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Optimal Price Indices for Targeting Inflation Under Incomplete Markets

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Abstract

In models with complete markets, targeting core inflation enables monetary policy to maximize welfare by replicating the flexible price equilibrium. In this paper, we develop a two-sector two-good closed economy new Keynesian model to study the optimal choice of price index in markets with financial frictions. Financial frictions that limit credit-constrained consumers' access to financial markets make demand insensitive to interest rate fluctuations. The demand of credit-constrained consumers is determined by their real wage, which depends on prices in the flexible price sector. Thus, prices in the flexible price sector influence aggregate demand and, for monetary policy to have its desired effect, the central bank has to stabilize price movements in the flexible price sector. Also, in the presence of financial frictions, stabilizing core inflation is no longer equivalent to stabilizing output fluctuations. Our analysis suggests that in the presence of financial frictions a welfare-maximizing central bank should adopt flexible headline inflation targeting—a target based on headline rather than core inflation, and with some weight on the output gap. We discuss why 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.

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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 number 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).

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 the 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 cannot smooth their consumption—that is, they simply consume their current labor

[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 (2004) 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 (2004).

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 is influenced by 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 a 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]

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, constituting 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. [5]

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[2] We introduce this friction in a manner similar to that of Gali, Lopez-Salido and Valles (2004).
[3] A negative productivity shock related to a good with a low price elasticity of demand could increase the income of net sellers of that good and raise the expenditure of net buyers on that good.
[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 smaller in absolute terms than the elasticity normally used in other models, most of which assume a unitary price elasticity.
[5] Walsh (2010) documents the high pass-through from food price inflation to non-food inflation in middle- and low-income countries.

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. Under incomplete markets, by contrast, 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 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 of different policy rules using alternative measures of inflation.

The paper is organized as follows. In the next section, we present some empirical facts to further motivate the analysis. In Section 3, we develop a two-sector, two-good model with heterogeneous agents that encapsulates the features discussed above. 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.

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 plots the expenditure on food (as a percentage of total expenditure) against log real per capital income for the year 1996.[6] 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 we present recent data on shares of food expenditure in total expenditure for selected emerging and advanced economies.[7] As expected, expenditure on food constitutes a much larger share of total household expenditure in emerging markets relative to advanced economies.

Income and price elasticities of the demand for food are important for our analysis. Figure 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.[8] We present the income elasticity of food for

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

[7] 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.

[8] A low income elasticity of demand also means that, as family income increases, consumption of the commodity will not increase by much.

selected emerging market and advanced economies in Table 2. The income elasticity of food in emerging markets is on average twice as large as that in advanced economies. Figure 3 plots, for a large sample of countries, the Slutsky own price elasticity of food against the log real per capita GDP for the year 1996.[9] 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 2.[10] 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 the price elasticity of food is much lower than what is 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.

In order to examine the extent of credit constraints in emerging markets, in Table 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. On average, more than half of the population in emerging markets does not have access to the formal financial system.

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 4-5). Values of average inflation, average volatility and the persistence of inflation (for the period March 1991 – September 2009) are reported in Table 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 reported. 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 more than twice as volatile in emerging market economies compared to

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[9] The Slutsky own price elasticity is estimated by keeping real income constant.

[10] Frisch elasticity values lie between Slutsky and Cournot values and can be considered as an average own price elasticity.

advanced countries. The two measures of inflation exhibit a high degree of persistence in both sets of economies.[11]

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.[12] In Canada, in the period from the spring of 1999 to the fall of 2001, headline inflation remained above core inflation for 30 months in succession (Figure 4a). In Thailand, headline inflation has remained above core inflation for more than 5 consecutive years (Figure 5a). The core inflation measure excludes a number of expenditure items and is less representative of the cost of living. Thus, differences in the behavior of headline inflation (ostensibly a more accurate measure of the cost of living) and core inflation over an extended period may have important welfare implications.

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 is rendered more realistic by incorporating two features that are relevant to all economies but are particularly important for emerging markets--a fraction of consumers who are credit constrained and

[11] In a cross-country study, Walsh (2010) finds that food price inflation is in fact more persistent than non-food price inflation. This holds for both advanced and emerging market economies, although he finds that food price inflation is more persistent in emerging markets.
[12] 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.

a subsistence level of food consumption. 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.[13] 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.

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 consume both the flexible price good (food) and all of the differentiated sticky price goods (non food).[14] 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:

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

[13] 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.
[14] 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).

where the argument C_t^i is the composite consumption index of household *i* in period t. C_t^i includes the flexible price good and the entire continuum of the differentiated goods. It 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

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

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 by household *i* in period *t* 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.[15] This form is selected to model the role of food in the economy. Since food is a necessity, households must consume a minimum amount C^* of food for survival.[16] 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.

[15] Expenditure system corresponding to Klein-Rubin utility function is referred to as the Stone-Geary linear expenditure system; Stone (1954) and Geary (1949).
[16] This is also similar to habit persistence with C^* being independent of time.

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 in each period.[17] 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 rather than household-level idiosyncratic shocks, we assume that all the households in the food sector face the same shock.

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 good indexed by z (where $z \in [0,1]$). $A_{s,t}$ is a random productivity shock. We assume that the shock is identical for all households in the non-food sector.

[17] There is no storage technology in the model. So consumers in the flexible price sector cannot smooth their consumption by saving their output. We have made this restrictive assumption to keep the model tractable. Moreover, 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 India's agricultural sector have no access to formal finance.

3.2 Consumption Decision

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

$$P_{f,t}C^f_{f,t} + P_{s,t}C^f_{s,t} = W_t^f N_t^f \tag{7}$$

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 food sector. The optimal allocation for a given level of spending between food and all the differentiated non-food 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

$$P_t = \left[\gamma (P_{f,t})^{1-\eta} + (1-\gamma)(P_{s,t})^{1-\eta}\right]^{\frac{1}{1-\eta}} \tag{8}$$

The budget constraint can be written as:

$$P_t C_t^f = W_t^f N_t^f - P_{f,t}C^* \tag{9}$$

Demand for the flexible price good is given by

$$C^f_{f,t} = \gamma \left(\frac{P_{f,t}}{P_t}\right)^{-\eta} C_t^f + C^* \tag{10}$$

Demand for the sticky price good is given by

$$C_{s,t}^{f} = (1-\gamma)\left(\frac{P_{s,t}}{P_t}\right)^{-\eta} C_t^{f} \tag{11}$$

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

$$P_{s,t} = \left[\int_0^1 X_t(z)^{1-\theta} dz\right]^{\frac{1}{1-\theta}} \tag{12}$$

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

$$c_t^{f}(z) = \left(\frac{X_t(z)}{P_{s,t}}\right)^{-\theta} C_{s,t}^{f} \tag{13}$$

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

$$\phi_n \frac{(N_t^f)^{\psi}}{(C_t^f)^{-\sigma}} = \frac{W_t^f}{P_t} \tag{14}$$

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).[18] In this setup, 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

[18] Alternatively, we could use 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.

$$P_t C_t^s + B_t = \int_0^1 W_t^s(z) N_t^s(z) dz + \int_0^1 \Pi_t^s(z) dz + R_{t-1} B_{t-1} - P_{f,t} C^* \qquad (15)$$

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

$$(C_t^s)^{-\sigma} = \beta E_t \left\{ (C_{t+1}^s)^{-\sigma} \frac{R_t}{\Pi_{t+1}} \right\} \qquad (16)$$

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

$$\phi_n \frac{(N_t^s(z))^{\psi}}{(C_t^s)^{-\sigma}} = \frac{W_t^s(z)}{P_t} \qquad (17)$$

Demand for the flexible price good is given by

$$C_{f,t}^s = \gamma \left(\frac{P_{f,t}}{P_t} \right)^{-\eta} C_t^s + C^* \qquad (18)$$

Demand for the sticky price good is given by

$$C_{s,t}^s = (1-\gamma) \left(\frac{P_{s,t}}{P_t} \right)^{-\eta} C_t^s \qquad (19)$$

and the demand for each differentiated good is given by

$$c_t^s(z) = \left(\frac{X_t(z)}{P_{s,t}} \right)^{-\theta} C_{s,t}^s \tag{20}$$

3.3 Firms

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

$$P_{f,t} = \frac{W_t^f}{A_{f,t}} \tag{21}$$

The supply function for the flexible price firm is obtained by combining equations (5), (14) and (21), and is given by:

$$\frac{P_{f,t}}{P_t} = \phi_n \frac{\left(y_{f,t} / A_{f,t} \right)^{\psi}}{A_{f,t} (C_t^f)^{-\sigma}} \tag{22}$$

