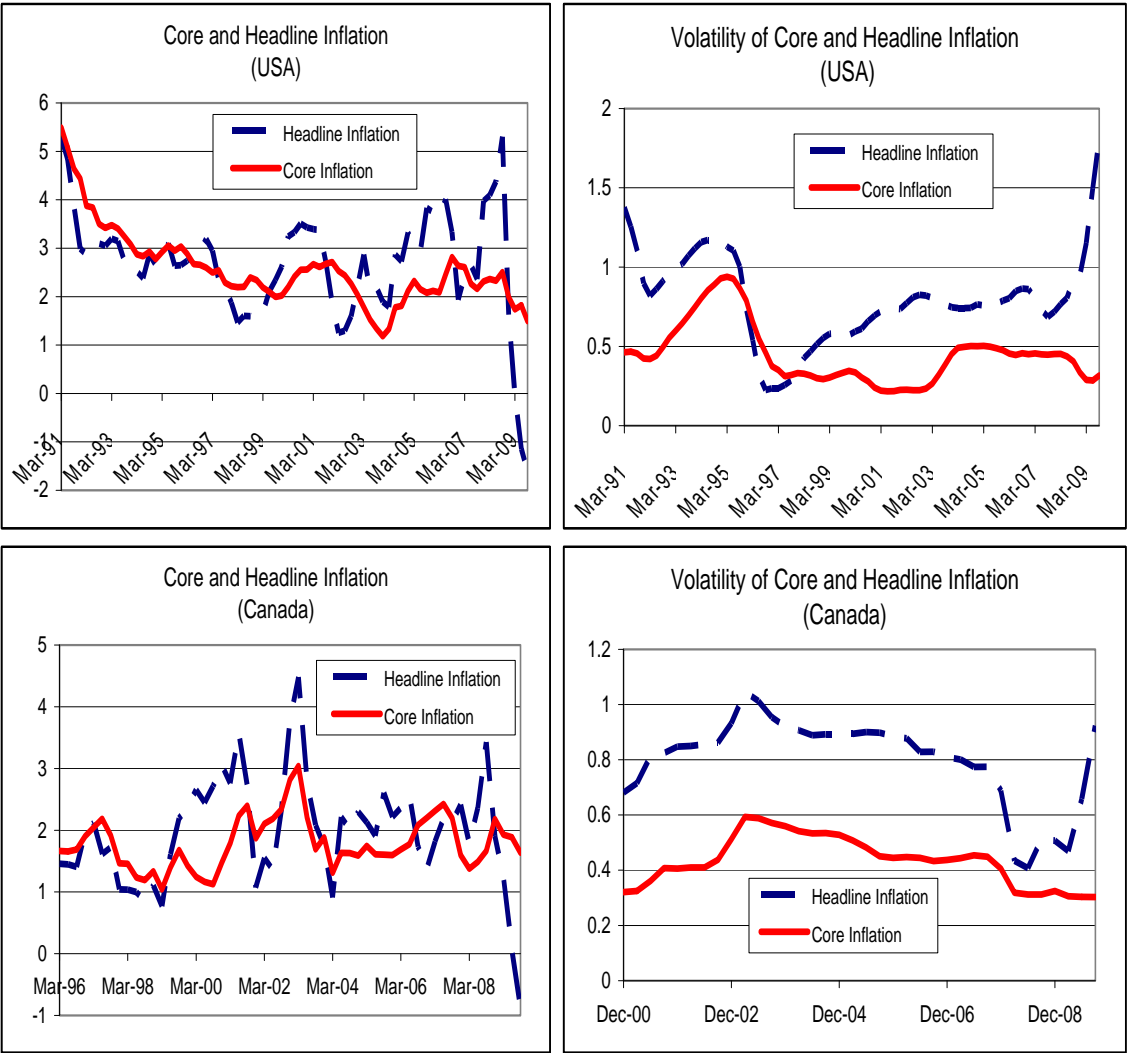
Figure 1.4: Levels and Volatility of Inflation
Core index for USA is defined as CPI excluding food and energy while for Canada it is defined as CPI excluding food, energy and indirect taxes. Inflation is year on year inflation calculated using quarterly price index. Volatility is measured as the standard deviation of inflation using a rolling 20-quarter (5-years) window. We also computed the volatility using 8-years and 10-years window and the results are similar. Source: CEIC and authors' calculations.
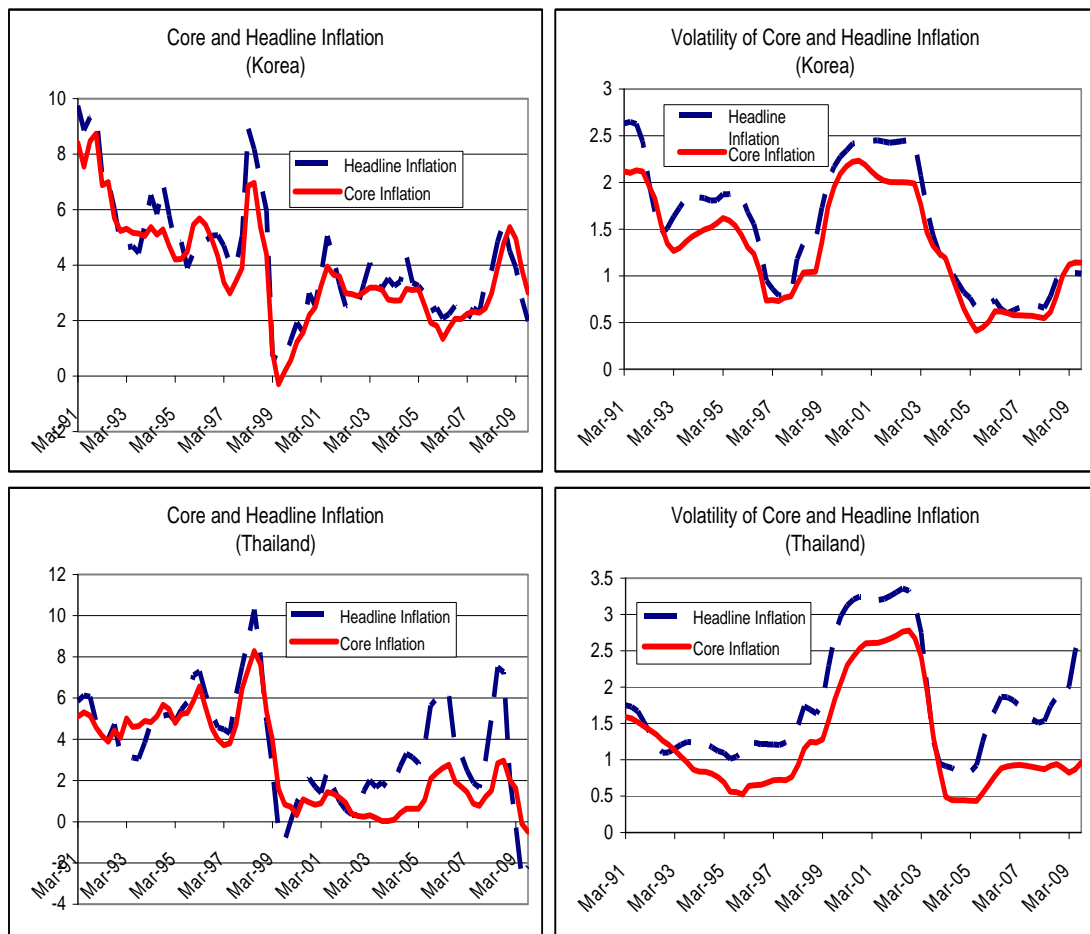
Figure 1.5: Levels and Volatility of Inflation
Core index for Korea is defined as CPI excluding agricultural product and oil while for Thailand it is defined as CPI excluding unprocessed food and energy. Inflation is year on year inflation using quarterly price index. Volatility is measured as the standard deviation of inflation using a rolling 20-quarter (5-years) window. We also computed the volatility using 8-years and 10-years window and the results are similar. Source: CEIC and authors' calculations.

Table 1.4: Average Inflation, Volatility and Persistence of Inflation

	Average Inflation		*Average Volatility*		*Persistence*	
	Headline Inflation	Core Inflation	Headline Inflation	Core Inflation	Headline Inflation	Core Inflation
USA	2.67	2.58	0.80	0.45	0.84*** (0.09)	0.92*** (0.04)
Canada	1.96	1.78	0.80	0.43	0.75*** (0.13)	0.77*** (0.10)
Korea	4.23	3.85	1.54	1.32	0.85*** (0.05)	0.88*** (0.03)
Thailand	3.62	2.87	1.78	1.24	0.90*** (0.06)	0.95*** (0.05)

Core price index in USA excludes food and energy from the CPI while in Canada it excludes indirect taxes also in addition to food and energy. Thailand's core index excludes unprocessed food and energy while in Korea it excludes agricultural products and oil. Inflation is a year on year inflation calculated using quarterly price index. Volatility is measured as the standard deviation of inflation using a rolling 20 quarter (5 years) window. Persistence parameter is the estimated co-efficient from a simple AR(1) model. The symbol *** indicates statistical significance at the 1% level. Newey West corrected standard errors (with a lag of 3) are reported in brackets.
a. Data for Canada is for March 1996 – September 2009.
Source: CEIC and authors' calculations.

We also look at the evolution of two price indices over time. It is expected that they would deviate from each other in the short run (as the core measure is constructed to eliminate the fluctuations which do not reflect the underlying inflation developments). However, since transitory shocks (shocks to food and energy) do not change the underlying trend, headline inflation should return to its original level in a short period (Mishkin, 2007). In other words, the headline inflation measure should not remain above the core inflation measure for an extended period.

To verify this, we examine the two measures of inflation for two representative core inflation targeting countries – Canada and Thailand.[10] In Canada, in the period

---

[10] Canada is an advanced economy that adopted IT in 1991 while Thailand, an emerging market economy, adopted IT in 2000. Canada targets core inflation excluding food, energy and indirect taxes. Thailand targets core inflation, which excludes food and energy prices.

from the spring of 1999 to the fall of 2001, headline inflation remained above core inflation for 30 months in succession (Figure 1.4a). In Thailand, headline inflation has remained above core inflation for more than 5 consecutive years (Figure 1.5a). The core inflation measure excludes a number of expenditure items and hence is less representative of the cost of living. Thus, differences in the behavior of headline inflation (which is supposed to be more accurate measure of cost of living) and core inflation over an extended period may have important welfare implications.

1.3 The Model

Our model builds upon a large literature that has developed and analyzed dynamic sticky price models (Clarida, Gali and Gertler, 1999; Woodford, 1996; Rotemberg and Woodford, 1997, 1999; Aoki, 2001). The model incorporates a fraction of credit constrained consumers and subsistence level food consumption added to capture the characteristics of emerging market economies. The model has two sectors and two goods—one type of flexible price good, food (C_F), whose prices adjust instantaneously, and a continuum of monopolistically produced sticky price goods, $c(z)$ indexed in $z \in (0,1)$ which we call non-food and whose prices adjust sluggishly.[11] In the subsequent discussion, we interchangeably use the term food sector for the flexible price sector and the term non-food sector for the sticky price sector.

1.3.1 Households

The economy is populated by a continuum of $1 + \lambda$ infinitely lived households, where $\lambda > 0$, is the continuum of households in the flexible price sector (food sector). Each household owns a firm and produces one good. They provide labor to the firms in their respective sector (we assume that labor is immobile across sectors) and

---

[11] We model the sticky price sector by a continuum of monopolistic firms so that these firms have market power and they can set prices. This is done to introduce price stickiness in this sector.

consume both the flexible price good (food) and all of the differentiated sticky price goods (non food).[12] The representative consumer, i, is indexed by f (flexible price sector) and s (sticky price sector). Household i, maximizes the discounted stream of utility

$$E_0 \sum_{t=0}^{\infty} \beta^t [u(C_t^i, N_t^i)] \tag{1}$$

where $\beta \in (0,1)$ is the discount factor. The utility function takes the form:

$$u(C_t^i, N_t^i) = \frac{(C_t^i)^{1-\sigma}}{1-\sigma} - \phi_n \frac{(N_t^i)^{1+\psi}}{1+\psi} \tag{2}$$

where the argument C_t^i, is the composite consumption index of household i of the flexible and all of the continuum of the differentiated goods, and is defined as

$$C_t^i = \left[\gamma^{\frac{1}{\eta}} \left(C_{f,t}^i - C^* \right)^{1-\frac{1}{\eta}} + (1-\gamma)^{\frac{1}{\eta}} (C_{s,t}^i)^{1-\frac{1}{\eta}} \right]^{\frac{1}{1-\frac{1}{\eta}}} \tag{3}$$

where

$$C_{s,t}^i = \left[\int_0^1 c_t^i(z)^{\frac{\theta}{\theta-1}} \right]^{\theta/\theta-1} \tag{4}$$

The elasticity of substitution between the flexible price and sticky price goods is given by $\eta \in [0, \infty]$ and $\gamma \in [0,1]$ is the weight on food in the consumption index. The parameter $\theta > 1$ is the elasticity of substitution between any two differentiated goods, n_t^i is the aggregate labor supplied and σ is the risk aversion factor (inverse of elasticity of inter temporal substitution). The parameter ψ is the inverse of Frisch elasticity and ϕ_n is a scaling factor.

The utility function used here is of a generalized Klein-Rubin form.[13] This form is selected to model the role of food in the economy. Since food is a necessity,

---

[12] We have assumed the immobility of labor for simplicity and to capture the large inter-sectoral wage differential in emerging markets. Gali, Lopez-Salido and Valles (2004) have demonstrated in their model that, even with free labor mobility, financial frictions lead to similar results as ours (aggregate demand going up even when the central bank raises the policy interest rate).

[13] Expenditure system corresponding to Klein-Rubin utility function is referred to as the Stone-Geary linear expenditure system; Stone (1954) and Geary (1949).

households must consume a minimum amount, C^* of food for survival.[14] We assume that all households always have enough income to buy the subsistence level of food. Even though the subsistence level food consumption does not bind, it plays a vital role by altering the elasticity of substitution between food and non-food and the marginal utility of food and non-food consumption.

1.3.1.1 Flexible Price Sector (Food Sector) Households

Households in the flexible price sector (food sector) do not have access to financial markets and they consume their wage income each period.[15] So these households are akin to the "rule of thumb" consumers. Each household in the sector owns one firm and produces food by linear technology in labor, given by

$$Y_{f,t} = A_{f,t} N_t^f \tag{5}$$

$A_{f,t}$ is a random productivity shock. Since we are interested in analyzing the effects of sector specific shocks, we assume that all the households in the food sector face the same shock.

1.3.1.2 Sticky Price Sector (Non Food Sector) Households

Households in this sector can buy one period nominal bonds and smooth their consumption. Each household owns a firm and provides labor to each firm in the sector. They hold one share in each firm of the sector. Each firm uses a linear technology in labor given by

$$Y_t(z) = A_{s,t} N_t^s(z) \tag{6}$$

where $Y_t(z)$ is a sticky price good and $N_t^s(z)$ is the labor used in the firm producing

---

[14] This is also in similar to habit persistence with C^* being independent of time.
[15] There is no storage technology in the model. So consumers in the flexible price sector can't smooth their consumption by saving their output. We have made this restrictive assumption to keep the model tractable. Table 3 shows that more than 50 percent of individuals in emerging markets lack access to formal finance. Basu et al. (2005) have documented that 80 percent of individuals in the agriculture sector in India have no access to formal finance.

good indexed by z (where $z \in [0,1]$). $A_{s,t}$ is a random productivity shock. Since we are interested in analyzing sector-specific rather than household-level shocks, we assume that the shock is identical for all households in the non-food sector.

1.3.2 Consumption Decision

1.3.2.1 Food Sector Households (Credit Constrained Consumers)

All households in this sector face an identical budget constraint every period (as their wage income is the same in every period). A representative household maximizes its lifetime utility given by equation (1) subject to the budget constraint

$$P_{f,t}C_{f,t}^{f} + P_{s,t}C_{s,t}^{f} = W_{t}^{f}N_{t}^{f}$$

where $P_{f,t}$ is the market price of food, $P_{s,t}$ is the price index of non-food (defined below) and W_{t}^{f} is the nominal wage in the sector. The optimal allocation for a given level of spending between food and all of the differentiated goods leads to a Dixit-Stiglitz demand relation. The total expenditure to attain a consumption index C_{t}^{f} is given by $P_{t}C_{t}^{f}$ where P_{t} is defined as

$$P_{t} = \left[\gamma(P_{f,t})^{1-\eta} + (1-\gamma)(P_{s,t})^{1-\eta}\right]^{\frac{1}{1-\eta}} \tag{7}$$

The budget constraint can be written as:

$$P_{t}C_{t}^{f} = W_{t}^{f}N_{t}^{f} - P_{f,t}C^{*} \tag{8}$$

Demand for the flexible price good is given by

$$C_{f,t}^{f} = \gamma\left(\frac{P_{f,t}}{P_{t}}\right)^{-\eta}C_{t}^{f} + C^{*} \tag{9}$$

Demand for the sticky price good is given by

$$C_{s,t}^{f} = (1-\gamma)\left(\frac{P_{s,t}}{P_{t}}\right)^{-\eta}C_{t}^{f} \tag{10}$$

where $P_{s,t}$ is the Dixit-Stiglitz price index defined as

$$P_{s,t} = \left[\int_0^1 X_t(z)^{1-\theta} dz \right]^{\frac{1}{1-\theta}}$$ (11)

$X_t(z)$ is the price of differentiated good indexed on z at time t. Demand for each differentiated good is given by

$$c_t^f(z) = \left(\frac{X_t(z)}{P_{s,t}} \right)^{-\theta} C_{s,t}^f$$ (12)

The labor supply decision is given by the usual first order condition with respect to N_t^f:

$$\phi_n \frac{(N_t^f)^{\psi}}{(C_t^f)^{-\sigma}} = \frac{W_t^f}{P_t}$$ (13)

1.3.2.2 Non Food Sector households (Unconstrained Consumers)

Each household in this sector provides labor to each one of the firms in the sector and also holds one share in each firm. This setting is the one followed by Woodford (2003).[16] In this set up each household faces the same budget constraint each period and hence chooses the same consumption stream. A representative household maximizes the lifetime utility given by equation (1) subject to the following budget constraint

$$P_t C_t^s + B_t = \int_0^1 W_t^s(z) N_t^s(z) dz + \int_0^1 \Pi_t(z) dz + (1+i_{t-1}) B_{t-1} - P_{f,t} C^*$$ (14)

where B_t represent the quantity of one period nominal riskless discount bond bought in period t and maturing in period t+1, where i_t is the nominal interest rate between period t and t+1. $W_t^s(z)$ and $N_t^s(z)$ represent respectively the nominal wage prevalent in firm z and the amount of labor supplied to firm z by the household respectively. $\Pi_t(z)$ is the profit of firm z. Maximization with respect to C_t^s yields the Euler

---

[16] Alternatively, we could have used the other set up specified in Woodford (2003) in which each household produces one of the differentiated products and there exist a complete range of securities through which they can insure fully against idiosyncratic risks. In that formulation also each household will choose the same consumption stream and therefore the analysis will be the same as in the present setting.

equation

$$(C_t^s)^{-\sigma} = \beta E_t \left\{ (C_{t+1}^s)^{-\sigma} \frac{1+i_t}{1+\pi_{t+1}} \right\} \tag{15}$$

where $\pi_t = \dfrac{P_t - P_{t-1}}{P_{t-1}}$ is headline inflation. The labor supply decision of the household to a firm indexed by z is given by

$$\phi_n \frac{(N_t^s(z))^{\psi}}{(C_t^s)^{-\sigma}} = \frac{W_t^s(z)}{P_t} \tag{16}$$

Demand for the flexible price good is given by

$$C_{f,t}^s = \gamma \left(\frac{P_{f,t}}{P_t} \right)^{-\eta} C_t^s + C^* \tag{17}$$

Demand for the sticky price good is given by

$$C_{s,t}^s = (1-\gamma) \left(\frac{P_{s,t}}{P_t} \right)^{-\eta} C_t^s \tag{18}$$

and the demand for each differentiated good is given by

$$c_t^s(z) = \left(\frac{X_t(z)}{P_{s,t}} \right)^{-\theta} C_{s,t}^s \tag{19}$$

1.3.3 Firms

1.3.3.1 Firms in the Flexible Price Sector (Food Sector)

Firms are assumed to be price takers. Given a market price $P_{f,t}$ they set their price such that

$$P_{f,t} = \frac{W_t^f}{A_{f,t}} \tag{20}$$

The supply function for the flexible price firm--obtained by combining equations 5, 13 and 20 is given by:

$$\frac{P_{f,t}}{P_t} = \phi_n \frac{\left(Y_{f,t} \big/ A_{f,t} \right)^{\psi}}{A_{f,t}(C_t^f)^{-\sigma}} \tag{21}$$

The market-clearing condition for food implies

$$\lambda Y_{f,t} = C_{f,t} = \gamma \left(\frac{P_{f,t}}{P_t} \right)^{-\eta} C_t + (1+\lambda)C^* \tag{22}$$

where we have defined $\lambda C_t^f + C_t^s = C_t = Y_t$ \hspace{1cm} (23)

It can be considered as the total composite demand and hence equal to supply in equilibrium.

1.3.3.2 Firms in the Sticky Price Sector

We follow Calvo (1983) and Woodford (1996) in modeling price stickiness. A fraction $\alpha \in (0,1)$ of firms cannot change their price in each period. Firms are free to change the price at time t; they choose a price X_t to maximize the following objective function:

$$\underset{X_t}{Max} \, E_t \left[\sum_{i=0}^{\infty} (\alpha\beta)^i Q_{t,t+1} \left[X_t(z)Y_{t,t+i}(z) - TC_{t,t+i}(Y_{t,t+i}(z)) \right] \right] \tag{24}$$

where $Q_{t,t+i} = \beta^i \left(\frac{C_{t+i}^s}{C_t^s} \right)^{-\sigma} \frac{P_t}{P_{t+i}}$ is the stochastic discount factor and $Y_{t,t+i}(z)$ is the output of firm in period $t+i$ when it has set its price in period t that is given by

$$Y_{t,t+i}(z) = \left(\frac{X_t(z)}{P_{s,t+i}} \right)^{-\theta} Y_{s,t+i} \tag{25}$$

where we have made use of the market clearing conditions

$$Y_t(z) = \left(\frac{X_t(z)}{P_{s,t}} \right)^{-\theta} C_{s,t} \tag{26}$$

and $Y_{s,t} = C_{s,t} = (1-\gamma) \left(\frac{P_{s,t}}{P_t} \right)^{-\eta} C_t$ \hspace{1cm} (27)

The sticky sector price index is expressed by

$$P_{s,t} = \left[\alpha(P_{s,t-1})^{1-\theta} + (1-\alpha)X_t^{1-\theta}(z) \right]^{\frac{1}{1-\theta}} \tag{28}$$

The price X_t solves the following first order condition

$$E_t\left[\sum_{i=0}^{\infty}(\alpha\beta)^i Q_{t,t+i}Y_{t,t+i}(z)\left\{X_t(z)-\frac{\theta}{\theta-1}MC_{t+i}^r\right\}\right]=0 \quad [17]$$
(29)

where

$$\frac{MC_{t+i}}{P_{t+i}}=MC_{t+i}^r=\phi_n\frac{\left(Y_{t,t+i}(z)\big/A_{s,t+i}\right)^{\psi}}{A_{s,t+i}(C_{t+i}^s)^{-\sigma}}$$
(30)

and $\dfrac{\theta}{\theta-1}$ is the constant markup over the marginal cost.

Equations (7), (8), (15), (21), (22), (27), (28), (29) and (30), coupled with a monetary policy rule to choose the nominal interest rate, jointly determine the equilibrium path of consumption, output and price index in both the sectors.

1.3.4 Inflation and Relative Prices

We define the relative prices as follows:

$\dfrac{P_{f,t}}{P_t}=x_{f,t}$, relative price of food, $\dfrac{P_{s,t}}{P_t}=x_{s,t}$, relative price of non-food; and $\dfrac{X_t}{P_{s,t}}=x_t$, relative price charged by firms which are free to choose the price in time t. We define the gross headline inflation as $\Pi_t=\dfrac{P_t}{P_{t-1}}$, and gross inflation in the sticky price sector as $\Pi_{s,t}=\dfrac{P_{s,t}}{P_{s,t-1}}$. The relationship between headline and core inflation (inflation in the sticky price sector) is given by:

$$x_{s,t}=\frac{P_{s,t}}{P_{s,t-1}}\frac{P_{s,t-1}}{P_{t-1}}\frac{P_{t-1}}{P_t}=\frac{\Pi_{s,t}x_{s,t-1}}{\Pi_t}$$
(31)

The system of equations in terms of stationary variables is presented in Appendix I.

1.3.5 Steady State

We characterize the steady state with constant prices (zero inflation) and no price

---

[17] Since the technology is linear, $MC_{t,t+i}=MC_{t+i}$ That is, marginal cost is independent of the level of production.

stickiness in the economy.[18] This implies that $\Pi_t = 1$ and $\Pi_{s,t} = 1$ for all t. Under symmetric equilibrium, each firm faces the same demand and set the same price. Thus, $X_t = P_{s,t}$ and $x_t = 1$. Therefore, $x_{s,t} = \frac{\theta}{\theta - 1} MC_t^r$. In the steady state, all firms set a price which is a constant markup over the real marginal cost.[19]

We assume that productivity is the same in both the sectors and normalize it to one.

1.3.6 Monetary Policy Rule

We assume that the monetary authority sets the short term nominal interest (R_t) according to a simple Taylor (1993) type rule of the following form

$$\log(R_t / \bar{R}) = \rho_i \log(R_{t-1} / \bar{R}) + \rho_\pi \log(\Pi_t / \bar{\Pi}) + \rho_y \log(Y_t / \bar{Y}) \tag{32}$$

where $\bar{Y}, \bar{\Pi}$ and $\bar{R}$ are the steady state values of output, inflation and nominal interest rate. ρ_i represents the Central Banker's preference for interest rate smoothing. ρ_π and ρ_y are the weights on inflation and output gap assigned by the policy makers.[20] We characterize core inflation as the inflation in the sticky price sector, $\Pi_{s,t}$, and headline inflation as the over all inflation, Π_t, for our policy experiments.

We evaluate our model under the following monetary policy regimes:

Strict Core Inflation Targeting: The central bank cares only about interest rate smoothing and stabilizing inflation in the sticky price sector.

$$\log(R_t / \bar{R}) = \rho_i \log(R_{t-1} / \bar{R}) + \rho_\pi \log(\Pi_{s,t} / \bar{\Pi}_s) \tag{33}$$

Strict Headline Inflation Targeting: The central bank cares only about interest rate

---

[18] Our model exhibits monetary super-neutrality. Therefore, the level of steady state inflation does not affect steady state values of real variables.

[19] We also compute the welfare gains when the steady state involves a tax rate which is set such that the steady state level of output in the sticky price sector is efficient. All our results go through under this alternative characterization of steady state.

[20] We include an interest rate smoothing parameter in our monetary policy rule as the benefits of such smoothing are well documented in the literature (see, e.g., Lowe and Ellis, 1997; Sack and Wieland, 1999). Various authors have argued that moving interest rates in small steps increases its impact on the long-term interest rate; it also reduces the risks of policy mistakes and prevents large capital losses and systemic financial risks. Mohanty and Klau (2004) find that all emerging market central banks put substantial weight on interest rate smoothing. Clarida et al.(1998) find that central banks of advanced economies also put a large weight on interest rate smoothing.

smoothing and stabilizing headline inflation.

$$\log(R_t / \bar{R}) = \rho_i \log(R_{t-1} / \bar{R}) + \rho_\pi \log(\Pi_t / \bar{\Pi}) \tag{34}$$

Flexible Core Inflation Targeting: The central bank cares about interest rate smoothing and in addition to stabilizing sticky price inflation also tries to stabilize output by assigning a weight to the output gap (deviation of output from trend).

$$\log(R_t / \bar{R}) = \rho_i \log(R_{t-1} / \bar{R}) + \rho_\pi \log(\Pi_{s,t} / \bar{\Pi}_s) + \rho_y \log(Y_t / \bar{Y}) \tag{35}$$

Flexible Headline Inflation Targeting: The central bank cares about interest rate smoothing and in addition to stabilizing sticky price inflation also tries to stabilize output.

$$\log(R_t / \bar{R}) = \rho_i \log(R_{t-1} / \bar{R}) + \rho_\pi \log(\Pi_t / \bar{\Pi}) + \rho_y \log(Y_t / \bar{Y}) \tag{36}$$

1.3.7 Exogenous Shock Process

We assume that the productivity in the flexible price sector and sticky price sector follow AR(1) processes

$$A_{f,t+1} = \rho_{af} A_{f,t} + \xi_t \quad , \ \xi_t \sim \text{i.i.d. } (0, \ \sigma_{af}) \tag{37}$$

$$A_{s,t+1} = \rho_{as} A_{s,t} + \upsilon_t \quad , \ \upsilon_t \sim \text{i.i.d. } (0, \ \sigma_{as}) \tag{38}$$

In the literature, exclusion of food prices from the price index has been justified on the ground that shocks to food (and energy) prices represent supply shocks. In order to compare our model with those in the prior literature and also to highlight the role of adverse supply shocks on the choice of price index, we focus on productivity shocks.

1.3.8 Competitive Equilibrium

A stationary competitive equilibrium is a set of processes

$C_t^f, C_t^s, x_{f,t}, x_{s,t}, y_{f,t}, y_{s,t}, y_t, \pi_{s,t}, \pi_t, R_t, x_t, mc_t$ for t = 0,1,… that remain bounded in some neighborhood around the deterministic steady state and satisfy equations (1) – (11) of Appendix I, given the exogenous stochastic processes $A_{f,t}$, $A_{s,t}$ and the monetary policy rule given by equation (32).

1.3.9 Complete Markets Specification

We follow the setting of Aoki (2001) to study the choice of price index under complete markets. In this setting each household can insure one another against idiosyncratic income risks. It implies that given same initial wealth each household will choose an identical consumption sequence.[21] Thus, under this complete markets setting

$$C_t^f = C_t^s = \frac{C_t}{1+\lambda} = \frac{Y_t}{1+\lambda} \tag{39}$$

and aggregate demand is given by

$$\left(\frac{Y_t}{1+\lambda}\right)^{-\sigma} = \beta E_t \left[\left(\frac{Y_{t+1}}{1+\lambda}\right)^{-\sigma} \frac{R_t}{\Pi_t}\right] \tag{40}$$

where R_t is the gross nominal interest rate. Equations (2), (4)-(10) of Appendix I and (39)-(40) define the system of equations that combined with the monetary policy rule and exogenous stochastic processes for $A_{f,t}$ and $A_{s,t}$ determine the equilibrium path of the economy in the complete markets setting.

1.3.10 Welfare Evaluations

We are interested in the choice of policy rule that yields the highest level of lifetime utility within the class of policy rules considered.[22] In particular, we evaluate policy rules according to the amount of lifetime utility:

$$V_t^i \equiv E_t \sum_{j=0}^{\infty} \beta^j U(C_{t+j}^i, N_{t+j}^i) \text{ for } i = f, s \tag{41}$$

We compute the total welfare of the economy as a weighted sum of households' welfare

---

[21] Insurance contracts are assumed to be written before households know which sector they are assigned to. The insurance contracts make the marginal utility of nominal income identical across the households at any time t.

[22] We study the policy rule which is implementable and optimal as defined by Schmitt-Grohe and Uribe (2007). Implementability refers to the local uniqueness of rational expectations equilibrium while optimality means that it yields the highest lifetime utility within the class of policy rules considered.

$V_{total} = \lambda * V_t^f + V_t^s$. Formally, we compute V_{total} associated with each policy rule and look for a policy rule that yields the highest value of V_{total}.

1.3.11 Solution Method

Following Kydland and Prescott (1982) and King, Plosser and Rebelo (1988), it has become commonplace to characterize the solution of nonlinear models using approximation methods, with first-order approximation techniques being the norm. However, it is now widely accepted that first-order approximation techniques are ill-suited for the comparison of different policy environments using aggregate utility as a welfare criterion.[23] To enable accurate welfare comparisons across alternative policy environments, we need at least a second-order approximation of the equilibrium welfare function (Schmitt-Grohe and Uribe, 2004; Woodford, 2003).[24]

In recent years, scholars have come up with various methods to produce second-order accurate approximation to the solutions of DSGE models. Jin and Judd (2002), Collard and Juillard (2000) and Schmitt-Grohe and Uribe (2004) have used the perturbation method for second and higher order approximations. Kim and Kim (2003) and Sutherland (2002) have developed the bias correction method that produces similar results as the second order perturbation method.

We compute the second-order accurate consumer welfare measure with different monetary policy regimes as in Schmitt-Grohe and Uribe (2004). To produce an accurate second-order approximation of the welfare function, we use a second-order approximation to the policy function. The policy function is approximated using the perturbation method by employing a scale parameter for the standard deviations of the

---

[23] Up to a first-order approximation, lifetime utility, V_t, is equal to its non-stochastic steady state value. Hence, given the same non-stochastic steady state, all policy rules yield the same amount of welfare to a first-order approximation (Schmitt-Grohe and Uribe, 2007).
[24] See Kim and Kim (2003). However, if one is sure that nonlinearity is small in certain dimensions one can justify using a first-order approximation by making specific assumptions, Woodford (2003).

exogenous shocks as an argument of the policy function and taking a second-order Taylor expansion with respect to the state variables as well as the scale parameter. We use an approximation algorithm developed by Schmitt-Grohe and Uribe (2004) with suitable modifications.

1.3.12 Measuring Welfare Gains

Strict core inflation targeting is regarded as the welfare maximizing policy rule in the literature. Therefore, we evaluate the welfare gains associated with a particular policy regime by comparing it to the strict core inflation targeting rule allocation. Let the strict core inflation targeting rule allocation be denoted by *r*, and an alternative policy regime be denoted by *a*. We define the welfare associated with the core allocation conditional on the economy being at its non-stochastic steady state at time zero:

$$V_0^r = E_0 \sum_{t=0}^{\infty} \beta^t U(C_t^r, N_t^r)$$

where C_t^r and N_t^r are the consumption and hours under the strict core inflation targeting policy rule. Similarly, the conditional welfare under the alternative regime *a* is defined as

$$V_0^a = E_0 \sum_{t=0}^{\infty} \beta^t U(C_t^a, N_t^a)$$

The use of the conditional rather than unconditional expectation is consistent with the approach followed by Schmitt-Grohe and Uribe (2007) and Kollman (2004). The use of the conditional expectation is preferable in our framework given that different policy regimes will typically have different stochastic steady states even though their non-stochastic states are identical. Hence, as pointed out by Schmitt-Grohe and Uribe (2007), the unconditional expectation of utility ignores the transitional dynamics leading to the stochastic steady state. As a result, we follow the procedure of conditioning our calculation of expected utility on the fact that the economy starts

from its non-stochastic steady state.

In order to evaluate the welfare implications of a particular policy regime, we calculate the fraction of a consumer's consumption that would make them indifferent between regimes. Let ω be the welfare gain of adopting an alternative policy rule other than strict core inflation targeting. We define ω as a fraction of additional strict core inflation targeting regime's consumption process that would make a household as well off under regime a as under strict core inflation targeting regime. Then

$$V_0^a = E_0 \sum_{t=0}^{\infty} \beta^t U((1+\omega)C_t^r, N_t^r) \tag{43}$$

Under this specification, a positive value of ω means that welfare is higher under the alternative policy rule. Rearranging equation (43), the welfare gain ω is given by

$$\omega = \left[\frac{V_0^a + D_0^r}{V_0^r + D_0^r} \right]^{\frac{1}{1-\sigma}} - 1 \tag{44}$$

where $D_0^r = E_0 \sum_{t=0}^{\infty} \beta^t \left\{ \phi_n \frac{\left(N_t^r\right)^{1+\psi}}{1+\psi} \right\}$

A value of $\omega * 100 = 1$, represents a one percentage point of permanent consumption gain under the alternate policy regime.

We study the choice of the optimal price index under two market settings–(i) complete markets (similar to Rotemberg and Woodford, 1997; Aoki, 2001) and (ii) an incomplete market structure characterized by the presence of 'rule of thumb' consumers (similar to Gali, Lopez-Salido and Valles, 2004). We compute the welfare gains associated with the four monetary policy regimes defined by equations (33)-(36).

1.3.13 Parameter Selection

Parameter selection for the model is a challenging task. There is no consensus on the values of some parameters. Moreover, most of the parameters used in the literature are based on micro data from advanced countries. Hence, our approach will be to pick

baseline parameters from the existing literature and to then do extensive sensitivity analysis with respect to the choice of key parameters.

We choose β=0.9902, which amounts to an annual interest rate of 4% (Prescott, 1986). We assume that λ=1 (that is, we have one representative consumer in each sector, similar to Aoki, 2001). We use σ=2 as the baseline value of the risk aversion parameter, (i.e., the intertemporal elasticity of substitution is 0.5). This is in the range of values usually assumed in RBC studies and is also the most common value used in the literature on emerging markets (Aguair and Gopinath, 2005; Schmitt-Grohe and Uribe, 2006; Devereux, Lane and Xu, 2004).[25]

Following Chari, Kehoe and MacGrattan (1999), Basu and Fernald (1994, 1995), Basu and Kimball (1997) and Basu (1996) we choose θ=10 (elasticity of substitution between different differentiated goods), which implies a markup of 11 percent. Next, we set the probability that a price does not adjust in a given period (α) at 0.66 (Ferrero, Gertler, Svensson, 2008; Rotemberg and Woodford, 1997). This implies that prices remain fixed for a mean duration of 3 quarters, which is consistent with the micro evidence.

The appropriate value of the Frisch elasticity ($1/\psi$) is both important and controversial. The range of values used in the literature goes from 0.25 to 1.[26] For our benchmark case we assume it to be 0.33 (ψ=3). We choose the scaling parameter ϕ_n such that in steady state the average hours worked is 0.38. The elasticity of substitution between food and non food, η, is another parameter for which we don't have a good approximation. As the demand for food is inelastic, we choose the value

---

[25] Friend and Blume (1975) present empirical evidence suggesting that its value is around 2 for industrial countries. Other estimates for these countries suggests that it lies between 0 and 5 (e.g., Hansen and Singleton, 1983; Dunn and Singleton, 1986).
[26] Christiano, Eichenbaum and Evans (1996) estimate it to be 0.25 while Rotemberg and Woodford (1997) estimate it to be 0.40. Blundell and MaCurdy (1999) estimate the intertemporal elasticity of labor supply to be in the range of [0.5, 1].

of $\eta = 0.6$ for the baseline case.[27]

One important feature of emerging markets is the high share of expenditure on food in total household expenditure. Based on the household surveys from emerging markets, the average expenditure on food is around 42 percent (see Table 2.1). In addition, we assume that on average half of the households' steady state food consumption is required for subsistence.[28] To match these values in the baseline model we choose subsistence level food consumption parameter, $C^* = 0.1013$ and the weight on food in the utility function, γ equal to 0.3050 so that in steady state the average household expenditure on food is 42%. For the monetary policy parameters, we follow Woodford (2003), Gali et al. (2004) and Mohanty and Klau (2004) and choose $\rho_i = 0.7$, $\rho_\pi = 2$ and $\rho_Y = 0.5$.

The major argument about leaving out food from the core price index is that the shocks in that sector are seasonal and transient. We choose the value of AR(1) coefficient of the food sector shock at 0.25 (implying that the shock lasts for four quarters, which seems reasonable given the heavy dependence of agriculture on weather conditions in emerging markets). Following the literature, we set the value of the AR(1) coefficient of the non food sector shock at 0.95 (Aguair and Gopinath, 2007; Schmitt-Grohe and Uribe, 2006). Volatility of productivity shocks in emerging markets is higher than in advanced countries (Robe 2002, Aguair and Gopinath, 2007). We choose the standard deviation of food productivity shock, $\sigma_{af} = 0.03$ and the standard deviation of non-food productivity shock, $\sigma_{as} = 0.02$.[29] Table 1.5 shows a full set of baseline parameter values for the calibrations.

---

[27] With the subsistence level of food consumption, this parameter choice implies a price elasticity of demand for food of about -0.3 in the steady state, which is close to the USDA estimate.

[28] Naik and Moore (1996) find that about 50 percent of current consumption is due to habit formation in food consumption.

[29] For advanced countries like the U.S., the values typically used in the literature are in the range of 0.005 to 0.009.

Table 1.5: Parameter Calibration – Baseline Model

Parameters	Definitions	Values
σ	Risk aversion	2
β	Subjective discount factor	0.9902
ψ	Inverse of Frisch elasticity	3
α	Probability of firm not changing price	0.66
η	Elasticity of substitution between food and non-food	0.60
γ	Weight on food in the price index	0.3050
λ	Household with credit constraint	1
θ	Elasticity of substitution between different non-food goods	10
ρ_Y	Weight on output gap in Taylor rule	0.5
ρ_π	Weight on inflation gap in Taylor rule	2
ρ_i	Weight on interest rate smoothing in Taylor rule	0.70
ρ_{af}	Persistence of food productivity shock	0.25
ρ_{as}	Persistence of non-food productivity shock	0.95
σ_{af}	Standard deviation of food productivity shock	0.03
σ_{as}	Standard deviation of non-food productivity shock	0.02

1.4 Baseline Results

We present the results in terms of the conditional welfare gains associated with each policy choice. Welfare gains are defined as additional lifetime consumption needed to make the level of welfare under strict core inflation targeting identical to that under the evaluated policy. Thus, a positive number indicates that welfare is

higher under the alternative policy than under strict core inflation targeting policy. The choice of strict core inflation targeting as a benchmark for comparison is motivated by the fact that in the literature it is considered the optimal policy choice for maximizing welfare. We present the results for three alternative policy regimes – strict headline inflation targeting, flexible headline inflation targeting and flexible core inflation targeting as defined by equations (33)-(36).

Table 1.6 shows the welfare gains from targeting different price indices under complete and incomplete market settings. Under complete markets, the choice of targeting strict core inflation is the best policy.

