Does U.S. Monetary Policy Respond to Oil and Food Prices?[☆]

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Abstract

A common view is that U.S. monetary policy does not respond to the changes in volatile energy and food prices. Despite this view, the popular New Keynesian models assume Taylor-type rules under which the short-term interest rates react to headline inflation. This paper evaluates the fit of alternative Taylor rules within an estimated New Keynesian model. A main finding is that the U.S. central bank includes energy and food prices in its policy rule, although the weight assigned to these prices is much smaller than their share in the economy.

Keywords: DSGE models, Multiple Calvo, Taylor rules, sector-specific shocks, core inflation

JEL Classification: E10, E30

[☆] All errors remain my own.

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1. Introduction

It is often noted that the U.S. central bank puts lots of emphasis on core inflation (see, for example, Blinder and Reis (2005) and Mishkin (2007)). Mishkin (2007) explicitly notes that "The Federal Reserve, for example, pays particular attention to the rate of growth of the core personal consumption expenditure (PCE) deflator, which excludes food and energy prices".

Despite this insight, the standard models (e.g. Smets and Wouters (2007) (SW)) assume Taylor-type rules under which the short-term interest rates react to the changes in headline inflation (i.e. GDP deflator). As the discussion between John Taylor (2007) and Ben Bernanke (2015) indicates, the choice of inflation measure matters significantly for the interest rate implied by the rule. Using the Taylor rule with a measure of headline inflation (i.e. the GDP deflator), Taylor argues that the U.S. monetary policy was too easy, relative to what the rule suggests, during the period from 2002-2005. Based on this observation, Taylor argues that this loose monetary policy leads to the 2008 financial crisis. On the other hand, Bernanke changes the measure of inflation used by Taylor with a measure of core inflation (i.e. core PCE), which exclude the volatile energy and food prices. He finds that during that period U.S. monetary policy is consistent with the predictions of his version of the Taylor rule.

Given the fact that new Keynesian models are used for monetary policy analysis at central banks around the world and that policy prescription of the rule is affected by the choice of inflation measure, it is important to evaluate the fit of alternative Taylor rules with different measures of inflation within a New Keynesian model. This is the challenge this paper takes up. I consider two different rules. One of the rules is the same as that in the SW model. Under this rule, the central banks adjusts the short-term interest rate according to the changes in headline inflation as well as the output gap and the change in the output gap. The second rule is the same as the SW rule but reacts to the changes in an inflation index, rather than headline inflation. The inflation index is an appropriately weighted average of core inflation and energy and food prices.

The main finding of this paper is that the Taylor rule under which the central bank reacts to the changes in core inflation but does not ignore the changes in energy and oil prices fits the data better than the rule employed in the SW model. The share of core inflation in the inflation index is around 90%, while the share of energy and food prices in the index is 10%. The weight energy and food prices receive in the inflation index is small, relative to its share in the economy. The share of energy and food prices in the economy is 34%. This rule performs significantly better than both the rules that target core inflation only and the rule that targets headline inflation.

While there are studies (e.g. Cúrdia et al. (2015)) that replace GDP deflator data with core inflation data in the SW model, to the best of my knowledge, this is the first paper that compares the empirical performance of the two rules within the same model. A possible reason for the lack of such studies may be that, as has been emphasised by Boivin and Giannoni (2006), the existing macroeconomic modelling approach tends to favour simplicity and only one price index is used in estimation.

To overcome this issue, I use a multi-sector version of the SW model (Multiple Calvo-SW), as proposed by Kara (2015). I consider a special case of the MC-SW model in which there are two sectors and the sectors differ in their contract length, in their share in the economy and in the variances of sector-specific shocks. In one of the sectors, prices are relatively flexible, while in the other they are sticky. Following the literature (e.g. Aoki (2001) and Woodford (2003)), core inflation is defined as inflation in the sticky-price sector, while inflation in the flexible-price sector represents energy and food prices. The latter assumption is consistent with the micro evidence on prices (see Klenow and Malin (2011) for a survey). As I will discuss in more detail later in the text, the series for flexible-price inflation is very similar to that for energy and food prices. Thus, in the model there are two sectoral price indices and an aggregate price index. Data for three price indices along with the other macroeconomic data commonly used to estimate new Keynesian models are used to estimate the model. Sectoral price data are compiled by Bils et al. (2012). The data are based on the U.S. CPI data and are grouped into two sub-groups according to how frequently prices change. Consistent with the conventional wisdom and the empirical findings reported in Boivin et al. (2009), estimation results show that in the flexible sector standard deviation of the sector-specific shocks are much larger than those in the sticky sector.

This paper is closely related to the paper by Blinder and Reis (2005). Blinder and Reis estimate the Taylor rule in a univariate setting from 1987 to 2005 and find that a Taylor rule with core inflation fits the data better than a Taylor rule with headline inflation. My results are consistent with theirs. However, I find that a Taylor rule that includes energy and food prices as an additional targeting variable fits the data better than a Taylor rule with core inflation.