The market-clearing condition for food implies

$$Y_{f,t} = \lambda y_{f,t} = C_{f,t} = \gamma \left(\frac{P_{f,t}}{P_t} \right)^{-\eta} C_t + (1+\lambda) C^* \tag{23}$$

where we have defined $\lambda C_t^f + C_t^s = C_t = Y_t$ (24)

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

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:

$$\underset{X_t(z)}{Max}\, E_t\left[\sum_{j=0}^{\infty}(\alpha\beta)^j Q_{t,t+j}\left[X_t(z)y_{t,t+j}(z)-TC_{t,t+j}(y_{t,t+j}(z))\right]\right] \tag{25}$$

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

$$y_{t,t+j}(z)=\left(\frac{X_t(z)}{P_{s,t+j}}\right)^{-\theta}Y_{s,t+j} \tag{26}$$

where we have made use of the market clearing conditions

$$y_t(z)=c_t(z)=\lambda c_t^f(z)+c_t^s(z)=\left(\frac{X_t(z)}{P_{s,t}}\right)^{-\theta}\left(\lambda C_{s,t}^f+C_{s,t}^s\right) \tag{27}$$

$$\lambda C_{s,t}^f+C_{s,t}^s=C_{s,t}=(1-\gamma)\left(\frac{P_{s,t}}{P_t}\right)^{-\eta}C_t=Y_{s,t} \tag{28}$$

$$y_t(z)=\left(\frac{X_t(z)}{P_{s,t}}\right)^{-\theta}C_{s,t}=\left(\frac{X_t(z)}{P_{s,t}}\right)^{-\theta}Y_{s,t} \tag{29}$$

The sticky sector price index is expressed by

$$P_{s,t}=\left[\alpha(P_{s,t-1})^{1-\theta}+(1-\alpha)X_t^{1-\theta}(z)\right]^{\frac{1}{1-\theta}} \tag{30}$$

The price $X_t(z)$ solves the following first order condition

$$E_t\left[\sum_{j=0}^{\infty}(\alpha\beta)^j Q_{t,t+j}\, y_{t,t+j}(z)\left\{X_t(z)-\frac{\theta}{\theta-1}MC^r_{t+j}(z)\right\}\right]=0 \qquad (31)$$

where

$$\frac{MC_{t+j}(z)}{P_{t+j}}=MC^r_{t+j}(z)=\phi_n\frac{\left(y_{t,t+j}(z)\big/A_{s,t+j}\right)^{\psi}}{A_{s,t+j}(C^s_{t+j})^{-\sigma}} \qquad (32)$$

and $\frac{\theta}{\theta-1}$ is the constant markup over the marginal cost.[19]

Equations (8), (9), (16), (22), (23), (28), (30), (31) and (32), 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.

3.4 Inflation and Relative Prices

We define the relative prices as follows:

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

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

$$x_{s,t} = \frac{P_{s,t}}{P_{s,t-1}} \frac{P_{s,t-1}}{P_{t-1}} \frac{P_{t-1}}{P_t} = \frac{\Pi_{s,t} x_{s,t-1}}{\Pi_t} \tag{33}$$

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

3.5 Steady State

We characterize the steady state with constant prices (zero inflation) and no price stickiness in the economy.[20] This implies that $\Pi_t = 1$ and $\Pi_{s,t} = 1$ for all *t*. Under symmetric equilibrium, each firm faces the same demand and sets 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.[21] We assume that productivity is the same in both the sectors and normalize it to one.

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

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

where $\bar{Y}, \bar{\Pi}$ and $\bar{R}$ are the steady state values of output, inflation and the nominal interest rate, respectively. The term 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.[22] 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.

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

[21] 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.

[22] 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

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.

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

Strict Headline Inflation Targeting: The central bank cares only about interest rate smoothing and stabilizing headline inflation.

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

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).

$$\log(R_t / \bar{R}) = \rho_i \log(R_{t-1} / \bar{R}) + \rho_\pi \log(\Pi_{s,t} / \bar{\Pi}_s) + \rho_y \log(Y_t / \bar{Y}) \tag{37}$$

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

$$\log(R_t / \bar{R}) = \rho_i \log(R_{t-1} / \bar{R}) + \rho_\pi \log(\Pi_t / \bar{\Pi}) + \rho_y \log(Y_t / \bar{Y}) \tag{38}$$

3.7 Exogenous Shock Process

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

$$A_{f,t+1} = \rho_{af} A_{f,t} + \xi_t \quad , \; \xi_t \sim \text{i.i.d. } (0,\ \sigma_{af}) \tag{39}$$

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.

$$A_{s,t+1} = \rho_{as} A_{s,t} + \upsilon_t \qquad , \upsilon_t \sim \text{i.i.d. } (0, \ \sigma_{as}) \tag{40}$$

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.

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 (52) – (62) of Appendix I, given the exogenous stochastic processes $A_{f,t}$, $A_{s,t}$ and the monetary policy rule given by equation (34).

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 all households can insure one another against idiosyncratic income risks completely. It implies that given same initial wealth each household will choose an identical consumption sequence.[23] Thus, under this complete markets setting

$$C_t^f = C_t^s = \frac{C_t}{1+\lambda} = \frac{Y_t}{1+\lambda} \tag{41}$$

and aggregate demand is given by

$$\left(\frac{Y_t}{1+\lambda}\right)^{-\sigma} = \beta E_t \left[\left(\frac{Y_{t+1}}{1+\lambda}\right)^{-\sigma} \frac{R_t}{\Pi_t} \right] \tag{42}$$

[23] 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*.

Equations (53), (55)-(61) of Appendix I and (41)-(42) define the system of equations that combined with the monetary policy rule and exogenous stochastic processes $A_{f,t}$ and $A_{s,t}$ determine the equilibrium path of the economy in the complete markets setting.

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.[24] In particular, we evaluate policy rules according to the value of lifetime utility:

$$V_t^i \equiv E_t \sum_{j=0}^{\infty} \beta^j U(C_{t+j}^i, N_{t+j}^i) \text{ for } i = f,s \tag{43}$$

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

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.[25] To enable accurate welfare comparisons across alternative policy

[24] 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.

[25] 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 up to a first-order approximation (Schmitt-Grohe and Uribe, 2007).

environments, we need at least a second-order approximation of the equilibrium welfare function (Schmitt-Grohe and Uribe, 2004; Woodford, 2003).[26]

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-order 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 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.

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:

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[26]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).

$$V_0^r = E_0 \sum_{t=0}^{\infty} \beta^t U(C_t^r, N_t^r) \tag{44}$$

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

$$V_0^a = E_0 \sum_{t=0}^{\infty} \beta^t U(C_t^a, N_t^a) \tag{45}$$

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

$$V_0^a = E_0 \sum_{t=0}^{\infty} \beta^t U((1+\omega)C_t^r, N_t^r) \tag{46}$$

Under this specification, a positive value of ω means that welfare is higher under the alternative policy rule. Rearranging equation (46), the welfare gain ω is given by

$$\omega = \left[\frac{V_0^a + D_0^r}{V_0^r + D_0^r} \right]^{\frac{1}{1-\sigma}} - 1 \tag{47}$$

where $$D_0^r = E_0 \sum_{t=0}^{\infty} \beta^t \left\{ \phi_n \frac{\left(N_t^r\right)^{1+\psi}}{1+\psi} \right\} \tag{48}$$

A value of ω*100 = 1, represents a one percentage point of permanent consumption gain under the alternative 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 (35)-(38).