Table 1.6: Welfare Gains of Various Inflation Targeting Rules

	Complete Markets			Incomplete Markets		
	Strict Headline Targeting	Flexible Headline Targeting	Flexible Core Targeting	Strict Headline Targeting	Flexible Headline Targeting	Flexible Core Targeting
Welfare gain (in % of strict core inflation targeting consumption)	-0.07	-0.22	-0.19	3.21	4.18	1.58

Welfare gain here represents the welfare gain associated with each policy choice. Welfare gains ($\omega*100$) are defined as the percent increase in the strict core inflation targeting consumption process necessary to make the level of welfare under strict core inflation targeting policy identical to that under the evaluated policy. Thus, a positive number indicates that welfare is higher under alternative policy than under the strict core inflation targeting policy. Targeting policy rules are defined in equations (33) - (36).

Figure 1.6 plots the impulse responses of various macroeconomic variables to a one percent negative food productivity shock under complete markets. Each variable's response is expressed as the percentage deviation from its steady state level. Impulse responses under strict core inflation targeting rule are shown in red. The dashed lines

(in blue) are impulse responses under the strict headline inflation targeting rule.[30]
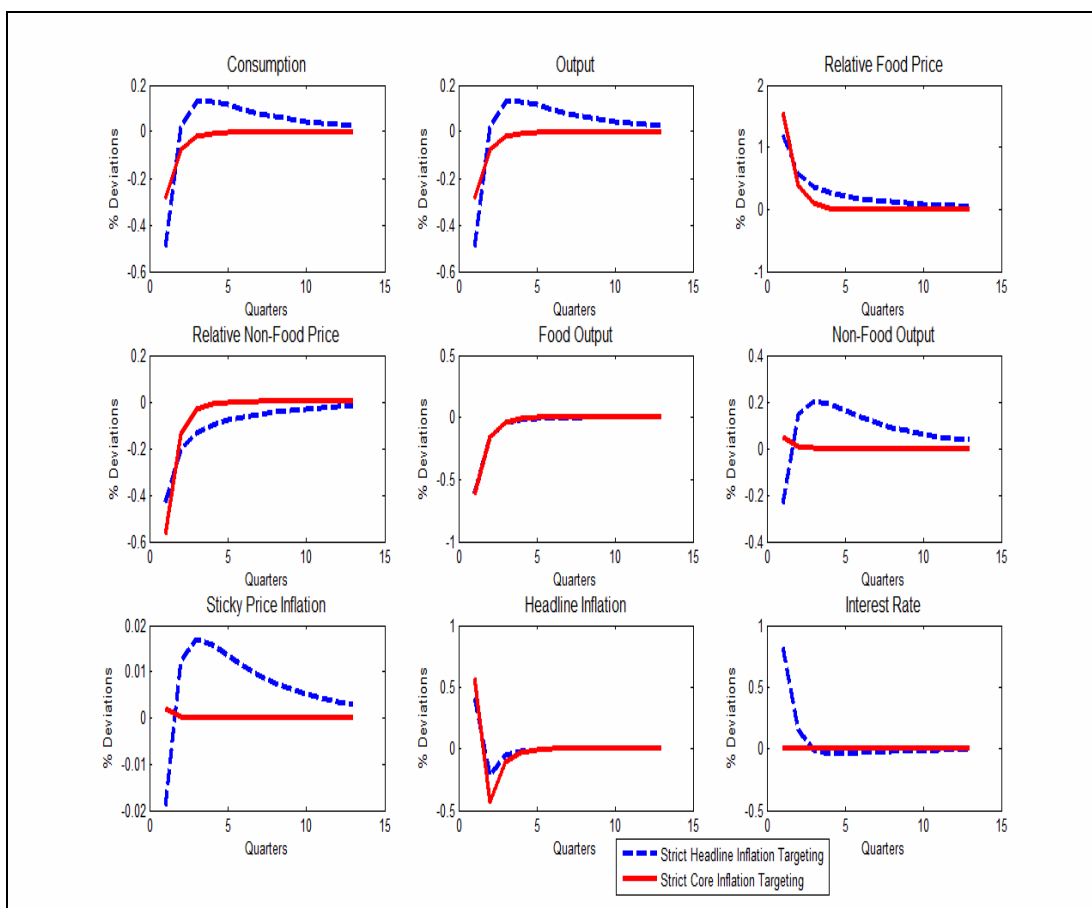
Figure 1.6: Impulse Responses to a 1% Negative Food Productivity Shock (Complete Markets, with subsistence level food consumption)
Each variable's response is expressed as the percentage deviation from its steady state level. Strict core inflation targeting means that central bank follows the policy regime given by equation (33). Strict headline inflation targeting means that central bank follows the policy regime given by equation (34).

As evident, strict headline inflation targeting regime results in a higher volatility of consumption and output. Also, the policy response is more aggressive under strict headline inflation targeting which leads to a further decline in output. These results are similar to the ones documented in the existing literature on inflation targeting.

---

[30] We only plot the impulse responses under strict core inflation targeting and strict headline inflation targeting rules as the welfare losses are much higher under other two policy regimes (Table 6).

Following an increase in inflation, the central bank raises interest rates, reducing aggregate demand (as consumers postpone their consumption following an increase in interest rates) and, thus, inflation. So, under complete markets, inflation and output move in the same direction and therefore stabilizing inflation is equivalent to stabilizing output (Aoki, 2001). It also implies that there are no additional welfare gains by adopting flexible inflation targeting. Thus, under complete markets, strict core inflation targeting is the welfare maximizing policy choice for the central bank.

However, in the presence of credit constrained consumers, flexible headline inflation targeting appears to be a better policy choice. Figure 1.7 plots the impulse responses of various macroeconomic variables to a one percent negative food productivity shock.[31] As evident, aggregate demand responds differently to monetary tightening under the two policy regimes. The central bank is able to reduce aggregate demand by increasing interest rates only when it targets headline inflation. Aggregate demand, instead of going down, goes up if central bank follows strict core inflation targeting. Thus, headline inflation targeting outperforms strict core inflation targeting. Since in the presence of financial frictions inflation and output may move in opposite directions in response to interest rate changes, stabilizing output results in welfare gains. Thus, flexible headline inflation targeting is the optimal policy choice when markets are not complete.

---

[31] We only plot the impulse responses under strict core inflation targeting and flexible headline inflation targeting rules as the welfare losses are much higher under the other two policy rules (Table 2.6).
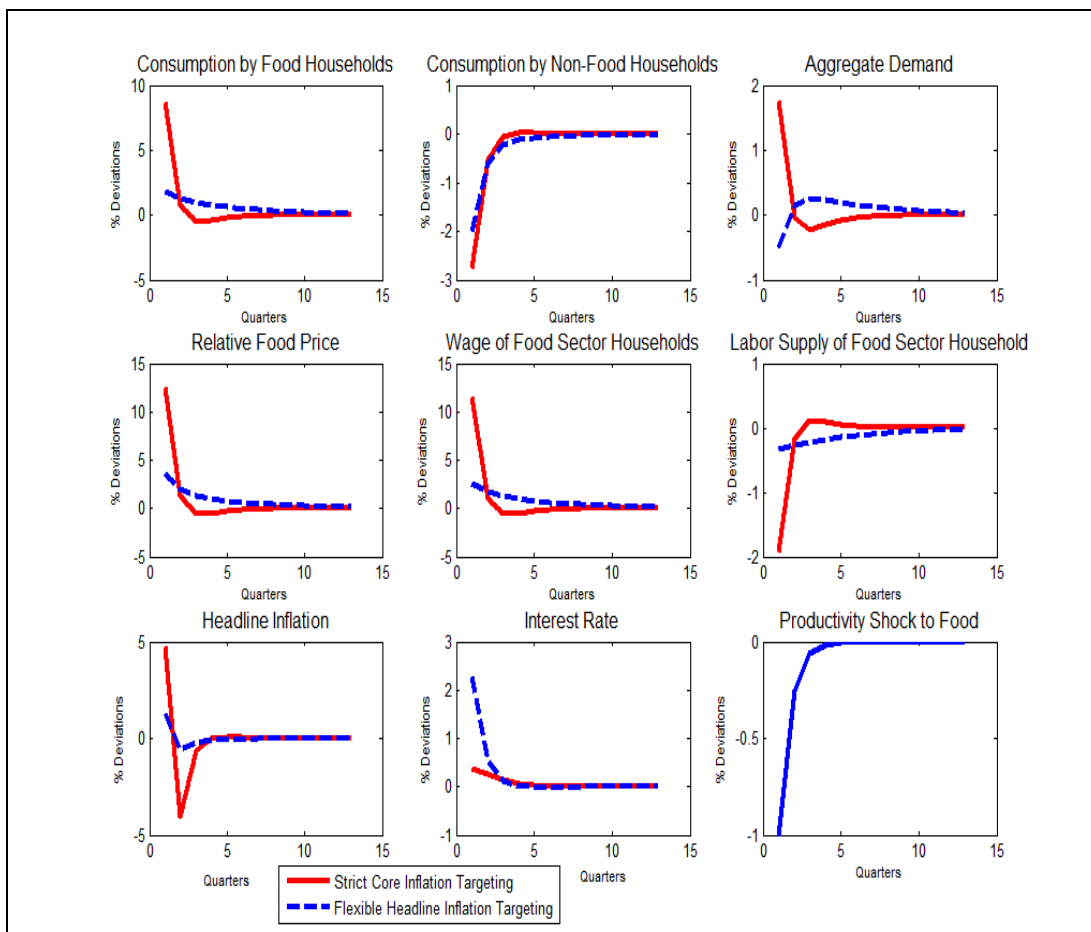
Figure 1.7: Impulse Responses to a 1% Negative Food Productivity Shock (Incomplete Markets, with subsistence level food consumption)
Each variable's response is expressed as the percentage deviation from its steady state level. Strict core inflation targeting means that central bank follows the policy regime given by equation (33). Flexible headline inflation targeting means that central bank follows the policy regime given by equation (36).

In order to examine the mechanics behind this result, we look at the properties of aggregate demand under incomplete markets. In the presence of financial frictions, the consumption choices of different households vary (as opposed to complete markets, where the consumption choice of all households is identical). While consumption demand of unconstrained households is responsive to interest rates (as they optimize inter-temporally), consumption demand of credit-constrained households is independent of interest rate changes (their horizon is static and they consume their

35

entire income each period) and depends only on their current period wage income. Since only a fraction of aggregate demand is influenced by interest rate changes, a monetary tightening does not automatically result in the decline of aggregate demand. The response of aggregate demand crucially depends on the behavior of credit-constrained households.

Figure 1.7 shows that, following a negative shock to food productivity, the central bank raises the interest rate which lowers the demand of unconstrained households (as it is optimal for them to postpone consumption). However, it has no bearing on the demand of credit-constrained consumers. An increase in the relative price of food following a negative food productivity shock increases the wage income and, therefore, consumption demand of credit-constrained households. Thus, the demand of the two types of households moves in the opposite direction following a negative shock to food productivity. Which of the two demands dominate is determined by the policy regime. Since core inflation targeting ignores the increase in food price inflation, the increase in food prices (and, therefore, the wage income of the food sector households) is higher than under headline inflation targeting. This higher wage income translates into higher consumption demand by credit-constrained consumers (as they consume all of their current wage income), which more than compensates for the lower consumption demand of unconstrained consumers. Consequently, aggregate demand rises. By contrast, when the central bank targets headline inflation, price increases in the food sector are much lower and the rise in income and, therefore, the increase in consumption demand in that sector is not enough to compensate for the decline in the demand of unconstrained consumers. Thus, monetary intervention is effective in achieving its objective of reducing aggregate demand only when central bank targets flexible headline inflation.

To formalize the above arguments, we examine the log-linearized aggregate demand

equation, which is given by[32]

$$c_t = -\frac{\varsigma_s}{\sigma}E_t(i_t - \pi_{t+1}) + E_t c_{t+1} - \varsigma_f E_t \Delta c_{f,t+1}$$

where $\varsigma_s = \dfrac{\bar{C}_s}{\bar{C}}$ is the steady state share of the sticky price households' consumption,

$\varsigma_f = \dfrac{\lambda \bar{C}_f}{\bar{C}}$ is the steady state share of flexible price households' consumption and

$$c_{f,t} = \left[\frac{1+\dfrac{a}{\psi}}{1+\dfrac{a\sigma}{\psi}}\right]w_t^f + \left[\frac{a-1}{1+\dfrac{a\sigma}{\psi}}\right]a_{f,t}$$

where $a = \dfrac{x_{f,t} * y_{f,t}}{\bar{C}_f} > 1$

The aggregate demand equation can be written as

$$c_t = -\frac{\varsigma_s}{\sigma}E_t(i_t - \pi_{t+1}) + E_t c_{t+1} - \varsigma_f E_t \left(\left[\frac{1+\dfrac{a}{\psi}}{1+\dfrac{a\sigma}{\psi}}\right]\Delta w_t^f + \left[\frac{a-1}{1+\dfrac{a\sigma}{\psi}}\right]\Delta a_{f,t+1}\right) \qquad (45)$$

and $w_t^f = x_{f,t} + a_{f,t}$ \hfill (46)

Equations (45) and (46) suggest that, in the presence of credit-constrained consumers, a link is established between aggregate demand and the relative price of food. Thus, in the presence of financial frictions, relative prices affect aggregate demand in addition to the aggregate supply.[33] Thus, in the presence of financial frictions, managing aggregate demand requires the central bank to choose a policy regime which would contain the rise in wages of credit-constrained consumers (and, therefore, the increase in their demand).

1.4.1 Welfare distribution

The focus of our paper is on average welfare but the incomplete market setting

---

[32] Aggregate demand is the sum of the log-linearized consumption demand of food and non-food households.
[33] Under complete markets, relative prices only affect aggregate supply (Aoki, 2001).

allows us to look at the welfare distribution in the economy. We find that in our model flexible headline inflation targeting is better for both the credit-constrained households and unconstrained households. However, we find that the welfare gains are higher for unconstrained consumers when central bank targets flexible headline inflation. Since there is no tradeoff involved in terms of welfare, the central bank is not likely to face any political pressures in implementing this policy.

1.5 Sensitivity Analysis

Our main result is that in the presence of financial frictions flexible headline inflation targeting is the welfare-maximizing policy choice. In this section, we evaluate the robustness of this result to changes in some of the key parameters – the elasticity of substitution between food and non-food goods (η), inverse of Frisch elasticity (ψ), price stickiness (α), mark-up in the sticky price sector (θ), and the proportion of credit-constrained households in the economy (λ). We do additional sensitivity analysis with respect to the persistence and volatility of the food productivity shock and Taylor rule coefficients. When interpreting the results it is worth noting that since the steady state values of the models differ, it is only possible to make a comparison across regimes and not across different models.

Our key results are driven by the behavior of credit-constrained consumers. Since the wage income of constrained consumers depends crucially on the price elasticity of the demand for food, we first conduct sensitivity analysis with respect to parameters influencing the price elasticity of demand. The presence of a subsistence level for food expenditures affects the marginal utility of food and non-food consumption. It also lowers the elasticity of substitution between food and non-food. The demand for food is given by equation (22), which is the sum of an iso-elastic term $\gamma(x_{f,t})^{-\eta} C_t$ and a price inelastic term $(1+\lambda)C^*$. Thus, the price elasticity of demand is a weighted sum

of these two terms (the weights are η and zero, respectively). Thus, the presence of subsistence food consumption lowers the price elasticity of the demand for food. Table 1.7 shows welfare gains from different policy rules in the absence of a subsistence level of food consumption. Clearly, our main result does not depend on the presence of subsistence level of food consumption.

Table 1.7: Welfare Gains Associated with Different Inflation Targeting Rules without Subsistence Level Food

	Welfare gain(in % of strict core inflation targeting consumption)					
	Complete Markets			*Incomplete Markets*		
Elasticity of Substitution	Strict Headline Targeting	Flexible Headline Targeting	Flexible Core Targeting	Strict Headline Targeting	Flexible Headline Targeting	Flexible Core Targeting
0.4	-0.10	-0.16	-0.12	1.15	1.42	0.77
0.5	-0.10	-0.16	-0.13	0.12	0.24	0.16
0.6[a]	-0.09	-0.16	-0.14	-0.03	0.02	0.02

See notes to table 1.6.
a. This is the baseline value of this parameter.

Next we examine the sensitivity of the results to the elasticity of substitution between food and non-food, η (Table 1.8). Under complete markets, core inflation targeting is the most appropriate policy choice for any value of the elasticity of substitution. However, under incomplete markets, flexible headline inflation targeting continues to dominate other policies for values of the elasticity as high as $\eta = 0.8$. For higher values of this elasticity, strict core inflation targeting seems to do marginally better than strict headline inflation targeting. The difference between strict core inflation targeting and strict headline inflation targeting is almost negligible for higher values of this elasticity.

Table 1.8: Welfare Gains of Various Inflation Targeting Rules for Different Values of Elasticity of Substitution (η)

Welfare gain(in % of strict core inflation targeting consumption)

Elasticity of Substitution	Complete Markets			Incomplete Markets		
	Strict Headline Targeting	Flexible Headline Targeting	Flexible Core Targeting	Strict Headline Targeting	Flexible Headline Targeting	Flexible Core Targeting
0.6[a]	-0.07	-0.22	-0.19	3.21	4.18	2.10
0.7	-0.07	-0.22	-0.20	0.19	0.54	0.23
0.8	-0.06	-0.22	-0.20	-0.02	0.09	0.02
0.9	-0.05	-0.22	-0.20	-0.04	-0.03	-0.05
1.5	-0.03	-0.22	-0.22	-0.01	-0.11	-0.11
2.0	-0.02	-0.22	-0.22	0.00	-0.12	-0.12

See notes to table 1.6.
a. This is the baseline value of this parameter.

The price elasticity of food demand is an important parameter determining the income of credit-constrained households. For low values of the elasticity of substitution, following a negative shock to productivity of food the demand for food does not go down substantially and leads to a large increase in the wage income of food-producing (credit-constrained) households. Increased demand of credit-constrained consumers is enough to counteract the decline in the demand of unconstrained households. However, when the elasticity of substitution is high, demand for food goes down substantially and the increase in the income and demand of credit-constrained households is no longer sufficient to compensate for the decline

in the demand of unconstrained households. In fact, for sufficiently high values of the elasticity of substitution, the wage income of credit-constrained households may even go down.

Again, even though we cannot strictly compare the impulse responses, it is instructive to plot them for different values of the elasticity of substitution to understand how varying the elasticity of substitution affects various macroeconomic variables. Figure 1.8 shows the impulse responses of various macroeconomic variables to a 1 percent negative food productivity shock under flexible headline inflation targeting for a high value of the elasticity of substitution ($\eta = 2$) and also a low value ($\eta = 0.6$). For low values of the elasticity of substitution, a positive deviation (from the respective steady state) in the food price and wage of credit-constrained households is large. When the elasticity of substitution is high, the wage of credit-constrained consumers in fact declines relative to the steady state value (as the increase in the price of food is significantly lower).
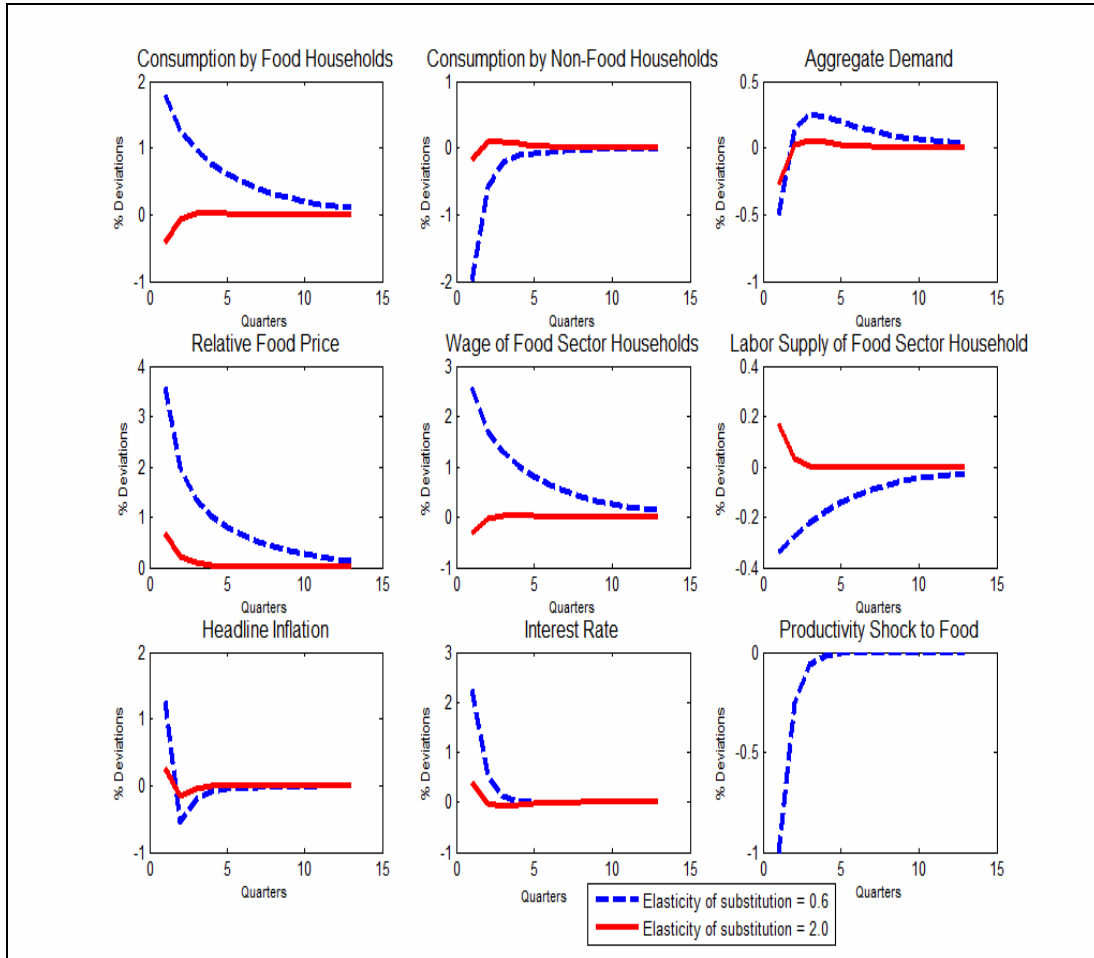
Figure 1.8: Impulse Responses to a 1% Negative Food Productivity Shock under Flexible Headline Inflation Targeting Rule (Incomplete Markets with different elasticity of substitution of food).
Each variable's response is expressed as the percentage deviation from its steady state level. These impulse responses are generated with central bank following the flexible headline inflation targeting given by equation (36).

In Table 1.9 – 1.12, we present the results of sensitivity analysis with respect to the inverse of the Frisch elasticity (ψ), price stickiness (α), fraction of credit-constrained households (λ) and the mark-up in the sticky price sector (θ). We have selected the most common values of these parameters used in the literature to carry out the sensitivity experiments. As evident, our results are robust to the selection of parameter values around their baseline values.

42

Table 1.9: Welfare Gains for Different Parameter Values of Inverse of Frisch Elasticity, (ψ)

Inverse of Frisch Elasticity	Strict Headline Targeting	Flexible Headline Targeting	Flexible Core Targeting
2	0.00	0.38	0.38
3[a]	3.21	4.18	1.58
4	1.32	2.12	1.01

See notes to table 1.6. Parameter value of 2 implies labor elasticity of 0.5 while parameter value of 4 implies labor elasticity of 0.25.
a. This is the baseline value of this parameter.

Table 1.10: Welfare Gains for Different Parameter Values of Price Rigidity, (α)

Probability of firms not changing prices	Strict Headline Targeting	Flexible Headline Targeting	Flexible Core Targeting
0.50	2.30	2.90	1.24
0.66[a]	3.21	4.18	1.58
0.75	3.64	5.24	2.89

See notes to table 1.6. Parameter value of 0.5 implies that the mean duration prices remain fixed is 2 quarters while value of 0.75 implies the mean duration prices remain fixed is 4 quarters.
a. This is the baseline value of this parameter.

Table 1.11: Welfare Gains for Different Parameter Values of Credit Constraint Consumers, (λ)

Credit constrained consumers	Strict Headline Targeting	Flexible Headline Targeting	Flexible Core Targeting
1.00[a]	3.21	4.18	1.58
2.00	0.05	0.89	0.73
3.00	-0.03	0.75	0.73

See notes to table 1.6. Parameter value of 2 implies that 66% of households are in flexible price sector and credit constrained. Value of 3 implies that 75% of households are in flexible price sector are credit constrained.
a. This is the baseline value of this parameter.

Table 1.12: Welfare Gains for Different Parameter Values of Elasticity of Substitution Between different Non-Food Goods, (θ)

Elasticity of substitution between food and non-food goods	Strict Headline Targeting	Flexible Headline Targeting	Flexible Core Targeting
5	2.65	3.27	1.55
10[a]	3.21	4.18	1.58
15	3.36	4.85	2.54

See notes to table 1.6. θ, also determines the mark up in the sticky price sector. Value of 5 implies a mark up of 25% and value of 15 implies a mark up of 7%.
a. This is the baseline value of this parameter.

Following Gali et al. (2004), we conduct sensitivity analysis with respect to the coefficients of the Taylor rule (Table 1.13 – 1.15). Flexible headline inflation targeting performs better than other regimes irrespective of the choice of Taylor rule coefficients. We also compute the Taylor rule parameters associated with optimal strict core inflation targeting under the baseline case and compare the welfare gains associated with adopting flexible headline inflation targeting.[34]We find that the welfare gains are still positive.

---

[34] For computing optimal parameters, we restrict our search to [0, 3] for ρ_π and [0, 1] for ρ_i. We find that the best rule requires $\rho_\pi = 3$ and $\rho_i = 0.95$. The value of ρ_π is the largest value that we allow for in our search. If we left this parameter unconstrained, then optimal policy would call for an arbitrarily large coefficient on inflation. The reason is that in that case, under the optimal policy, inflation would in effect be forever constant so that the economy would be characterized by zero inflation volatility (Schmitt-Grohe and Uribe, 2007).

Table 1.13: Welfare Gains of Changing Coefficient on Inflation Gap in Taylor rule, (ρ_π)

Weight on inflation gap	Strict Headline Targeting	Flexible Headline Targeting	Flexible Core Targeting
0.50	-2.74	5.32	3.76
1.00	2.40	4.94	2.95
1.50	3.12	4.53	2.45
2.00[a]	3.21	4.18	1.58
2.50	3.15	3.87	1.84
3.00	3.04	3.62	1.65

See notes to table 1.6. Other Taylor rule parameters have been kept at their baseline value (ρ_i=0.7, ρ_π=2)

a. This is the baseline value of this parameter.

Table 1.14: Welfare Gains of Changing Coefficient on Output Gap in Taylor rule, (ρ_Y)

Weight on output gap	Strict Headline Targeting	Flexible Headline Targeting	Flexible Core Targeting
0.00	3.21		
0.50[a]		4.18	1.58
1.00		4.25	2.72
1.50		2.26	3.03
2.00		4.25	3.23
2.50		4.25	3.36

See notes to table 1.6. Other Taylor rule parameters have been kept at their baseline value (ρ_i=0.7, ρ_π=2).

a. This is the baseline value of this parameter.

Table 1.15: Welfare Gains of Changing Interest Smoothing Parameter in Taylor rule, (ρ_i)

Weight interest rate smoothing	Strict Headline Targeting	Flexible Headline Targeting	Flexible Core Targeting
0.00	-5.58	3.79	2.73
0.10	-3.11	4.01	2.71
0.20	-1.20	4.16	2.66
0.30	0.26	4.25	2.59
0. 40	1.36	4.28	2.48
0.50	2.18	4.27	2.36
0.60	2.78	4.23	2.23
0.70[a]	3.21	4.18	2.10
0.80	3.52	4.11	1.97
0.90	3.73	4.05	1.86

See notes to table 1.6. Other Taylor rule parameters have been kept at their baseline value (ρ_π =2, ρ_Y =0.5).
a. This is the baseline value of this parameter.

   Shocks to productivity in the food sector are regarded as transitory and highly volatile. So we do additional sensitivity analysis for various combinations of the degrees of persistence and volatility of these shocks. From the results shown in Table 1.16, it is evident that our results are robust to various combinations and also that welfare gains from adopting flexible headline targeting is even higher if shocks are less persistent and highly volatile. Of course, in the case of an advanced economy like the U.S. where the volatility of these shocks is an order of magnitude smaller than in typical emerging markets, the potential welfare gains are considerably smaller.

Table 1.16: Welfare Gains of Flexible Headline Inflation Targeting for Different Combinations of Persistence and Volatility of Food Productivity Shock

		Volatility of Shocks		
		0.02	0.03	0.04
Persistence	0.10	2.27	4.62	7.99
	0.25	2.08	4.18	7.18
	0.50	1.81	3.55	6.04
	0.95	0.77	1.19	1.75

See notes to table 1.6. Persistence of food productivity is the co-efficient of AR(1) process in equation (32). Volatility of food productivity shock is the standard error of random shock to the productivity. Persistence and volatility of non-food shock is held constant at 0.95 and 0.02 respectively in the above welfare cost calculations

1.5.1 Extensions of the Model

We consider two extensions of our baseline model.[35] The first extension looks at an alternative characterization of complete markets.[36] Most existing models with complete markets assume that agents can insure against income risks *ex ante.* This assumption implies that, given the same initial wealth, consumers will choose identical consumption stream. A more realistic way of characterizing complete markets is to assume that consumers can insure against income risks but only *ex post.* This means that they can only insure against fluctuations in their income. Under this alternate market structure, each type of household chooses consumption streams to maximize its lifetime utility subject to its idiosyncratic budget constraint. Under this scenario, we present in Table 1.17 the welfare gains under flexible headline inflation targeting. It appears that for our baseline model, flexible headline inflation targeting does better than strict core inflation targeting. However for higher values of elasticity

---

[35] See Appendix III for details.

[36] One could regard this as a complete market setting, <u>conditional</u> on worker assignment to sectors, which is determined ex-ante. In Aoki (2001), complete markets are characterized by worker assignment to sectors ex-post.

of substitution, strict core inflation targeting is an optimal policy choice.

Table 1.17: Welfare Gains under Alternate Complete Market Structure

Elasticity of Substitution	Flexible Headline Inflation Targeting
0.6[a]	0.24
0.7	0.05
0.8	-0.02

See notes to table 1.6.
a. This is the baseline value of this parameter

A second extension of our baseline model looks at a more general case where agents in both sectors can be credit constrained. We assume that a fraction $\lambda_1 > 0$ and $\lambda_2 > 0$ of households in the flexible price sector and sticky price sector, respectively, can insure against income risks ex post.[37] We look at combinations of λ_1 and λ_2 such that 50 percent of the households in the economy are credit constrained.[38] Table 1.18 presents the welfare gains of pursuing flexible headline inflation targeting for some possible combinations of λ_1 and λ_2. It is clear that even under this general setting targeting flexible headline inflation outperforms a strict core inflation targeting rule.

---

[37] This implies that $1 + \lambda - (\lambda_1 + \lambda_2)$ fraction of households are credit constrained.

[38] This is consistent with the empirical evidence that only about 42 percent of households in emerging markets have access to formal finance (Table 3).

Table 1.18: Welfare Gains under General Model

Fraction of households in sticky price sector with access to formal finance	Fraction of households in flexible price sector with access to formal finance	Welfare gains of flexible headline inflation targeting
0.10	0.90	0.38
0.20	0.80	0.22
0.30	0.70	0.21
0.40	0.60	0.22
0.50	0.50	0.24
0.60	0.40	0.26
0.70	0.30	0.28
0.80	0.20	0.29
0.90	0.10	0.30

See notes to table 1.6. We have chosen the combination λ_1 and λ_2 such that overall 50% of households in the economy are credit constrained.

1.6 Concluding Remarks

Inflation targeting, which had become widely popular in both advanced and emerging market economies over the last two decades, has come under attack after the global financial crisis as it is believed to leave no room for central bankers to pay attention to asset price bubbles. Whatever the outcome of that broader debate, the reality is that the primary objective of most central banks, whether or not they explicitly target inflation, is still to keep inflation low and stable. To achieve this objective, the choice of the appropriate price index to measure inflation remains a key operational issue. Previous research has indicated that central banks should only focus on stabilizing core inflation. However, these results rely heavily on the assumption that markets are complete and that price stickiness is the only source of distortion in the economy.

In this paper, we have developed a more realistic model with the following key

features –incomplete markets, characterized by the presence of credit-constrained consumers; households requiring a minimum subsistence level of food to survive; low price elasticity of demand for food items and a high share of expenditure on food in households' total expenditure. These features, particularly the last one, are especially relevant for emerging market economies.

We show that, in the presence of credit-constrained consumers, targeting core inflation is no longer welfare maximizing. Also, stabilizing inflation is not sufficient to stabilize output when markets are not complete. Under these conditions, flexible headline inflation targeting—which involves targeting headline inflation and putting some weight on the output gap--is the optimal monetary policy rule.

Our results differ from those of traditional models due to the presence of financial frictions in the economy. Lack of access to finance makes the demand of credit-constrained households insensitive to interest rate fluctuations. Their demand is determined by real wages, which depend on prices in the flexible price sector. Thus, if the central bank ignores the fluctuations in the flexible price sector, aggregate demand may in fact move in the opposite direction to what is intended by the monetary policy intervention. To have the desired effect on aggregate demand, the central bank has to target a price index that would dampen the response of credit-constrained consumers. In our setting, this means that the central bank should target headline inflation.

Our results have special significance for central banks in emerging markets, where food consumption remains a major component of household consumption expenditures and the share of the population that is credit-constrained is large. While our model is a simple one, it amply highlights the significance of financial frictions for the choice of optimal price index and the optimal monetary policy rule. The widely-accepted result of focusing on core CPI in order to stabilize inflation and output needs a careful re-examination in the presence of financial frictions.

REFERENCES

Amato, Jeffery D., and Stefan Gerlach, 2001, "Inflation Targeting in Emerging Market and Transition Economies: Lessons After a Decade," CEPR Discussion Paper No. 3074.

Amato, Jeffery D., and Thomas Laubach, 2003, "Rule-of-Thumb Behavior and Monetary Policy," *European Economic Review*, Vol. 47, No. 5, pp. 791-831.

Aguiar, Mark, and Gita Gopinath, 2007, "The Role of Interest Rates and Productivity Shocks in Emerging Market Fluctuations," Working Papers No. 445, Central Bank of Chile.

Aguiar, Mark, and Gita Gopinath, 2007, "Emerging Market Business Cycles: The Cycle Is the Trend," *Journal of Political Economy*, Vol. 115, pp. 69-102.

Aoki, Kosuke, 2001, "Optimal Monetary Policy Responses to Relative Price Changes," *Journal of Monetary Economics*, Vol. 48, No. 1, pp. 55-80.

Basu, Priya, and Pradeep Srivastava, 2005, "Scaling-up Microfinance for India's Rural Poor," World Bank Policy Research Working Paper No. 3646.

Basu, Susanto, 1996, "Procyclical Productivity: Increasing Returns or Cyclical Utilization*?" Quarterly Journal of Economics*, Vol. 111, No. 3, pp.719-751.

Basu, Susanto, and John G. Fernald, 1994, "Constant Returns and Small Markups in U.S. Manufacturing," International Finance Discussion Paper 483, Board of Governors of the Federal Reserve System.

Basu, Susanto, and John G. Fernald, 1995, "Are Apparent Productivity Spillovers a Specification Error?" *Journal of Monetary Economics*, Vol. 36, No. 1, pp.165-188.

Basu, Susanto, and Miles S. Kimball, 1997, "Cyclical Productivity with Unobserved Input Variation," NBER Working Paper No. 5915.

Bernanke, Ben S., Laubach, Tomas, Mishkin, Frederic S., and Adam S. Posen, 1999, "Inflation Targeting: Lessons from International Experience," (Princeton, NJ: Princeton University Press).

Blundell, Richard, and Thomas MaCurdy, 1999, "Labor Supply: A Review of Alternative Approaches," *Handbook of Labor Economics*, Vol. 3, eds. Orley Ashenfelter, and David Card (The Netherlands: Elsevier Science), pp.1559-1695.

Calvo, Guillermo A., 1983, "Staggered Prices in a Utility-Maximizing Framework," *Journal of Monetary Economics,* Vol. 12, No. 3, pp. 383-398.

Campbell, John Y., and N. Gregory Mankiw, 1989, "Consumption, Income, and Interest Rates: Reinterpreting the Time Series Evidence," NBER *Macroeconomics Annual*, Vol. 4, eds. Olivier Jean Blanchard and Stanley Fischer (Cambridge, MA: MIT Press), pp. 185-216.

Campbell, John Y., and N. Gregory Mankiw, 1990, "Permanent Income, Current Income, and Consumption," *Journal of Business and Economic Statistics*, Vol. 8, No. 3, pp. 265-279.

Campbell, John Y., and N. Gregory Mankiw, 1991, "The Response of Consumption to Income: a Cross-country Investigation," *European Economic Review*, Vol. 35, No. 4, pp. 723-767.

Christiano, Lawrence, Eichenbaum, Martin, and Charles Evans, 1996, "The Effects of Monetary Policy Shocks: Evidence from the Flow of Funds," *Review of Economics and Statistics*, Vol. 78, No. 1, pp. 16-34.

Clarida, Richard, Gali, Jordi, and Mark Gertler, 1998, "Monetary Policy Rules in Practice: Some International Evidence," *European Economic Review*, Vol. 42, No. 6, pp. 1033-1067.

Clarida, Richard, Gali, Jordi, and Mark Gertler, 1999, "The Science of Monetary Policy: A New Keynesian Perspective," *Journal of Economic Literature*, Vol. 37, No. 4, pp. 1661-1707.

Collard, Fabrice, and Michel Juillard, 2001, "Accuracy of Stochastic Perturbation Methods: the Case of Asset Pricing Models," *Journal of Economic Dynamics and Control*, Vol. 25, No. 6-7, pp. 979–999.

Devereux, Michael B., Lane, Philip R., and Juanyi Xu, 2004, "Exchange Rates and Monetary Policy in Emerging Market Economies," Institute for International Integration Studies Discussion Paper 36, Trinity College Dublin.

Dunn, Kenneth B., and Kenneth J. Singleton, 1986, "Modeling the Term Structure of Interest Rates Under Non-separable Utility and Durability of Goods," *Journal of Financial Economics*, Vol. 17, No. 1, pp. 27-55.

Ferrero, Andrea, Gertler, Mark, and Lars E.O. Svensson, 2008, "Current Account Dynamics and Monetary Policy," NBER Working Paper No. 13906.

Friend, Irwin, and Marshall E. Blume, 1975, "The Demand for Risky Assets," *American Economic Review*, Vol. 65, No. 5, pp. 900-922.

Fuhrer, Jeffrey C., 2000, "Habit Formation in Consumption and Its Implications for Monetary-Policy Models," *American Economic Review*, Vol. 90, No.3, pp. 367-90.

Fuhrer, Jeffery C., and Glenn D. Rudebusch, 2003, "Estimating the Euler Equation for Output," Federal Reserve Bank of Boston, mimeo.

Gali, Jordi, Lopez-Salido, David J., and Javier Valles, 2004, "Rule-of-Thumb Consumers and The Design Of Interest Rate Rules," *Journal of Money, Credit and Banking*, Vol. 36, No. 4, pp. 739-763.

Geary Roy C., 1949, "A Note on A Constant Utility Index of the Cost of Living," *Review of Economic Studies*, Vol. 18, No. 1, pp. 65-66.

Goodfriend, Marvin, and Robert G. King, 1997, "The New Neoclassical Synthesis and the Role of Monetary Policy," in *NBER Macroeconomics Annual*, Vol. 12, eds. Ben S. Bernanke, and Julio J. Rotemberg (Cambridge, MA: MIT Press), pp. 231-83.

Goodfriend, Marvin, and Robert G. King, 2001, "The Case for Price Stability," in *The First ECB Central Banking Conference: Why Price Stability?* Eds. Alicia G. Herroro, Vitor Gaspar, Lex Hoogduin, Julian Morgan, and Bernhard Winkler (Frankfurt am Main: European Central Bank), pp. 53-94.

Gordon, Robert J., 1975, "Alternative Responses of Policy to External Supply
    Shocks," *Brookings Papers on Economic Activity,* Vol. 1, No. 75, pp. 183-206.

Jappelli, Tullio, 1990, "Who is Credit Constrained in the US Economy?" *Quarterly
    Journal of Economics*, Vol. 105, No. 1, pp. 219-234.

Jin, He- Hui, and Kenneth L. Judd, 2002, "Perturbation Methods for General Dynamic
    Stochastic Models," Manuscript, Stanford University.

Kim, Jinill, and Sunghyun H. Kim, 2003, "Spurious Welfare Reversals in International
    Business Cycle Models," *Journal of International Economics*, Elsevier, Vol.
    60, No. 2, pp. 471-500.

King, Robert G., Plosser, Charles I., and Sergio T. Rebelo, 1988, "Production,
    Growth, and Business Cycles I: the Basic Neoclassical Model," *Journal of
    Monetary Economics*, Vol. 21, No. 2-3, pp. 191–232.

Kollmann, Robert, 2004. "Welfare-Maximizing Operational Monetary and Tax Policy
    Rules," CEPR Discussion Papers 4782.

Kydland, Finn E., and Edward C. Prescott, 1982, "Time to Build and Aggregate
    Fluctuations," *Econometrica,* Vol. 50, No. 6, pp. 1345–1370.

Larsen, Lars P., and Kenneth J. Singleton, 1983, "Stochastic Consumption, Risk
    Aversion, and the Temporal Behavior of Asset Returns," *The Journal of
    Political Economy*, Vol. 91, No. 2, pp. 249-265.

Lowe, Philip, and Luci Ellis, 1997, "The smoothing of official interest rates,"
    Monetary policy and inflation targeting, Reserve Bank of Australia, pp. 287-
    312.

Mishkin, Frederic S., and Klaus Schmidt-Hebbel, 2001, "One Decade of Inflation
    Targeting in the World: What do We Know and What do We Need to Know?"
    NBER Working Paper No. 8397.

Mishkin, Frederic S., 2007, "Inflation Dynamics," speech delivered at the Annual
    Macro Conference, Federal Reserve Bank of San Francisco, San Francisco,
    March 23, www.federalreserve.gov/newsevents.