The remainder of the paper is organised as follows. Section 2 presents the model. Section 3 discusses the data used in the estimation and the methodology for the estimation. Section 4 compares the models, presents estimation results and, finally, explores the robustness of the conclusions to alternative specifications. Section 5 concludes the paper.

2. The model

The model is based on Kara (2015). Kara(2015) incorporates heterogeneity in price stickiness into the SW model, along the lines suggested by Carvalho (2006). The model is referred to as MC-SW. Here I allow for the possibility that sectors are hit by sector-specific shocks. Due to data limitations, a special version of the model with two sectors is considered. In this section, the equations describing price setting in the model are presented, which are, apart from the assumption of sector-specific shocks are exactly the same as those in Kara (2015) [1]. The remaining equations are the same as those in the SW and are listed in Appendix A.

In the model there is a continuum of monopolistically competitive firms indexed by $f\epsilon[0,1]$, each producing a differentiated good $Y_t(f)$. The unit interval of firms is divided into N sectors, $i = 1...N$. In this paper, it is assumed that N=2. The share of each sector is α_i. Within each sector, there

[1] In Kara (2016), I use the same model to test whether the model can match the empirical findings from factor models that sectoral prices adjust faster to sector-specific shocks than to monetary policy shocks. The results suggest that it can, making a stronger case for the model.

is a Calvo-style contract. In sector i, the hazard rate is given by ω_i. The pricing rule for the firms in sector i (in logs) is given by

$$\bar{x}_{it} = \omega_i \frac{\bar{mc}_t}{\zeta \epsilon_p + 1} + (1 - \omega_i)(E_t \bar{x}_{it+1} + E_t \pi_{t+1}) + \varepsilon_{it}^p \tag{1}$$

where $\bar{mc}_t = (1 - \alpha) w_t + \alpha r_t^k - \varepsilon_t^a$ is the marginal cost. w_t is wages, r_t^k is the rental rate of capital and ε_t^a is the total factor productivity. ε_{it}^p denotes the sector-specific price shocks, $\bar{x}_{it} = x_{it} - p_t$ is the real reset price in sector i, x_{it} is the nominal reset price, p_t is the general price level and π_t is inflation. ϵ_p is the percentage change in the elasticity of demand due to a one percent change in the relative price at the steady state and ζ is the steady state price-markup and is related to the fixed costs in production. These two terms determine how responsive the firms are to the changes in real marginal cost. In each sector i relative prices are related to the reset prices in that sector as follows:

$$\bar{p}_{it} = \omega_i \bar{x}_{it} + (1 - \omega_i)(\bar{p}_{it-1} - \pi_t) \tag{2}$$

where $\bar{p}_{it} = p_{it} - p_t$ denotes the logarithmic deviation of the aggregate price in sector i (p_{it}) from the aggregate price level. The nominal aggregate price level in the economy is simply the weighted average of all ongoing prices. This relation implies that

$$\sum_{i=1}^{N} \alpha_i \bar{p}_{it} = 0 \tag{3}$$

These equations can also represent the Calvo model. Noting that $\bar{p}_{it} = \bar{p}_{it-1} = 0$ and dropping subscript i gives the Calvo model.

2.1. Monetary Policy rules

The central bank is assumed to follow a generalised Taylor rule under which the short term interest rate is adjusted to respond to changes in an inflation index, in the output gap and in the growth rate of the output gap:

$$r_t = \rho r_{t-1} + (1-\rho)\left(r_\pi \pi_t^{index} + r_y \tilde{y}_t\right) + r_{\Delta y}\Delta\tilde{y}_t + \varepsilon_t^m \tag{4}$$

where $\tilde{y}_t = y_t - y_t^*$ is the output gap, $\Delta\tilde{y}_t = \tilde{y}_t - \tilde{y}_{t-1}$, y_t is the actual level of output, y_t^* is the natural level of output, $r-$coefficients and ρ denote the coefficients in front of the targeting variables. Finally, π^{index} is an inflation index, which is an appropriately weighted average sectoral inflation rates and is given by

$$\pi_t^{index} = \bar{\alpha}_1\pi_1 + \bar{\alpha}_2\pi_2 \tag{5}$$

where $\bar{\alpha}$-coefficients sum to one and are the main focus of the paper. They determine the extent to which the central bank respond to sectoral inflation rates. When $\bar{\alpha_1} = \alpha_1$ and $\bar{\alpha_2} = \alpha_2$, then this rule gives the policy rule in SW. The approach of this paper is to vary $\bar{\alpha_1}$ between 0 and α_1, where $\alpha_1 = 0.34$. For each case, the model is estimated and the corresponding marginal likelihood is computed.