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 real interest rate of 4 percent (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 DSGE models and is also the most common value used in the literature on emerging markets (Aguair and Gopinath, 2005; Schmitt-Grohe and Uribe, 2007; Devereux, Lane and Xu, 2004).[27]

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 ($\frac{1}{\psi}$) is both important and controversial. The range of values used in the literature goes from 0.25 to 1.[28] For our benchmark case we assume it to be 0.33 (ψ=3). We choose the scaling parameter ϕ_n such that the average hours worked in the steady state is 0.38. The elasticity of substitution between food and non-food goods, η, is another parameter for which we don't have a good approximation. As the demand for food is inelastic, we set η= 0.6 for the baseline case.[29]

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 1). In addition, we assume that on average half of the households' steady state food consumption is required for subsistence.[30] 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

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[27] 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).

[28] 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].

[29] 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.

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

consumption index, γ equal to 0.3050 so that the steady state 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 in favor of excluding 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, 2007). Volatility of productivity shocks in emerging markets is higher than in advanced countries (Pallage and Robe, 2003; Aguair and Gopinath, 2007). We choose the standard deviation of food productivity shock, σ_{af} =0.03 and the standard deviation of non-food productivity shock, σ_{as} =0.02.[31] Table 5 shows a full set of baseline parameter values for the calibrations.

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 (35)-(38).

[31] 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 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. Figure 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.[32] 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.

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 7 plots the impulse responses of various macroeconomic variables to a one percent negative food productivity shock.[33] 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

[32] 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).

[33] We only plot the impulse responses under strict core inflation targeting and flexible headline inflation targeting rules. The welfare gains relative to core inflation targeting are also positive but lower under the other two policy rules (Table 6).

(both strict and flexible) 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.

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 each household 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 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 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 opposite directions following a negative shock to food productivity.

Which of the two demands dominates is determined by the policy regime. Since core inflation targeting ignores food price inflation, the increase in food prices (and, therefore, the wage income of the food sector households) is higher than the increase 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 the central bank targets flexible headline inflation.

To formalize the above arguments, we examine the log-linearized aggregate demand equation, which is given by[34]

$$\hat{c}_t = -\frac{\varsigma_s}{\sigma} E_t\left(\hat{R}_t - \hat{\pi}_{t+1}\right) + E_t \hat{c}_{t+1} - \varsigma_f E_t \Delta \hat{c}_{f,t+1} \tag{49}$$

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

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

$$\hat{c}_{f,t} = \left[\frac{1+\frac{a}{\psi}}{1+\frac{a\sigma}{\psi}}\right]\hat{W}_t^f + \left[\frac{a-1}{1+\frac{a\sigma}{\psi}}\right]\hat{A}_{f,t} \tag{50}$$

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

and $\hat{W}_t^f = \hat{x}_{f,t} + \hat{A}_{f,t}$ (51)

Equations (50) and (51) suggest that, in the presence of credit-constrained consumers, a link is established between aggregate demand and the relative price of food. This is because, in the presence of financial frictions, relative prices affect aggregate demand in

[34] Aggregate demand is the sum of the log-linearized consumption demand of food and non-food households. Variables with a hat denote log deviations from the corresponding steady state values.

addition to aggregate supply.[35] Thus, the presence of financial frictions implies that managing aggregate demand requires the central bank to choose a policy regime that would limit the rise in wages of credit-constrained consumers (and, therefore, the increase in their demand).

4.1 Welfare Distribution

The focus of our paper is on average welfare but the incomplete markets setting allows us to look at the welfare distribution in the economy. We do not report those results in detail here but note that in our model flexible headline inflation targeting is better for both the credit-constrained households and unconstrained households. Since there is no tradeoff involved in terms of welfare of the two groups, the central bank is not likely to face any political pressures in implementing this policy.

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), the degree of price stickiness (α), the elasticity of substitution between different non-food goods which determines the mark-up in the sticky price sector (θ), and the proportion of credit-constrained households in the economy (λ). We conduct additional sensitivity analysis with respect to the persistence and volatility of the food productivity shock and Taylor rule coefficients. When interpreting the results it should be noted 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

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[35] Under complete markets, relative prices only affect aggregate supply (Aoki, 2001).

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 (23), which is the sum of an iso-elastic term $\gamma(x_{f,t})^{-\eta}C_t$ and a price inelastic term $(1+\lambda)C^*$. 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 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.

Next, we examine the sensitivity of the results to the elasticity of substitution between food and non-food goods, denoted by η (Table 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 η = 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.

The elasticity of substitution 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 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).

In Tables 9-12, 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. Our results appear robust to the selection of parameter values around their baseline values.

Following Gali et al. (2004), we conduct sensitivity analysis with respect to the coefficients of the Taylor rule (Table 13). 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.[36] We find that the welfare gains are still positive.

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[36] 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

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 14, it is evident that our results are robust to various combinations and also that welfare gains from adopting flexible headline targeting are 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.

5.1 Extensions of the Model

We consider two extensions of our baseline model. The first extension looks at an alternative characterization of complete markets. Most existing models with complete markets assume that agents can insure against income risks *ex ante*. In other words, insurance contracts are written before households know which sector they are in (see, e.g., Aoki, 2001). This assumption implies that, given the same initial wealth, consumers will choose identical consumption streams. A more realistic way of characterizing complete markets is to assume that consumers can insure against income risks but only after being assigned to a particular sector. One could regard this as a complete market setting *conditional* on worker assignment to sectors, which is determined *ex-ante* (before insurance contracts are written). In other words, a household cannot insure against cross-sector income risk. Under this alternate market structure, each type of household chooses a consumption stream to maximize its lifetime utility subject to its idiosyncratic budget constraint (see Appendix III for more details). In Table 15, we present the welfare gains under this market structure and with 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 the elasticity of substitution between food and nonfood goods, the welfare gains are essentially zero.

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policy, inflation would in effect be forever constant so that the economy would be characterized by zero inflation volatility (Schmitt-Grohe and Uribe, 2007).

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 16 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.

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.

[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).

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 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.[39]

[39] In related work, Catao and Chang (2010) show that, for a small open economy that is a net buyer of food, the high volatility of world food prices implies that headline CPI inflation targeting is welfare improving relative to core CPI targeting.

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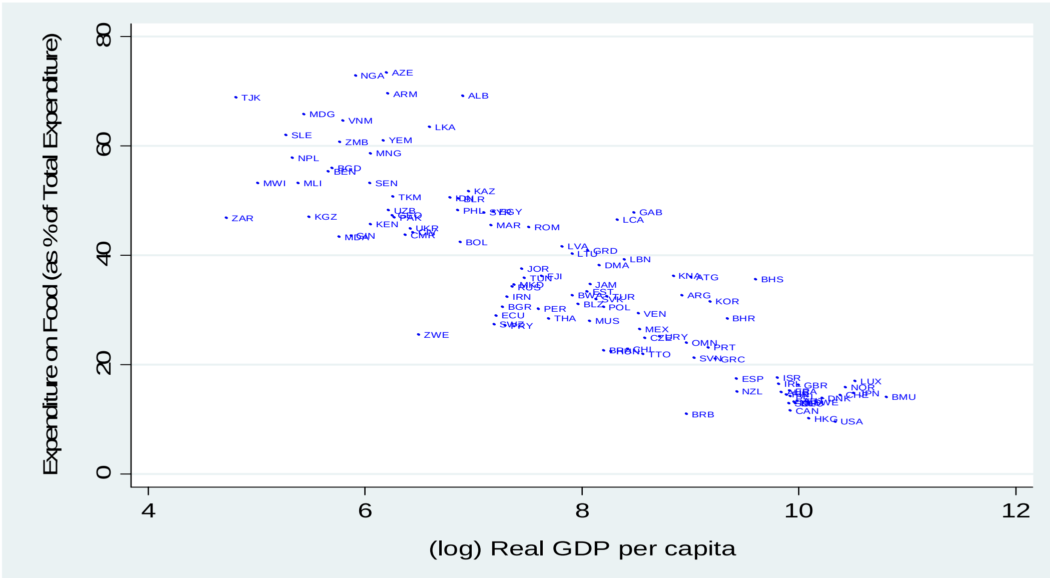
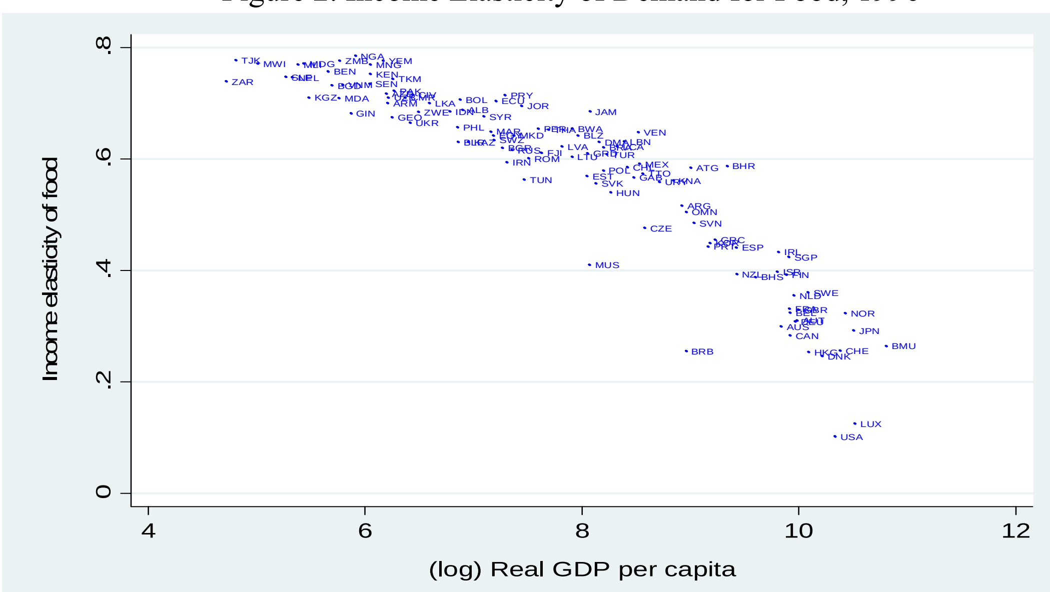
Figure 1. Share of Expenditure on Food,1996
(as percent of total household expenditure)