Mishkin, Frederic S., 2008, "Does Stabilizing Inflation Contribute to Stabilizing Economic Activity," at East Carolina University's Beta Gamma Sigma Distinguished Lecture Series, Greenville, North Carolina. February 25, 2008**.**

Mohanty, Madhusudan S., and Marc Klau, 2004, "Monetary Policy Rules in Emerging Market Economies: Issues and Evidence," BIS Working Papers No. 149, Bank of International Settlement.

Muscatelli, Anton V., Tirelli Patrizio, and Carmine Trecroci, 2003, "Fiscal and Monetary Policy Interactions in a New Keynesian Model with Liquidity Constraints," University of Milan Bicocca, mimeo.

Narayan, Y. Naik, and Michael J. Moore, 1996, "Habit Formation and Intertemporal Substitution in Individual Food Consumption," *Review of Economics and Statistics*, Vol. 78, No. 2, pp. 321-328.

Parker, Jonathan A., 1999, "The Response of Household Consumption to Predictable Changes in Social Security Taxes," *American Economic Review*, Vol. 89, pp. 959-973.

Ravn, Morten O., Schmitt-Grohe, Stephanie, and Martin Uribe, 2008, "The Macroeconomics of Subsistence Points", *Macroeconomic Dynamics*, Vol. 12, April 2008, pp. 136-147.

Rose, Andrew K., 2006, "A Stable International Monetary System Emerges: Inflation Targeting is Bretton Woods, Reversed," NBER Working Paper No. W12711.

Rotemberg, Julio J., and Michael Woodford, 1997, "An Optimization-Based Econometric Framework for the Evaluation of Monetary Policy," in *NBER Macroeconomics Annual*, Vol. 12, eds. Ben S. Bernanke and Julio J. Rotemberg (Cambridge, Mass.: MIT Press), pp. 297-346.

Rotemberg, Julio J., and Michael Woodford, 1999, "Interest-Rate Rules in an Estimated Sticky-Price Model," in *Monetary Policy Rules*, ed. J. B. Taylor (Chicago, IL: University of Chicago), pp. 57-126.

Sack, Brian, and Volker Wieland, 1999 "Interest-rate Smoothing and Optimal Monetary Policy: A Review of Recent Empirical Evidence," *Finance and Economics Discussion Series,* Federal Reserve Board, Washington DC.

Schmitt-Grohe, Stephanie, and Martin Uribe, 2004, "Solving Dynamic General Equilibrium Models Using a Second-Order Approximation to the Policy Function," *Journal of Economic Dynamics and Control*, Vol. 28, pp. 755-775.

Schmitt-Grohe, Stephanie, and Martin Uribe, 2007, "Optimal Simple and Implementable Monetary and Fiscal Rules," *Journal of Monetary Economics*, Vol. 54, No. 6, pp. 1702-1725.

Seale, James, Jr., Regmi, Anita, and John A. Bernstein, 2003, "International Evidence on Food Consumption Patterns," Technical Bulletin No. 1904, United States Department of Agriculture.

Shea, John, 1995, "Union Contracts and the Life-Cycle/Permanent-Income Hypothesis," *American Economic Review*, Vol. 85, No. 1, pp. 186-200.

Souleles, Nicholas S., 1999, "The Response of Household Consumption to Income Tax Refunds," *American Economic Review*, Vol. 89, No. 4, pp. 947-958.

Stone, Richard, 1954, "Linear Expenditure System and Demand Analysis: An Application to the Pattern of British Demand," *Economic Journal*, Vol. 64, pp. 511-527.

Sutherland, Alan, 2002, "A Simple Second-Order Solution Method for Dynamic General Equilibrium Models," Discussion Paper Series, Department of Economics 0211, Department of Economics, University of St. Andrews.

Taylor, John B., 1993, "Discretion versus Policy Rules in Practice," Carnegie-Rochester Conference Series on Public Policy 39, December, pp. 195-214.

Woodford, Michael, 1996, "Control of the Public Dept: A Requirement for Price Stability?" NBER Working Paper No. 5684.

Woodford, Michael, 2003, *Interest and Prices: Foundations of a Theory of Monetary Policy* (Princeton, NJ: Princeton University Press).

World Bank, 2008, "Finance for All? Policies and Pitfalls in Expanding Access," World Bank policy research report.

Wynne, Mark A., 1999, "Core Inflation: A Review of Some Conceptual Issues," Research Department Working Paper no. 9903, Federal Reserve Bank of Dallas.

APPENDICES

Appendix I

This appendix gives the system of equations (in terms of stationary variables) characterizing the competitive equilibrium under the incomplete market settings.

Demand equation for flexible price sector household

$$C_t^f = x_{f,t} y_{f,t} - x_{f,t} C^* \tag{1}$$

Supply equation of flexible price sector (food sector) firm

$$x_{f,t} = \phi_n (y_{f,t})^{\psi} (C_t^f)^{\sigma} (A_{f,t})^{-(1+\psi)} \tag{2}$$

Demand equation for sticky price sector household

$$(C_t^s)^{-\sigma} = \beta E_t \left\{ (C_{t+1}^s)^{-\sigma} \frac{R_t}{\Pi_t} \right\} \text{,where } R_t \text{ is the gross nominal interest rate} \tag{3}$$

Supply equation of sticky price sector (non-food sector) firm

$$x_t x_{s,t} = \frac{\theta}{\theta-1} \frac{E_t \left[\sum_{i=0}^{1} (\alpha\beta)^i Q_{t,t+i} \left(\frac{P_{s,t}}{P_{s,t+i}} \right)^{-\theta} Y_{s,t+i} \left(\frac{P_{t+i}}{P_t} \right) MC_{t+i}^r \right]}{E_t \left[\sum_{i=0}^{1} (\alpha\beta)^i Q_{t,t+i} \left(\frac{P_{s,t}}{P_{s,t+i}} \right)^{-\theta} Y_{s,t+i} \right]} \tag{4}$$

Price Index in sticky price good sector

$$1 = \left[\alpha (\Pi_{s,t})^{-(1-\theta)} + (1-\alpha) x_t^{1-\theta} \right]^{\frac{1}{1-\theta}} \tag{5}$$

Real marginal cost in the sticky price sector

$$MC_t^r = \phi_n (y_{s,t})^{\psi} (C_t^s)^{\sigma} (A_{s,t})^{-(1+\psi)} = \phi_n ((x_t)^{-\theta} Y_{s,t})^{\psi} (C_t^s)^{\sigma} (A_{s,t})^{-(1+\psi)} \tag{6}$$

Market clearing equation for flexible price good

$$Y_{f,t} = \lambda y_{f,t} = C_{f,t} = \gamma (x_{f,t})^{-\eta} C_t + (1+\lambda) C^* \tag{7}$$

Market clearing condition for sticky price good

$$Y_{s,t} = C_{s,t} = (1-\gamma)(x_{s,t})^{-\eta} C_t \tag{8}$$

Aggregate Price Index

$$1 = \left[\gamma (x_{f,t})^{1-\eta} + (1-\gamma)(x_{s,t})^{1-\eta} \right]^{\frac{1}{1-\eta}} \tag{9}$$

Relation between headline and sticky price index

$$x_{s,t} = \frac{\Pi_{s,t} x_{s,t-1}}{\Pi_t} \qquad (10)$$

Aggregation equation

$$\lambda C_t^f + C_t^s = C_t = Y_t \qquad (11)$$

Appendix II

Derivation of welfare gains associated with different policy regimes-

Welfare gain is given by

$$V_0^a = E_0 \sum_{t=0}^{\infty} \beta^t U((1+\omega)c_t^r, n_t^r)$$

$$V_0^a = E_0 \sum_{t=0}^{\infty} \beta^t \left\{ \frac{(1+\omega)^{1-\sigma}\left(C_t^r\right)^{1-\sigma}}{1-\sigma} \right\} - E_0 \sum_{t=0}^{\infty} \beta^t \left\{ \phi_n \frac{\left(n_t^r\right)^{1+\psi}}{1+\psi} \right\}$$

$$= (1+\omega)^{1-\sigma} E_0 \sum_{t=0}^{\infty} \beta^t \left\{ \frac{\left(C_t^r\right)^{1-\sigma}}{1-\sigma} \right\} - E_0 \sum_{t=0}^{\infty} \beta^t \left\{ \phi_n \frac{\left(n_t^r\right)^{1+\psi}}{1+\psi} \right\}$$

$$V_0^a = (1+\omega)^{1-\sigma} U_0^r - D_0^r$$

where

$$U_0^r = E_0 \sum_{t=0}^{\infty} \beta^t \left\{ \frac{\left(C_t^r\right)^{1-\sigma}}{1-\sigma} \right\} \text{ and } D_0^r = E_0 \sum_{t=0}^{\infty} \beta^t \left\{ \phi_n \frac{\left(n_t^r\right)^{1+\psi}}{1+\psi} \right\}$$

Using $V_0^r = U_0^r - D_0^r$ we can solve for

$$\omega = \left[\frac{V_0^a + D_0^r}{V_0^r + D_0^r} \right]^{\frac{1}{1-\sigma}} - 1$$

60

Appendix III

Alternate Complete Market Structure

Most of the traditional models with complete markets assume that agents can insure against income risks *ex ante.* This assumption implies that given the same initial wealth, consumers will choose identical consumption stream. A more realistic alternate way of characterising complete markets is to assume that consumers can only insure against income risks *ex post.* This means that they can only insure against the fluctuations in their income. Under this alternate market structure, each type of household chooses consumption streams to maximize their lifetime utility subject to their idiosyncratic budget constraint.

Flexible Price Sector Household

A representative household in flexible price sector maximizes the lifetime utility given by equation (1) subject to the following budget constraint[39]

$$P_t C_t^f + B_t^f + \frac{\kappa}{2}\left(B_t^f - B^f\right)^2 = W_t^f N_t^f + (1+i_{t-1})B_{t-1}^f - P_{f,t}C^* \qquad (46)$$

where B_t^f represent the quantity of one period nominal riskless discount bond bought in period t and maturing in period t+1.

Maximization with respect to C_t^f yields the Euler equation

$$(1+\kappa(B_t^f - B^f))(C_t^f)^{-\sigma} = \beta E_t\left\{(C_{t+1}^f)^{-\sigma}\frac{1+i_t}{1+\pi_{t+1}}\right\} \qquad (47)$$

Sticky Price Sector Household

Whereas a representative household in sticky price sector maximizes the lifetime

---

[39] In order to solve the model by linearizing it around the steady state with available techniques we assume that households face a small quadratic adjustment cost, $\frac{\kappa}{2}\left(B_t^f - B^f\right)^2$, where κ is a parameter and B^f is the steady state value of the bond holding.

utility given by equation (1) subject to the following budget constraint[40]

$$P_t C_t^s + B_t^s + \frac{\kappa}{2}(B_t^s - B^s)^2 = \int_0^1 W_t^s(z)N_t^s(z)dz + \int_0^1 \Pi_t(z)dz + (1+i_{t-1})B_{t-1}^s - P_{f,t}C^* \quad (48)$$

where B_t^s represent the quantity of one period nominal riskless discount bond bought in period t and maturing in period t+1.

Maximization with respect to C_t^s yields the Euler equation

$$(1+\kappa(B_t^s - B^s))(C_t^s)^{-\sigma} = \beta E_t \left\{ (C_{t+1}^s)^{-\sigma} \frac{1+i_t}{1+\pi_{t+1}} \right\} \quad (49)$$

Bond markets clear: $\lambda B_t^f + B_t^s = 0$ $\quad\quad$ (50)

Equations (2), (4)-(11) of Appendix I and (46)-(50) expressed in terms of stationary variables define the system of equations that combined with the monetary policy rule and exogenous stochastic processes for $A_{f,t}$ and $A_{s,t}$ determine the equilibrium path of the economy under this setting.

General Case

We consider a more general case where households in each sector can be credit constraint. Let $\lambda_1 > 0$ and $\lambda_2 > 0$ be the fraction of households who have access to financial markets in the flexible price sector and in the sticky price sector respectively. So in this general setting there are four different kinds of agents in the economy based on the sector of economy and access to financial markets. Here again we assume that households with an access to financial markets can only insure against the income risks *ex post*.

---

[40] In order to solve the model by linearizing it around the steady state with available techniques we assume that households face a small quadratic adjustment costs, $\frac{\kappa}{2}(B_t^s - B^s)^2$, where κ is a parameter and B^s is the steady state value of the bond holding.

Flexible Price Sector Household

Unconstrained Household

A representative who has access to financial markets in the flexible price sector maximizes the lifetime utility given by equation (1) subject to the following budget constraint[41]

$$P_t C_{1t}^f + B_t^f + \frac{\kappa}{2}\left(B_t^f - B^f\right)^2 = W_t^f N_{1t}^f + (1+i_{t-1})B_{t-1}^f - P_{f,t}C^* \tag{51}$$

Maximization with respect to C_{1t}^f yields the Euler equation

$$(1+\kappa(B_t^f - B^f))(C_{1t}^f)^{-\sigma} = \beta E_t\left\{(C_{1t+1}^f)^{-\sigma}\frac{1+i_t}{1+\pi_{t+1}}\right\} \tag{52}$$

Labor supply decision of the household is given by

$$\phi_n \frac{(N_{1t}^f)^{\psi}}{(C_{1t}^f)^{-\sigma}} = \frac{W_t^f}{P_t} \tag{53}$$

Constrained Households

A representative credit constrained consumer in the flexible price sector maximizes the lifetime utility given by equation (1) subject to the following budget constraint

$$P_t C_{2t}^f = W_t^f N_{2t}^f - P_{f,t}C^* \tag{54}$$

Labor supply decision of the household is given by

$$\phi_n \frac{(N_{2t}^f)^{\psi}}{(C_{2t}^f)^{-\sigma}} = \frac{W_t^f}{P_t} \tag{55}$$

Sticky Price Sector Household

Unconstrained Household

A representative who has access to financial markets in the sticky price sector maximizes the lifetime utility given by equation (1) subject to the following budget

---

[41] In order to solve the model by linearizing it around the steady state with available techniques we assume that households face a small quadratic adjustment cost, $\frac{\kappa}{2}\left(B_t^f - B^f\right)^2$, where κ is a parameter and B^f is the steady state value of the bond holding.

63

constraint[42]

$$P_t C_{1t}^s + B_t^s + \frac{\kappa}{2}(B_t^s - B^s)^2 = \int_0^1 W_t^s(z)N_{1t}^s(z)dz + \int_0^1 \Pi_t(z)dz + (1+i_{t-1})B_{t-1}^s - P_{f,t}C^* \quad (56)$$

Maximization with respect to C_{1t}^s yields the Euler equation

$$(1+\kappa(B_t^s - B^s))(C_{1t}^s)^{-\sigma} = \beta E_t \left\{ (C_{1t+1}^s)^{-\sigma} \frac{1+i_t}{1+\pi_{t+1}} \right\} \quad (57)$$

Labor supply decision of the household to a firm indexed by z is given by

$$\phi_n \frac{(N_{1t}^s(z))^{\psi}}{(C_{1t}^s)^{-\sigma}} = \frac{W_t^s(z)}{P_t} \quad (58)$$

Constrained Household

A representative credit constrained household in the sticky price sector maximizes the lifetime utility given by equation (1) subject to the following budget constraint

$$P_t C_{2t}^s = \int_0^1 W_t^s(z)N_{2t}^s(z)dz + \int_0^1 \Pi_t(z)dz - P_{f,t}C^* \quad (59)$$

Labor supply decision of the household to a firm indexed by z is given by

$$\phi_n \frac{(N_{2t}^s(z))^{\psi}}{(C_{2t}^s)^{-\sigma}} = \frac{W_t^s(z)}{P_t} \quad (60)$$

Firms

Flexible Price Sector

Firms in the flexible price sector are price taking and therefore price of flexible price good is given by equation (16). Combining with the labor supply decision of households given by equations (53) and (55) and recognizing that $Y_{f1,t} = A_{f,t}N_{1t}^f$ and $Y_{f2,t} = A_{f,t}N_{2t}^f$ the supply function of firms in flexible price sector are given by

---

[42] In order to solve the model by linearizing it around the steady state with available techniques we assume that households face a small quadratic adjustment costs, $\frac{\kappa}{2}(B_t^s - B^s)^2$, where κ is a parameter and B^s is the steady state value of the bond holding.

$$\frac{P_{f,t}}{P_t} = \phi_n \frac{\left(Y_{f1,t}/A_{f,t}\right)^{\psi}}{A_{f,t}(C_{1t}^f)^{-\sigma}} \tag{61}$$

$$\frac{P_{f,t}}{P_t} = \phi_n \frac{\left(Y_{f2,t}/A_{f,t}\right)^{\psi}}{A_{f,t}(C_{2t}^f)^{-\sigma}} \tag{62}$$

Sticky Price Sector

Since firms are symmetric, in equilibrium they will all choose the same price.[43]

Marginal cost of firms held by unconstrained and constrained households is therefore given by

$$\frac{MC_t}{P_t} = MC_t^r = \phi_n \frac{\left(Y_{1t}(z)/A_{s,t}\right)^{\psi}}{A_{s,t}(C_{1t}^s)^{-\sigma}} \tag{63}$$

$$\frac{MC_t}{P_t} = MC_t^r = \phi_n \frac{\left(Y_{2t}(z)/A_{s,t}\right)^{\psi}}{A_{s,t}(C_{2t}^s)^{-\sigma}} \tag{64}$$

Where we have used the fact that $Y_{1t}(z) = A_{s,t}N_{1t}^s(z)$ and $Y_{2t}(z) = A_{s,t}N_{2t}^s(z)$

Aggregation

Demand for flexible price and sticky price good by households is given by expressions similar to equation (9), (10), (17) and (18) with C_t^f and C_t^s replaced by C_{it}^f and C_{it}^s where $i = 1, 2$.

Total demand for flexible price good is given by

$$C_{f,t} = \gamma\left(\frac{P_{f,t}}{P_t}\right)^{-\eta} C_t + (1+\lambda)C^* \tag{65}$$

where $C_t = \lambda_1 C_{1t}^f + (\lambda - \lambda_1)C_{2t}^f + \lambda_2 C_{1t}^s + (1-\lambda_2)C_{2t}^s$ (66)

And the total demand for sticky price good is given by

---

[43] Those who can change prices will choose the same price while others will continue with the prices fixed earlier.

$$C_{s,t} = \gamma \left(\frac{P_{s,t}}{P_t} \right)^{-\eta} C_t \tag{67}$$

Markets Clear

Market for flexible price good clears

$$\lambda Y_{f,t} = \lambda_1 Y_{f1,t} + (\lambda - \lambda_1) Y_{f2,t} = C_{f,t} \tag{68}$$

where

$$Y_{f1,t} = A_{f,t} N_{1t}^f \text{ and } Y_{f2,t} = A_{f,t} N_{2t}^f$$

Market for sticky price good clears

$$\lambda Y_{s,t} = \lambda_2 Y_{s1,t} + (1 - \lambda_1) Y_{s2,t} = C_{s,t} \tag{69}$$

where

$$Y_{s1,t} = A_{s,t} N_{1t}^s \text{ and } Y_{s2,t} = A_{s,t} N_{2t}^s$$

Bond market clears

$$\lambda_1 B_t^f + \lambda_2 B_t^s = 0 \tag{70}$$

Equations (4), (5), (9), (10) of Appendix I and (51), (52), (54), (56), (57), (59), (61)-(64), (68) and (70) expressed in terms of stationary variables define the system of equations that combined with the monetary policy rule and exogenous stochastic processes for $A_{f,t}$ and $A_{s,t}$ determine the equilibrium path of the economy under this general setting.

CHAPTER 2
AN ESTIMATED MODEL WITH MACROFINANCIAL LINKAGES FOR INDIA*

2.1 Introduction

Among macroeconomic practitioners there is growing recognition of the linkages between the financial sector and the real economy and, in particular, the role that balance sheets play in the transmissions of shocks to the economy. These linkages were highlighted during the September 2008 global financial crisis and the resulting slowdown on the global economy. In particular, Bernanke and Gertler (1989) showed in a seminal paper that the presence of asymmetric information in credit markets and monitoring costs would make the external finance premium faced by borrowers dependent on the strength of their balance sheets (their net worth). Moreover, because of the procyclical nature of net worth, this premium would tend to fall during booms and rise during recessions. Bernanke, Gertler, and Gilchrist (1999, BGG hereafter), Kiyotaki and Moore (1997), Carlstrom and Fuerst (1997), and others have since demonstrated that these financial frictions may significantly amplify both real and nominal shocks to the economy. In the literature, this link between the cost of borrowing and net worth has become known as the "financial accelerator".

In addition, Krugman (1999), Aghion, Bacchetta, and Banerjee (2001) and others have argued that exchange rate and interest rate fluctuations - through their effect on balance sheets - are likely to have more serious consequences in emerging market economies that in industrialized countries.

A contributing factor to this is - as noted by Elekdag, Justiniano, and Tchakarov (2005) - that borrowers in emerging market economies tend to rely more on foreign currency borrowing. In this setting, a depreciation could trigger a deterioration in the balance sheets of borrowers with a negative net open foreign exchange position, eroding their net worth and increasing the cost of borrowing. By reducing the demand for capital, this erodes the value of borrowers' existing capital stock and their net worth, putting further upward pressure on borrowing costs. Papers exploring the importance of the financial accelerator for emerging market economies dependent on foreign currency borrowing include Elekdag, Justiniano, and Tchakarov (2005) and Batini, Levine and Pearlman (2009).

In this paper, we develop and estimate a small open-economy Dynamic Stochastic General Equilibrium (DSGE) model that incorporates the financial accelerator mechanism proposed by BGG in a setting where firms are able to borrow in both domestic and foreign currency. The model is estimated on post-1996 Indian data using Bayesian estimation techniques. This is, to our knowledge, the first attempt at estimating a DSGE model for India.

India provides an interesting backdrop for our analysis. India's monetary policy framework has evolved considerably over the past decades (RBI, 2009). In particular, the opening up of the economy in the early 1990s and financial sector liberalization has been reflected in changes in the nature of monetary management (Mohan, 2004). The basic objectives of monetary policy - maintaining price stability and ensuring sufficient credit to support growth - have remained unchanged. However, the opening up of the capital account - while necessary for providing sufficient capital for investment purposes and for reducing the cost of borrowing - exposes the economy to sudden stops in capital flows. In particular, volatile capital flows and its impact on the

68

exchange rate have implications not only for domestic demand and inflation, but for financial stability, with the result that maintenance of financial stability is of increasing concern to the Reserve Bank of India (Mohan, 2004). In order to meet these multiple challenges, the RBI has switched from a more traditional monetary targeting framework to a indicator based approach which seeks to strike a balance between price stability and reducing exchange rate volatility. However, as noted in the Rajan report on financial sector reform (Rajan, 2008), further refinements to the monetary policy framework may be necessary to cope with the rise in capital inflows.

Over the last 5 years capital inflows have more than quadrupled, amounting to nearly 10 percent of GDP in 2007 and far exceeding the current account deficit. There has also been significant volatility as highlighted by the sharp outflows during the last quarter of 2008 and first quarter of 2009 and the subsequent dramatic recovery. These sharp swings in capital flows makes it difficult for the Reserve Bank of India (RBI) to strike a balance between its different objectives, resulting in spurts of exchange rate volatility when a particular level of the exchange rate becomes too difficult to sustain, either because of inflationary pressures or because sterilization operations become too costly or harder to manage (Rajan, 2008).

The trade-offs policymakers face in the conduct of monetary policy will largely be determined by type of shocks hitting the economy and the strength of macro-financial linkages--in particular the role that capital flows and balance sheets play in the transmissions of shocks to the economy (WEO, 2009). Given the key role played by the corporate sector - fuelled to a large extent by bank credit and increasingly external commercial borrowing (ECB) denominated in foreign currency - in India's rapid economic growth in recent years (Oura, 2008), these macrofinancial linkages have likely grown in importance. In particular, the importance of bank credit as a source of financing increases the importance of corporates' net worth as a tool to mitigate

asymmetric information in credit markets while rising ECBs makes the balance sheet of corporates more sensitive to exchange rate fluctuations.

At the same time, India is equipped with a large equity market whose development has to a large extent been fuelled by large inflows from foreign institutional investors (FIIs). IMF (forthcoming) shows that stock market capitalization - an commonly used indicator of corporates' net worth (see e.g. Christiano, Motto, and Rostagno, 2007) - is one of the key determinants of the flow of ECBs. As a result, equity market developments--including the amount of inflows from FIIs--are likely to have a direct bearing on the cost of financing for corporates in India, further increasing the importance of macrofinancial linkages in the economy.

The rest of this paper is structured as follows. Section 2 presents the main components of the model. Section 3 briefly describes the data and the estimation methodology before we present the results of the estimation in Section 4. In section 5 we employ the estimated model to analyze the optimality of monetary policy in India before a final section concludes.

2.2 The Model

The model is an expanded version of the small open-economy DSGE model outlined in Saxegaard (2006a). The augmented model features a financial accelerator mechanism similar to that proposed by BGG to study the effect of financial frictions on the real economy. The model incorporates financial frictions by assuming that firms have to borrow at a premium over domestic and foreign interest rates to finance part of their capital acquisition cost as in Christensen and Dib (2006), and Gertler, Gilchrist, and, Natalucci (2007). Under this framework, information asymmetry between lenders and borrowers creates the financial friction by establishing a link between the cost of borrowing and the financial health of the firms. The external

finance premium, in turn, is inversely related to the net worth of the entrepreneurs. Figure 2.1 provides a visual representation of the estimated model.

The basic structure of model consists of four kinds of agents – households, entrepreneurs, capital producers and retailers. Households consume a composite of domestic and imported goods and provide labor. They have access to foreign capital markets and make deposits which are used by the entrepreneurs to purchase capital. Entrepreneurs produce intermediate goods using labor and capital purchased from capital producers. They finance the acquisition of capital partly through their net worth and partly through borrowing domestically and from abroad. Entrepreneurs produce intermediate goods under perfect competition and sell their product to retailers who differentiate them at no cost and sell them either in domestic market or export overseas. Retailers operate in a monopolistically competitive environment and face a quadratic adjustment costs in changing prices á la Rotemberg (1982). Capital producers use a combination of existing capital stock and investment good purchased from retailers and abroad to produce capital. The market for capital, labor and domestic loans are competitive. The model is completed with a description of the fiscal and monetary authority. Our model differs from BGG in its characterization of monetary policy using a modified Taylor-type rule. We assume that the Reserve Bank of India adjusts short-term interest rates in response to inflation, output and nominal exchange rate changes.
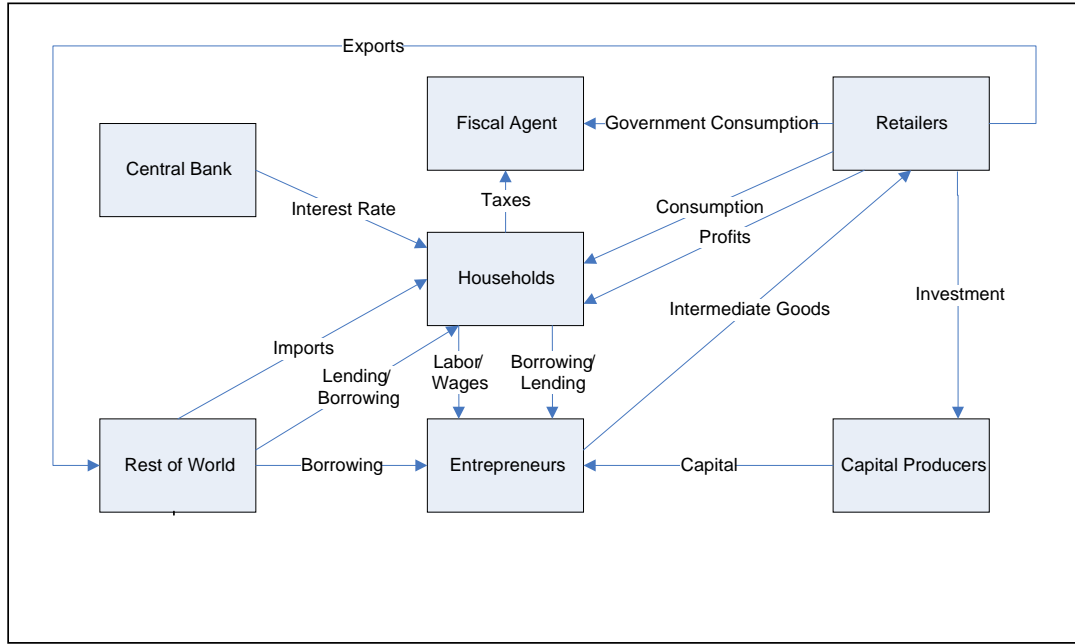
Figure 2.1: Flow Chart of the Model

In order to provide a rationale for monetary stabilization policy, three sources of inefficiencies are included in the model: (a) monopolistically competitive retail market; (b) sluggish price adjustment in retail sector and (c) capital adjustment costs. While relatively simple, the framework captures many of the rigidities which previous studies have found are important to describe the dynamics in data and serves as useful starting point for developing a DSGE model for India.

2.2.1 Household

The economy is populated with a continuum of infinitely lived households with preferences defined over consumption, $C_t(j)$ and labor effort $L_t(j)$. The objective of household is to maximize the expected value of a discounted sum of period utility function given by

$$E_0 \sum_{t=0}^{\infty} \beta^t U(C_t(j), L_t(j)) \qquad (1)$$

$\beta \in (0,1)$ is the discount factor and U is a period utility function. We include the habit

persistence according to the following specification

$$U(C_t(j), L_t(j)) = \varsigma_{c,t}(1-b)\ln(C_t(j) - bC_{t-1}) - \frac{\varsigma_{L,t}}{\psi} L_t(j)^{\psi} \qquad (2)$$

where C_{t-1} is lagged aggregate consumption and $b \in (0,1)$. $\varsigma_{C,t}$ and $\varsigma_{L,t}$ are preference shocks to the marginal utility of consumption and the supply of labor respectively. Note that in symmetric steady-state $C_t(j) = C_{t-1}$, the marginal utility of consumption is independent of the habit persistence parameter b. The aggregate consumption bundle $C_t(j)$ consists of domestically produced goods, $C_{H,t}(j)$ and an imported foreign good, $C_{F,t}(j)$ and is given by

$$C_t(j) \equiv \left[\alpha^{\frac{1}{\eta}} \left(C_{H,t}(j) \right)^{\frac{\eta-1}{\eta}} + (1-\alpha)^{\frac{1}{\eta}} \left(C_{F,t}(j) \right)^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}} \qquad (3)$$

where $C_{H,t}(j)$ is an index of consumption of domestic goods given by the constant elasticity of substitution (CES) function

$$C_{H,t}(j) = \left(\int_0^1 C_{H,t}(s)^{\frac{\varepsilon-1}{\varepsilon}} ds \right)^{\frac{\varepsilon}{\varepsilon-1}} \qquad (4)$$

where $s \in [0,1]$ denotes the variety of the domestic good. Parameter $\eta \in [0, \infty]$ is the elasticity of substitution between domestic and foreign goods and $\varepsilon_t > 1$ is the elasticity of substitution between the verities produced within the country. $\alpha \in [0,1]$ can be interpreted as a measure of home bias.

We assume that households have an access to foreign financial markets or nominal contingent claims that span all relevant household specific uncertainty about future income and prices, interest rates, exchange rates and so on. As a result each household face the same intertemporal budget constraint

$$P_t C_t(j) + e_t B_{t+1}^f(j) + P_t \tau_t(j) + P_t D_t(j) = e_t B_t^f(j)(1+i_{t-1}^f) + \int_0^1 \Pi_t^r(s) ds + W_t L_t(j) \qquad (5)$$

$$+ (1+i_{t-1}) P_t D_{t-1}(j) \quad, \forall t$$

Where B_t^f is the net holding of foreign currency one period bond that matures in

period t, paying an interest rate of i_t^f. Households make deposit D_t with financial intermediary and earn an interest of i_t. $\int_0^1 \Pi_t^r(s)ds$ represents nominal profit from the ownership of domestic retail firms. τ_t is the lump sum tax in the economy and W_t is the nominal wage rate. P_t is the CPI index given by

$$P_t \equiv \left[\alpha\left(P_{H,t}\right)^{1-\eta} + +(1-\alpha)\left(P_{F,t}\right)^{1-\eta}\right]^{\frac{1}{1-\eta}} \tag{6}$$

where $P_{H,t}$ is the domestic price index given by

$$P_{H,t} = \left(\int_0^1 P_{H,t}(s)^{1-\varepsilon_t} ds\right)^{\frac{1}{1-\varepsilon_t}} \tag{7}$$

and $P_{F,t}$ is the price of the imported goods.[44]

Households choose the paths of $\left\{C_t(j), L_t(j), D_t(j), B_{t+1}^f(j)\right\}_{t=0}^{\infty}$ to maximize expected lifetime utility given by equation (1) subject to the sequence of constraints given by equation (5) and the initial value of B_t^f.

Ruling out Ponzi type schemes, we get the following first order conditions

$$\frac{(1-b)\varsigma_{C,t}}{C_t(j) - bC_{t-1}} = \lambda_t P_t \tag{8}$$

$$\varsigma_{L,t} L_t(j)^{\psi-1} = \lambda_t W_t \tag{9}$$

where λ_t is the lagrange multiplier associated with the budget constraint. Given the well documented departures from uncovered interest parity (UIP), we follow Kollman (2002) and introduce an exogenous shock into the consumers first order condition for foreign currency bond holdings. The first order conditions are given by

$$1 = (1+i_t)E_t\left\{\rho_{t,t+1}\frac{P_t}{P_{t+1}}\right\} \tag{10}$$

$$1 = (1+i_t^f)E_t\left\{\rho_{t,t+1}\frac{P_t}{P_{t+1}}\frac{e_{t+1}}{e_t}\right\} + \Xi_t \tag{11}$$

---

[44] We assume that the price of imported goods is set in the same manner as the domestic prices in the exporting country i.e. the price of imports adjust sluggishly and is given by an equation similar to equation (45).

where $\rho_{t,t+1} = \beta \dfrac{\lambda_t}{\lambda_{t+1}} = \dfrac{\varsigma_{C,t}(C_{t+1}(j) - bC_t)}{\varsigma_{C,t+1}(C_t(j) - bC_{t-1})}$ is the stochastic discount factor and Ξ_t is

a shock to the UIP. Up to a log-linear approximation equations (11) and (12) imply

$E_t \ln(e_{t+1}/e_t) \approx i_t - i_t^f$. The optimum allocation of expenditure between domestic and imported goods is given by

$$C_{H,t}(j) = \alpha \left(\frac{P_{H,t}}{P_t} \right)^{-\eta} C_t(j) \tag{12}$$

$$C_{F,t}(j) = (1-\alpha) \left(\frac{P_{F,t}}{P_t} \right)^{-\eta} C_t(j) \tag{13}$$

and the demand for each variety of domestic goods is given by

$$C_{H,t}(s) = \alpha \left(\frac{P_{H,t}(s)}{P_{H,t}} \right)^{-\eta} C_{H,t}(j) \tag{14}$$

2.2.2 Production Sector

2.2.2.1 Entrepreneurs

We model the behavior of entrepreneurs as proposed by Bernanke, Gertler and Gilchrist (1999). We follow the modeling framework of Gertler, Gilchrist and Natalucci (2007) and Elekdag, Justiniano and Tchakarov (2005) while introducing financial accelerator in an open economy context. Entrepreneurs combine labor hired from households with capital purchased from the capital producers, to produce intermediate goods in a perfectly competitive setting. They are risk neutral and have a finite horizon for planning purposes. The probability that an entrepreneur will survive until the next period is ν_t, so that the expected live horizon is $\dfrac{1}{1-\nu_t}$.[45]

The number of new entrepreneurs entering the market each period is equal to the number of entrepreneurs exiting, implying a stationary population. To get started, new

---

[45] This assumption ensures that entrepreneur's net worth (the firm equity) will never be enough to fully finance the new capital acquisition.

entrepreneurs receive a small transfer of funds from exiting entrepreneurs.

At the end of each period t, entrepreneurs purchase capital K_{t+1}, to be used in the subsequent period at a price q_t. They finance capital acquisition partly through their net worth available at the end of period t, n_{t+1}, and partly through borrowing domestically and through raising foreign currency denominated debt. Total borrowing B_t is given by

$$B_t = q_t K_{t+1} - n_{t+1} \tag{27}$$

where q_t is the real price per unit of capital. Fraction of loan raised domestically B_t^d is exogenous to the model and is given by ϖ. Thus,

$B_t^d = \varpi(q_t K_{t+1} - n_{t+1})$ and $B_t^a = (1 - \varpi)(q_t K_{t+1} - n_{t+1})$ where B_t^a is the amount of loans raised abroad. Entrepreneurs use units of K_t capital and L_t units of labor to produce output Y_t^W, using a constant returns to scale technology

$$Y_t^W \leq \theta_t K_t^{\varphi} L_t^{1-\varphi}, \qquad \varphi \in (0,1) \tag{28}$$

where θ_t is a stochastic disturbance to total factor productivity. Entrepreneur maximizes profits by choosing K_t and L_t subject to the production function given by equation (28). First order conditions for this optimization problem are

$$W_t = (1-\varphi) P_{H,t}^W \frac{Y_t^W}{L_t} \tag{29}$$

$$r_{K,t} = \frac{P_{H,t}^W}{P_t}(\varphi)\frac{Y_t^W}{K_t} \tag{30}$$

where $P_{H,t}^W$ is the price of the wholesale good and $r_{K,t}$ is the marginal productivity of capital.[46] The expected marginal real return on capital acquired at t and used in $t+1$ yields the expected gross return $E_t(1 + r_{t+1}^k)$, where

$$E_t(1 + r_{t+1}^k) = E_t\left[\frac{r_{K,t+1} + (1-\delta)q_{t+1}}{q_t}\right] \tag{31}$$

and δ is the rate of depreciation of capital and $r_{K,t+1}$ is the marginal productivity of

---

[46] Since the firms are perfectly competitive, $P_{H,t}^W = MC_t^W$.

capital at *t+1*.

Following Bernanke, Gertler and Gilchrist (1999), we assume that there exists an agency problem which makes external finance more expensive than internal funds. While entrepreneurs costlessly observe their output, which is subject to random outcomes, lenders can not verify output outcomes costlessly. After observing the outcome, entrepreneurs decide whether to repay their debt or to default. If they default, lenders audit the loan and recover the outcome less the monitoring costs. This agency problem makes loans riskier and lenders charge a premium over the risk free rate. Thus, enterpreneurs' marginal external financing cost is the product of the gross premium and the gross real opportunity cost of funds (the risk free interest rate) that would arise in the absence of capital market frictions.

Therefore, the expected marginal cost of borrowing, $E_t f_{t+1}$ is given by

$$E_t f_{t+1} = (1+\Gamma_t) \left\{ \Theta\left(\frac{n_{t+1}}{q_t K_{t+1}}\right) \varpi E_t \left[\frac{1+i_t}{\pi_{t+1}}\right] + \Theta\left(\frac{n_{t+1}}{q_t K_{t+1}}\right)(1-\varpi)E_t\left[\frac{1+i_t^f}{\pi_{t+1}^*}\frac{RER_{t+1}}{RER_t}\right]\right\} \qquad (32)$$

$$\Theta' < 0 \text{ and } \Theta(1)=1$$

where Θ is the gross finance premium which depends on the size of the borrower's equity stake in the project (or, alternatively, the borrowers' leverage ratio). Γ_t is the shock to the cost of borrowing , $\pi_t = \dfrac{P_t}{P_{t-1}}$, is the gross domestic inflation and $\pi_t^* = \dfrac{P_t^*}{P_{t-1}^*}$, is the gross world inflation. RER_t is the real exchange rate defined as

$$RER_t = \frac{e_t P_t^*}{P_t}.^{47}$$

We characterize the risk premium by Θ by $\left(\dfrac{n_{t+1}}{q_t K_{t+1}}\right)^\sigma$, where σ represents the elasticity of external finance premium with respect to a change in the leverage position of entrepreneurs. As $\left(\dfrac{n_{t+1}}{q_t K_{t+1}}\right)$ falls, entrepreneur relies on uncollateralized borrowing

---

[47] We assume that law of one price holds for each of the differentiated goods.

(higher leverage) to a larger extent to fund his project. Since this increases the incentive to misreport the outcome of the project, the loan becomes riskier and the cost of borrowing rises. Entrepreneurs' demand for capital depends on the expected marginal return and the expected cost of borrowing. Thus, demand for capital satisfies the following optimality condition

$$E_t(1+r_{t+1}^k) = (1+\Gamma_t)\left\{\Theta\left(\frac{n_{t+1}}{q_t K_{t+1}}\right)\varpi E_t\left[\frac{1+i_t}{\pi_{t+1}}\right] + \Theta\left(\frac{n_{t+1}}{q_t K_{t+1}}\right)(1-\varpi)E_t\left[\frac{1+i_t^f}{\pi_{t+1}^*}\frac{RER_{t+1}}{RER_t}\right]\right\} \quad (33)$$

Above equation provides the foundation for the financial accelerator. It links entrepreneurs' financial position to the marginal cost of funds and, hence to the demand for capital. Also, movements in the price of capital, q_t, may have significant effects on the leverage ratio. In this way the model captures the link between asset price movements and collateral stressed in the theory of credit cycles (Kiyotaki and Moore, 1997).[48] At the beginning of each period, entrepreneurs collect their returns on capital and honor their debt obligations. Aggregate entrepreneurial net worth evolves according to

$$n_{t+1} = v_t V_t + (1-v_t)H_t \quad (34)$$

where V_t is the net worth of the surviving entrepreneurs carried over from the previous period, $1-v_t$ is the fraction of new entrepreneurs entering and H_t (which is exogenous in the model) are the transfers from exiting to newly entering entrepreneurs. V_t is given by

$$V_t = \begin{bmatrix} (1+r_t^k)q_{t-1}K_t - (1+\Gamma_t)\Theta\left(\dfrac{n_t}{q_{t-1}K_t}\right)\left[\dfrac{1+i_{t-1}}{\pi_t}\right](\varpi(q_{t-1}K_t - n_t)) \\[4mm] -(1+\Gamma_t)\Theta\left(\dfrac{n_t}{q_{t-1}K_t}\right)E_t\left[\dfrac{1+i_{t-1}^f}{\pi_t^*}\dfrac{RER_t}{RER_{t-1}}\right]((1-\varpi)(q_{t-1}K_t - n_t)) \end{bmatrix} \quad (35)$$

---

[48] Though the behavior described above is true for an individual entrepreneur, we appeal to the assumptions in Bernanke, Gertler and Gilchrist (1999) that permit us to write it as an aggregate condition. See Bernanke et.al (1999) and Carlstrom and Fuerst (1997) for details. It implies that gross finance premium may be expressed as a function of aggregate leverage ratio, i.e. it is not entrepreneur specific.