Source: WDI and International Food Consumption Patterns Dataset, Economic Research Service, USDA.

Note: Expenditure on food includes expenditure on food prepared at home and consumed plus beverages and tobacco.

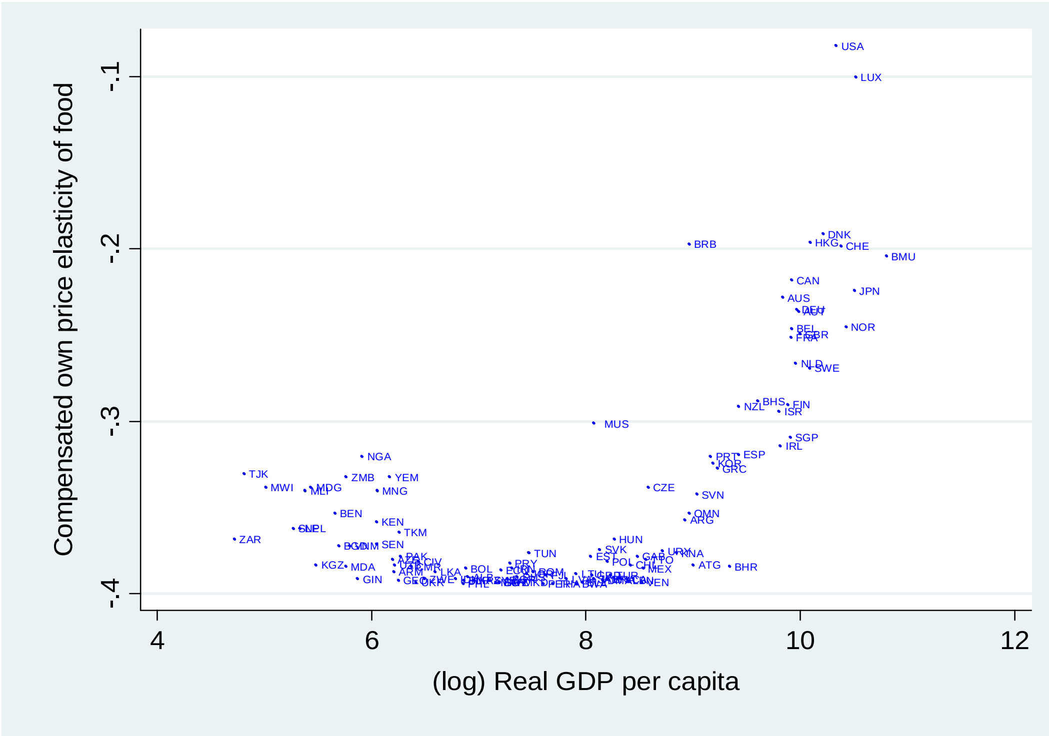
Figure 2. Income Elasticity of Demand for Food, 1996



Source: WDI and International Food Consumption Patterns Dataset, Economic Research Service, USDA.

Notes: 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.

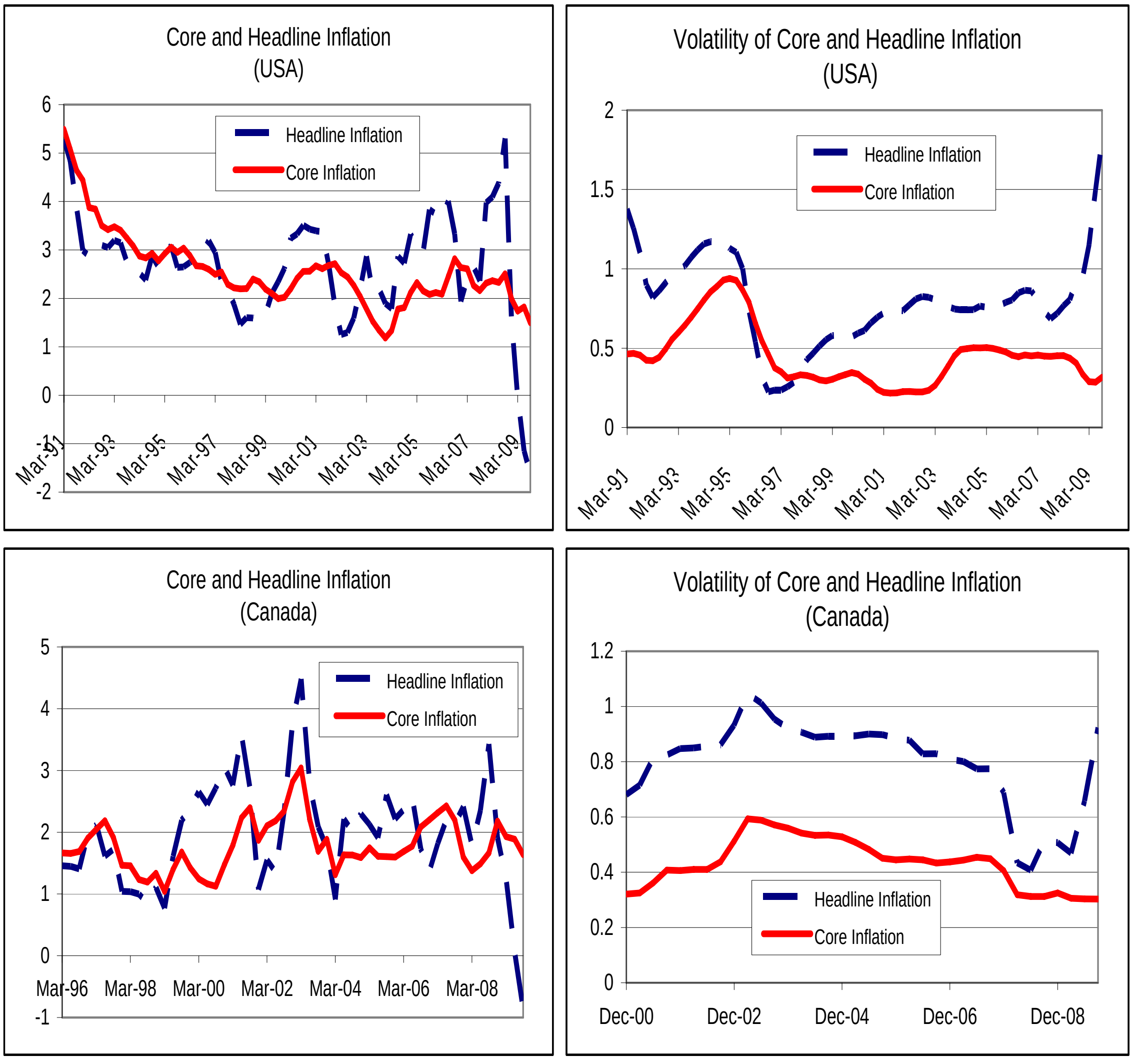
Figure 3. Slutsky Own-Price Elasticity of Demand for Food, 1996



Source: WDI and International Food Consumption Patterns Dataset, Economic Research Service, USDA.

Notes: Country-specific elasticity value represents a percentage change in demand for food if food prices increase by 1 percent (keeping real income constant). Food includes food prepared at home and consumed plus beverages and tobacco.

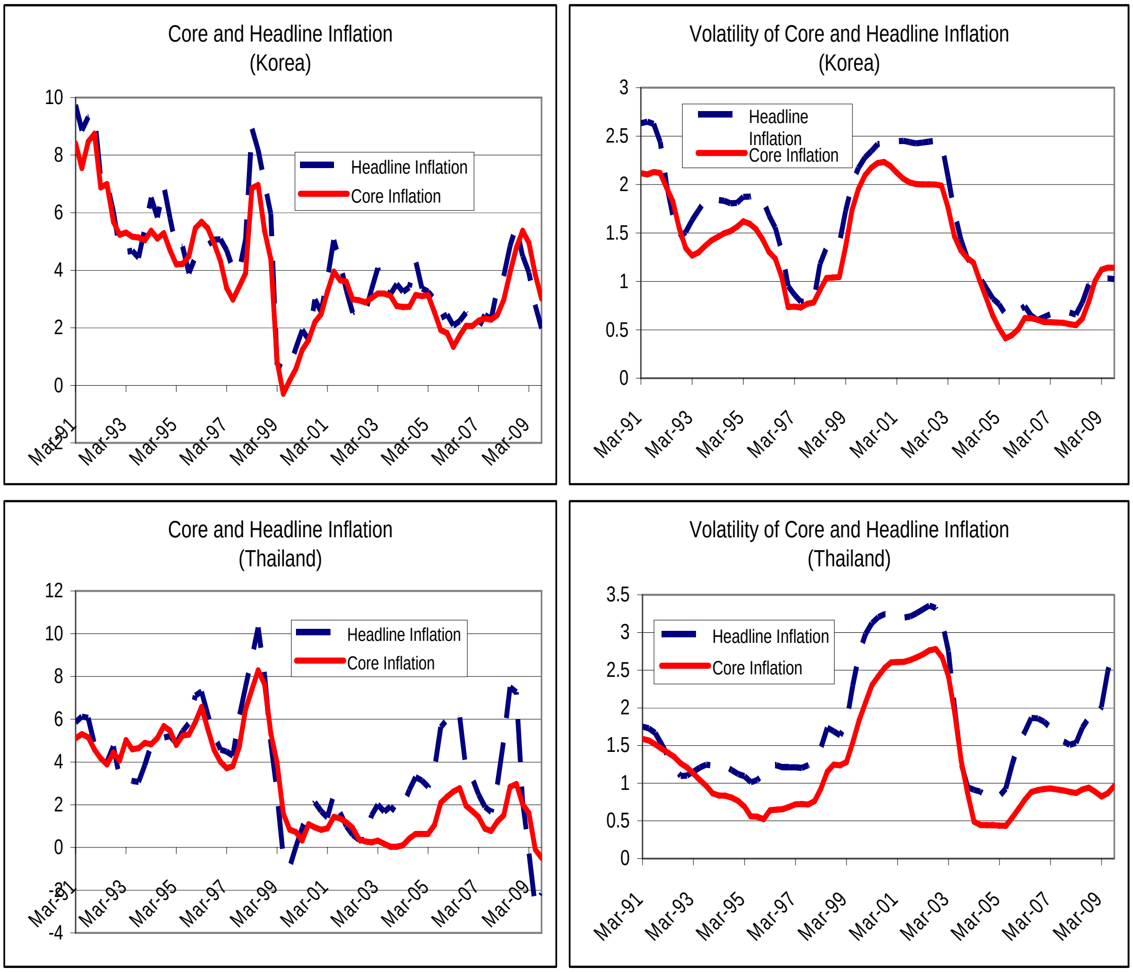
Figure 4. Levels and Volatility of Inflation



Source: CEIC and authors' calculations.

Notes: 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-year) window. We also computed the volatility using 8-year and 10-year rolling windows and the results were similar.

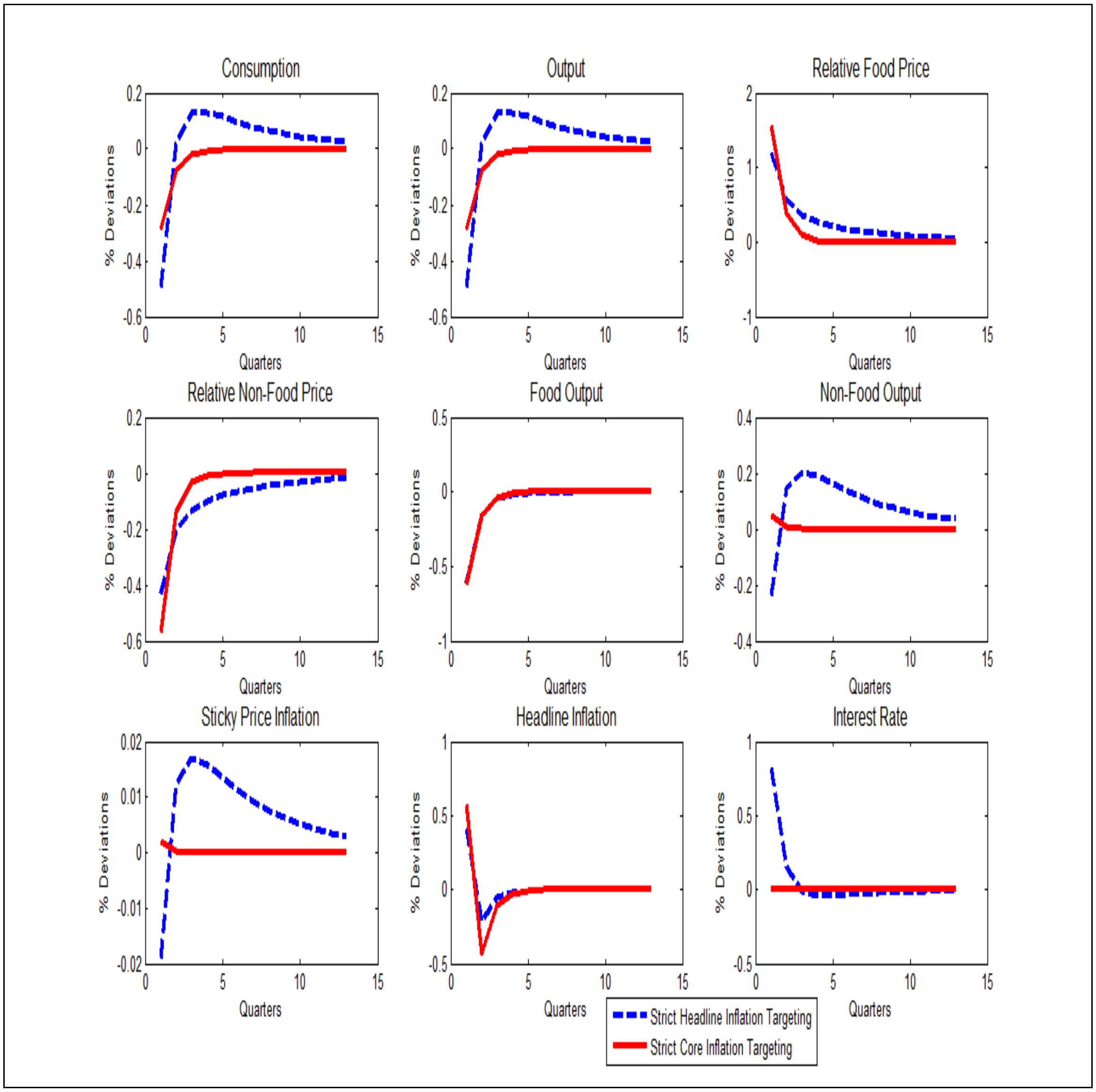
Figure 5. Levels and Volatility of Inflation



Source: CEIC and authors' calculations.