As equations (34) and (35) suggest, the principal source of movements in net worth stems from unanticipated movements in returns and borrowing costs. In this regard, unforecastable variations in asset prices, q_t, is the main source of fluctuations in $(1+r_t^k)$. On the cost side, unexpected movements in inflation and exchange rates are the major sources of fluctuations in net worth. An unexpected deflation or depreciation, for example, reduces entrepreneurial net worth, thus enhancing the financial accelerator mechanism. Entrepreneurs going out of business at time t consume and transfer some funds to new entrepreneurs out of the residual equity $(1-v_t)V_t$. Thus consumption by entrepreneurs are given by

$$C_t^e = (1-v_t)(V_t - H_t) \tag{36}$$

2.2.2.2 Capital Producers

Capital producers combine the existing capital stock, K_t, leased from the entrepreneurs to transform an input I_t, gross investment, into new capital K_{t+1} using a linear technology.[49] We assume that capital producers face a quadratic adjustment costs given by

$$\left(\frac{\kappa}{2}\left(\frac{I_t}{K_t}-\delta\right)^2\right)K_t.$$

where κ is the capital adjustment cost parameter. The aggregate capital stock evolves according to

$$K_{t+1} = (1-\delta)K_t + \varsigma_{I,t}I_t - \left(\frac{\kappa}{2}\left(\frac{I_t}{K_t}-\delta\right)^2\right)K_t \tag{37}$$

where $\varsigma_{I,t}$ is a shock to the marginal efficiency of investment (Greenwood et al. 1988). Gross investment consists of domestic and foreign final good and we assume that it is in the same proportion as in the consumption basket

---

[49] This set up follows Bernanke et al. (1999) and assumes that capital producers rent the capital stock from entrepreneurs and use it to produce new capital. Since this takes place within the period we assume that the rental rate is zero.

$$I_t \equiv \left[\alpha^{\frac{1}{\eta}} \left(I_{H,t} \right)^{\frac{\eta-1}{\eta}} + (1-\alpha)^{\frac{1}{\eta}} \left(I_{F,t} \right)^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}} \qquad (38)$$

Optimal demand for domestic and imported investment is given by

$$I_{H,t} = \alpha \left(\frac{P_{H,t}}{P_t} \right)^{-\eta} I_t \qquad (39)$$

$$I_{F,t} = (1-\alpha) \left(\frac{P_{F,t}}{P_t} \right)^{-\eta} I_t \qquad (40)$$

Price of investment is the same as the domestic price index given by equation (6).

Capital producing firms maximize expected profits

$$\underset{I_t}{Max}\, E_t \left\{ q_t \left[\varsigma_{I,t} I_t - \left(\frac{\kappa}{2} \left(\frac{I_t}{K_t} - \delta \right)^2 \right) K_t \right] - I_t \right\}$$

and the first order condition for the supply of capital is given by

$$q_t \left[\varsigma_{I,t} - \kappa \left(\frac{I_t}{K_t} - \delta \right) \right] = 1 \qquad (41)$$

2.2.2.3 Retailers

There is a continuum of retailers $s \in [0,1]$. They purchase wholesale goods at a price equal to the nominal marginal costs, MC_t^W (the marginal cost in the entrepreneurs' sector) and differentiate them at no cost.[50] They sell their product in a monopolistically competitive domestic and export market. Final domestic good, Y_t^W, is a CES composite of individual retail goods

$$Y_{H,t} = \left(\int_0^1 Y_{H,t}(s)^{\frac{\varepsilon_t - 1}{\varepsilon_t}} ds \right)^{\frac{\varepsilon_t}{\varepsilon_t - 1}} \qquad (42)$$

Corresponding price of the composite consumption good, $P_{H,t}$, is given by equation

---

[50] Entrepreneurs sell their goods in a perfectly competitive market so $P_{H,t}^W = MC_t^W$. Retail sector is defined only to introduce nominal rigidity into the economy. Since they differentiate goods costlessly, the marginal cost of producing final goods is same as MC_t^W.

(7). Demand facing each retailer can be written as

$$Y_{H,t}(s) = \left(\frac{P_{H,t}(s)}{P_{H,t}} \right)^{-\varepsilon_t} Y_{H,t} \tag{43}$$

For simplicity we assume that the aggregate export demand function is given by

$$Q_t^X = \left(\frac{P_{X,t}}{P_t^*} \right)^{-\varsigma_t}, \varsigma_t > 0 \tag{44}$$

where $P_{X,t} = eP_{H,t}$ is the price of exports, P_t^* is the world price index and Q_t^X is total exports. ς_t, is the price elasticity of exports.

2.2.2.4 Price Setting by Retailers

Following Ireland (2001) and Rotemberg (1982), there is sluggish price adjustment to make the intermediate goods pricing decision dynamic. This ensures that monetary policy has real effects on the economy. Following Julliard et al. (2004), we assume that retailers face an explicit cost of price adjustment measured in terms of intermediate goods and is given by

$$\frac{\vartheta_d}{2} \left[\frac{P_{H,t}(s)/P_{H,t-1}(s)}{\pi} - 1 \right]^2 (Q_t^d + Q_t^X)$$

where Q_t^d is the total domestic demand, $\vartheta_d \geq 0$ is the parameter determining the cost of price adjustment relative to last period's price level and π is the steady state inflation. Following Saxegaard (2006b), real profits are given by

$$\Pi_t^r \left[P_{H,t}(s), P_{x,t}(s) \right] = \left[\frac{P_{H,t}(s)}{P_t} - \frac{MC_t^W}{P_t} \right] \left[\frac{P_{H,t}(s)}{P_{H,t}} \right]^{-\varepsilon} Q_t^d + \left[\frac{e_t P_{X,t}(s)}{P_t} - \frac{MC_t^W}{P_t} \right] \left[\frac{P_{X,t}(s)}{P_{X,t}} \right]^{-\varepsilon} Q_t^x$$

$$- \frac{\vartheta_d}{2} \left[\frac{P_{H,t}(s)/P_{H,t-1}(s)}{\pi} - 1 \right]^2 (Q_t^d + Q_t^x)$$

where e_t is the nominal exchange rate, expressed as the domestic currency price of

foreign currency.[51] Note also that we allow for a shock to the elasticity of substitution between differentiated goods ε_t, which determines the size of the markup of intermediate good firms. Alternatively, the shock to ε_t can be interpreted as a cost-push shock of the kind introduced into the New Keynesian model by Clarida, Gali and Gertler (1999).

The optimal price setting equation for domestic good (non-tradable good) can then be written as[52]

$$P_{H,t} = \frac{\varepsilon_t}{\varepsilon_t - 1} MC_t^W - \frac{\vartheta_d}{\varepsilon_t - 1} P_t \frac{\pi_{H,t}}{\pi} \left[\frac{\pi_{H,t}}{\pi} - 1 \right]$$
$$+ \frac{\vartheta_d}{\varepsilon_t - 1} P_t E_t \left\{ \rho_{t,t+1} \frac{Y_{H,t+1}}{Y_{H,t}} \frac{\pi_{H,t+1}}{\pi} \left[\frac{\pi_{H,t+1}}{\pi} - 1 \right] \right\} \tag{45}$$

where $\pi_{H,t} = P_{H,t}/P_{H,t-1}$, is the domestic price inflation.

Where we have used the fact that all retailer firms are alike to impose symmetry and we assume that the law of one price holds in the export market so that $P_{X,t} = P_{H,t}/e_t$. Above equation reduces to the well known result that prices are set as a markup over marginal costs if the cost of price adjustment, $\vartheta_d = 0$. In general however, the goods price will follow a dynamic process and the firm's actual markup will differ from, but gravitate towards the desired markup. Profits from retail activity are rebated lump-sum to households (i.e. households are the ultimate owners of retail outlets).

2.2.3 The Government

The fiscal authority is assumed to purchase an exogenous stream of the final good G_t which is financed by levying a lump-sum tax on households. For simplicity we

---

[51] An increase in e_t implies depreciation of the domestic currency.

[52] We assume that price of imported goods are set in the similar function. So the price setting equation for the price of imported good is given by a similar expression with $\pi_{M,t}$, import price inflation, in place of $\pi_{H,t}$ and ϑ_m in place of ϑ_d.

assume that the fiscal authority has no access to international capital markets. Its period by period budget constraint is given by

$$G_t = \tau_t \tag{46}$$

Government buys both domestic and foreign final goods and we assume that it is in the same proportion as the consumers

$$G_t \equiv \left[\alpha^{\frac{1}{\eta}} \left(G_{H,t} \right)^{\frac{\eta-1}{\eta}} + (1-\alpha)^{\frac{1}{\eta}} \left(G_{F,t} \right)^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}} \tag{47}$$

Optimal demand for governments' domestic and imported consumption is given by

$$G_{H,t} = \alpha \left(\frac{P_{H,t}}{P_t} \right)^{-\eta} G_t \tag{48}$$

$$G_{F,t} = (1-\alpha) \left(\frac{P_{F,t}}{P_t} \right)^{-\eta} G_t \tag{49}$$

In choosing a specification for the monetary policy reaction function, we assume a simple Taylor rule type function given by:

$$i_t = \rho_i i_{t-1} + (1-\rho_i)i + \rho_Y \log(Y_t - Y) + \rho_\pi \log(\pi_t - \pi) + \rho_q \log(e_t - e) + \varepsilon_{i,t} \tag{50}$$

where ρ_π, ρ_Y are ρ_q the weights on inflation, output gap and nominal exchange rate depreciation assigned by the policy makers.[53] ρ_i represents the Central Banker's preference for interest rate smoothing. Y, π, i and e are the steady state values of output, inflation, nominal interest rate and nominal exchange rate depreciation. $\varepsilon_{i,t}$ is a monetary policy shock to capture unanticipated increase in the nominal interest rate. Equation (51) is essentially a simple Taylor rule with partial adjustment. We interpret this rule as being a form of flexible inflation targeting in the sense of Bernanke and

---

[53] We include an interest rate smoothing parameter in our monetary policy rule as the benefits of such smoothing are well documented in the literature (see, e.g., Lowe and Ellis, 1997; Sack and Wieland, 1999). Various authors have argued that moving interest rates in small steps increases its impact on the long-term interest rate; it also reduces the risks of policy mistakes and prevents large capital losses and systemic financial risks. Mohanty and Klau (2004) find that all emerging market central banks put substantial weight on interest rate smoothing. Clarida et al. (1998) find that central banks of advanced economies also put a large weight on interest rate smoothing.

Mishkin (1997).

2.2.4 Market Clearing and Aggregation

Domestic households, exiting entrepreneurs, capital producers, government and rest of the world buy final goods from retailers. The economy wide resource constraint is given by[54]

$$Y_{H,t} = C_{H,t} + C_{H,t}^e + I_{H,t} + G_{H,t} + Q_t^X = Q_t^d + Q_t^X \tag{51}$$

where

$$Q_t^d = C_{H,t} + C_{H,t}^e + I_{H,t} + G_{H,t} \tag{52}$$

The national income accounting equation is given by

$$P_t * ZZ_t = P_t(C_t + C_t^e + I_t + G_t) + P_{X,t}Q_t^X - P_{F,t}Q_t^M + \frac{\vartheta_d}{2}\left[\frac{P_{H,t}/P_{H,t-1}}{\Pi} - 1\right]^2 P_{H,t}Y_{H,t}$$

where Q_t^M is the total imports and ZZ_t is the real GDP. Markets for loan and deposits clear –

$$D_t = B_t^d \tag{53}$$

The model allows for non-zero holdings of foreign currency bonds by households and foreign currency denominated debt by entrepreneurs. In particular, it is well known (see inter alia Schimtt-Grohe and Uribe, 2003) that unless adjustments are made to the standard model, the steady state of an small open-economy model with foreign currency bonds will depend upon initial conditions and will display dynamics with random walk properties. In particular, if the domestic discount rate exceeds the real rate of return on foreign currency bonds, then domestic holdings of foreign currency bonds will increase perpetually. Beyond the obvious conceptual problems of such an outcome our analysis is constrained by the fact that the available techniques used to solve non-linear business cycle models of the type considered here are only valid locally around a stationary path.

---

[54] Following Bernanke et al. (1999) we ignore monitoring costs in the general equilibrium.

Fortunately, a number of modifications to the standard model are available which enable us to overcome this issue. In this paper, we follow Schmitt-Grohe and Uribe (2003) and specify a foreign debt elastic risk-premium whereby holders of foreign debt are assumed to face an interest rate that is increasing in the country's net foreign debt. In particular, i_t^f, the interest rate at which households and entrepreneurs can borrow foreign currency equals the exogenous world interest rate plus a spread that is a decreasing function of economy's net foreign asset position:

$$(1+i_t^f) = (1+i_t^*) - \chi_d \left[\left((B_t + L_t^f)/P^* - \vartheta_t \right) - \left((B + L^f)/P^* - \vartheta \right) \right] / \Omega \qquad (54)$$

where χ_d is a parameter which captures the degree of capital mobility in the market for foreign-currency borrowing and lending by households and Ω is the steady-state value of exports. As in Schmitt-Grohe and Uribe (2003) we include the steady-state level of debt so that the risk-premium is nil in steady state. Note that under perfect capital mobility (χ_d=0), the country would face an infinite supply or demand of foreign capital and the model would not have a well-defined steady state. As Kollmann (2002) points out, the model in this case becomes a version of the permanent income theory of consumption, with non-stationary consumption and net assets.

2.2.5 Specification of Stochastic Processes

We include a number of shocks in order to ensure that the model is not stochastically singular and in order to be better able to reproduce the dynamics in the data. In particular, the number of exogenous shocks must be at least as large as the number of observed variables in order to estimate the model using classical Maximum Likelihood or Bayesian methods. Our model includes thirteen structural shocks: three shocks to technology and preferences ($\theta_t, \varsigma_{C,t}, \varsigma_{L,t}$), three foreign shocks to world interest rates, world inflation, and the price elasticity of exports ($\pi_t^*, i_t^* \ \zeta_t$), two

shocks to investment efficiency and firms' markup ($\varsigma_{I,t}, \varepsilon_t$), two financial shocks to the cost of borrowing by entrepreneurs and the survival rate of entrepreneurs (Γ_t, ν_t), a monetary policy shock, a government spending shock ($\varepsilon_{i,t}, G_t$), and a UIP shock (Ξ_t). With the exception of the monetary policy shock, which is assumed to be a white noise processes, all shocks are assumed to follow a first-order autoregressive process.[55]

2.3 Data and Estimation Strategy

We estimate the model using the Bayesian estimation module in DYNARE (Juillard, 2001). Bayesian inference has a number of benefits. First, it formalizes the use of prior empirical or theoretical knowledge about the parameters of interest. Second, Bayesian inference provides a natural framework for parameterizing and evaluating simple macroeconomic models that are likely to be fundamentally mis-specified. Thus, as pointed out by Fernandez-Villaverde and Rubio-Ramirez (2004) and Schorfheide (2000), the inference problem is not to determine whether the model is `true' or the `true' value of a particular parameter, but rather to determine which set of parameter values maximize the ability of the model to summarize the regular features of the data. Finally, Bayesian inference provides a simple method for comparing and choosing between different mis-specified models that may not be nested on the basis of the marginal likelihood or the posterior probability of the model. In particular, Geweke (1998) shows that the marginal likelihood is directly related to the predictive performance of the model which provides a natural benchmark for assessing the usefulness of economic models for policy analysis and forecasting.

Bayesian estimation requires construction of the posterior density of the

---

[55] In addition to our thirtheen structural shocks, we follow the approach adopted in Juillard, Karam, Laxton, and Pesenti (2004) of allowing for measurement errors in the data.

parameters of interest given the data. If we denote the set of parameters to be estimated as θ using observations on a set of variables X, the posterior density can be written as $p(\theta \mid X)$. The posterior density is thus the probability distribution of θ, conditional on having observed the data X. It forms the basis for inference in the Bayesian framework. Following Bayes law, the posterior density is proportional to the product of the prior density of the parameters $p(\theta)$ and the distribution of the data given the parameter set $f(X \mid \theta)$:

$$p(\theta \mid X) = \frac{p(\theta) f(X \mid \theta)}{f(X)}$$

where $f(X)$ is the marginal distribution of the data. The conditional distribution function of the data given the parameter set $f(X \mid \theta)$ is equivalent to the likelihood function of the set of parameters given the data $L(\theta \mid X)$. The likelihood function can be calculated from the state-space representation of the model using the Kalman filter (see Ljungqvist and Sargent (2004) for details). Bayesian inference therefore requires (i) the choice of prior densities for the parameters of interest, and (ii) construction of the posterior from the prior densities and the likelihood function. The remainder of this section discusses briefly how to construct the posterior distribution. The choice of prior is discussed later, together with the estimation results.

Given the likelihood function and a set of prior distributions, an approximation to the posterior mode of the parameters of interest can be calculated using a Laplace approximation. The posterior mode obtained in this way is used as the starting value for the Metropolis-Hastings algorithm (see Bauwens, Lubrano, and Richard (1999) for details). This algorithm allows us to generate draws from the posterior density $p(\theta \mid X)$. At each iteration a proposal density (a normal distribution with mean equal to the previously accepted draw) is used to generate a new draw which is accepted as a draw from the posterior density $p(\theta \mid X)$ with probability p. The

probability *p* depends on the value of the posterior and the proposal density at the candidate draw, relative to the previously accepted draw. We generate 100000 draws in 4 chains in this manner, discarding the first 50000 draws to reduce the importance of the starting values.

2.3.1 Data

To estimate the model we use information on ten key macroeconomic variables for India running from 1996Q2 to 2007Q4: GDP, private consumption expenditure, investment, exports, imports (all expressed in constant prices), the real exchange rate, the rate of depreciation of the nominal exchange rate, wholesale price inflation, the nominal interest rate, and the Bombay Stock Exchange SENSEX Index.[56]

The 3-month Treasury Bill rate is used as a proxy of the nominal interest rate and the real effective exchange rate calculated by the IMF is used as proxy for the real exchange rate. As in Christiano, Motto, and, Rostagno (2009) we use the value of the stock exchange index (deflated using the wholesale price index) to proxy the net worth of entrepreneurs. All variables are expressed as deviations from a Hodrick-Prescott time trend and, with the exception of the real and nominal exchange rates, the nominal interest rate, and the SENSEX, are seasonally adjusted using the X12 filter. All data are taken from the CEIC database.

2.3.2 Calibration of Steady State Parameters

As in Saxegaard (2006a), we calibrate the parameters in the model that determine the steady state based on findings from previous studies and the data. We then estimate the parameters that determine the dynamic properties of the model away from the steady-state. The list of calibrated parameters include the rate of time

---

[56] More recent data is not included given the increased volatility associated with the global financial crisis.

preference, β, the depreciation rate of capital, δ, the cost share of capital, φ, the price elasticity of aggregate non-tradables and imports, η, the price elasticity of exports, ζ, the share of non-tradables in the WPI, α, the steady-state markup for retailers, $\varepsilon/(\varepsilon-1)$, in addition to several steady-state ratios which are set so as to replicate the average in the data.

The substitution elasticity between imported and domestically produced goods is set at 1.5, close to the value used by Saxegaard (2006a) for the Philippines, while the elasticity of substitution of exports, ζ, is set to 4.89, a value consistent with the steady state export to GDP ratio. With the share of non-tradables in the WPI, α, set at 0.8, this corresponds to a steady state export to GDP ratio of 19 percent and a steady state import to GDP ratio of 21 percent. The share of government expenditure in GDP is set at 11 percent as in the data. The capital share in the production φ and the capital depreciation rate, δ, are set to 0.33 and 0.025, respectively; values commonly used in the literature. The steady-state markup factor is set to 9 percent so that $\varepsilon=12$. Share of domestic loans to total loans, ϖ, is set to 0.8 (IMF country report, 2009).

We set the steady-state annual nominal interest rate at 7 percent which corresponds to the annualized average quarterly rate of bank rate for the period we have data on. Similarly, steady-state inflation is set equal to 4.5 percent which corresponds to the average seasonally adjusted quarterly WPI inflation over the period on an annualized basis. Intertemporal optimization by consumers implies that the subjective discount rate, β, is set equal to 0.994 which is the inverse of the quarterly real steady-state interest rate. We set world inflation equal to 2.5 percent on an annual basis which implies a steady-state depreciation rate of the nominal exchange rate of 2 percent on an annual basis and a world interest rate of 5 percent per annum. The calibrated parameter values and the implied steady-state ratios are summarized in Table 2.1.

2.3.3 Prior Distribution of Estimated Parameters

Our choice of prior distributions for the estimated parameters is guided both by theoretical considerations and empirical evidence. Given the lack of significant empirical evidence, however, we choose relatively diffuse priors that cover a wide range of parameter values. For the structural parameters, we choose either *gamma* distributions or *beta* distributions in the case when a parameter - such as the autoregressive shock processes - is restricted by theoretical considerations to lie between zero and one. Given the lack of evidence regarding the policy reaction function of the Reserve Bank of India, we use *uniform* distributions for the parameters of the monetary policy rule. Finally, as in much of the literature the inverted *gamma* distribution is used for the standard errors of the shock processes. This distribution guarantees a positive variance but with a large domain. The choice of priors for the parameters to be estimated is summarized in Table 2.2.

Table 2.1: Calibrated Parameters

Parameters	Definitions	*Values*
π	Domestic inflation	$1.045^{1/4}$
π^*	World inflation	$1.025^{1/4}$
i	Policy rate	$1.070^{1/4}$
i^*	World interest rate	$1.05^{1/4}$
e	Nominal exchange rate depreciation	2 %
β	Subjective discount factor	0.994
ψ	Inverse of Frisch elasticity	1.5
η	Price elasticity of non-tradable and imports	1.5
ε	Elasticity of substitution between different domestic goods	12
α	Share of non-tradable in CPI	0.8
ζ	Price elasticity of exports	2.4
φ	Share of capital in production	0.33
δ	Quarterly depreciation rate of capital	0.025
ϖ	Share of domestic loans in total loans	0.8
ν	Probability of entrepreneurial survival	0.98
χ_d	Degree of capital mobility	0.0019
H	Transfer from exiting to new entrepreneurs	0.01

Steady- state Ratio		
Variables	*Definitions*	*Values*
G/Y	Government spending to GDP	0.11
Q^X/Y	Exports to GDP	0.19
Q^M/Y	Import to GDP	0.21
K/N	Capital to entrepreneurs' net worth	2

Table 2.2: Parameter Priors and Posterior Estimates

Parameter	Description	Density	Prior Mean	Prior S.D.	Posterior Mean	Posterior 90% Interval	
ρ_i	Interest Rate Smoothing	Beta	0.7	0.2	0.829	0.647	0.999
ρ_π	Inflation Stabilization	Uniform	0	3	0.890	0.002	1.737
ρ_Y	Output Stabilization	Uniform	-1	1	-0.017	-0.049	0.014
ρ_q	Exchange Rate Stabilization	Uniform	0	3	2.438	1.852	3.000
b	Habit Persistence	Beta	0.5	0.2	0.499	0.150	0.885
ϑ_d	Cost of Non-tradable Goods Price Adjustment	Gamma	100	20	118.220	84.184	151.489
ϑ_m	Cost of Imported Goods Price Adjustment	Gamma	100	20	100.043	67.992	151.489
κ	Capital Stock Adjustment Costs	Gamma	12	2	23.008	19.430	26.462
σ	Elasticity of External Finance Premium	Beta	0.07	0.02	0.057	0.038	0.074

As mentioned previously, we assume that firms incur a quadratic cost of price adjustment, measured in terms of current inflation, relative to the previous period's inflation rate. We use the *gamma* distribution to restrict the adjustment cost parameters (ϑ_d, ϑ_m) to the positive manifold and, given the lack of evidence on the degree of nominal rigidity in emerging markets, specify a mean of 100 with a standard deviation of 20. As noted by Gali and Gertler (1999) an adjustment cost of 100

corresponds approximately to the assumption that firms change prices (or inflation) every 3.74 quarters. There is considerable uncertainty surrounding the appropriate value of the capital cost adjustment cost parameter (κ) in the model. While Kollmann (2002) finds a value of 1.43 in their model, Ireland (2001) and Ireland (2003) find values above 30. The mean of the prior on the capital adjustment cost parameter (κ) is set at 15 (as in Kollmann (2002)) with a *gamma* distribution.

Our choice of prior distributions for the parameters of the monetary policy reaction function is based on the fact that there is little evidence regarding the Reserve Bank of India's interest rate setting behavior.[57] As a result, we choose *uniform* priors for the feedback parameters on inflation, output, and the rate of exchange rate depreciation in the policy rule with a relatively large domain. In particular, we choose *uniform* prior distributions with a minimum of 0 and a maximum of 3 for the feedback parameter on WPI inflation (ρ_π) and the rate of exchange rate depreciation (ρ_q). This encompasses the estimates found by Mohanty and Klau (2004). For the feedback parameter on the output gap (ρ_Y), we choose a *uniform* distribution with a minimum of -1 and a maximum of 1. This is consistent with the finding in Mohanty and Klau (2004) that several emerging market central banks do not base their policy response on movements in the output gap in a systematic fashion. The lagged interest rate prior (ρ_i) follows a *beta* distribution with mean 0.7 and standard deviation of 0.2. This is consistent with the estimate in Mohanty and Klau (2004).

The prior on the habit persistence parameter (*b*) is assumed to follow a *beta* distribution to ensure that it remains bounded between 0 and 1. We assume a mean of 0.5 and a standard deviation of 0.2 for the prior distribution. The mean of our prior is lower than the values used inter alia by Julliard, Karam, Laxton and Pesenti (2004)

---

[57] A notable exception is Mohanty and Klau (2004) who finds that the parameters of the monetary policy reaction function in India are much lower than in other countries in Asia. A more detailed comparison between their results and ours is done in the next section.

and Smets and Wouters (2003) reflecting the assumption that a higher share of consumers in India is likely to be cash-constrained and thus unable to smooth consumption. However, the relatively large standard deviation implies that the prior distribution is relatively diffuse and covers a broad range of estimates.

As in Dib, Mendicino, and Zhang (2008), we choose a prior with a *gamma* distribution for the elasticity of the external finance premium. We assume a mean of 0.07 which is consistent with previous findings in the literature (see inter alia Elekdag, Justiniano, and Tchakarov (2005), Christensen and Dib (2006), and Dib, Mendicino, and Zhang (2008) and a standard deviation of 0.02. For the risk premium on foreign-currency borrowing (χ_d) we use a *gamma* distribution with a mean of 0.0019, as in Saxegaard (2006b), and a standard error of 0.002.

Finally, for the priors of the autoregressive parameters and the standard errors of the stochastic processes, we follow the same procedure as in Smets and Wouters (2005) and Julliard, Karam, Laxton and Pesenti (2004). The persistence parameters are given a prior with a *beta* distribution to restrict the domain between 0 and 1. The mean of the distribution for each of the autoregressive parameters is set at 0.8. For the standard errors, we use the inverted *gamma* distribution with a diffuse prior. The inverted *gamma* distribution is commonly used for standard errors as it gives support to all positive values of the parameter and has characteristics which ease the computational burden of the estimation processes. In order to specify the precise mean of the prior distribution for the standard errors of the structural shocks, we have relied on the variance decomposition of the model. In other words, we experimented with different sized shocks until we arrived at a specification which entailed a reasonable contribution of each of the structural shocks to the total variability of our observed variables. This approach was preferred to relying on previous studies given that the importance of shocks cannot be directly inferred from the size of their standard errors

due to normalization issues.[58] In any case, the use of a diffuse prior reduces the importance of the mean of the prior distribution on the outcome of the estimation.

2.4 Empirical Results

Table 2.3 reports the estimated posterior model together with the 90 percentile of the posterior distribution. Figure 2.2 provides a visual representation of this information by plotting the prior and posterior distribution for each parameter that is estimated, together with the posterior mode. These plots allow us to make some statements about the relative importance of the prior and the data in the construction of the posterior distribution. Overall, our model yields plausible parameter estimates for the parameters of the model which are broadly in line with results from previous studies.

The estimate of the elasticity of the external finance premium with respect to firm leverage σ is equal to 0.057. This is slightly below the estimate of 0.066 for Korea in Elekdag, Justiniano, and Tchakarov (2005) and somewhat higher than estimate in Dib, Mendicino, and Zhang (2008) using Canadian data. The investment adjustment cost parameter κ is estimated at 23.0, significantly higher than the prior mean. As pointed out by Christensen and Dib (2006), capital adjustment costs have an important interaction with the financial accelerator. If capital adjustment costs are high, the price of capital will tend to be more volatile. As net worth responds directly to the price of capital (through capital gains and losses), it affects the external finance premium faced by corporates, leading to increased investment volatility.

---

[58] See Lubik and Schorfheide (2005) for details.
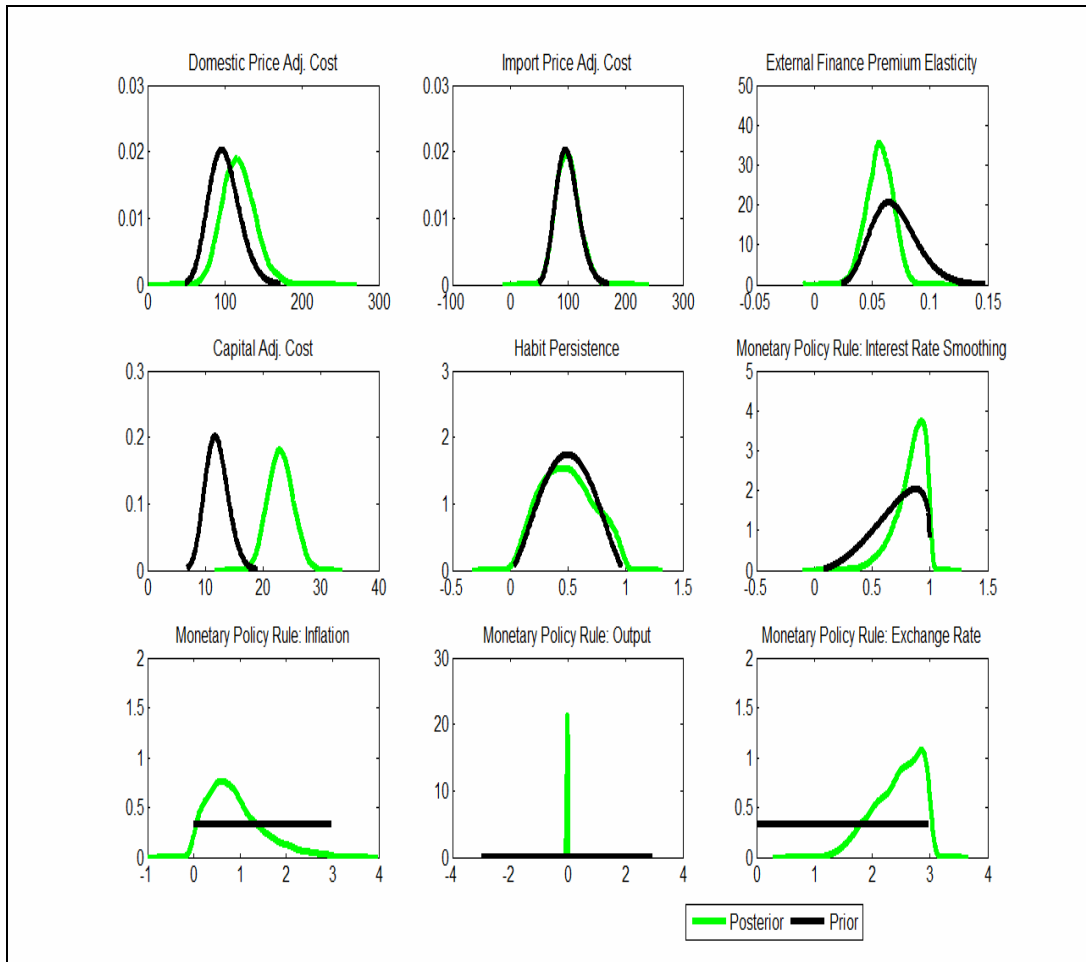
Figure 2.2: Prior and Posterior Distributions.
The marginal posterior densities are based on 4 chains, each with 100,000 draws
Metropolis algorithm discarding the first 50000 draws.

The habit persistence parameter (b) is estimated at 0.499, implying that there are significant delays in the effect of interest rate changes on aggregate expenditure, and consumption in particular. As we expected, these estimates are somewhat lower than found in other studies including Saxegaard (2006b) and Smets and Wouters (2005) given the higher share of cash-constrained consumers in India. With regards to the cost of price adjustment, our estimates suggest that domestic prices are more sluggish relatively to what is typically found in the literature. Moreover, the plots of the posterior in Figure 2 suggest that the data is quite informative about this parameter.

Our estimate of the cost of adjusting import prices, however, is close to the prior, which is not surprising given that we do not include data on import prices in our sample.

With regards to the estimates of the policy rule parameters, our results indicate that the Reserve Bank of India places a relatively high weight on controlling the rate of depreciation of nominal exchange rate. In particular the estimate of ρ_q, the coefficient that measures the response of monetary policy to exchange rate movements, is 3 times higher than ρ_π, the coefficient on inflation. Moreover, the results suggest that output stabilization does not play a significant part in the conduct of monetary policy, with the estimate of ρ_Y insignificantly different from zero. Because the model is estimated in levels, a simple transformation is necessary to be able to interpret these numbers. In particular, they imply that annual nominal interest rate increase by 0.9 percentage points if annual inflation is 1 percentage point above its equilibrium value. Similarly, annual interest rates increase by 1 percentage point if the nominal exchange rate depreciates by 1 percent more than the equilibrium rate of depreciation. Interestingly, these estimates are significantly higher than the estimates found by Mohanty and Klau (2004) in their study of the monetary policy reaction function for India. Their results suggest a 0.13 percentage point increase in annual interest rates if annual inflation increases by 1 percentage point, while a 0.18 percentage point increase in annual interest rates if the real exchange rate depreciations by 1 percent. While the fact that Mohanty and Klau (2004) is a partial equilibrium study means that their results are not directly comparable to ours, it is noteworthy that they also find a relatively strong response to movements in the exchange rate in India.

Finally, our estimates of the shock processes suggest that the shock to the markup and the price elasticity of exports are the most persistent stochastic processes. The persistence of the shock to uncovered interest parity suggests that departures from

uncovered interest parity are pervasive in the data. Our estimates of the standard errors of the structural shocks are also reported in Table 2.3 – 2.4Table 2.4. However, as pointed out by Lubik and Schorfheide (2005), the interpretation of these is not straightforward and is dependent on the scale of the variables.

Table 2.3: Parameter Priors and Posterior Estimates

Parameter	Description	Density	Prior		Posterior		
			Mean	S.D.	Mean	90% Interval	
ρ_θ	Technology Shock Persistence	Beta	0.8	0.1	0.808	0.658	0.959
ρ_{i^*}	Foreign Interest Rate Shock Persistence	Beta	0.8	0.1	0.831	0.718	0.945
ρ_{π^*}	Foreign Inflation Shock Persistence	Beta	0.8	0.1	0.785	0.643	0.948
ρ_{ε_t}	Markup Shock Persistence	Beta	0.8	0.1	0.860	0.731	0.978
ρ_Ξ	UIP Shock Persistence	Beta	0.8	0.1	0.794	0.654	0.931
ρ_{ς_L}	Labor Supply Shock Persistence	Beta	0.8	0.1	0.806	0.650	0.966
ρ_{ς_C}	Marginal Utility Shock Persistence	Beta	0.8	0.1	0.810	0.658	0.959
ρ_{ς_I}	Investment Efficiency Shock Persistence	Beta	0.8	0.1	0.785	0.640	0.947
ρ_{ς_t}	Export Elasticity Shock Persistence	Beta	0.8	0.1	0.857	0.759	0.916
ρ_G	Government Spending Shock Persistence	Beta	0.8	0.1	0.640	0.465	0.821
ρ_Γ	Borrowing Cost Shock Persistence	Beta	0.8	0.1	0.809	0.675	0.958
ρ_v	Survival Rate Shock Persistence	Beta	0.8	0.1	0.805	0.656	0.958

Table 2.4: Parameter Priors and Posterior Estimates

Parameter	Description	Density	Prior		Posterior		
			Mean	S.D.	Mean	90% Interval	
σ_θ	Size of Technology Shock	InvGamma	0.005	Inf	0.005	0.001	0.009
σ_{i^*}	Size of Foreign Interest Rate Shock	InvGamma	0.001	Inf	0.001	0.000	0.002
σ_{π^*}	Size of Foreign Inflation Shock	InvGamma	0.001	Inf	0.001	0.000	0.002
σ_{ε_t}	Size of Markup Shock	InvGamma	1	Inf	1.198	0.270	2.219
σ_Ξ	Size of UIP Shock	InvGamma	0.001	Inf	0.001	0.000	0.002
σ_{ς_L}	Size of Labor Supply Shock	InvGamma	0.01	Inf	0.010	0.002	0.021
σ_{ς_C}	Size Marginal Utility Shock	InvGamma	0.01	Inf	0.016	0.003	0.028
σ_i	Size of Monetary Policy Shock	InvGamma	0.005	Inf	0.004	0.002	0.007
σ_{ς_I}	Size of Investment Efficiency Shock	InvGamma	0.05	Inf	0.048	0.012	0.092
σ_{ζ_t}	Size of Export Elasticity Shock	InvGamma	0.1	Inf	0.320	0.190	0.454
σ_G	Size of Government Spending Shock	InvGamma	0.01	Inf	0.068	0.052	0.083
σ_Γ	Size of Borrowing Cost Shock	InvGamma	0.001	Inf	0.002	0.000	0.004
σ_v	Size of Survival Shock	InvGamma	0.001	Inf	0.002	0.000	0.004

2.4.1 Cross Validation with Alternative Models

As suggested by Christensen and Dib (2006) we compare the fit of our model, the Estimated FA model, against an alternative model without a financial accelerator. The alternative model, which we call the Estimated No-FA model, is identical to the FA

model with the exception that the parameter that captures the elasticity of the external finance premium with respect to firm leverage is constrained to equal zero. In addition, as suggested by Schorfheide (2000), we compare the fit our estimated model against a less restrictive non-structural reduced form Bayesian vector auto regression (BVAR) estimated using the popular Litterman prior (Sims and Zha, 1998). This provides a stringent test of the ability of our model to replicate the dynamics in the data and thus of its usefulness as a tool for policy analysis. Indeed, it is partly evidence suggesting that empirical DSGE models with a sufficient number of structural shocks compare favorably with BVARs which has prompted the increased interest in DSGE models in policy making.[59]

Bayesian econometrics provides a natural framework for assessing the empirical performance of different mis-specified models. Using Bayes Law again we can write the posterior probability of a model M_i as:

$$p(M_i \mid X) = \frac{p(M_i)L(M_i \mid X)}{f(X)}$$

where $p(M_i)$ is the prior belief attached to model i and $L(M_i \mid X)$ is the likelihood of the model given the data. Bayesian model selection is based on the posterior odds ratio of a particular model M_1 against another model M_2 which is given by:

$$\frac{p(M_1 \mid X)}{p(M_2 \mid X)} = \frac{p(M_1)L(M_1 \mid X)}{p(M_2)L(M_2 \mid X)}$$

where $\dfrac{L(M_1 \mid X)}{L(M_2 \mid X)}$ - the ratio of marginal likelihoods for different models--represents a summary measure of the evidence provided by the data for choosing between two competing models.

Table 2.5 reports the marginal likelihood of the Estimated FA model, the

---

[59] See inter alia Smets and Wouters (2005), Julliard, Karam, Laxton, and Pesenti (2004) and Lubik and Schorfheide (2005).

Estimated No-FA model, and BVARs estimated on the same data set at lags 1 to 4. The higher marginal likelihood in the Estimated FA model relative to the Estimated No-FA Model suggests that the introduction of a financial accelerator mechanism does improve the model's ability to capture the movements observed in the data. As in Elekdag, Justiniano, and Tchakarov (2005), however, the Estimated FA model does not compare favorably to a BVAR with one lag although it dominates BVARs with more lags. This is not surprising as the marginal likelihood falls with increasing model complexity and increases with model fit. The improved fit of our Estimated FA model relative to a BVAR with one lag does not compensate for its higher complexity. Nevertheless, the fact that the Estimated FA model outperforms BVARs with more than one lag does provide some evidence in support of the Estimated FA model as a tool of policy analysis.

Table 2.5: Model Comparison

	Marginal Likelihood
Estimated FA model	876.49
Estimated no-FA model	873.64
BVAR(1)	1148.54
BVAR(2)	420.19
BVAR(3)	673.25
BVAR(4)	743.61

2.4.2 Impulse Responses

A useful way to illustrate the dynamics of the estimated model and the importance of the financial accelerator is to consider the impulse response functions when the financial accelerator is present and when it is not. The response of some key macroeconomic variables to a 100 bps increase in the nominal interest rate are shown

in Figure 3.3, to a positive technology shock in Figure 3.4, and to a shock to borrowing costs in Figure 3.5. Each variable's response is expressed as the percentage deviation from its steady-state level, with the exception of the rate variables, which are in percentage points. In Figure 2.3 – 2.5Figure 2.5 the impulse responses generated in the estimated FA model are shown in black. The impulse responses generated when the financial accelerator is not present are shown in green. As in Christensen and Dib (2006), we generate these impulse responses by setting the elasticity of the external finance premium with respect to firm leverage equal to zero, but keeping all the other parameter estimates from the estimated FA model. The difference between the black and the green lines should give an indication of the impact of the financial accelerator on a particular variable after a given shock.