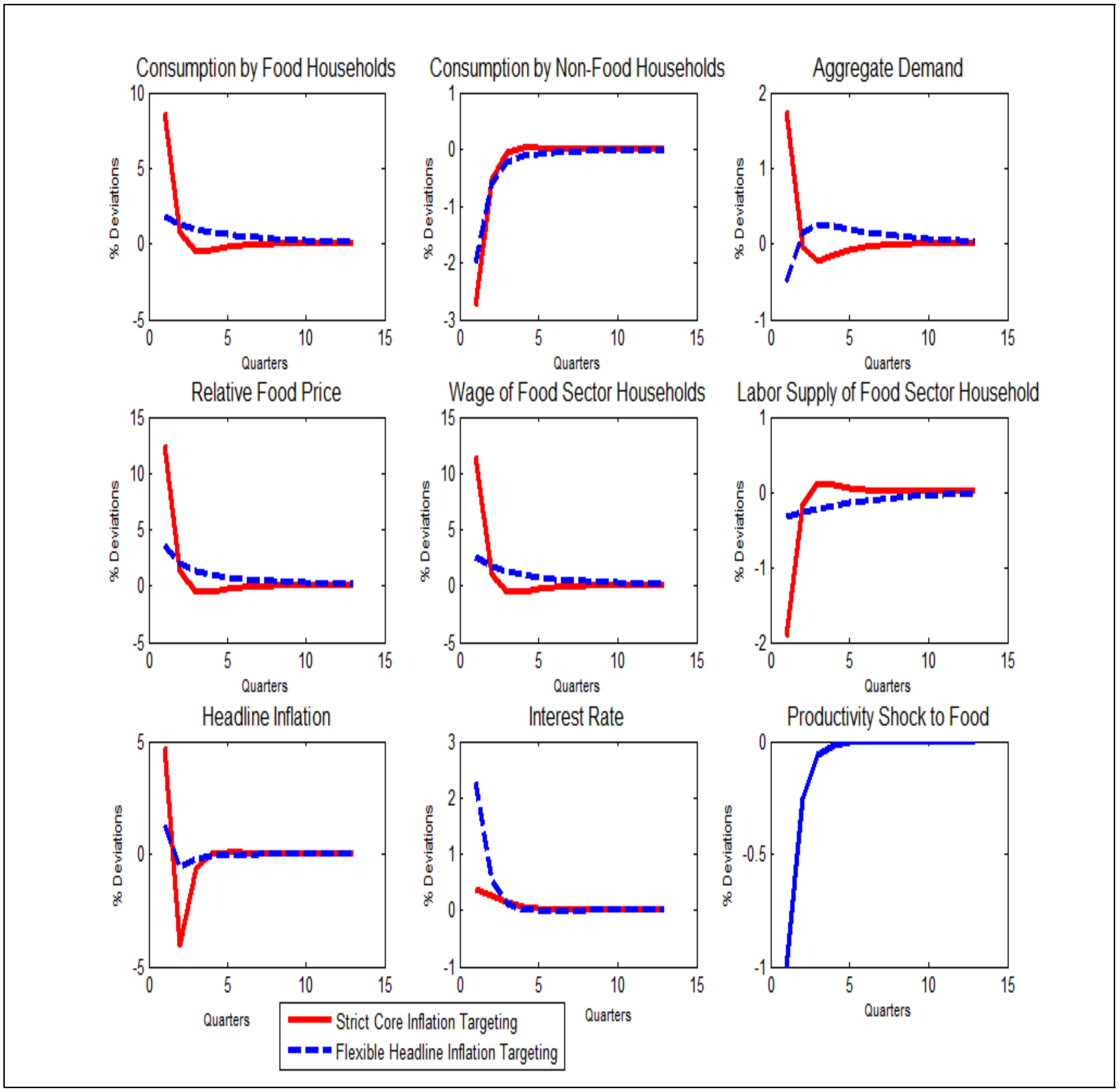
Notes: Core index for Korea is defined as CPI excluding agricultural products and oil while for Thailand it is defined as CPI excluding unprocessed food and energy. Inflation is year-on-year inflation using quarterly price index. Volatility is measured as the standard deviation of inflation using a rolling 20-quarter (5-year) window. We also computed the volatility using 8-year and 10-year rolling windows and the results were similar.

Figure 6. Impulse Responses to a 1% Negative Food Productivity Shock
(Complete Markets, with subsistence level food consumption)



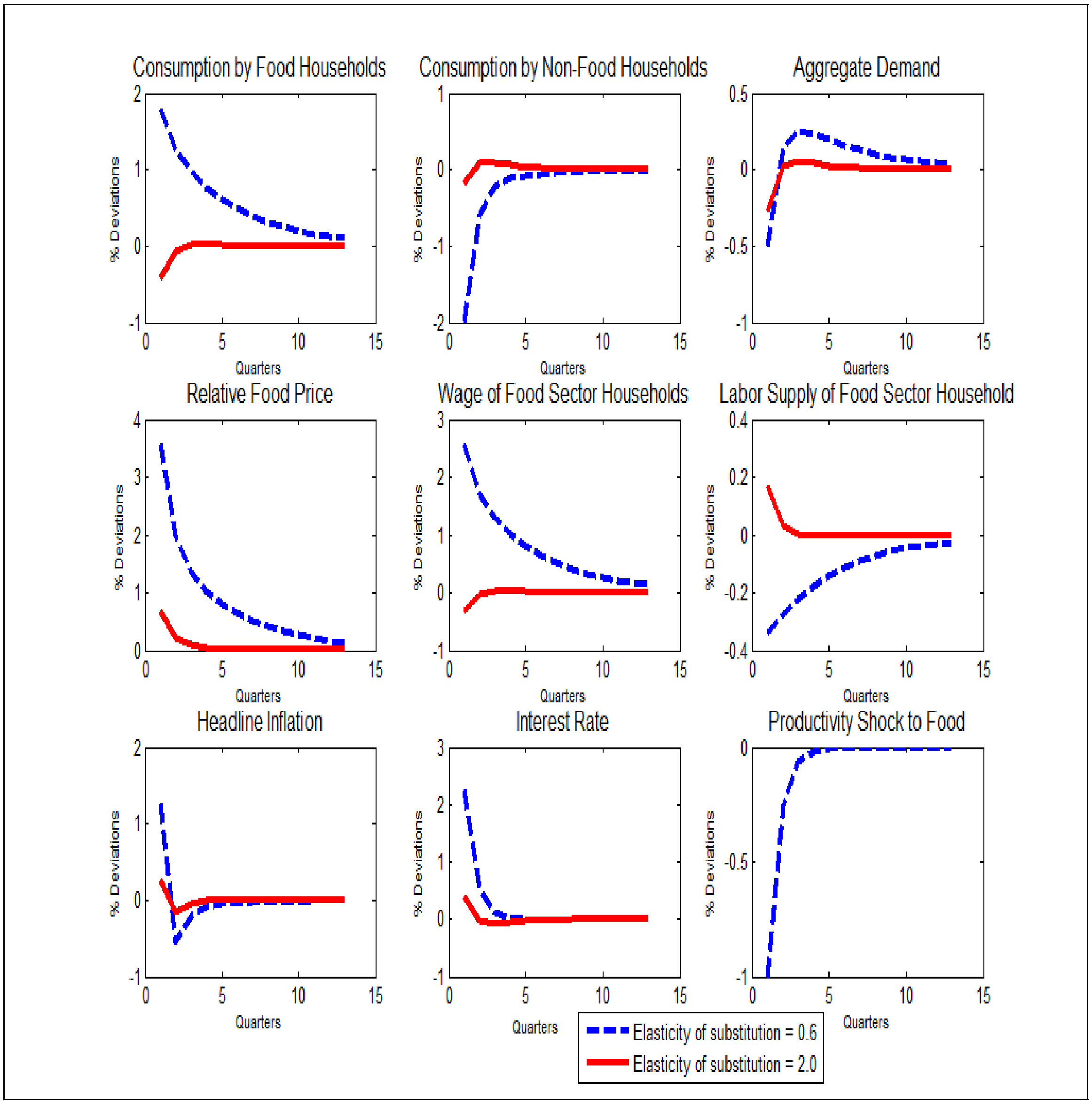
Notes: Each variable's response is expressed as the percentage deviation from its steady state level. Strict core inflation targeting means that central bank follows the policy regime given by equation (35). Strict headline inflation targeting means that central bank follows the policy regime given by equation (36).

Figure 7. Impulse Responses to a 1% Negative Food Productivity Shock
(Incomplete Markets, with subsistence level food consumption)



Notes: 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 (35). Flexible headline inflation targeting means that central bank follows the policy regime given by equation (38).

Figure 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)



Notes: 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 (38).

Table 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**

Source: Household Surveys, CEIC, International Food Consumption Patterns Dataset, Economic Research Service, USDA and authors' calculations.
Notes: 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.

Table 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**	**0.30**	**-0.22**

Source: WDI and International Food Consumption Patterns Dataset, Economic Research Service, USDA.
Notes: 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 increase by 1 percent (keeping real income constant). Food includes food prepared at home and consumed plus beverages and tobacco.

Table 3. Composite Measure of Access to Financial Services in Emerging Markets (2008)

	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**

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

Table 4. Average Inflation, Volatility and Persistence of Inflation
(March 1991 – September 2009)[a]

	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)

Source: CEIC and authors' calculations.
Note: Core price index in USA excludes food and energy from the CPI while in Canada it excludes indirect taxes 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 year-on-year inflation rate calculated using a quarterly price index. Volatility is measured as the standard deviation of inflation using a rolling 20 quarter (5 year) 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 (for MA(3) correction) are reported in brackets.
a. Data for Canada is for the period March 1996 – September 2009.

Table 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	Households with credit constraints (unconstrained households have measure 1)	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

Table 6. Welfare Gains from Alternative 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

Notes: Welfare gains (ω *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 the alternative policy than under the strict core inflation targeting policy. Targeting policy rules are defined in equations (35) - (38).

Table 7. Welfare Gains from Alternative Inflation Targeting Rules
Without Subsistence-Level Food

Welfare gain (in percent 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 6.

a. Baseline value of this parameter.

Table 8. Welfare Gains from Alternative Inflation Targeting Rules
for Different Values of Elasticity of Substitution (η)

Welfare gain (in percent 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
0.6[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 6.

a. Baseline value of this parameter.

Table 9. Welfare Gains from Alternative Inflation Targeting Rules
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

Notes: See notes to table 6. Parameter value of 2 implies labor elasticity of 0.5 while parameter value of 4 implies labor elasticity of 0.25.

a. Baseline value of this parameter.

Table 10. Welfare Gains from Alternative Inflation Targeting Rules
for Different Degrees 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

Notes: See notes to table 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. Baseline value of this parameter.

Table 11. Welfare Gains from Alternative Inflation Targeting Rules
for Different Shares of Credit-Constrained Consumers in Population (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

Notes: See notes to table 6. Parameter value of 2 implies that two-thirds of households are in the flexible price sector and are credit constrained. Parameter value of 3 implies that three-quarters of households are in the flexible price sector and are credit constrained.

a. Baseline value of this parameter.

Table 12. Welfare Gains from Alternative Inflation Targeting Rules
for Different Degrees of Elasticity of Substitution Between Different Non-Food Goods
(θ)

Elasticity of substitution between different 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

Notes: See notes to table 6. The parameter θ also determines the markup in the sticky price sector. A parameter value of 5 implies a markup of 25 percent and a value of 15 implies a mark up of 7 percent.

a. Baseline value of this parameter.

Table 13. Welfare Gains from Alternative Inflation Targeting Rules
for Different Taylor Rule Parameters

(a) 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

Notes: See notes to table 6. Other Taylor rule parameters have been kept at their baseline values (ρ_i=0.7, ρ_Y=0.5).

a. Baseline value of this parameter.

(b) 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

Nots: See notes to table 6. Other Taylor rule parameters have been kept at their baseline values (ρ_i =0.7, ρ_π =2).
a. Baseline value of this parameter.

(c) 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

Notes: See notes to table 6. Other Taylor rule parameters have been kept at their baseline values (ρ_π =2, ρ_Y =0.5).
a. Baseline value of this parameter.

Table 14. 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

Notes: See notes to table 6. Persistence of food productivity is the estimated coefficient of AR(1) process in equation (39). Volatility of food productivity shock is the standard deviation of random shocks to productivity. Persistence and volatility of non-food shocks is held constant at 0.95 and 0.02, respectively, in the above welfare cost calculations.

Table 15. Welfare Gains from Flexible Headline Inflation Targeting under Alternate Complete Market Structures

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

Notes: See notes to table 6.

a. Baseline value of this parameter, which represents the elasticity of substitution between food and nonfood goods.

Table 16. Welfare Gains from Flexible Headline Inflation Targeting
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 from 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

Notes: See notes to table 6. We have chosen combinations of λ_1 and λ_2 such that overall 50 percent of households in the economy are credit constrained.

Appendix I

Competitive Equilibrium with Incomplete Markets

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

$$C_t^f = x_{f,t} y_{f,t} - x_{f,t} C^* \tag{52}$$

Supply equation of flexible price sector (food sector) firm

$$x_{f,t} = \phi_n (y_{f,t})^{\psi} (C_t^f)^{\sigma} (A_{f,t})^{-(1+\psi)} \tag{53}$$

Demand equation for sticky price sector household

$$(C_t^s)^{-\sigma} = \beta E_t \left\{ (C_{t+1}^s)^{-\sigma} \frac{R_t}{\Pi_t} \right\} \tag{54}$$

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

$$x_t x_{s,t} = \frac{\theta}{\theta - 1} \frac{E_t \left[\sum_{j=0}^{1} (\alpha\beta)^j Q_{t,t+j} \left(\frac{P_{s,t}}{P_{s,t+j}} \right)^{-\theta} Y_{s,t+j} \left(\frac{P_{t+j}}{P_t} \right) MC_{t+j}^r(z) \right]}{E_t \left[\sum_{i=0}^{1} (\alpha\beta)^j Q_{t,t+j} \left(\frac{P_{s,t}}{P_{s,t+j}} \right)^{-\theta} Y_{s,t+j} \right]} \tag{55}$$

Price index in sticky price good sector

$$1 = \left[\alpha (\Pi_{s,t})^{-(1-\theta)} + (1-\alpha) x_t^{1-\theta} \right]^{\frac{1}{1-\theta}} \tag{56}$$

Real marginal cost in the sticky price sector

$$MC_t^r(z) = \phi_n (y_{s,t}(z))^{\psi} (C_t^s)^{\sigma} (A_{s,t})^{-(1+\psi)} = \phi_n ((x_t)^{-\theta} Y_{s,t})^{\psi} (C_t^s)^{\sigma} (A_{s,t})^{-(1+\psi)} \tag{57}$$

Market clearing equation for flexible price good

$$Y_{f,t} = \lambda y_{f,t} = C_{f,t} = \gamma(x_{f,t})^{-\eta} C_t + (1+\lambda)C^* \qquad (58)$$

Market clearing condition for sticky price good

$$Y_{s,t} = C_{s,t} = (1-\gamma)(x_{s,t})^{-\eta} C_t \qquad (59)$$

Aggregate Price Index

$$1 = \left[\gamma(x_{f,t})^{1-\eta} + (1-\gamma)(x_{s,t})^{1-\eta}\right]^{\frac{1}{1-\eta}} \qquad (60)$$

Relation between headline and sticky price index

$$x_{s,t} = \frac{\Pi_{s,t} x_{s,t-1}}{\Pi_t} \qquad (61)$$

Aggregation equation

$$\lambda C_t^f + C_t^s = C_t = Y_t \qquad (62)$$

Appendix II

Derivation of Welfare Gains Associated with Different Targeting Rules

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

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

Appendix III

Alternative Market Structures

A. Alternative Structure of Complete Markets

We consider a setting in which consumers can write contracts to insure against idiosyncratic income risks but only after being assigned to a particular sector. One could regard this as a complete market setting *conditional* on worker assignment to sectors, which is determined *ex-ante* (before insurance contracts are written). In other words, a household cannot insure against cross-sector income risk.