Figure 2.3 shows that the presence of a financial accelerator amplifies and propagates the impact of a contractionary monetary policy shock. In both models, the increase in the nominal interest rate raises the cost of domestic borrowing for consumers and thus leads to a contraction in consumption. It also raises the demand for domestic bonds and thus appreciates the domestic currency, while the net worth of entrepreneurs declines because of the declining return to capital and higher real interest costs associated with existing debt (the debt-deflation effect). Output contracts both as a result of decreased domestic demand and a result of decreased competitiveness following the appreciation of the real exchange rate. The contraction in demand in turn leads to a fall in inflation. In the presence of the financial accelerator, the external finance premium increases as a result of the decline in net worth and rising leverage. This pushes up the real borrowing cost for entrepreneurs, putting downward pressure on investment and the price of capital which further reduces net worth. This reduction in net worth leads to a further increase in the cost of borrowing (the premium goes up), thus reducing capital, investment and output further

(second round effects). This mechanism amplifies the magnitude and the persistence

of transitory monetary policy shocks as evident from the impulse responses.
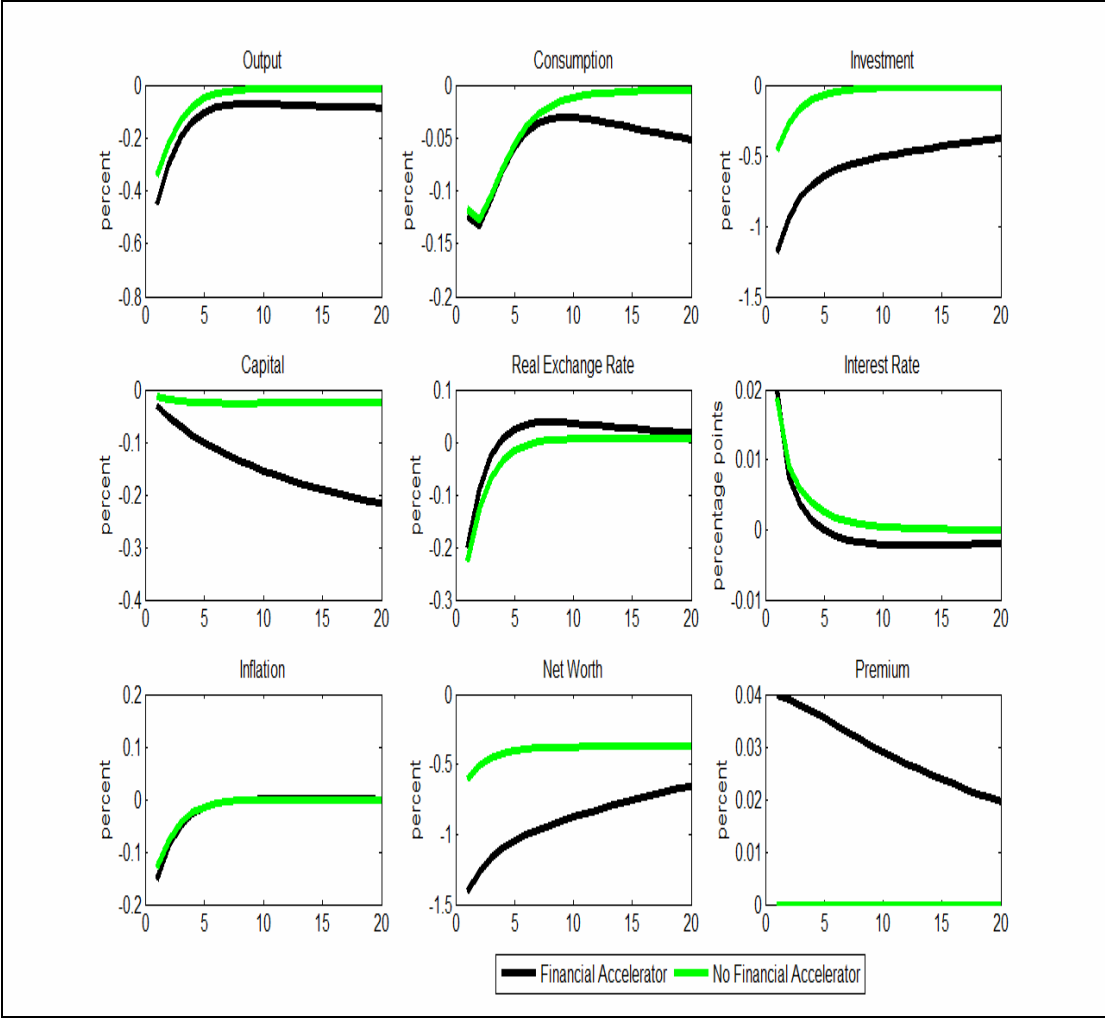
Figure 2.3: The Economy's Response to a 100 Bps Contractionary Monetary Policy Shock.
The impulse responses are computed using the mode of the posterior distribution of the model. Each variable's response is expressed as the percentage deviation from its steady state level. Interest rates are shown as absolute deviation from steady state. No Financial Accelerator model is obtained by setting the elasticity of the external finance premium with respect to firm leverage equal to zero, but keeping all other parameters same as in the baseline model.

Figure 2.4 shows that the financial accelerator has less of an impact following a

positive shock to technology. The technology shock increases the return to capital and thus leads to an increase in investment and output. At the same time, the improvement in technology reduces firms' marginal costs and thus reduces inflation. The higher return to capital and lower inflation have opposite effects on net worth but in our model the positive impact of the higher return to capital dominates. This is partly due to the endogenous response of monetary policy which pushes up nominal interest rates, thereby reducing the amount of deflation. When the financial accelerator is active, the rise in net worth pushes down the risk premium faced by entrepreneurs and leads to a larger response of investment and capital. While output is somewhat more volatile when the financial accelerator is present, the impact if significantly less than following a shock to monetary policy.

Figure 2.5 also shows that the financial accelerator amplifies the effects of a financial shock such as a shock to the borrowing costs faced by entrepreneurs. In both models, the higher borrowing cost depresses the demand for new capital and thus lowers investment, output, and inflation. The decline in absorption, in turn, reduces the demand for non-tradables and causes real exchange rate depreciation. The exchange rate depreciation (which raises the external borrowing cost of entrepreneurs), together with the decline in inflation, reduces entrepreneurs' net worth. In the presence of the financial accelerator, this increases the entrepreneurs' risk premium and reduces the demand for capital further. As a result, the decline in investment and output is much larger when the financial accelerator is present.
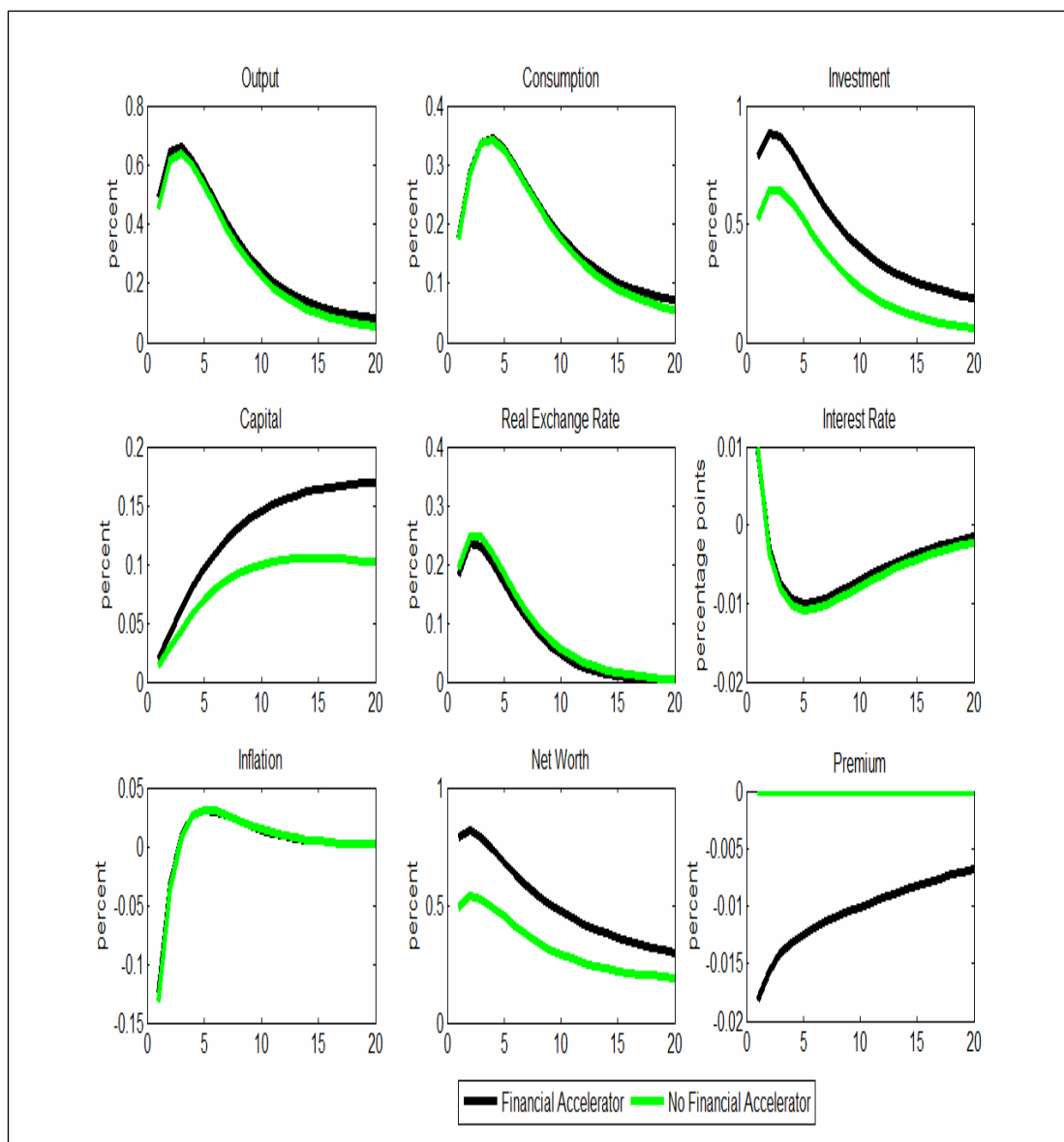
Figure 2.4: The Economy's Response to a 1 Percent Improvement in Technology
see notes to figure 2.3.
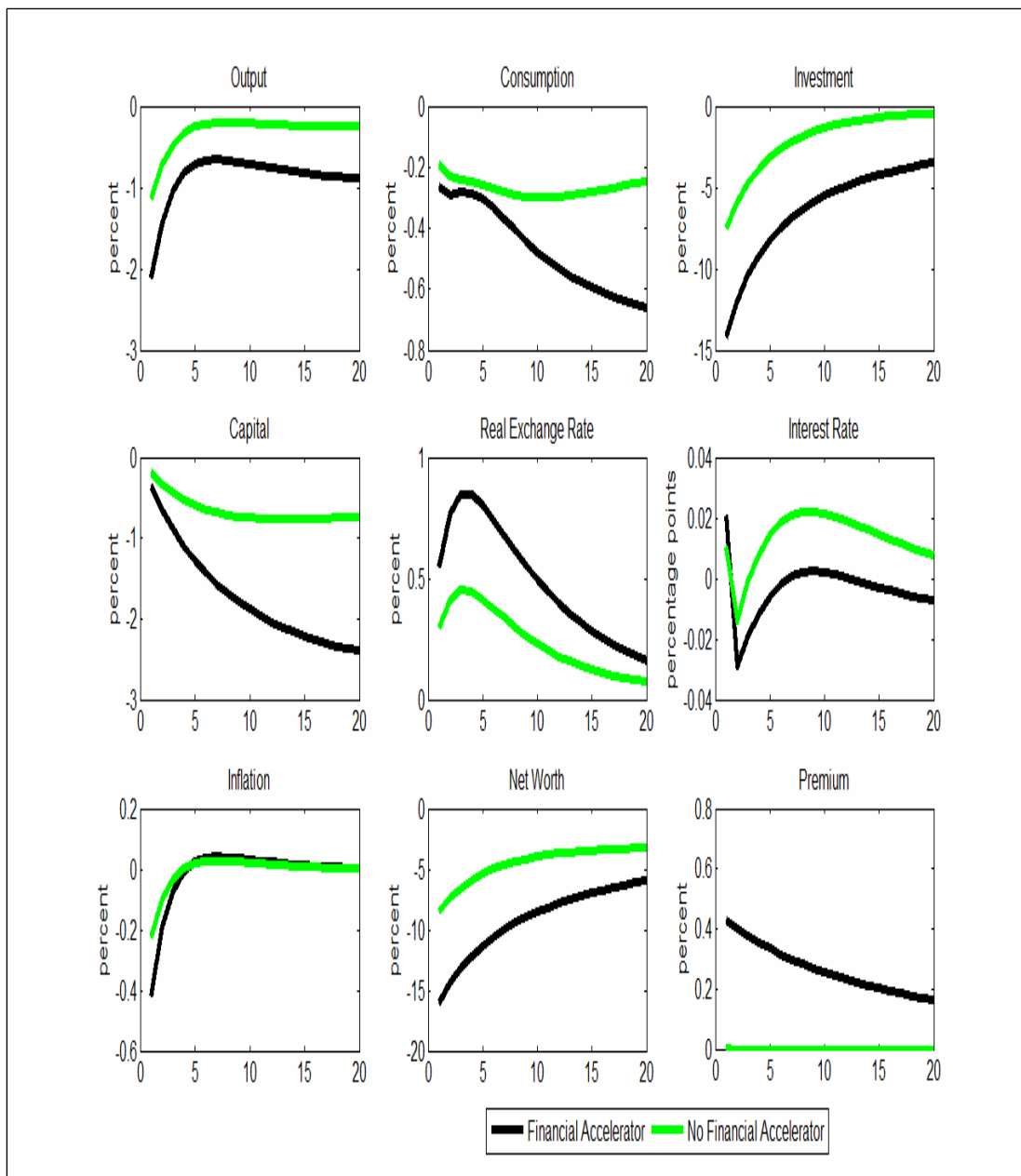
Figure 2.5: The Economy's Response to a 1 Percent Increase in Entrepreneur's Borrowing Cost
see notes to figure 2.3.

As in previous studies, therefore, the financial accelerator amplifies and propagates the impact of shocks on investment. The impact of the financial accelerator on other variables including output and inflation depends, however, on the type of shock. Following a contractionary monetary policy shock and a shock to entrepreneurs' cost of borrowing, output and inflation volatility increases when the financial accelerator is present. The financial accelerator has much less of an impact, however, on the economy following a shock to technology. This is consistent with the results in other studies including Christensen and Dib (2006).

2.5 Optimal Policy

How does the estimated monetary policy rule compare to a policy rule which maximizes consumer welfare? To answer this question we search for the parameters of the monetary policy reaction function in equation 45 that maximizes a second-order approximation of consumer welfare.[60] The results of this exercise are presented in Table 2.6, while the volatility implied by the different rules and the resulting consumer welfare is presented in Table 2.7.

Table 2.6: Parameters of an Optimal Policy Rule

	ρ_i	ρ_π	ρ_Y	ρ_q
Estimated Policy Rule	0.83	0.89	0.02	2.44
Optimal Policy Rule	0.995	5.75	0.00	1.05

---

[60] In the non-stochastic flexible-price equilibrium or steady-state, monetary policy is neutral in the sense that all the monetary rules we consider imply the same non-stochastic steady-state for the economy. Furthermore, given that up to a first-order (Taylor series) approximation consumer welfare is equal to its non-stochastic steady-state value, changes in the monetary policy regime will only have second-order (or higher) effects on welfare. As a result, we follow the majority of the literature in approximating welfare using a second-order Taylor series approximation to expected utility. This method leads to a loss-function similar to that widely assumed in the earlier literature on monetary policy evaluation.

Table 2.7: Standard Deviation of Key Macroeconomic Variables

	GDP	Consumption	Investment	Nominal Exchange Rate	Real Exchange Rate
Estimated Policy Rule	0.1100	0.0547	0.0520	0.0020	0.0126
Optimal Policy Rule	0.0971	0.0537	0.0485	0.0064	0.0134
	WPI Inflation	Net Worth	Premium	Welfare	Consumption Cost
Estimated Policy Rule	0.0036	1.6081	0.0059	-120.00	0.004
Optimal Policy Rule	0.0013	1.4621	0.005	-119.66	--

The parameters of a policy rule that maximizes welfare differs significantly from the parameters of the estimated policy rule. Our results suggest that the estimated policy rule places too little emphasis on inflation stabilization and too much emphasis on stabilizing the rate of depreciation of the nominal exchange rate. The lower than optimal weight on inflation stabilization in the estimated policy rule, coupled with a significantly higher than optimal weight on exchange rate stabilization, suggests that the RBI places more emphasis on stabilizing the rate of depreciation than on reducing inflation volatility. As a result, inflation volatility is higher under the estimated policy rule than under the optimal rule, while exchange rate volatility is lower. Both the estimated rule and the optimal rule feature significant interest-rate inertia, which implies that the authorities react to inflation much more aggressively in the long run

than in the short run.[61]

At the same, time the emphasis on stabilizing the rate of depreciation of the nominal exchange rate in the estimated policy rule comes at the expense of higher volatility in the real economy (despite the fact that the weight on output stabilization is broadly similar in both rules), while the volatility of financial sector variables - in particular borrowing costs and net worth - is also higher.

We calculate a second-order accurate measure of consumer welfare associated with different monetary policy regimes as in Schmitt Grohe and Uribe (2004). In particular, we calculate the expectation of lifetime utility as of time zero, V_0, associated with a particular monetary regime, denoted with the superscript, r:

$$V_0^r = E_0 \sum_{t=0}^{\infty} \beta^t U(C_t^r, N_t^r) \tag{55}$$

conditional on the economy being at its non-stochastic steady-state at time zero. In order to evaluate the cost of the estimated monetary policy rule relative to the welfare optimizing rule, we follow Schmitt Grohe and Uribe (2004) and calculate the fraction of a consumer's consumption that would make them indifferent between different regimes. In particular, λ is defined as the fraction of the household's consumption under the optimal policy rule that consumers would have to give up to be as well off under the empirical policy rule as under the optimal policy rule so that a value of $\lambda * 100 = 1$ represents a one percentage point of permanent consumption gain under the alternate policy regime. Formally λ is defined as:

$$V_0^{est} = E_0 \sum_{t=0}^{\infty} \beta^t U((1 - \lambda)C_t^{opt}, N_t^{opt}) \tag{56}$$

where V_0^{est} denotes the expectation of lifetime utility as of time zero under the estimated policy rule while L_0^{opt} and C_0^{opt} refer to the amount of labor and

---

[61] Interest rate inertia is in fact somewhat higher in the optimal rule reflecting possibly the impact interest rate volatility has on the volatility of net worth and thus the real economy.

consumption under the optimal rule. For the particular functional form in our model this implies:

$$\lambda = 1 - e^{\left[\frac{1-\beta}{\varsigma_{C,t}(1-b)}\left(V_0^{est} - V_0^{opt}\right)\right]} \tag{57}$$

where V_0^{opt} denotes the expectation of lifetime utility as of time zero under the optimal policy rule. From Table 2.7 we see that the welfare loss under the sub-optimal estimated policy rule is equivalent to a not insignificant 0.4 percent of permanent consumption.[62] This is close to the welfare gain found by Kollmann (2002) but lower than that found by Ambler, Dib, and Rebei (2004).

It is useful to compare our results to those in Schmitt Grohe and Uribe (2007) who calculate welfare maximizing policy rules using a closed-economy model calibrated using U.S. data and to those in Leith, Moldovan, and Rossi (2009) who analyze the welfare maximizing policy rule under different degrees of habit persistence. We also compare our results to those in Ambler, Dib, and Rebei (2004) who look at an open-economy model estimated using Canadian and U.S. data, although their results are not directly comparable to ours given the inclusion of money growth in the policy rule and the absence of interest rate smoothing. Both Leith, Moldovan, and Rossi (2009) and Schmitt Grohe and Uribe (2007) find that a significant degree of interest rate smoothing--albeit less than in our model--is optimal and contributes to substantially lower macroeconomic volatility. Leith, Moldovan, and Rossi (2009) and Schmitt Grohe and Uribe (2007) also find that a high weight on inflation stabilization, and a zero weight on output stabilization is optimal. Schmitt Grohe and Uribe (2007) restrict the weight on inflation stabilization to be less than 3 on the grounds that higher values may not be implementable. However, they note than in the absence of such a

---

[62] In other words, consumption in every period over the life time of a consumer would be 0.4 percent lower under the estimated rule than under the optimal rule.

restriction the optimal weight is 332. Similarly, Leith, Moldovan, and Rossi (2009) find that an estimate around 30 is optimal for the amount of habit persistence we estimate in our model. Ambler, Dib, and Rebei (2004) on the other hand, find a much lower optimal weight on inflation (1.2) and a higher weight on output stabilization (0.2).

Figure 2.6 illustrates our results by simulating the path of output, inflation, the rate of depreciation of the nominal exchange rate, and the nominal interest rate under the estimated policy rule and the optimal policy rule, using the estimated path of the stochastic shocks in the model. These plots confirm that inflation volatility would have been lower if monetary policy had been conducted according to the optimal policy rule. This was particularly true toward the end of 2004 (WPI inflation increased to 8.1 percent y.o.y. in the third quarter of 2004) and in 2006-07. At the same time, the rate of depreciation of the nominal exchange rate displays a significantly higher amount of volatility during the whole sample period under the optimal rule. Finally, the simulation of the nominal interest rate suggest that interest rates would have been higher toward the end of the sample - given the relatively high inflation--if monetary policy had been conducted according to the optimal policy rule.
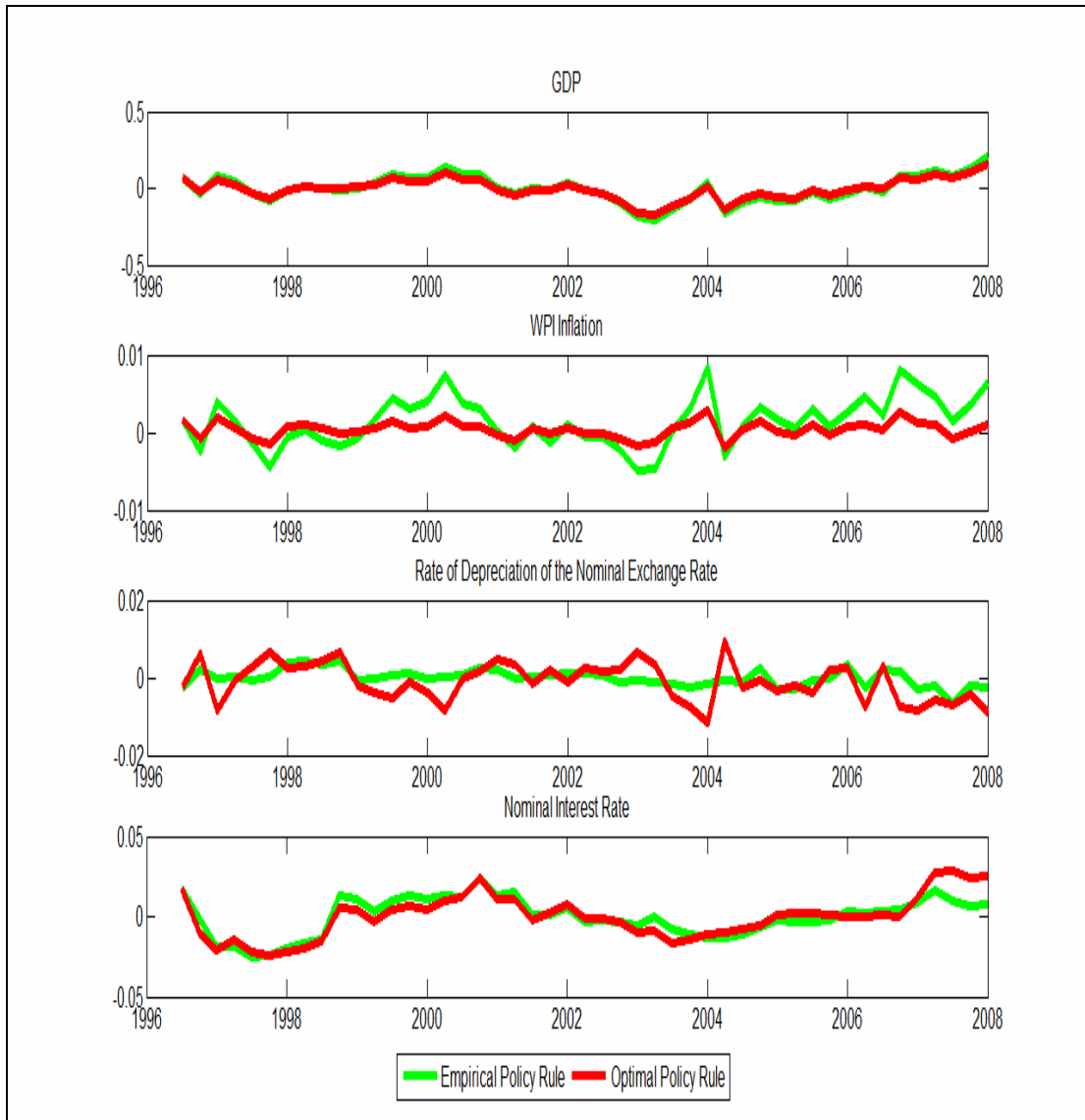
Figure 2.6: Path of Key Macroeconomic Variables Under Different Policy Rules
These plots are generated using the estimated path of the stochastic shocks in the model.

2.6 Concluding Remarks

The aim of this paper has been to estimate a DSGE model with macrofinancial linkages for India and to use it to analyze the conduct of monetary policy. The DSGE model used is an extension of the model developed in Saxegaard (2006a) augmented to include a financial accelerator mechanism similar to that proposed by BGG to study

the effect of financial frictions on the real economy.

As is increasingly common in this literature, the model was estimated using Bayesian estimation techniques. Bayesian estimation techniques provide a natural framework for evaluating macroeconomic models that are bound to be mis-specified along several dimensions. Our results yielded plausible estimates for the model parameters, although an examination of the posterior distributions suggested that the data was not informative about a number of parameters. In addition, the cross validation tests suggest that the introduction of a financial accelerator mechanism does improve the model's ability to capture the dynamics observed in the data. Furthermore, we provide evidence that our model with the financial accelerator provides a fit of the data that outperforms a BVAR at more than one lag.

Our results when using the model to examine the conduct of monetary policy - using consumer welfare as the benchmark against which to analyze alternative policies - suggest that the RBI puts a higher than optimal weight on stabilizing the rate of depreciation of the nominal exchange rate and a lower than optimal weight on inflation stabilization even in the presence of financial accelerator effects. This comes at the expense of higher inflation volatility as well as higher volatility in the real economy and in financial sector variables. However, exchange rate volatility is substantially lower under the monetary policy reaction function implied by the data relative to the welfare optimizing policy rule. In welfare terms, our analysis suggests that the optimal policy rule entails a welfare gain equivalent to 0.4 percent of permanent consumption relative to the empirical policy rule.

REFERENCES

Aghion, Philippe, Bacchetta, Philippe and Abhijit Banerjee, 2001, "Currency Crises and Monetary Policy in an Economy with Credit Constraints," *European Economic Review* Vo. 47, No. 7, pp. 1121-1150.

Ambler, Steve, Dib, Ali, and Nooman Rebei, 2004, "Optimal Taylor Rules in an Estimated Model of a Small Open Economy," Working Paper No. 04-36, Bank of Canada.

Batini, Nicoletta., Levine, Paul L., and Joshep Gerson Pearlman, 2009, "Monetary and Fiscal Rules in an Emerging Small Open Economy," IMF Working Paper No. 09/22, International Monetary Fund.

Bauwens, Luk, Lubrano, Michel, and Jean Francois Richard, 1999, "Bayesian Inference in Dynamic Econometric Models," (Princeton: Oxford University Press).

Bernanke, Ben and Mark Gertler, 1989, "Agency Costs, Net Worth, and Business Fluctuations," *American Economic Review* Vol. 79, No. 1, pp. 14-31.

Bernanke, Ben, Gertler, Mark, and Simon Gilchrist, 1999, "The Financial Accelerator in a Quantitative Business Cycle Framework," in *Handbook of Macroeconomics*, Edition 1, Vol. 1, eds. John B. Taylor and Michael Woodford (Amsterdam: North Holland).

Bernanke, Ben, and Frederic S. Mishkin, 1997, "Inflation Targeting: A New Framework for Monetary Policy?" *Journal of Economic Perspectives*, Vol. 11, No. 2, pp. 97-116.

Carlstrom, Charles, and Timothy S. Fuerst, 1997, "Agency Costs, Net Worth, and Business Fluctuations: A Computable General Equilibrium Analysis," *American Economic Review*, Vol. 87, No. 5, pp. 893-910.

Christensen, Ian, and Ali Dib, 2006, "Monetary Policy in an Estimated DSGE Model with a Financial Accelerator," Working Paper No. 06-9, Bank of Canada.

Christiano, Lawrence, Motto, Roberto, and Massimo Rostagno, 2007, October, " Shocks, Structures or Monetary Policies? The Euro Area and U.S. After 2001," NBER Working Paper No. 13521.

Christiano, Lawrence, Motto, Roberto, and Massimo, Rostagno, 2009, "Financial factors in business cycles," mimeo, European Central Bank.

Clarida, Richard, Gali, Jordi, and Mark Gertler, 1999, "The Science of Monetary Policy: A New Keynesian Perspective," *Journal of Economic Literature*, Vol. 37, No. 4, pp. 1661-1707.

Dib, Ali, Mendicino, Caterina, and Yahong Zhang, 2008, "Price Level Targeting in a Small Open Economy with Financial Frictions: Welfare Analysis," Working Paper No. 08-40, Bank of Canada.

Elekdag, Selim, Justiniano, Alejandro, and Ivan Tchakarov, 2005, "An Estimated Small Open Economy Model of the Financial Accelerator," Working paper WP/05/44, International Monetary Fund.

Fernandez- Villaverde, Jesus, and Juan Francisco Rubio-Ramirez, 2004, "Comparing Dynamic Equilibrium Models to Data: A Bayesian Approach," *Journal of Econometrics* Vol. 123, No. 1, pp. 153-187.

Gertler, Mark, Gilchrist, Simon, and Fabio M. Natalucci, 2007, "External Constraints on Monetary Policy and the Financial Accelerator," *Journal of Money, Credit and Banking,* Vol. 39, No. 2, pp. 295-330.

Geweke, John, 1998, "Using Simulation Methods for Bayesian Econometric Models: Inference, Development and Communication," Staff Report 249, Federal Reserve Bank of Minneapolis.

IMF, 2009, October, "World Economic Outlook," Washington: International Monetary Fund.

Ireland, Peter, 2001, "Sticky-price Models of the Business Cycle: Specification and Stability," *Journal of Monetary Economics*, Vol.47, No.1, pp. 3-18.

Ireland, Peter, 2003, "Endogenous Money or Sticky Prices?"*Journal of Monetary Economics*, Vol. 50, No.8, pp. 1623-1648.

Juillard, Michel, 2001, April, "Dynare: A Program for the Simulation of Rational Expectation Models," Computing in Economics and Finance 2001 213 Society for Computational Economics.

Julliard, Michel, Karam, Philippe , Laxton, Douglas, and Paolo Pesenti, 2004, "Welfare-based Monetary Policy Rules in an Estimated DSGE Model of the U.S. Economy," Working Paper Series No. 613, European Central Bank.

Kiyotaki, Nobuhiro, and John, Moore, 1997, April, "Credit Cycles," *Journal of Political economy,* Vol. 105, No.2, pp. 211-248.

Kollmann, Robert, 2002, "Monetary Policy Rules in the Open Economy: Effects on Welfare and Business Cycles," *Journal of Monetary Economics*, Vol. 49, No.5, pp. 989-1015.

Krugman, Paul, 1999, "Balance Sheets, the Transfer Problem, and Financial Crisis," *Journal of International Tax and Public Finance,* Vol.6, No.4, pp. 459-472.

Leith, Campbell, Moldovan, Ioana, and Raffaele Rossi, 2009, "Optimal Monetary Policy in a New Keynesian Model with Habits in Consumption," Working Paper Series No. 1076, European Central Bank.

Ljungqvist, Lars and Thomas, J., Sargent, 2004, January, "Recursive Macreoconomic Theory," 2nd Edition, Volume 1, MIT Press.

Lubik, Thomas, and Frank Schorfheide, 2005, "A Bayesian Look at New Open Economy," Economic Working Paper Archive 521, The John Hopkins University, Department of Economics.

Mohan, Rakesh, 2004, "Challenges to Monetary Policy in a Globalizing Context," *Reserve Bank of India Bulletin*, January.

Mohanty, Madhusudan, and Marc Klau , 2004, "Monetary Policy Rules in Emerging Market Economies: Issues and Evidence," BIS Working paper No. 149, Bank for International Settlements.

Oura, Hiroko, 2008, "Financial Development and Growth in India: A Growing Tiger in a Cage?" IMF Working Paper No. 08/79, International Monetary Fund.

Rajan, Raghuram, 2008, "A Hundred Small Steps: Report on the Committee on Financial Sector Reforms," Technical Report, Planning Commission, Government of India.

RBI, 2009, "The Evolution of Monetary Policy, 2003-04," Special Volume of its Reports on Currency and Finance (Volume I), Reserve Bank of India.

Rotemberg, Julio, 1982, "Sticky Prices in the United States," *Journal of Political Economy,* Vol. 90, No.6, pp. 1187-1211.

Saxegaard, Magnus, 2006a, "Fiscal and Monetary Policy in an Estimated Model of the Philippine Economy," Manuscript.

Saxegaard, Magnus, 2006b, "Monetary Policy Rules in a Small Open Economy with External Liabilities," Manuscript.

Schmitt-Grohe, Stephanie, and Martin Uribe, 2003,"Closing Small open Economy Models," *Journal of International Economics*, Vol. 61, No. 1, pp. 163-185.

Schmitt-Grohe, Stephanie, and Martin Uribe, 2004, "Solving Dynamic General Equilibrium Models Using a Second-order Approximation to the Policy Function," *Journal of Economic Dynamics and Control*, Vol. 28, No. 4, pp. 755-775.

Schmitt-Grohe, Stephanie, and Martin, Uribe, 2007, "Optimal Simple and Implementable Monetary and Fiscal Rules," *Journal of Monetary Economics,* Vol. 54, No. 6, pp. 1702-1725.

Schorfheide, Frank, 2000, "Loss Function-based Evaluation of DSGE Models," *Journal of Applied Econometrics,* Vol. 15, No. 6, pp. 645-670.

Sims, Christopher, A, and Tao Zha, 1998, "Bayesian Methods for Dynamic Multivariate Models," *International Economic Review*, Vol. 39, No. 4, pp. 949-68.

Smets, Frank, and Raf Wouters, 2003, "An Estimated Dynamic Stochastic General Equilibrium Model of the Euro Area," *Journal of European Economic Association,* Vol. 1, No. 5, pp. 1123-1175.

Smets, Frank, and Raf Wouters, 2005, "Comparing Shocks and Frictions in U.S. and Euro Area Business Cycles: A Bayesian DSGE Approach," *Journal of Applied Econometrics,* Vol. 20, No. 2, pp. 161-183.

CHAPTER 3
A CREDIT AND BANKING MODEL FOR INDIA

3.1 Introduction

The global financial crisis has amply demonstrated that the performance of the real side of the economy is closely linked to the disturbances in the financial sector. Shocks originating in the credit markets have resulted in substantial loss of output and large-scale unemployment. One of the discerning features of this crisis has been a complete meltdown of financial intermediation activity. Inter-bank markets froze; credit became extremely costly, and at times totally unavailable. Tighter credit conditions not only exacerbated, but also protracted the crisis. Realizing that the recovery of the real economy depends crucially on the smooth functioning of the financial sector, central banks have taken substantive measures to unclog the credit markets. This crisis has made it amply clear that the banking sector can considerably affect the developments in the real economy, and to analyze and understand these linkages better, it is imperative to develop a dynamic stochastic general equilibrium (DSGE) model with macro-financial linkages and an active banking sector.

The importance of financial shocks in terms of how they affect the real economy has long been realized (Fisher, 1933), but most of the general equilibrium models developed to study macro-financial linkages have focused only on the demand side of the credit markets.[63] These models have abstracted from modeling the banking sector explicitly, and assume that credit transactions take place through the market (thereby not assigning any role to financial intermediaries such as banks). The growing importance of banks in the modern financial system and the current crisis has

---

[63] Bernanke, Gertler and Gilchrist (1999) and Iacoviello (2005) have introduced credit and collateral requirements to analyze the transmission and amplification of financial shocks.

demonstrated that the role of financial intermediation cannot be overlooked, and we need to model the supply of credit to understand business cycle fluctuations better. Also, modeling credit supply is essential to study the transmission of shocks originating in the credit markets.

The objective of this paper is to develop a small open economy New Keynesian model with financial frictions and an active banking sector for India, in order to understand the role of banking intermediation in the transmission of monetary impulses, and to analyze how shocks that originate in credit markets are transmitted to the real economy. The model developed is used to analyze issues related to monetary transmission and financial stability. We specifically look at (1) the monetary transmission mechanism in the presence of banking sector and financial frictions; (2) the role of banks in propagation of macroeconomic shocks; (3) the effects of a tightening of credit conditions; and (4) the effects of non-standard monetary policy tools.

Anand et al. (2010) have shown that a model with financial frictions, modeled with a financial accelerator mechanism similar to Bernanke, Gertler and Gilchrist (1999), improves the model's ability to capture the dynamics observed in the Indian data. We extend their basic model to include an active banking sector on the lines of Gerali et al. (2010). The banking sector is modified to include the non-monetary tools frequently used by the central bank in India. We depart from Iocaviello (2005) and Gerali et al. (2010) in modeling financial frictions, that we only introduce the balance sheet effects for firms. Though such frictions may be an important feature of households' balance sheets in advanced economies, they have played a relatively secondary role in the present crisis in India.

We introduce a banking sector which operates under a monopolistically competitive environment. Banks are modeled as comprising of three parts, two "retail

120

branches" and one "wholesale" unit. The two retail branches provide differentiated loans to entrepreneurs (loan branch) and raise differentiated deposits from households (deposit branch). These branches set rates in a monopolistic competitive fashion, subject to adjustment costs. The wholesale unit manages the capital position of the group and, in addition, raises wholesale loans and wholesale deposits. Banks combine deposits from the household and borrowing at interbank market with the bank capital to produce loans. While using deposits to make loans, banks observe cash reserve ratio (keeping a fraction of deposits in liquid form, which do not earn any interest) and statutory liquidity ratio (investing a fraction of deposits in government t-bills) imposed by the central bank. Cash reserve ratio requirements leave banks with fewer resources to lend, while the statutory liquidity ratio requirements force them to extend credit to governments at rates lower than the market rates. Both these factors increase the marginal cost of producing loans and affect the real side of the economy, through the borrowing costs of the firms. Bank capital is accumulated in each period out of retained earnings, and banks pay a quadratic cost if they deviate from the capital/loan requirement set by the central bank. Accumulation of bank capital from retained earnings creates a feedback loop between the real and the banking sector in the economy. As macroeconomic conditions deteriorate, profits of banks are affected negatively, and this weakens the ability of banks to raise new capital. Depending on the nature of the shock, this may force banks to cut down lending, or demand a higher price for credit, giving rise to the "credit cycle" observed in the recent recession episodes.

To the best of our knowledge this is the first open economy model with an explicit banking sector. Considering that borrowers in emerging market economies tend to rely more on foreign currency borrowing, exchange rate and world interest rate fluctuations through their effect on balance sheets play an important role in these

121

economies(Krugman, 1999, Aghion et al., 2001). A small open economy model provides an opportunity to analyze these channels. Another major contribution of this paper is to incorporate features to study the transmission mechanism of non-conventional monetary policy tools. Unlike most models available in the literature, this paper calibrates the model to an emerging economy (Indian data) which we think is a basic first step towards better understanding of monetary policy frameworks in emerging economies.

The analysis delivers the following results. First, the presence of financial frictions amplifies the magnitude and the persistence of transitory shocks. Second, market power of monopolistic banking sector amplifies the business cycle. However when interest rates are sticky, banking system attenuate the response to shocks. Third, the tightening of credit markets (modeled by a persistent negative shock to bank capital) can have substantive effects on the economy. Fourth, when the central bank resorts to using non-monetary tools, there is a larger contraction in output and consumption as compared to traditional monetary tightening (operating through nominal interest rate changes).

These results are driven by the two channels through which the financial sector interacts with the real economy – the financial accelerator channel, which establishes a link between the balance sheet of the firms (borrowers) and the real economy; and the banking sector channel, which creates a feedback loop between the real and the financial side of the economy through the bank's balance sheet.

In the present paper we only explore the role of banks and financial frictions in transmitting shocks, and how they affect the monetary transmission mechanism. However, this baseline model can be used to analyze several issues related to the financial sector and financial stability. It can be used to study the welfare costs of various financial frictions, as well as financial under-development. Also, estimating

the parameters of the model will enable it to be used to study the optimality of monetary policy.

The paper is organized in five sections. In the next section, we present some empirical facts to further motivate the analysis, and also review the relevant literature. In Section 3, we develop a small open economy New Keynesian model with financial frictions and an active banking sector, which forms the basis of further analysis. In Section 4 we analyze the impulse responses. Section 5 concludes.

3.2 Stylized Facts and Related Literature

We begin by presenting some basic stylized facts about the growing importance of macro-financial linkages and the banking sector in the Indian economy and then look at the monetary policy practices in India. We also review the recent attempts at introducing banking sector in traditional DSGE models.