Households in the Flexible Price Sector

A representative household in the flexible price sector maximizes its lifetime utility given by equation (1) subject to the following budget constraint[40]

$$P_t C_t^f + B_t^f + \frac{\kappa}{2}\left(B_t^f - B^f\right)^2 = W_t^f N_t^f + R_{t-1} B_{t-1}^f - P_{f,t} C^* \tag{63}$$

where B_t^f is the quantity of one-period nominal riskfree discount bonds bought in period t and maturing in period $t+1$. Maximization with respect to C_t^f yields the Euler equation

$$(1+\kappa(B_t^f - B^f))(C_t^f)^{-\sigma} = \beta E_t\left\{(C_{t+1}^f)^{-\sigma}\frac{R_t}{\Pi_{t+1}}\right\} \tag{64}$$

Households in the Sticky Price Sector

A representative household in the sticky price sector maximizes its lifetime utility given by equation (1) subject to the following budget constraint[41]

[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 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.

[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 costs, $\frac{\kappa}{2}\left(B_t^s - B^s\right)^2$, where κ is a parameter and B^s is the steady state value of the bond holding.

$$P_t C_t^s + B_t^s + \frac{\kappa}{2}(B_t^s - B^s)^2 = \int_0^1 W_t^s(z) N_t^s(z) dz + \int_0^1 \Pi_t(z) dz + R_{t-1} B_{t-1}^s - P_{f,t} C^* \quad (65)$$

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

$$(1+\kappa(B_t^s - B^s))(C_t^s)^{-\sigma} = \beta E_t \left\{ (C_{t+1}^s)^{-\sigma} \frac{R_t}{\Pi_{t+1}} \right\} \quad (66)$$

Bond markets clear: $\lambda B_t^f + B_t^s = 0$ (67)

Equations (53), (55)-(62) of Appendix I and (63)-(67) 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.

B. General Case with Credit-Constrained Households in Each Sector

We consider a more general case where households in each sector can be credit constrained. Let $\lambda_1 > 0$ and $\lambda_2 > 0$ be the fractions of households that 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 access to financial markets can only insure against income risks *ex post*.

Households in the Flexible Price Sector

Unconstrained Households

A representative household that has access to financial markets in the flexible price sector maximizes its lifetime utility given by equation (1) subject to the following budget constraint[42]

$$P_t C_{1t}^f + B_t^f + \frac{\kappa}{2}\left(B_t^f - B^f\right)^2 = W_t^f N_{1t}^f + R_{t-1} B_{t-1}^f - P_{f,t} C^* \quad (68)$$

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[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 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.

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

$$(1+\kappa(B_t^f - B^f))(C_{1t}^f)^{-\sigma} = \beta E_t\left\{(C_{1t+1}^f)^{-\sigma}\frac{R_t}{\Pi_{t+1}}\right\} \quad (69)$$

The labor supply decision of the household is given by

$$\phi_n \frac{(N_{1t}^f)^{\psi}}{(C_{1t}^f)^{-\sigma}} = \frac{W_t^f}{P_t} \quad (70)$$

Constrained Households

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

$$P_t C_{2t}^f = W_t^f N_{2t}^f - P_{f,t}C^* \quad (71)$$

The labor supply decision of the household is given by

$$\phi_n \frac{(N_{2t}^f)^{\psi}}{(C_{2t}^f)^{-\sigma}} = \frac{W_t^f}{P_t} \quad (72)$$

Households in the Sticky Price Sector

Unconstrained Households

A representative household in the sticky price sector that has access to financial markets maximizes its lifetime utility given by equation (1) subject to the following budget constraint[43]

$$P_t C_{1t}^s + B_t^s + \frac{\kappa}{2}(B_t^s - B^s)^2 = \int_0^1 W_t^s(z)N_{1t}^s(z)dz + \int_0^1 \Pi_t(z)dz + R_{t-1}B_{t-1}^s - P_{f,t}C^* \quad (73)$$

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

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

$$(1+\kappa(B_t^s - B^s))(C_{1t}^s)^{-\sigma} = \beta E_t\left\{(C_{1t+1}^s)^{-\sigma}\frac{R_t}{\Pi_{t+1}}\right\} \quad (74)$$

The labor supply decision of the household to a firm indexed by *z* is given by

$$\phi_n \frac{(N_{1t}^s(z))^{\psi}}{(C_{1t}^s)^{-\sigma}} = \frac{W_t^s(z)}{P_t} \quad (75)$$

Constrained Households

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

$$P_t C_{2t}^s = \int_0^1 W_t^s(z) N_{2t}^s(z)dz + \int_0^1 \Pi_t(z)dz - P_{f,t}C^* \quad (76)$$

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

$$\phi_n \frac{(N_{2t}^s(z))^{\psi}}{(C_{2t}^s)^{-\sigma}} = \frac{W_t^s(z)}{P_t} \quad (77)$$

Firms

Flexible Price Sector

Firms in the flexible price sector are price taking and therefore the price of the flexible price good is given by equation (21). Combining this with the labor supply decision of households given by equations (70) and (72) 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

$$\frac{P_{f,t}}{P_t} = \phi_n \frac{\left(y_{f1,t}/A_{f,t}\right)^{\psi}}{A_{f,t}(C_{1t}^f)^{-\sigma}} \quad (78)$$

$$\frac{P_{f,t}}{P_t} = \phi_n \frac{\left(y_{f2,t}/A_{f,t}\right)^{\psi}}{A_{f,t}(C_{2t}^f)^{-\sigma}} \quad (79)$$

Sticky Price Sector

Since firms are symmetric, in equilibrium they will all choose the same price.[44] The marginal costs of firms held by unconstrained and constrained households are therefore given by

$$\frac{MC_t(z)}{P_t} = MC_t^r(z) = \phi_n \frac{\left(y_{s1t}(z) \big/ A_{s,t} \right)^{\psi}}{A_{s,t}(C_{1t}^s)^{-\sigma}} \tag{80}$$

$$\frac{MC_t(z)}{P_t} = MC_t^r(z) = \phi_n \frac{\left(y_{s2t}(z) \big/ A_{s,t} \right)^{\psi}}{A_{s,t}(C_{2t}^s)^{-\sigma}} \tag{81}$$

where we have used the fact that $y_{s1t}(z) = A_{s,t} N_{1t}^s(z)$ and $y_{s2t}(z) = A_{s,t} N_{2t}^s(z)$

Aggregation

Household demand for flexible price and sticky price goods is given by expressions similar to equation (10), (11), (18) and (19) with C_t^f and C_t^s replaced by C_{it}^f and C_{it}^s where i =1, 2. Total demand for the flexible price good is given by

$$C_{f,t} = \gamma \left(\frac{P_{f,t}}{P_t} \right)^{-\eta} C_t + (1+\lambda) C^* \tag{82}$$

where $C_t = \lambda_1 C_{1t}^f + (\lambda - \lambda_1) C_{2t}^f + \lambda_2 C_{1t}^s + (1-\lambda_2) C_{2t}^s$ (83)

And the total demand for the sticky price good is given by

$$C_{s,t} = (1-\gamma) \left(\frac{P_{s,t}}{P_t} \right)^{-\eta} C_t \tag{84}$$

Market Clearing

The market for the flexible price good clears

$$Y_{f,t} = \lambda_1 y_{f1,t} + (\lambda - \lambda_1) y_{f2,t} = C_{f,t} \tag{85}$$

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

where

$y_{f1,t} = A_{f,t} N_{1t}^f$ and $y_{f2,t} = A_{f,t} N_{2t}^f$

The market for the sticky price good clears

$$Y_{s,t} = \lambda_2 y_{s1,t} + (1-\lambda_2) y_{s2,t} = C_{s,t} \quad (86)$$

where

$y_{s1,t} = A_{s,t} N_{1t}^s$ and $y_{s2,t} = A_{s,t} N_{2t}^s$

The bond market clears

$$\lambda_1 B_t^f + \lambda_2 B_t^s = 0 \quad (87)$$

Equations (55), (56), (60), (61) of Appendix I and (68), (69), (71), (73), (74), (76), (78)-(87) 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.