Banks have played an important role in the growth of the Indian economy. Figure 3.1 plots the domestic credit provided by the banking sector as a percentage of GDP (for the period 2001 – 2008). It is evident that the bank's role in providing credit has increased in the last decade. To see how the credit supply conditions changed during the present crisis, we plot the Reserve Bank of India (RBI) repo rate, reverse repo rate and call rate (Figure 3.2) for the period Jan 2008 – Jan 2010. Sharp peaks in the call money market rate, well above RBI's policy repo rate during the crisis period provides a clear indication of the credit crunch associated with the crisis. Thus, growing importance of banks and a close link between bank's credit supply and the real economy is clearly evident in India.
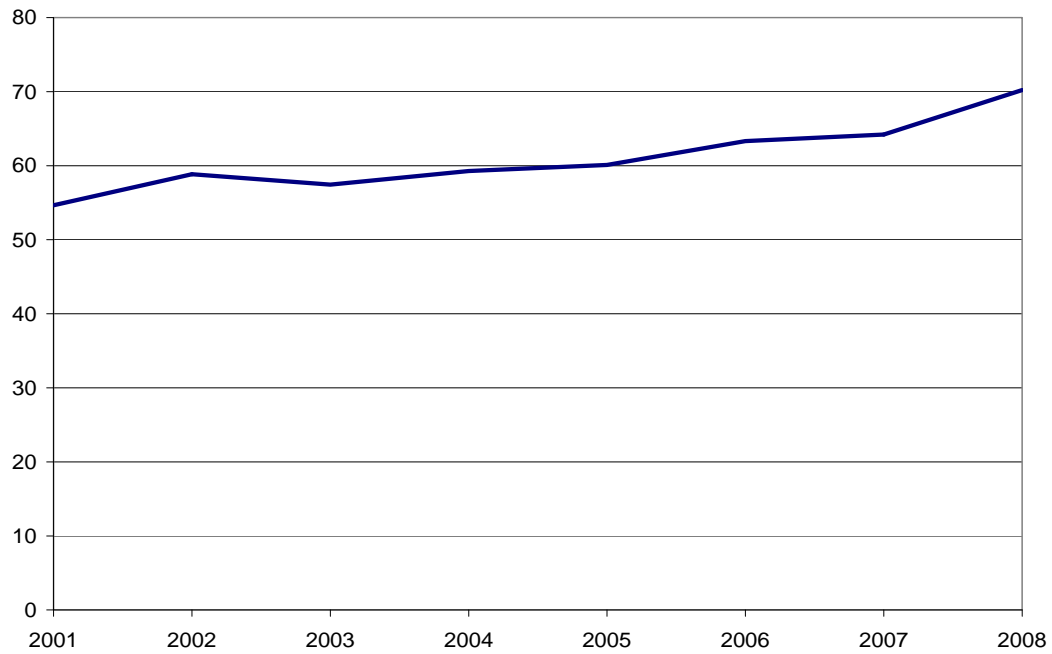
Figure 3.1: Domestic Credit Provided by Banking Sector (as percent of GDP)
Source: World Development Indicator, World Bank.
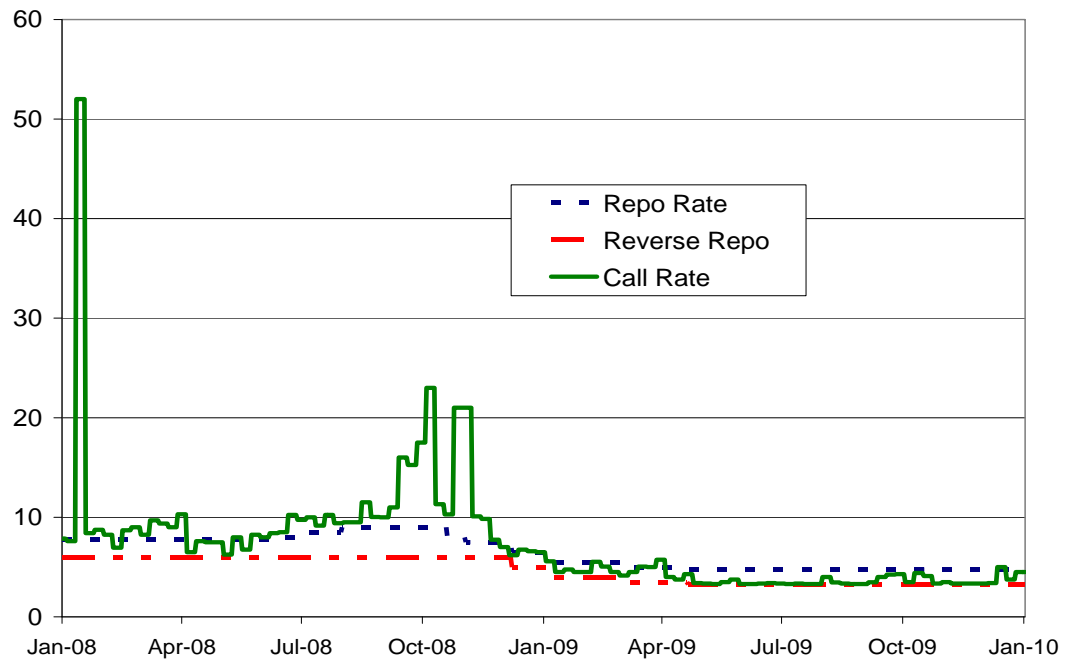
Figure 3.2: Interest Rates During the Crisis
Source: CEIC

Next, we look at the data on the source of corporate financing in India. While Indian companies finance the majority of their investment using retained earnings, Oura (2008) finds that they had been increasing their use of external funds (including domestic bank and capital market financing as well as overseas financing) to finance considerably larger investment during the recent period of 9 percent economic growth. As a result, India's corporate sector is increasingly exposed to global financing conditions. External funds have been a major source of funding for the Indian corporate sector in the last decade. In 2005 – 06 the median share of external funds to total funds in corporate financing was 64%. Firms which are younger (age < 5 years) have relied more heavily on external financing (median share of external funds to total funds for them was 86% in 2005-06).[64] If we look only at the core external fund (long term debt and equity only) then also corporate reliance on core external funds to total funds has been growing and stood at 16% in 2005-06. Again the younger firms (age < 5 yrs) rely more on core external funds (their median was 49% in 2005-06).[65] Also the use of foreign borrowing has increased. The ratio of average foreign borrowing to assets has gone up to 1.6 in 2005-2006 (as compared to 0.4 in 2001-02).[66] Greater reliance of corporations on external funds and foreign borrowing suggests that macro-financial linkages have likely grown in importance. Banks have been an important source of external financing for the corporate sector in India. In 2008-09 bank credit accounted for 21.6 percent of financing for corporates, second only to retained earnings (IMF Country Report, 2009). Table 3.1 presents the share of bank credit as a percent of total funding.

---

[64] Oura, 2008. External fund is defined as long term debt, equity and trade credits. The average median share of external funds to total funds is 70% over the period 1993-2006.
[65] Oura, 2008. Average median share of core external funds to total funds is 28% over the period 1993-2006.
[66] Oura, 2008.

Table 3.1: Source of Corporate Financing in India

	In percent of total funds				
	Foreign Direct Investment	Foreign Borrowing	Equity Issuance	Bank Credit	Retained Earnings
2003-04	11.8	-7.9	13.8	10.4	71.8
2004-05	6.8	5.9	7.2	27.9	52.3
2005-06	8.3	2.4	5.8	26.9	56.6
2006-07	14.7	10.8	5.0	21.8	47.7
2007-08	15.4	10.5	10.2	20.6	43.3

Source: India Staff Report, IMF, 2009.

India's monetary policy framework has evolved considerably over the past decades (RBI, 2009). In particular, the opening up of the economy in the early 1990s and financial sector liberalization has been reflected in changes in the nature of monetary management (Mohan, 2004). The basic objectives of monetary policy - maintaining price stability and ensuring sufficient credit to support growth - have remained unchanged. However, the opening up of the capital account - while necessary for providing sufficient capital for investment purposes and for reducing the cost of borrowing - exposes the economy to sudden stops in capital flows. In particular, volatile capital flows and its impact on the exchange rate have implications not only for domestic demand and inflation, but for financial stability, with the result that maintenance of financial stability is of increasing concern to the Reserve Bank of India (Mohan, 2004). In order to meet these multiple challenges, the RBI has switched from a more traditional monetary targeting framework to an indicator based approach which seeks to strike a balance between price stability and reducing exchange rate volatility.

RBI seems to rely on a number of instruments to achieve its ultimate objective of

price stability and growth. Table 3.2 shows the movement in key policy rates and reserve requirements during the period 2004 – 2009.

Even though the short term interest rate have emerged as the key instrument all over the world, it is evident that RBI still relies heavily on non-traditional monetary policy tools to carry out monetary policy operations.[67]

Choice of policy instrument depends largely on the stage of macro-economic and financial sector development and is an evolutionary process (Mohan, 2006). Use of short term interest rate as an effective policy tool requires an efficient monetary transmission mechanism, which in turn, requires well developed financial markets as well as absence of interest rate distortions. In India, although the money market, government debt and forex market have developed in recent years, they still lack the depth and sophistication. On the other hand corporate debt market is still to develop. Moreover, a number of administered interest rates continue to exist. Jha (2008) has found that the short-term interest rate, the principal policy tool used to affect inflation in countries working with inflation targeting, does not have a significant effect on inflation in India. Thus, it appears that the weak monetary transmission mechanism in India has necessitated the use of this rather crude tool by the RBI.

---

[67] International experience suggests that the use of open market operations has become more widespread in various countries, and reserve requirements have been lowered in many. It is generally being used in circumstances where bank liquidity needs to be adjusted rapidly in markets that are thin, and where the central bank needs to give clear, swift and unambiguous signals on the need for expansion or contraction of money supply.

Table 3.2: Movements in Key Policy Rates and Reserve Requirements (in percent)

Effective since	Reverse Repo Rate	Repo Rate	Cash Reserve Ratio	Statuary Liquidity Ratio
Jan 6, 2007	6.00	7.25	5.50(+0.25)	25
Jan31, 2007	6.00	7.50(+0.25)	5.50	25
Feb 17, 2007	6.00	7.50	5.75(+0.25)	25
Mar 3, 2007	6.00	7.50	6.00(+0.25)	25
Mar 30, 2007	6.00	7.75(+0.25)	6.00	25
Apr 14, 2007	6.00	7.75	6.25(+0.25)	25
Apr 28, 2007	6.00	7.75	6.50(+0.25)	25
Aug 4, 2007	6.00	7.75	7.00(+0.50)	25
Nov 10, 2007	6.00	7.75	7.50(+0.50)	25
Apr 26, 2008	6.00	7.75	7.75(+0.25)	25
May 10, 2008	6.00	7.75	8.00(+0.25)	25
May 24, 2008	6.00	7.75	8.25(+0.25)	25
Jun 11, 2008	6.00	8.00(+0.25)	8.25	25
Jun 25, 2008	6.00	8.50(0.50)	8.25	25
Jul 5, 2008	6.00	8.50	8.50(+0.25)	25
Jul 19, 2008	6.00	8.50	8.75(+0.25)	25
Jul 30, 2008	6.00	9.00(+0.50)	8.75	25
Aug 30, 2008	6.00	9.00	9.00(+0.25)	25
Oct11, 2008	6.00	9.00	6.50(-2.50)	25
Oct 20, 2008	6.00	8.00(-1.00)	6.50	25
Oct25, 2008	6.00	8.00	6.00(-0.50)	25
Nov 03, 2008	6.00	7.50(-0.50)	6.00	25
Nov 08, 2008	6.00	7.50	5.50(-0.50)	24(-1.00)
Dec 08, 2008	5.00(-1.00)	6.50(-1.00)	5.50	24
Jan 05, 2009	4.00(-1.00)	5.50(-1.00)	5.50	24
Jan 17, 2009	4.00	5.50	5.00(-0.50)	24
Mar 05, 2009	3.50(-0.50)	5.00(-0.50)	5.00	24
Apr 21, 2009	3.25(-0.25)	4.75(-0.25)	5.00	24
Oct 27, 2009	3.25	4.75	5.00	25(+1.00)
Jan 30, 2010[a]	3.25	4.75	5.75(+0.75)	25
Mar 19, 2010	3.50(+0.25)	5.00(+0.25)	5.75	25

Source: Reserve Bank of India
Notes: Reverse repo indicates absorptions of liquidity and repo signifies injection of liquidity. Figures in parentheses indicate changes in policy rates/ratios.
a. Implemented in two stages – 0.5 increase from Feb 13 and 0.25 increase from Feb 27, 2010.

Despite their relevance for policy making, most of the general equilibrium models generally lack interaction between financial markets and the real economy. Though a long tradition in economics starting from Irving Fishers' (1933) debt deflation explanation of the Great Depression; most of the theoretical works focused on partial equilibrium analysis till the seminal paper by Bernanke and Gertler (1989). They used information asymmetry in credit markets and monitoring costs to establish a link between the financial sector and the real economy. They showed that in such a setting, the borrowing costs of firms depend on the strength of their balance sheets (net worth).[68] Bernanke, Gertler and Gilchrist (1999), Kiyotaki and Moore (1997) and Carlstrom and Furest (1997) have demonstrated that the presence of financial frictions amplify the magnitude and the persistence of macroeconomic shocks. Gertler, Gilchrist and Natalucci (2007) and Eleckdag, Justiniano and Tchakarov (2005) extended the framework to small open economies. Iocaviello (2005) introduced the collateral constraints tied to real estate values of the firms and household level nominal debt to study the linkages between financial frictions and real economy. However all these models have used financial frictions on the firm/household side (or demand side of the credit market). All these models assume that credit transactions take place through markets, and do not assign any role to financial intermediaries such as banks. Also, they do not include the credit supply channel.

Recently there has been increasing interest in introducing a banking sector in dynamic models. The present crisis has underscored the need to model the supply side of credit markets to understand better the linkages between the financial sector and the real economy. In order to introduce the supply side of credit markets, researchers have followed three major approaches to model banking sector - (i) Perfectly competitive banks with banking costs; (ii) Monopolistically competitive banks and; (iii) Risky

---

[68] It is commonly referred to in the literature as a "Financial Accelerator".

banks with inter-bank lending. All these models try to generate a spread between the lending and deposit rates which adjusts along the cycle, establishing a link between the banking activity and the real economy.

In models with perfectly competitive banks, banking (producing loans, deposits, bank equity etc.) is a costly activity which requires resources. Costs of banking activities create a spread between lending and deposit rates (Edward and Vegh, 1997; Benes et al., 2009; Curdia and Woodford, 2009; Goodfriend and McCallum, 2007; and Christiano et al., 2009). Models with monopolistically competitive banks use the market power of banks to generate a spread between the deposit and lending rates, which adjusts along the cycle, thus affecting the real side of the economy (Gerali et al., 2010; Huelsewig and Wollmershauser, 2009; and Sudo and Ternishi, 2009). Risky banks and inter-bank lending models assume that banks operate under perfectly competitive markets and the production of loans is separate from the production of deposits. Banks rely on inter-bank lending and there is an endogenous probability of default by firms and banks. This probability of default induces a financial accelerator in these models as the rate of default is countercyclical (de Walque et al., 2009; and Gertler and Kiyotaki, 2009).

In this paper we follow Gerali et al. (2010) to introduce the banking sector in a model with financial frictions. Banks in our model operate in a monopolistically competitive environment and set deposit and lending rates. A wedge is created between the two rates as a result of the market power of banks. We model financial frictions a la Bernanke, Gertler and Gilchrist (1999).

3.3 Model

We build on the model of Anand et al. (2010) and include a banking sector on the lines of Gerali et al. (2010). The basic structure of model consists of four kinds of

agents – households, entrepreneurs, capital producers and retailers. Households consume a composite of domestic and imported goods and provide labor. They have access to foreign capital markets and make deposits with the banks. Households are the owner of banks and retail units. Entrepreneurs produce intermediate goods using labor and capital purchased from the capital producers. They finance the acquisition of capital partly through their net worth and partly through borrowing domestically (from banks) and from abroad. Banks raise deposits from households and give out loans to entrepreneurs. They operate in a monopolistically competitive environment – setting interest rates on deposits and loans to maximize profits. Banks combine deposits from the household and borrowing at inter-bank market with the reinvested profits (bank capital) to make loans to entrepreneurs. Entrepreneurs operate under perfect competition and sell their product to retailers who differentiate them at no cost and sell them either in domestic market or export overseas. Retailers operate in a monopolistically competitive environment and face a quadratic adjustment costs in changing prices á la Rotemberg (1982). Capital producers use a combination of existing capital stock and investment good purchased from retailers and abroad to produce capital. The market for capital, labor and domestic loans are competitive. The model is completed with a description of the fiscal and monetary authority.

In order to provide a rationale for monetary stabilization policy, three sources of inefficiencies are included in the model: (a) monopolistically competitive retail market; (b) sluggish price adjustment in retail sector and (c) capital adjustment costs. In addition sluggish interest rate adjustments and bank capital adjustment costs are the other sources of inefficiencies in the model. While relatively simple, the framework captures many of the rigidities which previous studies have found are important to describe the dynamics in the data and serves as a useful starting point for developing a credit and banking model for India. Figure 3.3 provides a visual representation of the

131
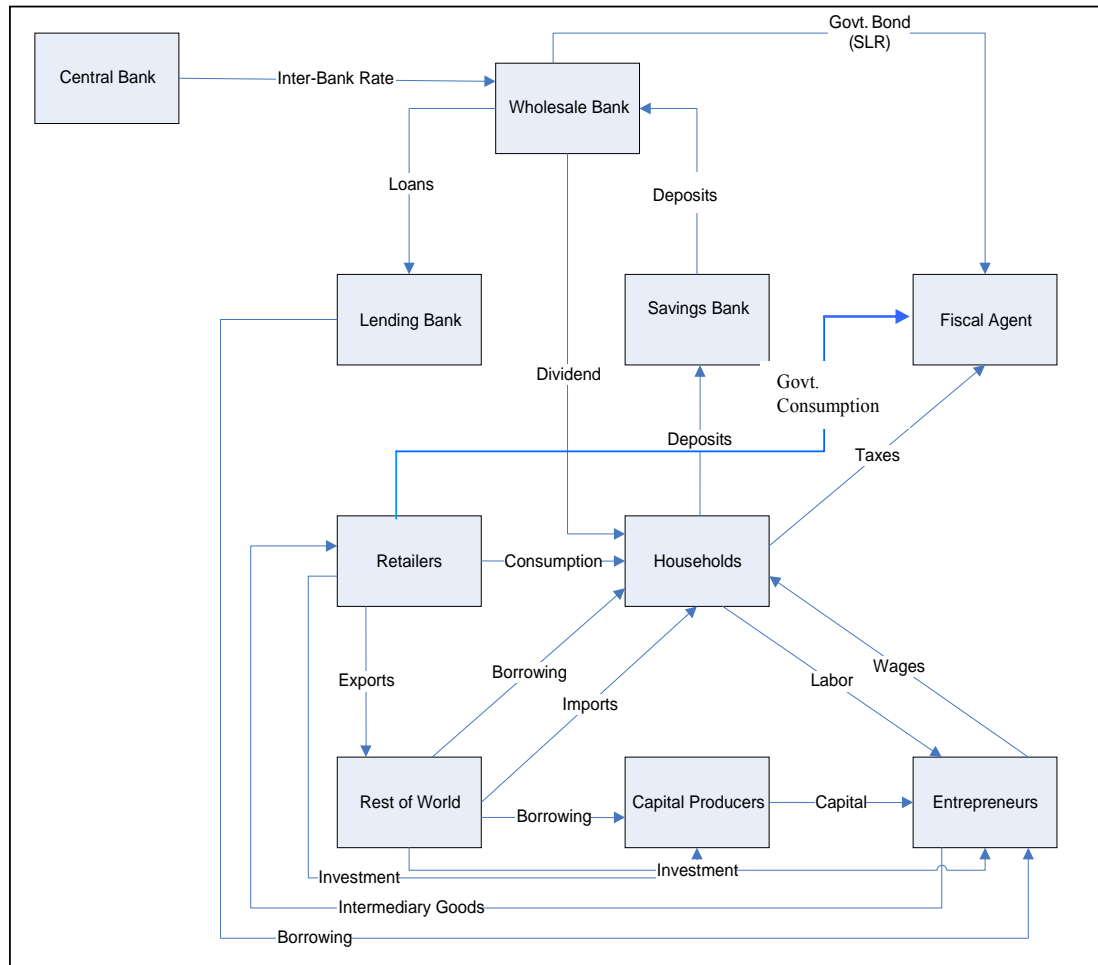
model.

Figure 3.3: Flow Chart of the Model

3.3.1 Household

The economy is populated with a continuum of infinitely lived households with preferences defined over consumption, $C_t(j)$ and labor effort $L_t(j)$. The objective of household is to maximize the expected value of a discounted sum of period utility function given by

$$E_0 \sum_{t=0}^{\infty} \beta^t U_t(C_t(j), L_t(j)) \qquad \beta \in (0,1), U' > 0, U'' < 0 \tag{1}$$

where β is the discount factor and U is a period utility function. We include the habit

persistence according to the following specification

$$U_t(C_t(j), L_t(j)) = \varsigma_{c,t}(1-b)\ln(C_t(j) - bC_{t-1}) - \frac{\varsigma_{L,t}}{\psi}L_t(j)^\psi \qquad (2)$$

where C_{t-1} is lagged aggregate consumption and $b \in (0,1)$. $\varsigma_{C,t}$ and $\varsigma_{L,t}$ are preference shocks to the marginal utility of consumption and the supply of labor respectively. Note that in symmetric steady-state $C_t(j) = C_{t-1}$, the marginal utility of consumption is independent of the habit persistence parameter b. The aggregate consumption bundle $C_t(j)$ consists of domestically produced goods, $C_{H,t}(j)$ and an imported foreign good, $C_{F,t}(j)$ and is given by

$$C_t(j) \equiv \left[\alpha^{\frac{1}{\eta}}\left(C_{H,t}(j)\right)^{\frac{\eta-1}{\eta}} + (1-\alpha)^{\frac{1}{\eta}}\left(C_{F,t}(j)\right)^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}} \qquad (3)$$

where $C_{H,t}(j)$ is an index of consumption of domestic goods given by the constant elasticity of substitution (CES) function

$$C_{H,t}(j) = \left(\int_0^1 C_{H,t}(s)^{\frac{\varepsilon_t-1}{\varepsilon_t}} ds \right)^{\frac{\varepsilon_t}{\varepsilon_t-1}} \qquad (4)$$

where $s \in [0,1]$ denotes the variety of the domestic good. Parameter $\eta \in [0,\infty]$ is the elasticity of substitution between domestic and foreign goods and $\varepsilon_t > 1$ is the elasticity of substitution between the verities produced within the country. $\alpha \in [0,1]$ can be interpreted as a measure of home bias.

We assume that households have an access to foreign financial markets or nominal contingent claims that span all relevant household specific uncertainty about future income and prices, interest rates, exchange rates and so on. As a result each household face the same intertemporal budget constraint

$$P_t C_t(j) + e_t B_{t+1}^f(j) + P_t \tau_t(j) + P_t D_t(j) = e_t B_t^f(j) i_{t-1}^f + \int_0^1 \Pi_t^r(s)ds + W_t L_t(j)$$

$$+ i_{t-1}^d P_t D_{t-1}(j) + \int_0^1 (1-\omega^b) P_t \Pi_{t-1}^b(i)di, \forall t \qquad (5)$$

Where B_t^f is the net holding of foreign currency one period bond that matures in period t, paying a gross interest rate of i_t^f. Households make deposit D_t with financial intermediary. Deposits pay the gross interest of i_t^d set by deposit banks between t and t+1. $\int_0^1 \Pi_t^r(s)ds$ represents nominal profit from the ownership of domestic retail firms and $\int_0^1 (1-\omega^b) P_t \Pi_{t-1}^b$ is the dividend earned from the ownership of banks. $(1-\omega^b)$ is the exogenously set dividend rule. τ_t is the lump sum tax in the economy and W_t is the nominal wage rate. P_t is the CPI index given by

$$P_t \equiv \left[\alpha \left(P_{H,t} \right)^{1-\eta} + + (1-\alpha) \left(P_{F,t} \right)^{1-\eta} \right]^{\frac{1}{1-\eta}} \qquad (6)$$

where $P_{H,t}$ is the domestic price index given by

$$P_{H,t} = \left(\int_0^1 P_{H,t}(s)^{1-\varepsilon_t} ds \right)^{\frac{1}{1-\varepsilon_t}} \qquad (7)$$

and $P_{F,t}$ is the price of the imported goods.[69]

Households choose the paths of $\{C_t(j), L_t(j), D_t(j), B_{t+1}(j)\}_{t=0}^{\infty}$ to maximize expected lifetime utility given by equation (1) subject to the sequence of constraints given by equation (5) and the initial value of B_t^f.

Ruling out Ponzi type schemes, we get the following first order conditions

$$\frac{(1-b)\varsigma_{C,t}}{C_t(j) - bC_{t-1}} = \lambda_t P_t \qquad (8)$$

$$\varsigma_{L,t} L_t(j)^{\psi-1} = \lambda_t W_t \qquad (9)$$

where λ_t is the lagrange multiplier associated with the budget constraint. The first order conditions are given by

---

[69] We assume that the price of imported goods is set in the same manner as the domestic prices in the exporting country i.e. the price of imports adjust sluggishly and is given by an equation similar to equation (46).

$$1 = (i_t^d)E_t\left\{\rho_{t,t+1}\frac{P_t}{P_{t+1}}\right\} \tag{10}$$

$$1 = (i_t^f)E_t\left\{\rho_{t,t+1}\frac{P_t}{P_{t+1}}\frac{e_{t+1}}{e_t}\right\} \tag{11}$$

where $\rho_{t,t+1} = \beta\dfrac{\lambda_t}{\lambda_{t+1}} = \dfrac{\varsigma_{C,t}(C_{t+1}(j)-bC_t)}{\varsigma_{C,t+1}(C_t(j)-bC_{t-1})}$ is the stochastic discount factor.

Up to a log-linear approximation equations (10) and (11) imply, $E_t \ln(e_{t+1}/e_t) \approx i_t^d - i_t^f$.

The optimum allocation of expenditure between domestic and imported goods is given by

$$C_{H,t}(j) = \alpha\left(\frac{P_{H,t}}{P_t}\right)^{-\eta}C_t(j) \tag{12}$$

$$C_{F,t}(j) = (1-\alpha)\left(\frac{P_{F,t}}{P_t}\right)^{-\eta}C_t(j) \tag{13}$$

and the demand for each variety of domestic goods is given by

$$C_{H,t}(s) = \alpha\left(\frac{P_{H,t}(s)}{P_{H,t}}\right)^{-\eta}C_{H,t}(j) \tag{14}$$

3.3.2 Banks

Banks intermediate all financial transactions between the agents in the model. We model banks as monopolistically competitive at the retail level. They hold some market power in conducting their intermediation activity, which allows them to set deposit rates and lending rates. This set up allows us to study how different degree of interest rate pass-through affects the transmission of shocks. We can think of each bank $i \in [0,1]$ in the model as composed of three parts - two retail branches and one wholesale branch. The retail branches raise differentiated deposits from the household and provide differentiated loans to entrepreneurs. The wholesale unit manages the capital position of the group and in addition raises wholesale loans and wholesale deposits in the inter-bank market.

Following Gerali et al.(2010) we assume that units of deposit and loan contracts bought by households and entrepreneurs are a composite CES basket of slightly differentiated products – each supplied by a branch of a bank i – with elasticities of substitution equal to ε_t^d and ε_t^l, respectively. We assume that each household (entrepreneur) has to purchase a deposit (loan) contract from each single bank in order to save (borrow) one unit of resources.[70] This assumption is similar to the standard Dixit-Stiglitz framework for goods markets.

Given the Dixit-Stiglitz framework, demand for an individual banks' deposit contract depends on the interest rate charged by the bank relative to the average rates in the economy and is given by

$$D_t(i) = \left(\frac{i_t^d(i)}{i_t^d}\right)^{\varepsilon_t^d} D_t \qquad (15)$$

where D_t is the aggregate demand of deposits and $i_t^d(i)$ is the deposit interest rate faced by each deposit bank $i \in [0,1]$.[71] i_t^d is the aggregate (average) deposit rate and is defined as

$$i_t^d = \left(\int_0^1 \left(i_t^d(i)\right)^{\varepsilon_t^d + 1} di\right)^{\frac{1}{\varepsilon_t^d + 1}} \qquad (16)$$

Similarly the demand for loans facing bank i is given by

$$L_t^d(i) = \left(\frac{i_t^l(i)}{i_t^l}\right)^{-\varepsilon_t^l} L_t^d \qquad (17)$$

where L_t^d is the aggregate demand of loans and $i_t^l(i)$ is the loan interest rate faced by

---

[70] Though this assumption may seem unrealistic, it is just a useful modeling device to capture the existence of market power in the banking industry. A similar approach has been adopted by Benes and Lees (2007). Arce and Andres (2009) set up a general equilibrium model featuring a finite number of imperfectly competitive banks in which the cost of banking services is increasing in customers' distance. Mandelman (2009) set up a model with segmented banking sector where collusive pricing decisions give rise to the market power.

[71] Aggregate deposit demand is given by $D_t = \left(\int_0^1 \left(D_t(i)\right)^{\frac{\varepsilon_t^d}{1+\varepsilon_t^d}} di\right)^{\frac{\varepsilon_t^d}{1+\varepsilon_t^d}}$

each lending bank $i \in [0,1]$.[72] i_t^l is the aggregate (average) lending rate and is defined as

$$i_t^l = \left(\int_0^1 \left(i_t^l(i) \right)^{1-\varepsilon_t^l} di \right)^{\frac{1}{1-\varepsilon_t^l}} \tag{18}$$

3.3.2.1 Retail Banking

Retail banking takes place in a monopolistically competitive setting. There is a continuum of two types of retail branches – deposit branch and loan branch.

3.3.2.1.1 Deposit Branch

Each deposit branch collects deposit $D_t(i)$ from households and passes it on to the wholesale branch which pays them a rate i_t^s. Also, we assume that there is a quadratic adjustment cost of intertemporally varying the deposit interest rate. This rigidity allows an interest rate spread that evolves over the cycle. We assume adjustment costs á la Rotemberg (1982), given by

$$Ad_t^{i_t^d}(i) = \frac{\phi_{i^d}}{2} \left(\frac{i_t^d(i)}{i_{t-1}^d(i)} - 1 \right)^2 D_t$$

where $\phi_{i^d} > 0$ is a cost adjustment parameter. The optimization problem of the saving bank is to choose the retail deposit interest rate $i_t^d(i)$ to maximize

$$Max E_0 \sum_{t=0}^{\infty} \beta^t \left[i_t^s D_t(i) - i_t^d(i) D_t(i) - Ad_t^{i_t^d}(i) \right]$$

subject to

$$D_t(i) = \left(\frac{i_t^d(i)}{i_t^d} \right)^{\varepsilon_t^d} D_t$$

In symmetric equilibrium, the first order condition of this optimization problem gives the optimal deposit interest rate

---

[72] Aggregate loan demand is given by $L_t^d = \left(\int_0^1 \left(L_t^d(i) \right)^{\frac{1-\varepsilon_t^l}{\varepsilon_t^l}} di \right)^{\frac{\varepsilon_t^l}{1-\varepsilon_t^l}}$

$$\frac{1+\varepsilon_t^d}{\varepsilon_t^d}i_t^d = i_t^s - \frac{\phi_{i^d}}{\varepsilon_t^d}\left(\frac{i_t^d}{i_{t-1}^d}-1\right)\frac{i_t^d}{i_{t-1}^d} + \beta\frac{\phi_{i^d}}{\varepsilon_t^d}\left(\frac{i_{t+1}^d}{i_t^d}-1\right)\frac{i_{t+1}^d}{i_t^d}\frac{D_{t+1}}{D_t} \tag{19}$$

Thus, the deposit rate is a mark down of the wholesale deposit rate and expected future gain of adjusting the deposit rate. With fully flexible rates, i_t^d is determined as a static mark-down over the wholesale deposit rate –

$$i_t^d = \frac{\varepsilon_t^d}{1+\varepsilon_t^d}i_t^s \tag{20}$$

3.3.2.1.2 Loan Branch

Each retail branch obtain wholesale loan $L_t^d(i)$ from the wholesale unit at the rate i_t^b. We assume that there is a quadratic adjustment cost of intertemporally varying the lending rate. This rigidity allows an interest rate spread that evolves over the cycle. We assume adjustment costs á la Rotemberg (1982), given by

$$Ad_t^{i^l}(i) = \frac{\phi_{i^l}}{2}\left(\frac{i_t^l(i)}{i_{t-1}^l(i)}-1\right)^2 L_t^d$$

where $\phi_{i^l} > 0$ is a cost adjustment parameter. The optimization problem of the lending bank is to choose the retail lending rate $i_t^l(i)$ to maximize

$$\max_{i_t^l} E_0 \sum_{t=0}^{\infty} \beta^t \left[i_t^l(i)L_t^d(i) - i_t^b(i)L_t^d(i) - Ad_t^{i^l}(i)\right]$$

subject to

$$L_t^d(i) = \left(\frac{i_t^l(i)}{i_t^l}\right)^{-\varepsilon_t^l} L_t^d$$

In symmetric equilibrium, the first order condition of this optimization problem gives the optimal deposit interest rate

$$i_t^l = \frac{\varepsilon_t^l}{\varepsilon_t^l-1}i_t^b - \frac{\phi_{i^l}}{\varepsilon_t^l-1}\left(\frac{i_t^l}{i_{t-1}^l}-1\right)\frac{i_t^l}{i_{t-1}^l} + \beta\frac{\phi_{i^l}}{\varepsilon_t^l-1}\left(\frac{i_{t+1}^l}{i_t^l}-1\right)\frac{i_{t+1}^l}{i_t^l}\frac{L_{t+1}^d}{L_t^d} \tag{21}$$

Thus, the lending rate is a mark up over the wholesale loan rate and expected future gain of adjusting the lending rate. With fully flexible rates, i_t^l is determined as a static mark-up over the wholesale loan rate –

$$i_t^l = \frac{\varepsilon_t^l}{\varepsilon_t^l - 1} i_t^b \qquad\qquad (22)$$

3.3.2.2 Wholesale Branch

Wholesale branch get the deposits from the deposit branch. In order to study the effect of non-traditional monetary policy interventions we introduce two such tools. We assume that wholesale branch meets the cash reserve ratio (CRR) and the statutory liquidity ratio (SLR) imposed by the central bank.[73] Central bank varies these requirements to control credit supply by changing the availability of resources available with the banks to make loans. Let α_t^s is the CRR and α_t^d is the SLR requirements. Then wholesale branch keep $\alpha_t^s D_t(i)$ in the form of cash and keep $R_t^b = \alpha_t^d D_t(i)$ in the form of government securities.[74] It earns an interest of i_t^t on the government securities. The wholesale branch combines net worth or bank capital $Z_t(i)$ with the remaining available deposit $(1 - \alpha_t^s - \alpha_t^d)D_t(i)$ and inter-bank loans, $B_t^{IB}(i)$, to make wholesale loans $L_t^d(i)$.

Since wholesale branch can finance their loans using either deposits or bank capital they have to obey a balance sheet identity

$$L_t^d(i) = (1 - \alpha_t^s - \alpha_t^d)D_t(i) + B_t^{IB}(i) + Z_t(i) \qquad\qquad (23)$$

As two sources of finance are perfect substitutes from the point of view of the balance sheet, we introduce some non-linearity (i.e. imperfect substitutability) in order to pin down the choices of the bank. We assume that there exists an (exogenously given) capital-to-assets (i.e. leverage) ratio κ^b for banks. In particular, the bank pays a quadratic cost whenever the capital-to-assets ratio ($Z_t(i)/L_t^d(i)$) moves away from κ^b. This modeling choice provides us a shortcut to study the implications and costs of

---

[73] CRR is the portion of deposits that banks are required to keep in the form of cash. SLR is the portion of bank holdings kept in the form of liquid government securities.
[74] Since CRR does not earn any profits and SLR earns a lower profit than lending in the market, banks optimally choose them at its minimum level defined by the central bank.

regulatory capital requirements and also gives bank capital a key role in determining the conditions of credit supply.

Bank capital is accumulated each period out of retained earnings according to

$$Z_t(i) = (1 - \delta^b)Z_{t-1}(i) + \omega^b \Pi^b_{t-1}(i) - m_t \qquad (24)$$

where $\Pi^b_{t-1}(i)$ is overall bank profits made by the three branches of bank i in nominal terms, $(1-\omega^b)$ summarizes the dividend policy of the bank, and δ^b measures resources used in managing bank capital and conducting overall banking intermediation activity. m_t is a mean zero shock to the bank capital. Since we assume that bank capital is accumulated out of retained earnings, the model has in-built feedback loop between the real and the financial side of the economy. As macroeconomic conditions deteriorate, banks profits are reduced, weakening their ability to raise new capital. Depending on the nature of the shock, it may result in the reduction of amount of loans banks are willing to give, thus exacerbating the original contraction.

The dividend policy is assumed to be exogenously fixed, so that bank capital is not a choice variable for the bank. The problem for wholesale branch is to choose loans $L^d_t(i)$, deposits $D_t(i)$, and interbank borrowing $B^{IB}_t(i)$ so as to maximize profits subject to the balance sheet constraint given by equation (23) and $R^b_t = \alpha^d_t D_t(i)$

$$\max_{L^d_t(i), D_t(i), B^{IB}_t(i)} E_0 \sum_{t=0}^{\infty} \beta^t \left[\begin{array}{c} i^b_t L^d_t(i) + i^t_t R^b_t(i) - i^s_t D_t(i) \\ -i_t B^{IB}_t(i) - Z_t(i) - \dfrac{\phi_z}{2}\left(\dfrac{Z_t(i)}{L^d_t(i)} - \kappa^b\right)^2 Z_t(i) \end{array} \right]$$

where i^s_t - the wholesale deposit rate and i^b_t - the wholesale loan rate are taken as given.[75] ϕ_Z is the cost of bank capital adjustment parameter. In a symmetric equilibrium, the first order condition gives

$$i^b_t = i_t - \phi_Z\left(\frac{Z_t}{L^d_t} - \kappa^b\right)\left(\frac{Z_t}{L^d_t}\right)^2 \qquad (25)$$

---

[75] Banks value the future stream of profits using the households discount factor since they are owned by households.

$$i_t^s = (1 - \alpha_t^s - \alpha_t^d)i_t + \alpha_t^d i_t^t \tag{26}$$

The above equations state a condition that links the rate on wholesale loans to the policy rate i_t and the leverage of the banking sector (Z_t/L_t^d) and wholesale deposit rate to the policy rate, t-bill rate and reserve requirements, α_t^s and α_t^d.

It highlights the role of bank capital and reserve requirements in determining the credit supply conditions. As long as there is a spread between lending and the policy rate - the bank would like to make as many loans as possible, increasing the leverage and thus profit per unit of capital. On the other hand, when leverage increases, the capital-to-asset ratio moves away from κ^b and banks pay a cost, which reduces profits. So, banks problem is to choose an optimal level of loans such that the marginal cost of reducing the capital-to-asset ratio exactly equals the spread between (wholesale) deposit and lending rate.

The spread between the wholesale lending rate and the policy rate is inversely related to the overall leverage of the banking system - in particular, when banks are scarcely capitalized and capital constraints become more binding (i.e. when leverage increases) margins become tighter.

Overall profits of bank i, are the sum of earnings from the wholesale unit and the retail branches. After deleting the intra-group transactions, profits is given by

$$\Pi_t^b(i) = i_t^l(i)L_t^d(i) - i_t^d(i)D_t(i) - Ad_t^{i_t^l} - Ad_t^{i_t^d} - \phi_Z\left(\frac{Z_t(i)}{L_t^d(i)} - \kappa^b\right)^2 Z_t(i) \tag{27}$$

3.3.3 Production Sector

3.3.3.1 Entrepreneurs

We model the behavior of entrepreneurs as proposed by Bernanke, Gertler and Gilchrist (1999). We follow the modeling framework of Gertler, Gilchrist and Natalucci (2007) and Elekdag, Justiniano and Tchakarov (2005) while introducing

financial accelerator in an open economy context. Entrepreneurs combine labor hired from households with capital purchased from the capital producers, to produce intermediate goods in a perfectly competitive setting. They are risk neutral and have a finite horizon for planning purposes. The probability that an entrepreneur will survive until the next period is v_t, so that the expected live horizon is $\frac{1}{1-v_t}$.[76]

The number of new entrepreneurs entering the market each period is equal to the number of entrepreneurs exiting, implying a stationary population. To get started, new entrepreneurs receive a small transfer of funds from exiting entrepreneurs.

At the end of each period t, entrepreneurs purchase capital K_{t+1}, to be used in the subsequent period at a price q_t. They finance capital acquisition partly through their net worth available at the end of period t, n_{t+1}, and partly through borrowing domestically and through raising foreign currency denominated debt. Total borrowing B_t is given by

$$B_t = q_t K_{t+1} - n_{t+1} \tag{28}$$

where q_t is the real price per unit of capital. Fraction of loan raised domestically B_t^d is exogenous to the model and is given by ϖ. Thus, $B_t^d = \varpi(q_t K_{t+1} - n_{t+1})$ and $B_t^a = (1-\varpi)(q_t K_{t+1} - n_{t+1})$ where B_t^a is the amount of loans raised abroad. Entrepreneurs use units of K_t capital and L_t units of labor to produce output Y_t^W, using a constant returns to scale technology

$$Y_t^W \leq \theta_t K_t^\varphi L_t^{1-\varphi}, \qquad \varphi \in (0,1) \tag{29}$$

where θ_t is a stochastic disturbance to total factor productivity. Entrepreneur maximizes profits by choosing K_t and L_t subject to the production function given by equation (29). First order conditions for this optimization problem are

---

[76] This assumption ensures that entrepreneur's net worth (the firm equity) will never be enough to fully finance the new capital acquisition.

$$W_t = (1-\varphi)P_{H,t}^W \frac{Y_t^W}{L_t} \tag{30}$$

$$r_{K,t} = \frac{P_{H,t}^W}{P_t}(\varphi)\frac{Y_t^W}{K_t} \tag{31}$$

where $P_{H,t}^W$ is the price of the wholesale good and $r_{K,t}$ is the marginal productivity of capital.[77] The expected marginal real return on capital acquired at t and used in $t+1$ yields the expected gross return $E_t(1+r_{t+1}^k)$, where

$$E_t(1+r_{t+1}^k) = E_t\left[\frac{r_{K,t+1}+(1-\delta)q_{t+1}}{q_t}\right] \tag{32}$$

and δ is the rate of depreciation of capital and $r_{K,t+1}$ is the marginal productivity of capital at $t+1$.

Following Bernanke, Gertler and Gilchrist (1999), we assume that there exists an agency problem which makes external finance more expensive than internal funds. While entrepreneurs costlessly observe their output, which is subject to random outcomes, banks can not verify output outcomes costlessly. After observing the outcome, entrepreneurs decide whether to repay their debt or to default. If they default, banks audit the loan and recover the outcome less the monitoring costs. This agency problem makes loans riskier and banks charge a premium over the lending rate. Thus, enterpreneurs' marginal external financing cost is the product of the gross premium and the gross real opportunity cost of funds that would arise in the absence of capital market frictions.

Therefore, the expected marginal cost of borrowing, $E_t f_{t+1}$ is given by

$$E_t f_{t+1} = (1+\Gamma_t)\left\{\Theta\left(\frac{n_{t+1}}{q_t K_{t+1}}\right)\varpi E_t\left[\frac{i_t^l}{\pi_{t+1}}\right] + \Theta\left(\frac{n_{t+1}}{q_t K_{t+1}}\right)(1-\varpi)E_t\left[\frac{i_t^f}{\pi_{t+1}^*}\frac{RER_{t+1}}{RER_t}\right]\right\} \tag{33}$$

$\Theta^{'} < 0$ and $\Theta(1) = 1$

where Θ is the gross finance premium which depends on the size of the borrower's

---

equity stake in the project (or, alternatively, the borrowers' leverage ratio). Γ_t is the shock to the cost of borrowing , $\pi_t = \dfrac{P_t}{P_{t-1}}$, is the gross domestic inflation

and $\pi_t^* = \dfrac{P_t^*}{P_{t-1}^*}$, is the gross world inflation. RER_t is the real exchange rate defined as

$$RER_t = \frac{e_t P_t^*}{P_t} .^{[78]}$$

We characterize the risk premium by Θ by $\left(\dfrac{n_{t+1}}{q_t K_{t+1}}\right)^{\sigma}$, where σ represents the elasticity of external finance premium with respect to a change in the leverage position of entrepreneurs. As $\left(\dfrac{n_{t+1}}{q_t K_{t+1}}\right)$ falls, entrepreneur relies on uncollateralized borrowing (higher leverage) to a larger extent to fund his project. Since this increases the incentive to misreport the outcome of the project, the loan becomes riskier and the cost of borrowing rises. Entrepreneurs' demand for capital depends on the expected marginal return and the expected cost of borrowing. Thus, demand for capital satisfies the following optimality condition

$$E_t(1+r_{t+1}^k) = (1+\Gamma_t)\left\{\Theta\left(\frac{n_{t+1}}{q_t K_{t+1}}\right)\varpi E_t\left[\frac{i_t^l}{\pi_{t+1}}\right] + \Theta\left(\frac{n_{t+1}}{q_t K_{t+1}}\right)(1-\varpi)E_t\left[\frac{i_t^f}{\pi_{t+1}^*}\frac{RER_{t+1}}{RER_t}\right]\right\} \quad (34)$$

Above equation provides the foundation for the financial accelerator. It links entrepreneurs' financial position to the marginal cost of funds and, hence to the demand for capital. Also, movements in the price of capital, q_t , may have significant effects on the leverage ratio. In this way the model captures the link between asset price movements and collateral stressed in the theory of credit cycles (Kiyotaki and Moore, 1997).[79] At the beginning of each period, entrepreneurs collect their returns on capital and honor their debt obligations. Aggregate entrepreneurial net worth evolves

---

[78] We assume that law of one price holds for each of the differentiated goods.

[79] Though the behavior described above is true for an individual entrepreneur, we appeal to the assumptions in Bernanke, Gertler and Gilchrist (1999) that permit us to write it as an aggregate condition. See Bernanke et.al. (1999) and Carlstrom and Fuerst (1997) for details. It implies that gross finance premium may be expressed as a function of aggregate leverage ratio, i.e. it is not entrepreneur specific.

according to

$$n_{t+1} = v_t V_t + (1 - v_t) H_t \tag{35}$$

where V_t is the net worth of the surviving entrepreneurs carried over from the previous period, $1 - v_t$ is the fraction of new entrepreneurs entering and H_t (which is exogenous in the model) are the transfers from exiting to newly entering entrepreneurs. V_t is given by

$$V_t = \begin{bmatrix} (1 + r_t^k) q_{t-1} K_t - (1 + \Gamma_t) \Theta \left(\dfrac{n_t}{q_{t-1} K_t} \right) \left[\dfrac{i_{t-1}^l}{\pi_t} \right] (\varpi (q_{t-1} K_t - n_t)) \\ - (1 + \Gamma_t) \Theta \left(\dfrac{n_t}{q_{t-1} K_t} \right) E_t \left[\dfrac{i_{t-1}^f}{\pi_t^*} \dfrac{RER_t}{RER_{t-1}} \right] ((1 - \varpi)(q_{t-1} K_t - n_t)) \end{bmatrix} \tag{36}$$

As equations (35) and (36) suggest, the principal source of movements in net worth stems from unanticipated movements in returns and borrowing costs. In this regard, unforecastable variations in asset prices, q_t, is the main source of fluctuations in $(1 + r_t^k)$. On the cost side, unexpected movements in inflation and exchange rates are the major sources of fluctuations in the net worth. An unexpected deflation or depreciation, for example, reduces entrepreneurial net worth, thus enhancing the financial accelerator mechanism. Entrepreneurs going out of business at time t consume and transfer some funds to new entrepreneurs out of the residual equity $(1 - v)V_t$. Thus consumption by entrepreneurs are given by

$$C_t^e = (1 - v)(V_t - H_t) \tag{37}$$

3.3.3.2 Capital Producers

Capital producers combine the existing capital stock, K_t, leased from the entrepreneurs to transform an input I_t, gross investment, into new capital K_{t+1} using a linear technology.[80] We assume that capital producers face a quadratic adjustment

---

[80] This set up follows Bernanke et al. (1999) and assumes that capital producers rent the capital stock from entrepreneurs and use it to produce new capital. Since this takes place within the period we assume that the rental rate is zero.

costs given by

$$\left(\frac{\kappa}{2}\left(\frac{I_t}{K_t}-\delta\right)^2\right)K_t.$$

where κ is the capital adjustment cost parameter. The aggregate capital stock evolves according to

$$K_{t+1}=(1-\delta)K_t+\varsigma_{I,t}I_t-\left(\frac{\kappa}{2}\left(\frac{I_t}{K_t}-\delta\right)^2\right)K_t \tag{38}$$

where $\varsigma_{I,t}$ is a shock to the marginal efficiency of investment (Greenwood et al. 1988). Gross investment consists of domestic and foreign final good and we assume that it is the same aggregation function as the consumption basket

$$I_t\equiv\left[\alpha^{\frac{1}{\eta}}\left(I_{H,t}\right)^{\frac{\eta-1}{\eta}}+(1-\alpha)^{\frac{1}{\eta}}\left(I_{F,t}\right)^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}} \tag{39}$$

Optimal demand for domestic and imported investment is given by

$$I_{H,t}=\alpha\left(\frac{P_{H,t}}{P_t}\right)^{-\eta}I_t \tag{40}$$

$$I_{F,t}=(1-\alpha)\left(\frac{P_{F,t}}{P_t}\right)^{-\eta}I_t \tag{41}$$

Price of investment is the same as the domestic price index given by equation (6). Capital producing firms maximize expected profits

$$\underset{I_t}{Max}\,E_t\left\{q_t\left[\varsigma_{I,t}I_t-\left(\frac{\kappa}{2}\left(\frac{I_t}{K_t}-\delta\right)^2\right)K_t\right]-I_t\right\}$$

and the first order condition for the supply of capital is given by

$$q_t\left[\varsigma_{I,t}-\kappa\left(\frac{I_t}{K_t}-\delta\right)\right]=1 \tag{42}$$

3.3.3.3 Retailers

There is a continuum of retailers $s\in[0,1]$. They purchase wholesale goods at a price equal to the nominal marginal costs, MC_t^W (the marginal cost in the

entrepreneurs' sector) and differentiate them at no cost.[81] They sell their product in a monopolistically competitive domestic and export market. Final domestic good, Y_t^W, is a CES composite of individual retail goods

$$Y_{H,t} = \left(\int_0^1 Y_{H,t}(s)^{\frac{\varepsilon_t-1}{\varepsilon_t}} ds \right)^{\frac{\varepsilon_t}{\varepsilon_t-1}} \tag{43}$$

Corresponding price of the composite consumption good, $P_{H,t}$, is given by equation (7). Demand facing each retailer can be written as

$$Y_{H,t}(s) = \left(\frac{P_{H,t}(s)}{P_{H,t}} \right)^{-\varepsilon_t} Y_{H,t} \tag{44}$$

For simplicity we assume that the aggregate export demand function is given by

$$Q_t^X = \left(\frac{P_{X,t}}{P_t^*} \right)^{-\zeta_t}, \zeta_t > 0 \tag{45}$$

where $P_{X,t} = eP_{H,t}$ is the price of exports, P_t^* is the world price index and Q_t^X is the total exports. ζ_t, is the price elasticity of exports.

3.3.3.4 Price Setting by Retailers

Following Ireland (2001) and Rotemberg (1982), there is sluggish price adjustment to make the intermediate goods pricing decision dynamic. This ensures that monetary policy has real effects on the economy. Following Julliard et al. (2004), we assume that retailers face an explicit cost of price adjustment measured in terms of intermediate goods and is given by

$$\frac{\vartheta_d}{2} \left[\frac{P_{H,t}(s)/P_{H,t-1}(s)}{\pi} - 1 \right]^2 (Q_t^d + Q_t^X)$$

where Q_t^d is the total domestic demand, $\vartheta_d \geq 0$ is the parameter determining the cost of

---

[81] Entrepreneurs sell their goods in a perfectly competitive market so $P_{H,t}^W = MC_t^W$. Retail sector is defined only to introduce nominal rigidity into the economy. Since they differentiate goods costlessly, the marginal cost of producing final goods is same as MC_t^W.

price adjustment relative to last period's price level and π is the steady state inflation. Following Saxegaard (2006b), real profits are given by

$$\Pi_t^r\left[P_{H,t}(s), P_{x,t}(s)\right] = \left[\frac{P_{H,t}(s)}{P_t} - \frac{MC_t^W}{P_t}\right]\left[\frac{P_{H,t}(s)}{P_{H,t}}\right]^{-\varepsilon} Q_t^d + \left[\frac{e_t P_{X,t}(s)}{P_t} - \frac{MC_t^W}{P_t}\right]\left[\frac{P_{X,t}(s)}{P_{X,t}}\right]^{-\varepsilon} Q_t^x$$

$$-\frac{\vartheta_d}{2}\left[\frac{P_{H,t}(s)/P_{H,t-1}(s)}{\pi} - 1\right]^2 (Q_t^d + Q_t^x)$$

where e_t is the nominal exchange rate, expressed as the domestic currency price of foreign currency.[82] Note also that we allow for a shock to the elasticity of substitution between differentiated goods ε_t, which determines the size of the markup of intermediate good firms. Alternatively, the shock to ε_t can be interpreted as a cost-push shock of the kind introduced into the New Keynesian model by Clarida, Gali and Gertler (1999).

The optimal price setting equation for domestic good (non-tradable good) can then be written as[83]

$$P_{H,t} = \frac{\varepsilon_t}{\varepsilon_t - 1} MC_t^W - \frac{\vartheta_d}{\varepsilon_t - 1} P_t \frac{\pi_{H,t}}{\pi}\left[\frac{\pi_{H,t}}{\pi} - 1\right]$$

$$+ \frac{\vartheta_d}{\varepsilon_t - 1} P_t E_t\left\{\rho_{t,t+1} \frac{Y_{H,t+1}}{Y_{H,t}} \frac{\pi_{H,t+1}}{\pi}\left[\frac{\pi_{H,t+1}}{\pi} - 1\right]\right\} \qquad (46)$$

where $\pi_{H,t} = P_{H,t}/P_{H,t-1}$, is the domestic price inflation.
We have used the fact that all retailer firms are alike to impose symmetry and we assume that the law of one price holds in the export market so that $P_{X,t} = P_{H,t}/e_t$. Above equation reduces to the well known result that prices are set as a markup over marginal costs if the cost of price adjustment, $\vartheta_d = 0$. In general however, the goods price will follow a dynamic process and the firm's actual markup will differ from, but

---

[82] An increase in e_t implies depreciation of the domestic currency.

[83] We assume that price of imported goods are set in the similar function. So the price setting equation for the price of imported good is given by a similar expression with
$\pi_{M,t}$, import price inflation, in place of $\pi_{H,t}$ and ϑ_m in place of ϑ_d.

gravitate towards the desired markup. Profits from retail activity are rebated lump-sum to households (i.e. households are the ultimate owners of retail outlets).

3.3.4 Central Bank and Government

3.3.4.1 Central Bank

We assume that the central bank adjusts the interbank rate, i_t in response to deviations in inflation and output from their steady state values. The monetary policy evolves according to the following Taylor-type-policy rule

$$\log\left(\frac{i_t}{i}\right) = \rho_i \log\left(\frac{i_{t-1}}{i}\right) + \rho_Y \log\left(\frac{Y_t}{Y}\right) + \rho_\pi \log\left(\frac{\pi_t}{\pi}\right) + \varepsilon_{i,t} \tag{47}$$

where ρ_π and ρ_Y are the weights on inflation and output gap assigned by the policy makers.[84] ρ_i represents the Central Banker's preference for interest rate smoothing. Y, π and i are the steady state values of output, inflation and nominal interest rate. $\varepsilon_{i,t}$ is a monetary policy shock to capture unanticipated increase in the nominal interest rate.

3.3.4.2 Government

The fiscal authority is assumed to purchase an exogenous stream of the final good G_t, which is financed by a levying lump-sum tax on households, and issuing securities held by the banks. For simplicity we assume that the fiscal authority has no access to international capital markets. Its period by period budget constraint is given by

---

[84] We include an interest rate smoothing parameter in our monetary policy rule as the benefits of such smoothing are well documented in the literature (see, e.g., Lowe and Ellis, 1997; Sack and Wieland, 1999). Various authors have argued that moving interest rates in small steps increases its impact on the long-term interest rate; it also reduces the risks of policy mistakes and prevents large capital losses and systemic financial risks. Mohanty and Klau (2004) find that all emerging market central banks put substantial weight on interest rate smoothing. Clarida et al. (1998) find that central banks of advanced economies also put a large weight on interest rate smoothing.

$$G_t + \left(\frac{1 + i_{t-1}^t}{\Pi_t} \right) R_{t-1}^b = \tau_t + R_t^b \tag{48}$$

Government buys both domestic and foreign final goods and we assume that it is the same aggregate function as the consumption basket

$$G_t \equiv \left[\alpha^{\frac{1}{\eta}} \left(G_{H,t} \right)^{\frac{\eta-1}{\eta}} + (1-\alpha)^{\frac{1}{\eta}} \left(G_{F,t} \right)^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}} \tag{49}$$

Optimal demand for governments' domestic and imported consumption is given by

$$G_{H,t} = \alpha \left(\frac{P_{H,t}}{P_t} \right)^{-\eta} G_t \tag{50}$$

$$G_{F,t} = (1-\alpha) \left(\frac{P_{F,t}}{P_t} \right)^{-\eta} G_t \tag{51}$$

3.3.5 Market Clearing and Aggregation

Domestic households, exiting entrepreneurs, capital producers, government and rest of the world buy final goods from retailers. The economy wide resource constraint is given by[85]

$$Y_{H,t} = C_{H,t} + C_{H,t}^e + I_{H,t} + G_{H,t} + Q_t^X = Q_t^d + Q_t^X \tag{52}$$

where

$$Q_t^d = C_{H,t} + C_{H,t}^e + I_{H,t} + G_{H,t} \tag{53}$$

The national income accounting equation is given by

$$P_t * ZZ_t = P_t (C_t + C_t^e + I_t + G_t) + P_{X,t} Q_t^X - P_{F,t} Q_t^M + \frac{\vartheta_d}{2} \left[\frac{P_{H,t}/P_{H,t-1}}{\Pi} - 1 \right]^2 P_{H,t} Y_{H,t}$$

where Q_t^M is the total imports and ZZ_t is the real GDP.

Markets for loan and deposits clear –

$$D_t = L_t^d = B_t^d \tag{54}$$

Funds in the inter-bank market mush implicitly balance at the end of each period:

---

[85] Following Bernanke et al. (1999) we ignore monitoring costs in the general equilibrium.

$$\int_0^1 B_t^{IB}(i)di = B_t^{IB} = 0 \qquad (55)$$

The model allows for non-zero holdings of foreign currency bonds by households and foreign currency denominated debt by entrepreneurs. In particular, it is well known (see inter alia Schimtt-Grohe and Uribe, 2003) that unless adjustments are made to the standard model, the steady state of an small open-economy model with foreign currency bonds will depend upon initial conditions and will display dynamics with random walk properties. In particular, if the domestic discount rate exceeds the real rate of return on foreign currency bonds, then domestic holdings of foreign currency bonds will increase perpetually. Beyond the obvious conceptual problems of such an outcome our analysis is constrained by the fact that the available techniques used to solve non-linear business cycle models of the type considered here are only valid locally around a stationary path.

Fortunately, a number of modifications to the standard model are available which enable us to overcome this issue. In this paper, we follow Schmitt-Grohe and Uribe (2003) and specify a foreign debt elastic risk-premium whereby holders of foreign debt are assumed to face an interest rate that is increasing in the country's net foreign debt. In particular, i_t^f, the interest rate at which households and entrepreneurs can borrow foreign currency equals the exogenous world interest rate plus a spread that is a decreasing function of economy's net foreign asset position:

$$i_t^f = i_t^* - \chi_d \left[\left(\left(B_t^f + L_t^f \right) \middle/ P^* - \vartheta_t \right) - \left(\left(B^f + L^f \right) \middle/ P^* - \vartheta \right) \right] \middle/ \Omega \qquad (56)$$

where χ_d is a parameter which captures the degree of capital mobility in the market for foreign-currency borrowing and lending by households and Ω is the steady-state value of exports. As in Schmitt-Grohe and Uribe (2003) we include the steady-state level of debt so that the risk-premium is nil in steady state. Note that under perfect capital mobility (χ_d=0), the country would face an infinite supply or demand of

foreign capital and the model would not have a well-defined steady state. As Kollmann (2002) points out, the model in this case becomes a version of the permanent income theory of consumption, with non-stationary consumption and net assets.

3.3.6 Specification of the Stochastic Processes

Our model includes fifteen structural shocks: three shocks to technology and preferences ($\theta_t, \varsigma_{C,t}, \varsigma_{L,t}$), three foreign shocks to world interest rates, world inflation, and the price elasticity of exports (π^*_t, i^*_t, ζ_t), two shocks to investment efficiency and firms' markup ($\varsigma_{I,t}, \varepsilon_t$), two financial shocks to the cost of borrowing by entrepreneurs and the survival rate of entrepreneurs (Γ_t, ν_t), a monetary policy shock, a government spending shock ($\varepsilon_{i,t}, G_t$), a shock to CRR (α^s_t), a shock to SLR(α^d_t) and a shock to back capital (m_t). Apart from monetary policy shock, ε_i, which is a zero mean i.i.d. shock with a standard deviation σ_i, the other structural shocks follow AR(1) processes:

$$x_t = (1 - \rho_x)x + \rho_x x_{t-1} + \varepsilon_{xt} \tag{57}$$

where $x_t = \{\theta_t, \varsigma_{C,t}, \varsigma_{L,t}, \pi^*_t, i^*_t, \zeta_t, G_t, \Gamma_t, \varepsilon_t, \varsigma_{I,t}, \alpha^s_t, \alpha^d_t, \nu_t, m_t\}$, $x \geq 0$ is the steady-state value of x_t, $\rho_x \in (-1,1)$, and ε_{xt} is normally distributed with zero mean and standard deviation σ_{xt}.

3.3.7 Calibration

Parameter selection for the model is a challenging task. There is no consensus on the values of some parameters, and for the banking parameters no corresponding estimates are available in the literature. Moreover, most of the parameters used in the literature are based on micro data from advanced countries. Hence, our approach is three pronged. We calibrate the parameters in the model that determine the steady state based on findings from previous studies and the data. For calibrating the

parameters which determine the dynamic properties of the model away from the steady state we use the values estimated in Anand et al (2010) for the Indian economy. While for banking sector parameters we calibrate them to match historical averages. Parameters are calibrated to capture features of Indian economy for the period of 1996Q2 - 2007Q4.

The discount factor β, is set to 0.9964 to match the historical average of nominal deposit interest rate. The appropriate value of the Frisch elasticity ($1/\psi$) is both important and controversial. The range of values used in the literature goes from 0.25 to 1.[86] For our benchmark case we assume it to be 0.66 (ψ=1.5). The substitution elasticity between imported and domestically produced goods is set at 1.5 (Saxegaard, 2006a), while the elasticity of substitution of exports, ζ, is set to 4.89, a value consistent with the steady state export to GDP ratio. With the share of non-tradables in the WPI, α, set at 0.8, this corresponds to a steady state export to GDP ratio of 19 percent and a steady state import to GDP ratio of 21 percent. The share of government expenditure in GDP is set at 11 percent as in the data. The capital share in the production φ and the capital depreciation rate, δ, are set to 0.33 and 0.025, respectively; values commonly used in the literature. The steady-state markup factor is set to 9 percent so that ε=12. Share of domestic loans to total loans, ϖ, is set to 0.8 (IMF country report, 2009).

We set the steady-state annual nominal interest rate at 7.4 percent which corresponds to the annualized average quarterly rate of bank rate for the period we have data on. Similarly, steady-state inflation is set equal to 4.5 percent which corresponds to the average seasonally adjusted quarterly WPI inflation over the period on an annualized basis. We set world inflation equal to 2.5 percent on an annual basis

---

[86] Christiano, Eichenbaum and Evans (1996) estimate it to be 0.25 while Rotemberg and Woodford (1997) estimate it to be 0.40. Blundell and MaCurdy (1999) estimate the intertemporal elasticity of labor supply to be in the range of [0.5, 1].

which implies a steady-state depreciation rate of the nominal exchange rate of 2 percent on an annual basis and a world interest rate of 5 percent per annum.

Following Christensen and Dib (2006), the steady state leverage ratio of entrepreneurs, *K/N*, is set to 0.5. The probability of entrepreneurial survival to next period, ν, is set at 0.98. Following Anand et al. (2010) we set elasticity of external finance premium with respect to firm leverage σ equal to 0.0566.[87]

For calibrating parameters which determine the dynamic properties of the model we follow the estimates of Anand et al. (2010). The habit persistence parameter, *b*, is set to 0.4986. Price adjustment costs of domestic goods and price adjustment costs of imported goods are set to 118.22 and 100.043 respectively. Capital cost adjustment cost is set equal to 23.008. Monetary policy parameters are chosen as $\rho_i = 0.8$, $\rho_\pi = 2$, $\rho_Y = 0.01$ which are in the range of values commonly used in the literature.

For the banking parameters, no corresponding estimates are available in the literature. The parameters ε^d and ε^l that measure the degree of monopoly power of deposit and lending banks are set equal to 31.12 and 2.51, respectively. These values are chosen to match the historical averages of deposit and loan rates, i^d and i^l. The parameter δ^b is set at the value 0.035, that ensures that the steady state value ratio of bank capital to total loans is exactly 0.09.[88] We follow the estimates of Gerali et al (2010) for setting the adjustment cost parameters for interest rates and bank capital to loan ratio. Cost of adjusting interest rates, ϕ_{i^d} and ϕ_{i^l} are set equal to 20 while the cost of bank capital adjustment, ϕ_Z is set equal to 10. Table 3.3- Table 3.5 shows a full set of calibrated parameter values and the steady state ratios.

---

[87] This is slightly below the estimate of 0.066 for Korea in Elekdag et al. (2005) and somewhat higher than estimate in Dib et al. (2008) for Canada.
[88] Steady state capital to loan ratio is set to 0.09 which is consistent with the regulatory capital requirements for banks (slightly higher than imposed by Basel II).

Table 3.3: Parameter Calibration: Based on Literature and Data

Parameters	Definitions	Values
β	Subjective discount factor	0.9964
ψ	Inverse of Frisch elasticity	1.5
η	Price elasticity of non-tradable and imports	1.5
ε	Elasticity of substitution between different domestic goods	12
α	Share of non-tradable in CPI	0.8
ζ	Price elasticity of exports	4.89
φ	Share of capital in production	0.33
δ	Quarterly depreciation rate of capital	0.025
ϖ	Share of domestic loans in total loans	0.8
ν	Probability of entrepreneurial survival	0.98
H	Transfer from exiting to new entrepreneurs	0.01

Table 3.4: Parameter Calibration: Based on Parameter Estimation

Parameters	Definitions	Values
b	Habit persistence parameter	0.50
σ	Elasticity of external finance premium	0.057
ϑ_d	Cost of domestic goods price adjustment	118.22
ϑ_m	Cost of imported goods price adjustment	100.04
κ	Capital adjustment cost	23.00
ε^d	Elasticity of substitution between different type of deposits	31.12
ε^l	Elasticity of substitution between different type of loans	2.51
ϕ_{i^d}	Deposit rate adjustment cost	20
ϕ_{i^l}	Lending rate adjustment cost	20
ϕ_Z	Bank capital to loan ratio adjustment cost	10
ρ_i	Weight on interest smoothing in Taylor rule	0.8
ρ_π	Weight on inflation gap in Taylor rule	2
ρ_Y	Weight on output gap in Taylor rule	0.01
χ_d	Degree of capital mobility	0.002

Table 3.5: Steady-State Values and Ratios

Steady-state values

Parameters	Definitions	Values
π	Domestic inflation	$1.045^{1/4}$
π^*	World inflation	$1.025^{1/4}$
i	Policy rate	$1.074^{1/4}$
i^d	Deposit rate	$1.06^{1/4}$
i^l	Lending rate	$1.125^{1/4}$
i^t	Government t-bill rate	$1.07^{1/4}$
i^*	World interest rate	$1.05^{1/4}$
e	Nominal exchange rate depreciation	2 %
α^s	Cash reserve ratio (CRR)	0.07
α^d	Statutory liquidity ratio (SLR)	0.25
$1-\omega^b$	Bank dividend paid to households	0.8
δ^b	Cost of running banks	0.035
κ^b	Bank capital to asset ratio	0.09

Steady-state ratios

Variables	Definitions	Values
G/Y	Government spending to GDP	0.11
Q^X/Y	Exports to GDP	0.19
Q^M/Y	Import to GDP	0.21
K/N	Capital to entrepreneurs' net worth	2
Z/L	Bank capital to loan	0.09

We calibrate the shocks' process parameters using values estimated in Anand et al. (2010). The parameter of credit tightening process is calibrated using the estimated values in Gerali et al. (2010). Since there are no parameter estimates available in

literature on non-monetary policy interventions, we choose the values of AR(1)

coefficients at 0.99.[89] Calibrated values of shock processes are presented in Table 3.6.

Table 3.6: Parameter Calibration: Stochastic Processes

Parameters	Definition	Steady-state value	Persistence	Standard Deviation
θ_t	Productivity	1	$\rho_\theta = 0.808$	$\sigma_\theta = 0.010$
$\varsigma_{C,t}$	Preference shock to marginal utility of consumption	1	$\rho_{\varsigma_C} = 0.810$	$\sigma_{\varsigma_C} = 0.015$
$\varsigma_{L,t}$	Preference shock to marginal utility of labor	1	$\rho_{\varsigma_L} = 0.806$	$\sigma_{\varsigma_L} = 0.010$
π_t^*	World inflation	$1.025^{1/4}$	$\rho_{\pi^*} = 0.785$	$\sigma_{\pi^*} = 0.001$
i_t^*	World interest rate	$1.05^{1/4}$	$\rho_{i^*} = 0.831$	$\sigma_{i^*} = 0.001$
ζ_t	Export elasticity shock	2.4	$\rho_\zeta = 0.857$	$\sigma_\zeta = 0.320$
G_t	Government spending	0.264	$\rho_G = 0.640$	$\sigma_G = 0.068$
ε_t	Mark up shock	12	$\rho_{\varepsilon_t} = 0.860$	$\sigma_{\varepsilon_t} = 1.198$
$\varsigma_{I,t}$	Investment efficiency	1	$\rho_{\varsigma_I} = 0.785$	$\sigma_{\varsigma_I} = 0.048$
α_t^s	Cash reserve ratio	0.07	$\rho_{\alpha^s} = 0.950$	$\sigma_{\alpha^s} = 0.005$
α_t^d	Statutory liquidity ratio	0.25	$\rho_{\alpha^d} = 0.950$	$\sigma_{\alpha^d} = 0.005$
$\varepsilon_{i,t}$	Monetary policy shock			$\sigma_i = 0.010$
v_t	Survival rate of entrepreneurs	0.98	$\rho_v = 0.805$	$\sigma_v = 0.002$
Γ_t	Cost of borrowing	0	$\rho_\Gamma = 0.809$	$\sigma_\Gamma = 0.002$
m_t	Bank capital shock	0	$\rho_m = 0.750$	$\sigma_m = 0.030$

---

[89] We do a simple OLS to get this co-efficient.

3.4 Impulse Response

The objective of this paper is to study the monetary transmission mechanism in the presence of financial frictions and financial intermediation. We are also interested in understanding how shocks in the financial sectors are transmitted to the real economy and to study the transmission mechanism of non-standard monetary policy policies.

In comparison to traditional DSGE models, our model has two additional channels for the transmission of shocks – the financial accelerator channel (credit demand channel) and the banking channel (credit supply channel). Our aim is to study how these channels affect the transmission of shocks.

A useful way to illustrate the importance of financial accelerator is to consider the impulse response functions when the financial accelerator is present and when it is not. Therefore, we analyze the impulse responses of key macroeconomic variables to the structural shocks in two models: (1) the full model with banking sector and financial frictions (baseline hereafter), and (2) a model with only banking sector (no-FA model, hereafter).[90]

In order to understand the role of banking sector, we compare our baseline model against a number of models where we shut down one feature of the model at a time: (1) a model where we shut down the bank capital channel; i.e. a model with a simplified balance-sheet for banks, including only deposits on the liability side (no-BK model, hereafter)[91]; (2) a model where we also remove stickiness in bank interest rate setting and allow for flexible rates (no-BK-FR model, hereafter)[92]; and (3) a

---

[90] no-FA model is obtained by setting the elasticity of the external finance premium with respect to firm leverage , σ equal to zero, but keeping all other parameters same as in the baseline model.

[91] To obtain no-BK model, we set the cost of bank capital adjustment, ϕ_Z equal to zero and rebate the banking profit to households in a lump-sum fashion.

[92] To get the no-BK-FR model, we set the costs to change rates ϕ_{i^d} and ϕ_{i^l} equal to zero in the no-BK model model.

model with perfectly competitive banks, i.e. a single interest rate model with financial frictions (no-B model, hereafter). [93] Strictly speaking even though we can not compare the impulse responses of our baseline model with that of no-B model, it is instructive to plot them to understand how the presence of banks affect the business cycle.

We use monetary policy shock and productivity shock to explore the effects of financial frictions and financial intermediation on the transmission of shocks. We then look at a shock to bank capital (which can be considered as reflecting tightening credit conditions) to understand how shocks originating in the credit market affect real variables. To analyze non-standard monetary policy transmission mechanism we focus on shocks to cash reserve ratio and shocks to the statutory liquidity ratio.

3.4.1 Monetary Policy Shock

The transmission of monetary shock is studied by analyzing the impulse responses to a 100 bps increase in the policy rate (i_t). Due to the presence of multiple channels, the overall effect on the transmission mechanism of monetary policy could in principle be ambiguous (Gerali et al. 2010). In order to understand the importance of financial frictions we plot the responses of baseline and no-FA model in Figure 3.4. Figure 3.5 plots the responses of baseline, no-BK, no-BK-FR and no-B model to see how the presence of banking sector impinges on the transmission of shock. Each variable's response is expressed as the percentage deviation from its steady state, with the exception of rate variables, which are in percentage points.

In all these models, increase in the nominal interest rate raises the cost of domestic borrowing for consumers and therefore leads to a contraction in consumption. It also

---

[93] We set $\alpha^s = \alpha^d = 0$ in the no-BK-FR model. Then we set the elasticities of loan and deposit, ε^l and ε^d equal to infinity. The steady state values of the two models differ as the effective lending rate and deposit rate faced by the agents are not the same. Also, absence of banks implies that there is no CRR or SLR requirement.

raises the demand for domestic bonds, and thus appreciates the domestic currency, while the net worth of entrepreneurs declines because of the declining return to capital and higher real interest costs associated with existing debt (debt-deflation effect). Output contracts both as a result of decreased domestic demand and a result of decreased competitiveness following the appreciation of the real exchange rate. The contraction in demand in turn leads to a fall in inflation. In the baseline model, bank loan rates and deposit rates increase less than the policy rate reflecting the imperfect pass-through of lending rates.

As evident from Figure 3.4, presence of financial frictions results in the amplification of the shock. Reduction in output, consumption, investment, net worth and capital is much larger under the baseline model as compared to the no-FA model. In the presence of a financial accelerator, the external finance premium increases as a result of the decline in the net worth and rising leverage. This pushes up the real borrowing cost for entrepreneurs, putting downward pressure on investment and the price of capital which further reduces the net worth. This reduction in net worth leads to a further increase in the cost of borrowing (the premium goes up), thus reducing capital, investment and output further (second round effects). This mechanism amplifies the magnitude and the persistence of transitory monetary policy shocks as evident from the impulse responses.
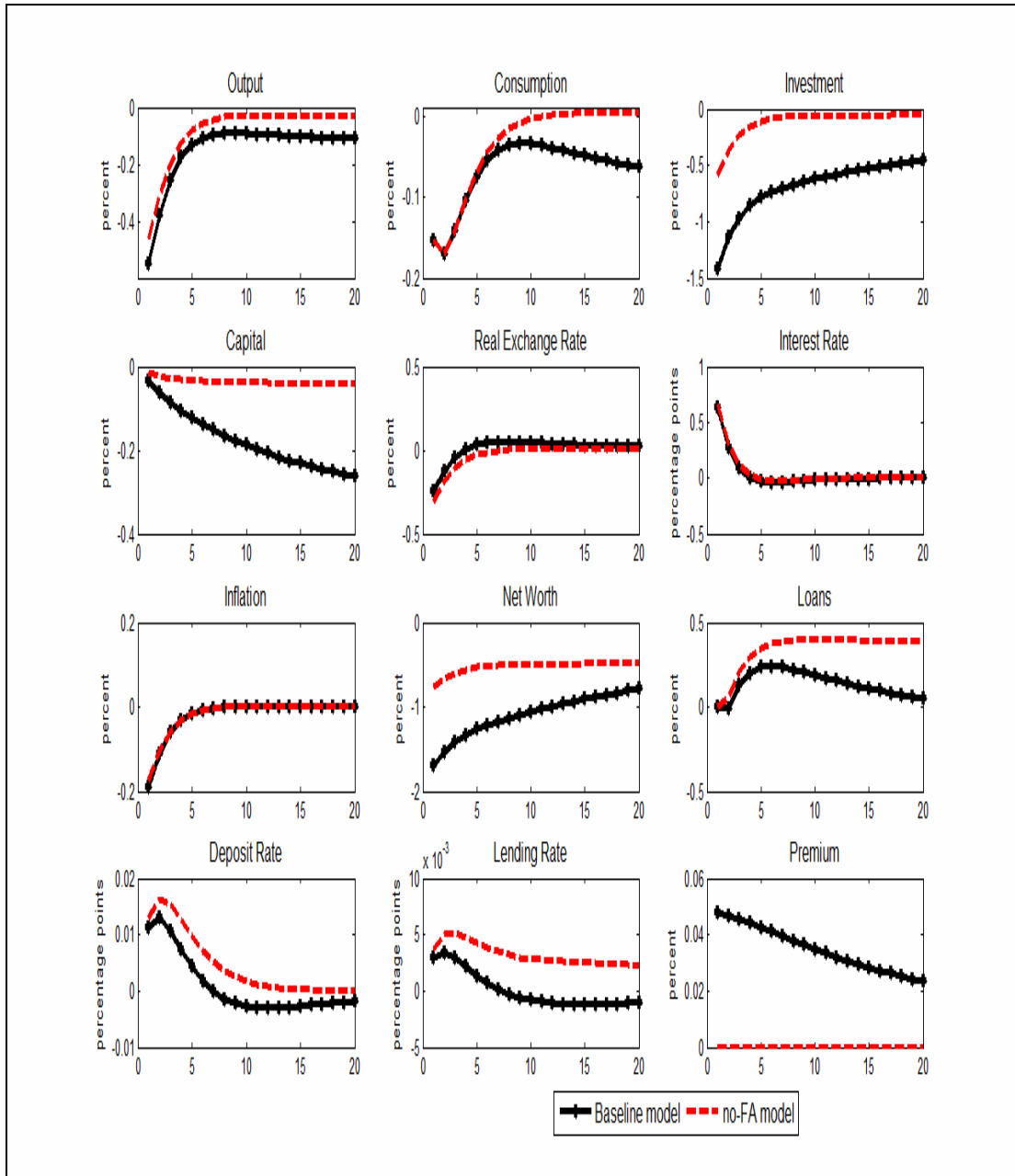
Figure 3.4: Impulse Responses to 100 Bps Contractionary Monetary Policy Shock (Baseline model and no-FA model)
Each variable's response is expressed as the percentage deviation from its steady state level. Interest rates are shown as absolute deviation from steady state. Baseline model represents the complete model with financial frictions and banking sector. no-FA model is obtained by setting the elasticity of the external finance premium with respect to firm leverage , σ equal to zero, but keeping all other parameters same as in the baseline model. So it represents a model without financial frictions.

Figure 3.5 gives an indication of how the presence of banking sector may affect the transmission of monetary shock. Comparing no-B model with no-BK-FR model highlights the role of imperfect competition in the credit market.[94] As we can see, market power of banking system increases the volatility of real variables. Market power of banks result in higher lending rates (as lending rate is a mark-up over the policy rate) increasing the cost of borrowing for the firms. Due to financial accelerator, external finance premium goes up, reducing the net worth further and forcing the firms to borrow more from banks at an increasingly higher cost. This mechanism results in the amplification of the monetary shock. Our result is similar to Mandelman (2009), where market power of banks result in the amplification of the shocks.

However, when we compare the baseline model with no-B model, we find that the presence of banking sector attenuates the response of monetary shock. This result is driven by the stickiness in interest rate setting, which prevents banks to fully pass on the policy rate increase to retail rates. Borrowing costs faced by the firms is lower than no-B case and therefore response of output, investment and capital is muted. Thus, the presence of banking sector with sticky interest rates has a dampening effect of policy shock on output, investment, capital and net worth. Gerali et al. (2010) has also found similar attenuating effect of the banking system in the presence of sticky bank rates.

---

[94] As no-BK-FR model add a simplified banking sector to the no-B model. In no-BK-FR model, only bank's market power channel is present (as both the bank capital channel and sticky interest rates channel are shut).

Figure 3.5: Impulse Responses to 100 Bps Contractionary Monetary Policy Shock (Baseline model, no-BK model, no-BK-FR model and no-B model).
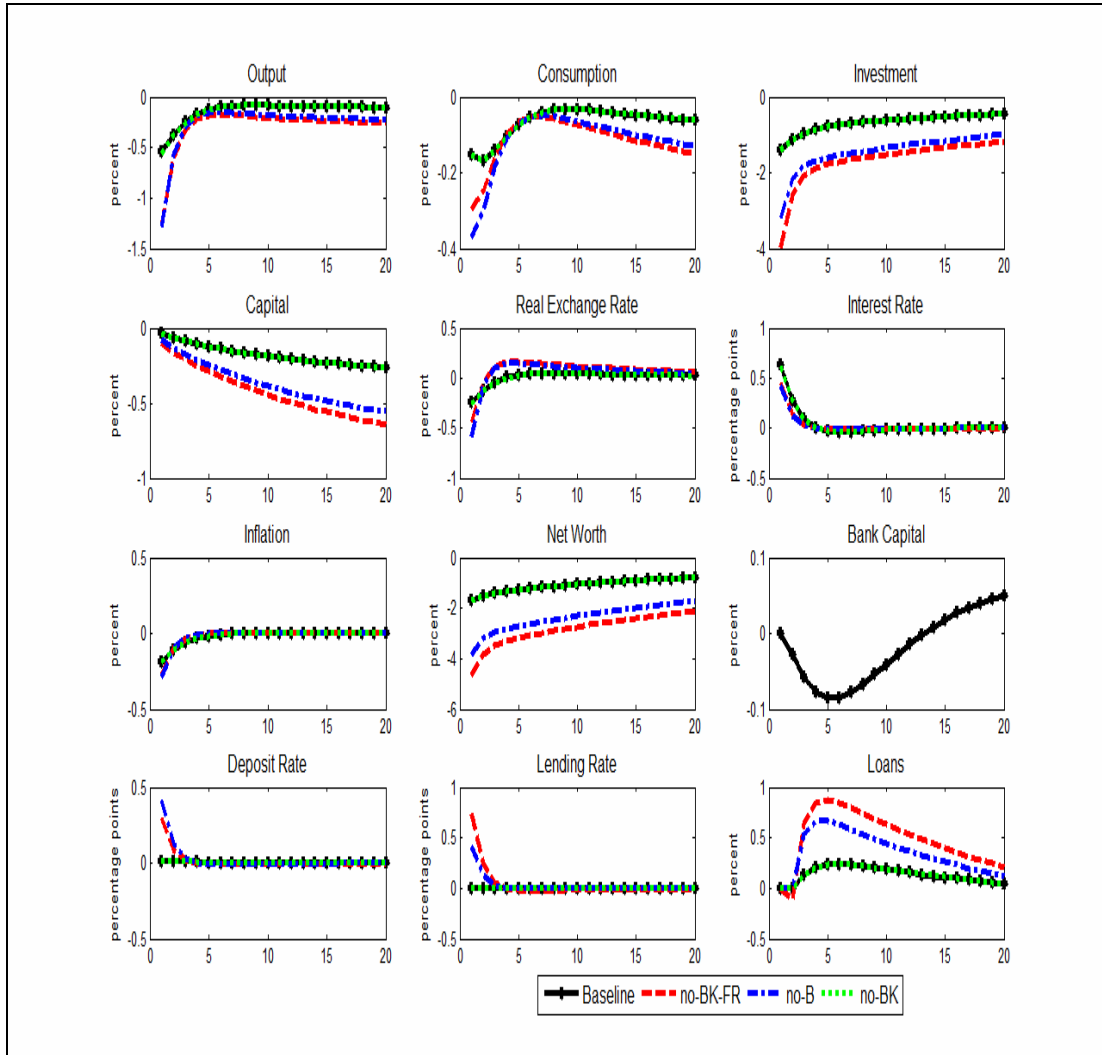Each variable's response is expressed as the percentage deviation from its steady state level. Interest rates are shown as absolute deviation from steady state. Baseline model represents the complete model with financial frictions and banking sector. In no-BK model we shut down the bank capital channel. We set the cost of bank capital adjustment, ϕ_Z equal to zero and rebate the banking profit to households in a lump-sum fashion. no-BK-FR model, also shuts down the sticky interest rate channel. It is obtained by setting ϕ_{i^d} and ϕ_{i^l} equal to zero in the no-BK model model. To obtain no-B model, we set $\alpha^s = \alpha^d = 0$ and the elasticities of loan and deposit, ε^l and ε^d equal to infinity. no-B model is a single interest rate model with financial frictions but no banking sector. The steady state values of the two models differ as the effective lending rate and deposit rate faced by the agents are not the same. Since the steady-state under the two models is different, this plot is only instructive.

Presence of bank capital in our model seems to have virtually no effect on the dynamics of the real variables. This partly reflects the use of rather small value of the capital cost adjustment parameter in this exercise. As an example, our calibration implies that a reduction of the capital-to-asset ratio by half (from its steady state value of 9%) would increase the spread between wholesale loan rates and the policy rate by only 20 basis points.

3.4.2 Technology Shock

The transmission of a technology shock is studied by looking at the impulse responses coming from the same set of models described in the pervious subsection. Figure 3.6 plots the responses of baseline and noFA model. Figure 3.7 plots the responses of baseline, no-B and no-BK-FR model to see how the presence of banking sector impinges on the transmission of shock.[95] Each variable's response is expressed as the percentage deviation from its steady state, with the exception of rate variables, which are in percentage points.

In all these models, negative technology shock decreases the return to capital and thus leads to decrease in investment and output. At the same time, negative productivity shock increases firms' marginal costs and thus increases inflation. The lower return to capital, and higher inflation, has opposite effects on net worth, but in our model the negative impact of the lower capital return to capital dominates. Higher inflation and domestic interest rates result in real appreciation thereby decreasing the demand for exports, which lead to further output contraction. Monetary policy accommodates the increase in inflation by raising the policy rate, and therefore decreasing loans, aggregate demand and output.

---

[95] Similar to monetary policy shock, bank capital have virtually no effect on real variables, so we do not present the impulse responses.
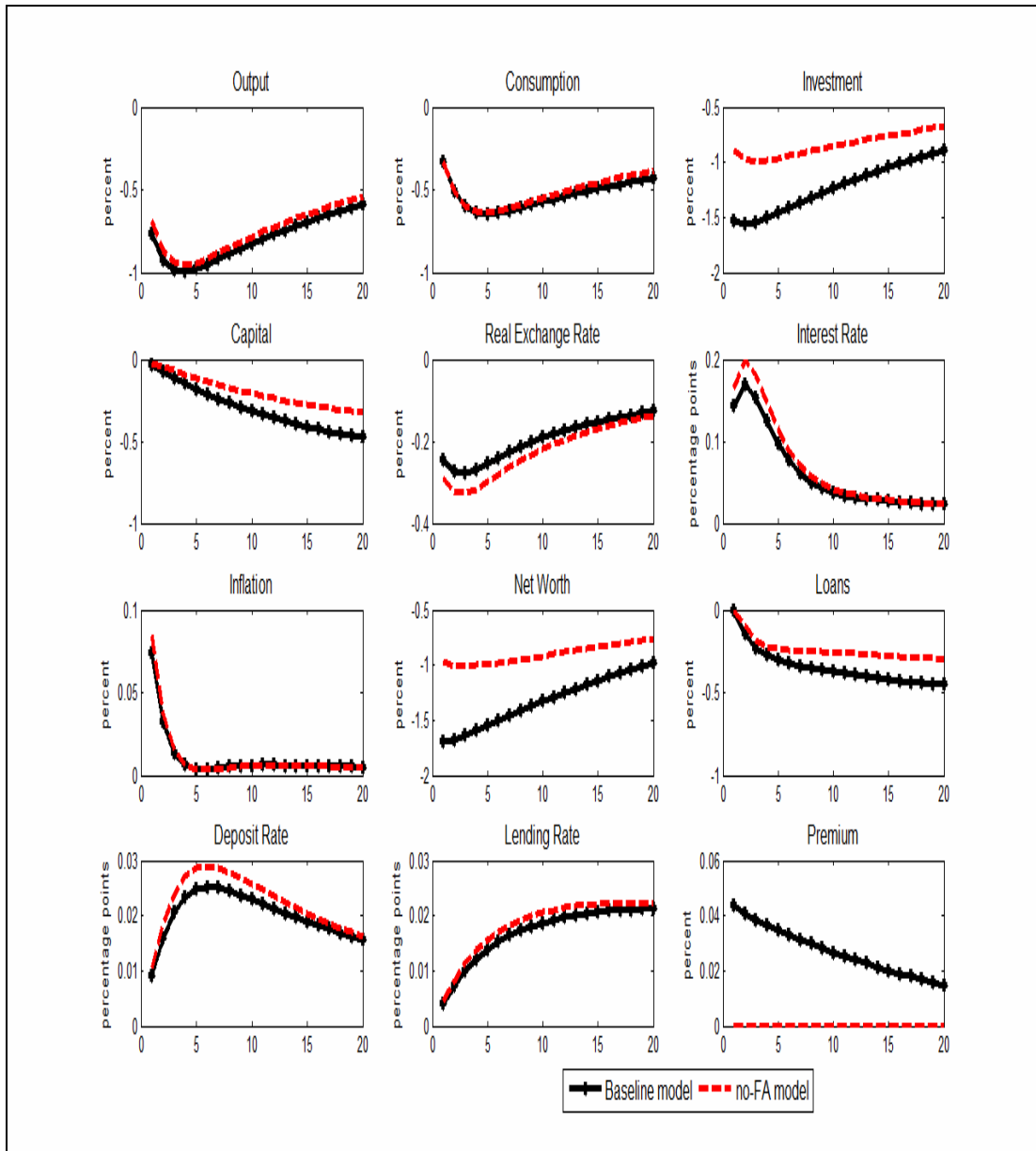
Figure 3.6: Impulse Responses to a 1% Negative Shock to Technology (Baseline model and no-FA model).
Each variable's response is expressed as the percentage deviation from its steady state level. Interest rates are shown as absolute deviation from steady state. Baseline model represents the complete model with financial frictions and banking sector. no-FA model is obtained by setting the elasticity of the external finance premium with respect to firm leverage , σ equal to zero, but keeping all other parameters same as in the baseline model. So it represents a model without financial frictions.

Figure 3.6 shows that the financial accelerator has less of an impact following a negative shock to technology. When the financial accelerator is active, the fall in net worth pushes up the risk premium faced by entrepreneurs and leads to a larger response of investment and capital. While output is somewhat more volatile when the financial accelerator is present, the impact is significantly less than following a shock to monetary policy.

Figure 3.7 gives an indication of how the presence of banking sector may affect the transmission of productivity shock. Comparing no-B model with no-BK-FR model indicates that the presence of monopolistic banking system amplifies the propagation of the shock. Similar to monetary policy shock, market power of banks result in higher lending rates (as banks apply a mark-up to the inter-bank rate) resulting in higher borrowing costs for the firms which in the presence of financial accelerator leads to a an increase in external finance premium, thus reducing capital, investment and output further. This mechanism results in the amplification and persistence of the negative shock. Again our result is similar to that of Mandelman (2009).

However, in the presence of sticky interest rates, banking sector attenuates the response of the technology shock (comparing baseline with no-B model). Since bank rates are sticky, increase in the retail rates are much less than the policy rate. Thus the borrowing cost for firms increase by less in the presence of sticky interest rate setting banks. Thus, the presence of banking sector with sticky interest rates has a dampening effect of policy shock on output, investment, capital and net worth.
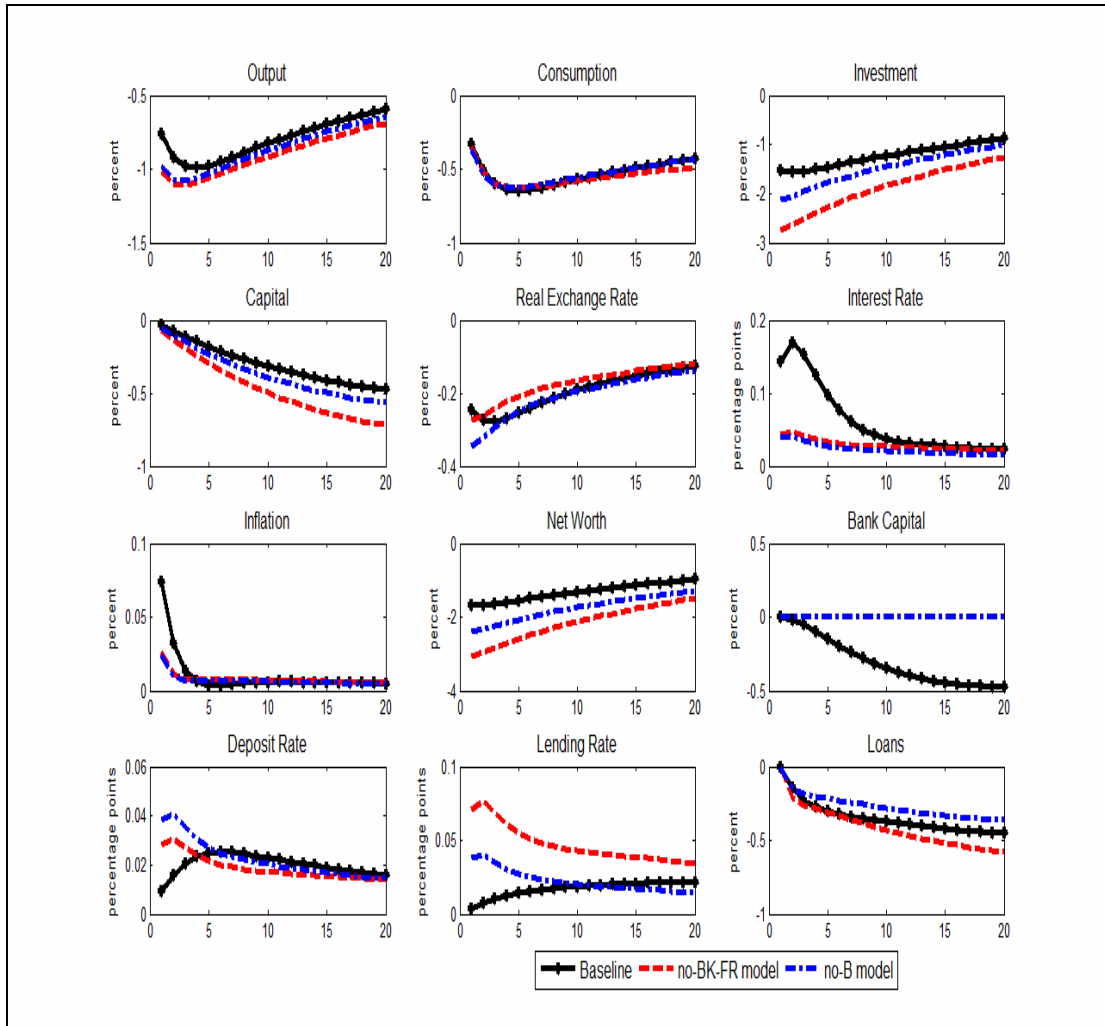
Figure 3.7: Impulse Responses to a 1% Negative Shock to Technology (Baseline model, no-B model and no-BK-FR model)

Each variable's response is expressed as the percentage deviation from its steady state level. Interest rates are shown as absolute deviation from steady state. Baseline model represents the complete model with financial frictions and banking sector. To obtain no-BK-FR model first we shut down the bank capital channel. We set the cost of bank capital adjustment, ϕ_z equal to zero and rebate the banking profit to households in a lump-sum fashion. Then we also shut down the sticky interest rate channel. It is obtained by setting ϕ_{i^d} and ϕ_{i^l} equal to zero in the no-BK model model. To obtain no-B model, we set $\alpha^s = \alpha^d = 0$ and the elasticities of loan and deposit, ε^l and ε^d equal to infinity. no-B model is a single interest rate model with financial frictions but no banking sector. The steady state values of the two models differ as the effective lending rate and deposit rate faced by the agents are not the same. Since the steady-state under the two models is different, this plot is only instructive.

3.4.3 The Effects of a Tightening of Credit Conditions

Starting in the summer of 2007, financial markets all across the globe fell under considerable strain. The initial deterioration in the U.S. sub-prime mortgage market quickly spread across other financial markets. Banks, in particular, suffered losses from write-offs and reported increasing funding difficulties. A number of them were forced to recapitalize and improve their balance sheets. In addition financial intermediaries tightened credit standards for the approval of loans. Against this background policymakers have been particularly concerned with the impact that a restriction in the availability and cost of credit might have on the real economy. Our model is well suited to analyze the effects of a tightening in credit conditions on the real activity. We carry out this exercise by implementing a persistent contraction in bank capital z.[96] The shock is calibrated in a way such that it determines a fall of bank capital by 5 percent on impact. In the exercise we assess the role of the adjustment costs on the bank capital/asset ratio by computing the impulse responses under different calibration of the parameter ϕ_z. We consider as benchmark a value of 10, and then a higher one, corresponding to 15, and a lower one equal to 5. Figure 3.8 presents the impulse response of macro variables to a negative shock to bank capital z.

By construction, the credit tightening brings about a fall in bank capital. In order to compensate for the loss in equity, banks increase the rate on deposits to attract them and increase their liability. At the same time, they increase the rates on loans to increase profits. This pushes up the costs of borrowing for entrepreneurs, reducing their net worth, which in turn decreases the demand for capital, leading to a decline in investment and output. Since banks try to re-build their capital, the spread increases.

---

[96] Similar to Gerali et al. (2010) we model the credit condition tightening as a simple negative shock to the bank capital. We realize that this is a very simplified depiction of the present crisis but we carry out this exercise to demonstrate the propagation mechanism of a shock originating in the credit markets.
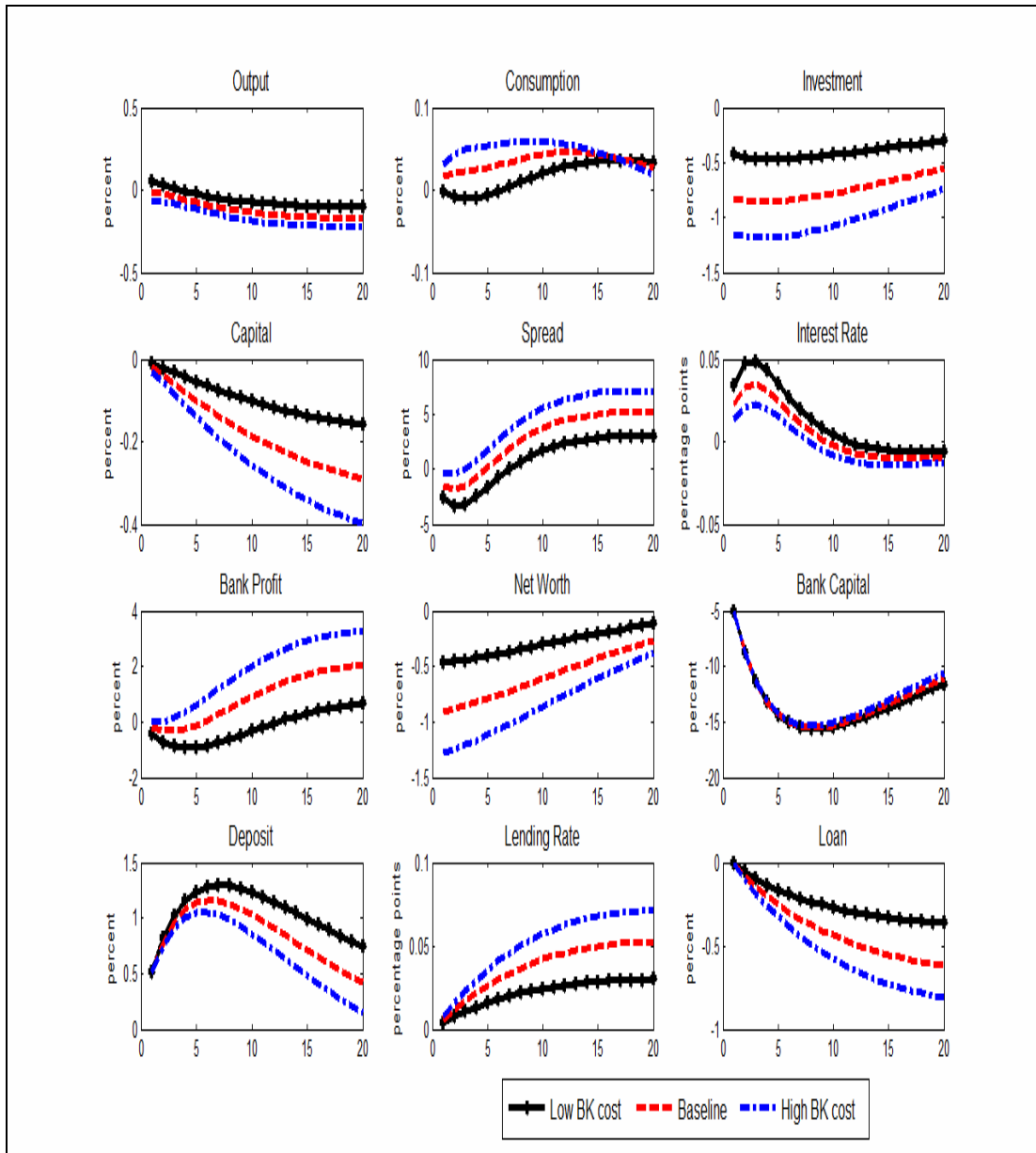
Figure 3.8: Impulse Responses to a Negative Shock to Bank Capital
(Baseline model with different bank capital adjustment costs)
Each variable's response is expressed as the percentage deviation from its steady state
level. Interest rates are shown as absolute deviation from steady state. Low BK cost
model has bank capital adjustment cost, $\phi_z = 5$ while High BK cost model has bank
capital adjustment cost, $\phi_z = 15$.

Higher the cost of adjusting the bank capital ratio, the larger is the increase in the

lending rates, resulting in larger decline in net worth, demand for capital, investment

and output. Output contracts on impact only when the adjustment cost is sufficiently large. With high adjustment costs, spread between wholesale loan and wholesale deposit rates increase; bank profits increase and compensates for the fall in equity. The bank capital-loan ratio converges faster to its steady state. Response of consumption depends on the size of the adjustment cost. Gerali et al. (2010) have also found similar results.

Next we analyze the monetary transmission mechanism associated with non-monetary tools generally employed by the central banks in emerging markets. Policymakers resort to this tool for generally two reasons – to control inflation by soaking up the liquidity (or decreasing aggregate demand), and to fund the government deficit. While analyzing the effect of these non-monetary policy tools, we assume that the central bank keeps the policy rate unchanged.

3.4.4 Shock to Cash Reserve Requirement

We present the impulse response of macroeconomic variables to a positive shock in CRR (increase in CRR by 50 bps) in Figure 3.9. The policy achieves its intended objective of reducing inflation. Since banks have less credit available to lend, they increase the lending rate. This results in higher borrowing costs for entrepreneurs, causing net worth to decline. Also a decline in inflation results in higher debt repayment which also reduces the net worth of the firms. It puts downward pressure on the demand for capital, resulting in the decline of investment and output. The financial accelerator mechanism results in further reduction in investment and output. Since banks are left with less credit to meet the loan requirements, they have to tap additional deposits and also use bank capital. Deposits go up. Since the bank's profitability goes down they use their bank capital to meet the demand for loans, resulting in a worsening of their balance sheet. Lowered economic activity results in

lower wage income and lower dividend income for the households. This reduces their consumption demand. Also as households shift to deposits, their current consumption demand is further reduced.
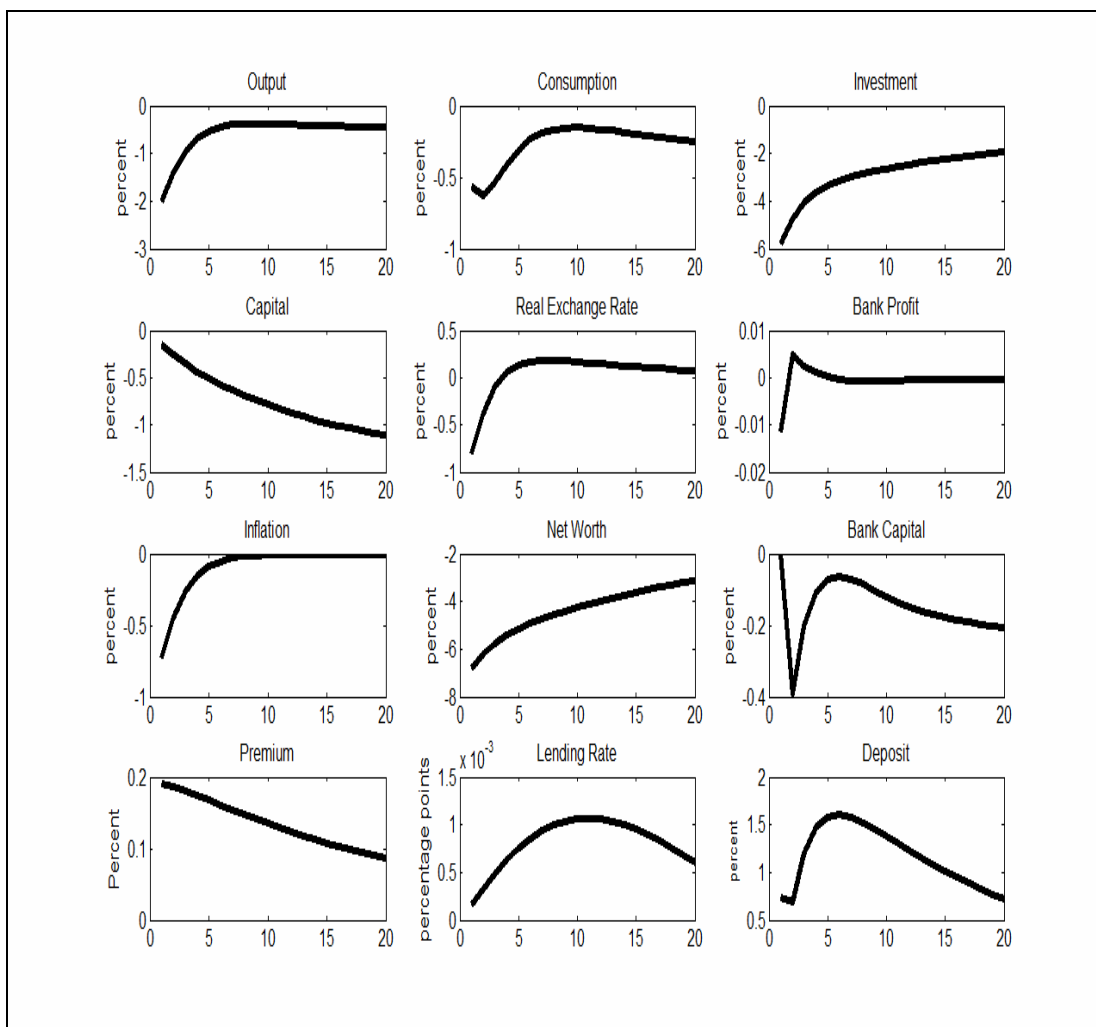
Figure 3.9: Impulse Responses to a Positive Shock to Cash Reserve Ratio (CRR)
Each variable's response is expressed as the percentage deviation from its steady state level. Interest rates are shown as absolute deviation from steady state. We assume that the central bank does not change the policy rate while changing the reserve requirements i.e. $i_t = i_{t-1}$.

3.4.5 Shock to Statutory Liquidity Ratio

We present the impulse response of a positive shock to SLR (increase in SLR by

50 bps) in Figure 3.10. Increase in the SLR requirement forces the banks to lend to government at a rate lower than the market rate (since they only earn the t-bill rate). In order to maximize their profits, banks raise the lending rates. Higher lending rates and declining inflation leads to an increase in the borrowing costs for the firms. Thus even though the policy rate is unchanged, borrowing costs for the firms go up. This sets in the financial accelerator mechanism, leading to contraction in output, investment and consumption. Since in our model the government has a balanced budget, increased t-bill holdings in each period result in lowering of t-bill rates, which further reduces the profits of banks. Lowered economic activity results in lower wage income and lower dividend income for the households. This reduces their consumption demand. Also as households shift to deposits, their current consumption demand is further reduced.
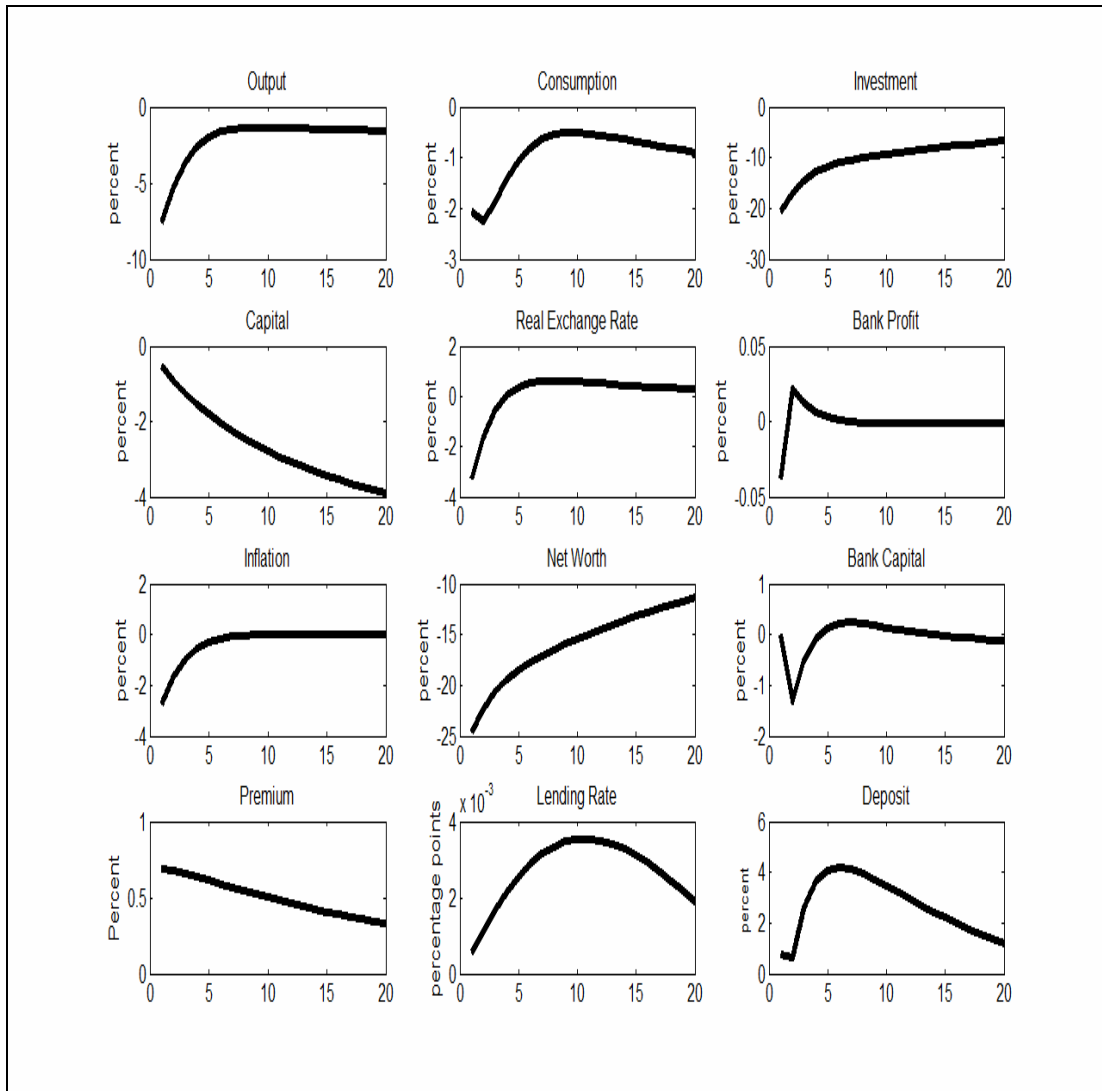
Even though the non-traditional monetary policy tool is able to achieve its objective, it results in a larger contraction of the economy as compared to traditional monetary tightening (see Figure 3.4).

Figure 3.10: Impulse Responses to a Positive Shock to Statutory Liquidity Ratio (SLR)
Each variable's response is expressed as the percentage deviation from its steady state level. Interest rates and spread are shown as absolute deviation from steady state. We assume that the central bank does not change the policy rate while changing the reserve requirements i.e. $i_t = i_{t-1}$.

We have examined monetary and productivity shocks to understand the role of the banking sector and financial frictions in the transmission of shocks and their effect on the real economy. Results are similar to those of Mandelman (2009) in terms of amplification of shocks when the interest rates are flexible. However, when rates are

sticky, our results are comparable to Gerali et al (2010), where the presence of banking sector attenuates the shocks. A similar attenuator effect arises also in Andres and Arce (2009) and Aslam and Santoro (2008). Our model also suggests that using non-traditional monetary tools may result in larger volatility than using a traditional monetary tightening.

3.5 Concluding Remarks

The present crisis has amply demonstrated that financial shocks can have a significant effect on the real economy, and fixing financial markets may hold a key to recovery and stability. Macro-financial linkages have become the focus of attention in both academia and central banks. This crisis has also highlighted the need of introducing banking sector (credit supply channel) in a standard DSGE model with financial frictions (credit demand channel) to study and analyze shocks emanating in the credit markets.

The aim of this paper has been to develop a small open economy model with financial frictions and a banking sector to understand the role of financial intermediation in the transmission of shocks, and to analyze the effects of credit market shocks on the real economy. The model includes a financial accelerator mechanism similar to that proposed by Bernanke et al. (1999). Banks are modeled as monopolistically competitive optimizing units. They combine deposits with the bank capital (accumulated out of retained earnings) to make loans while meeting the capital-asset requirement. We have introduced cash reserve ratio (CRR) and statutory liquidity ratio (SLR) in the model to study the non-monetary policy tools used by the central bank in India.

Our analysis suggests that the presence of financial frictions result in the amplification and persistence of shocks, while the presence of monopolistic sticky

interest rate setting banking sector attenuates the effect of shocks. However, if interest rates are flexible, market power of banking system results in the amplification of shocks. Other results suggest that tightening of credit markets (a negative shock to bank capital) have substantive effects on the economy, and when the central bank resorts to using non-monetary tools, there is a larger contraction in output and consumption as compared to traditional monetary tightening (operating through nominal interest rate changes).

The results are driven by the fact that we have two channels through which the financial sector interacts with the real economy. The banking sector affects the real economy through the credit supply channel. Presence of banks creates a wedge between the policy rate and rates which are relevant for the decision making of each agent in the economy, modifying the response of real variables. The financial accelerator mechanism works by altering the cost of borrowing faced by the firms.

The model developed in this paper can be used extensively to analyze several issues related to financial sector and financial stability. Since the model includes bank capital channel, our model is well suited to study the effects of bank recapitalization program being undertaken in India. Also, it is suited to analyze the effects of bank capital regulatory changes.

Our model with reserve requirements can be used to study the macro-economic consequences of using different policy tools and to rank them as well as to study the welfare costs of various financial frictions and financial under-development. It can also be extended to study the welfare costs of various rigidities in the financial markets. One such possible extension is to study the welfare implications of the presence of floor on deposit rates in India. This non-zero lower bound on deposits is created by government administered interest rates on small savings schemes. These schemes compete with banks for deposits and thus prevent the banks from reducing

deposit rates below these administered rates (which are significantly higher than market determined rates on debt papers of corresponding tenures). This non-zero lower bound on deposits in turn prevents banks from decreasing lending rates even when the policy rates are lowered to infuse liquidity in the economy.

By estimating the parameters of the model we can use it to study the optimality of current monetary policy in India. Also, it can then be used to assess the relative importance of shocks in explaining the business cycle fluctuations in India.

REFERENCES

Aghion, Philippe, Philippe Bacchetta, and Abhijit Banerjee, 2001, "Currency Crises and Monetary Policy in an Economy with Credit Constraints," *European Economic Review*, Vo. 47, No. 7, pp. 1121-1150.

Anand, Rahul, Peiris, Shanaka J., and Magnus Saxegaard, 2010, "An Estimated Model with Macrofianncial Linkages for India," IMF Working Paper No. 10/21, International Monetary Fund.

Andres, Javier, and Oscar J, Arce, 2009, "Banking Competition, Housing Prices and Macroeconomic Stability," Banko de España Working Paper No. 0830, Banko de España.

Aslam, Aqib and Emiliano Santoro, 2008, "Bank Lending, Housing and Spreads," University of Copenhagen, Department of Economics Discussion Papers No. 08-27.

Benes, Jaromir, and Kirdan, Lees, 2007, "Monopolistic Banks and Fixed Rate Contracts: Implications for Open Economy Inflation Targeting," mimeo, Reserve Bank of New Zealand.

Beneš , Jaromír , Inci, Otker-Robe, and David Vávra, 2009, "Modelling with Macro-Financial Linkages: Credit and Policy Shocks in Emerging Markets," IMF Working Paper No. 09/123, International Monetary Fund.

Bernanke, Ben and Mark Gertler, 1989, "Agency Costs, Net Worth, and Business Fluctuations," *American Economic Review*, Vol. 79, No. 1, pp. 14-31.

Bernanke, Ben, Gertler, Mark, and Simon Gilchrist, 1999, "The Financial Accelerator in a Quantitative Business Cycle Framework," in *Handbook of Macroeconomics*, Edition 1, Vol. 1, eds. John B. Taylor and Michael Woodford (Amsterdam: North Holland).

Blundell, Richard, and Thomas MaCurdy, 1999, "Labor Supply: A Review of Alternative Approaches," *Handbook of Labor Economics*, Vol. 3, eds. Orley Ashenfelter, and David Card (The Netherlands: Elsevier Science), pp.1559-1695.

Carlstrom, Charles and Timothy S. Fuerst, 1997, "Agency Costs, Net Worth, and Business Fluctuations: A Computable General Equilibrium Analysis," *American Economic Review*, Vol. 87, No. 5, pp. 893-910.

Christensen, Ian, and Ali Dib, 2006, "Monetary Policy in an Estimated DSGE Model with a Financial Accelerator," Working Paper No. 06-9, Bank of Canada.

Christiano, Lawrence, Eichenbaum, Martin, and Charles Evans, 1996, "The Effects of Monetary Policy Shocks: Evidence from the Flow of Funds," *Review of Economics and Statistics*, Vol. 78, pp. 16-34.

Christiano, Lawrence, Motto, Roberto, and Massimo, Rostagno, 2009, "Financial factors in business cycles," mimeo, European Central Bank

Clarida, Richard, Gali, Jordi and Mark Gertler, 1998, "Monetary Policy Rules in Practice: Some International Evidence," *European Economic Review*, Vol. 42, No. 6, pp. 1033-1067.

Clarida, Richard, Gali, Jordi, and Mark Gertler, 1999, "The Science of Monetary Policy: A New Keynesian Perspective," *Journal of Economic Literature*, Vol. 37, No. 4, pp. 1661-1707.

Curdia, Vasco and Michael Woodford, 2009, "Credit Frictions and Optimal Monetary Policy," BIS Working Papers No. 278, Bank of International Settlement.

De Walque, Gregory, Olivier, Pierrard, and Abdelaziz, Rouabah, 2009, "Financial Instability, Supervision and Liquidity Injections: A Dynamic General Equilibrium Approach," CEPR Discussion Paper No. 7202.

Dib, Ali, Mendicino, Caterina, and Yahong Zhang, 2008, "Price Level Targeting in a Small Open Economy with Financial Frictions: Welfare Analysis," Working Paper No. 08-40, Bank of Canada.

Edwards, Sebastian, and Carlos A. Vegh, 1997, "Banks and Macroeconomic Disturbances Under Predetermined Exchange Rates," NBER Working Paper No. 5977.

Elekdag, Selim, Justiniano, Alejandro, and Ivan Tchakarov, 2005, "An Estimated Small Open Economy Model of the Financial Accelerator," IMF Working Paper No. 05/44, International Monetary Fund.

Fernandez- Villaverde, Jesus, and Juan Francisco Rubio-Ramirez, 2004, "Comparing Dynamic Equilibrium Models to Data: A Bayesian Approach," *Journal of Econometrics*, Vol. 123, No. 1, pp. 153-187.

Fisher, Irving, 1933, "The Debt-Deflation Theory of Great Depressions," *Econometrica*, Vol. 1, No. 4, pp. 533-59.

Gerali, Andrea, Neri, Stefano, Sessa, Luca, and Federico, M., Signoretti, 2010, "Credit and Banking in a DSGE Model of the Euro Area," Economic Working Paper No. 740, Bank of Italy.

Gertler, Mark, Gilchrist, Simon, and Fabio M. Natalucci, 2007, "External Constraints on Monetary Policy and the Financial Accelerator," *Journal of Money, Credit and Banking,* Vol. 39, No. 2, pp. 295-330.

Gertler, Mark and Nobuhiro Kiyotaki, 2009, "Financial Intermediation and Credit Policy in Business Cycle Analysis," forthcoming in *Handbook of Monetary Economics*.

Geweke, John, 1998, "Using Simulation Methods for Bayesian Econometric Models: Inference, Development and Communication," Staff Report 249, Federal Reserve Bank of Minneapolis.

Goodfriend, Marvin, and Bennet, T. McCallum, 2007,"Banking and Interest Rates in Monetary Policy Analysis: A Quantitative Exploration," *Journal of Monetary Economics*, Vol. 54, No. 5, pp. 1480-1507.

Huelsewig, Oliver, Mayer, Eric, and Timo Wollmershauser, 2009, "Bank Behavior, Incomplete Interest Rate Pass-Through, and the Cost Channel of Monetary Policy Transmission," *Economic Modeling*, Vol. 26, No. 6, pp. 468-494.

Iacoviello, Matteo, 2005, "House Prices, Borrowing Constraints and Monetary Policy in the Business Cycle," *American Economic Review*, Vol. 95, No. 3, pp. 739-764.

Iacoviello, Matteo, and Stefano Neri, 2008, "Housing Market Spillovers: Evidence from an Estimated DSGE Model," Economic Working Paper No. 659, Bank of Italy.

Ireland, Peter, 2001, "Sticky-price Models of the Business Cycle: Specification and Stability," *Journal of Monetary Economics*, Vol.47, No.1, pp. 3-18.

Ireland, Peter, 2003, "Endogenous Money or Sticky Prices?" *Journal of Monetary Economics*, Vol. 50, No. 8, pp. 1623-1648.

International Monetary Fund, 2009, "India: Selected Issues," IMF Country Report No. 09/186.

International Monetary Fund, 2009, "India: Selected Issues," IMF Country Report No. 09/187.

Jha, Raghbendra, 2008, "Inflation Targeting in India: Issues and Prospects," *International Review of Applied Economics*, Vol. 22, No. 2, pp 259-70.

Julliard, Michel, Philippe Karam, Douglas Laxton, and Paolo Pesenti, 2004, "Welfare-based Monetary Policy Rules in an Estimated DSGE Model of the U.S. Economy," Working Paper Series No. 613, European Central Bank.

Kiyotaki, Nobuhiro, and John Moore, 1997, "Credit Cycles," *Journal of Political economy,* Vol. 105, No. 2, pp. 211-248.

Kollmann, Robert, 2002, "Monetary Policy Rules in the Open Economy: Effects on Welfare and Business Cycles," *Journal of Monetary Economics*, Vol. 49, No. 5, pp. 989-1015.

Krugman, Paul, 1999, "Balance Sheets, the Transfer Problem, and Financial Crisis," *Journal of International Tax and Public Finance,* Vol. 6, No. 4, pp. 459-472.

Lowe, Philip and Luci Ellis, 1997, "The smoothing of official interest rates," *Monetary policy and inflation targeting,*" Reserve Bank of Australia, pp. 287-312.

Mandelman, Fredrico, 2009, "Business Cycles and Monetary Regimes in Emerging Economies: A Role for a Monopolistic Banking Sector," forthcoming in *Journal of International Economics*.

Mohanty, Madhusudan, and Marc Klau , 2004, "Monetary Policy Rules in Emerging Market Economies: Issues and Evidence," BIS Working paper No. 149, Bank for International Settlements.

Mohan, Rakesh, 2004, "Challenges to Monetary Policy in a Globalizing Context," *Reserve Bank of India Bulletin*, January.

Mohan, Rakesh, 2006, "Coping with Liquidity Management in India: Practitioner's View," *Reserve Bank of India Bulletin*, April.

Oura, Hiroko, 2008, "Financial Development and Growth in India: A Growing Tiger in a Cage?" IMF Working Paper No. 08/79, International Monetary Fund.

Reserve Bank of India, 2009, The Evolution of Monetary Policy, 2003 – 04. Special Volume of its Reports on Currency and Finance (Vol. I), Reserve Bank of India.

Rotemberg, Julio, 1982, "Sticky Prices in the United States," *Journal of Political Economy,* Vol. 90, No. 6, pp. 1187-1211.

Rotemberg, Julio, and Michael Woodford, 1997, "An Optimization-Based Econometric Framework for the Evaluation of Monetary Policy," in *NBER Macroeconomics Annual*, Vol. 12, eds. Ben S. Bernanke and Julio J. Rotemberg (Cambridge, Mass.: MIT Press), pp. 297-346.

Sack, Brian and Volker Wieland, 1999 "Interest-rate Smoothing and Optimal Monetary Policy: A Review of Recent Empirical Evidence," *Finance and Economics Discussion Series,* Federal Reserve Board, Washington DC.

Saxegaard, Magnus, 2006a, "Fiscal and Monetary Policy in an Estimated Model of the Philippine Economy," Manuscript.

Saxegaard, Magnus, 2006b, "Monetary Policy Rules in a Small Open Economy with External Liabilities," Manuscript.

Schmitt-Grohe, Stephanie, and Martin Uribe, 2003,"Closing Small open Economy Models," *Journal of International Economics*, Vol. 61, No. 1, pp. 163-185.

Sudo, Nao, and Yuki Teranishi, 2009, "Optimal Monetary Policy under Heterogeneous Banks," mimeo, Institute for Monetary and Economic Studies, Bank of Japan.