3. Data and Estimation Strategy

The model is estimated using Bayesian techniques. In estimating the model, nine macroeconomic series at bimonthly frequency are used. Seven of these series are the same as those in SW: real output growth, consumption growth, investment growth, hours worked, wage inflation, price inflation and the federal funds rate. The remaining two are sectoral price indices constructed by BKM. To construct the sectoral price indices, BKM use the CPI Research Database maintained by the BLS. The sample period runs from January − February 1990 to September − October 2009. There are around 300 product categories in the dataset. If a product category's frequency of price adjustment is greater than one third, it is classified as flexible. Otherwise it is classified as sticky. The share of flexible-price sector is 34 percent, while the share of sticky-sector is 66 percent. All variables used in estimation, including inflation measures, are seasonally adjusted and are measured in percent. For a detailed discussion about the dataset, the reader is referred to BKM.

Measurement equations relating the model inflation variables to the observables are listed here, while for the remaining variables, which are the same as those in SW, are reported in the Appendix. BKM also provide the bimonthly analogs for the other macroeconomic variables.

$$\begin{aligned} \text{Flexible Price Inflation} &= \bar{\pi} + \pi_{1t} \\ \text{Sticky Price Inflation} &= \bar{\pi} + \pi_{2t} \\ \text{Aggregate Price Inflation} &= \bar{\pi} + \pi_t + \varepsilon_t^p \end{aligned} \tag{6}$$

where $\bar{\pi} = 100(\Pi_\star - 1)$ is the steady-state level of net inflation. ε_t^p captures sampling errors in inflation.

The definition of core inflation used in this paper is theory-based. Following Aoki (2001) and Woodford (2003), core inflation is defined as inflation in the sticky sector.

4. Estimation Results

I begin by estimating and comparing the models with different policy rules and discuss the resulting parameter estimates. Finally, I report findings from several robustness exercises.

4.1. Model Comparision: Core or Headline?

Following Cúrdia et al. (2015), marginal densities and the corresponding Kass and Raftery (KR) (1995) ratios are used to compare different models.The KR ratio is defined as two times the log of the Bayes factor.[2]

Figure 1 reports the model's log marginal densities under different policy rules. The x-axis of the figure shows the weight of flexible-sector inflation ($\bar{\alpha_1}$) in the inflation index.[3] The weight of sticky-sector inflation in the index ($\bar{\alpha_2}$) is given by (1-$\bar{\alpha_1}$). As the figure shows the model's performance, in terms of marginal densities, first improves but then deteriorates, as the weight of flexible-sector inflation increases in the index. The best performing model is the one with $\bar{\alpha_1} = 0.075$ and $\bar{\alpha_2} = 0.925$. The figure further shows that

[2]KR suggest the following rule of thumb for interpreting the ratios: more than 10 (very strong in favour of a model), 6-10 (strong), 2-6 (positive) and 0-2 (not worth more than a bare mention).

[3]For computational ease, the marginal density values plotted in Figure 1 are based on the Laplace approximation. After determining the best perfroming model, I run the Metropolis-Hastings algorithm for three cases: the best performing model, core-inflation targeting and headline inflation targeting. Marginal densities based on the Metropolis-Hastings algorithm are reported in Table 1. Consistent with the findings reported in SW, the numbers reported in Table 1 are very similar to those obtained based on the Laplace approximation.

the model with core-inflation targeting performs better than the model with headline-inflation targeting. The log marginal density for the best performing model along with those for the two models are reported in Table 1.

The log-marginal likelihood difference between the best performing model and the model in which the aggregate inflation is targeted is significant at around 6 points, translating into a KR ratio of above 10. This implies a very strong evidence to the model that mainly targets sticky-price inflation but do not completely ignore flexible-price inflation. The model in which the central bank solely cares about the changes in core inflation performs significantly worse than the model in which the changes in the inflation index is targeted. The difference between these two models implies a KR ratio of 6, providing a 'strong' support for the idea that the U.S. central bank does not completely ignore energy and food price changes.

4.2. Parameter Estimation Results

Table 2 reports the prior mean and the standard deviation of the parameters and the corresponding posterior distributions obtained by the Metropolis-Hastings algorithm in the best performing model. Table 3 presents the corresponding results for the shock processes. The table also reports the results for two other models: the model with core inflation targeting (i.e. $\bar{\alpha_1} = 0$) and the model with headline inflation targeting.

Let me first consider the parameter estimates from the best performing model. If we look at the estimates of the Taylor rule coefficients, we see that there is a high degree of interest-smoothing with an estimate of $\rho = 0.93$. The model suggests that the U.S. central bank implements an anti-inflationary policy with a coefficient on the inflation index of $r_\pi = 1.39$. The results suggest that the central bank cares about the fluctuations in the output gap. The coefficient on the output gap is around 0.2. The coefficient on the change in the output gap is small at around 0.03. The data appear to be informative about these parameters, as priors and posteriors have different locations, shapes and spreads.

A few other parameter values are worth commenting on. If we look at the estimates of sectoral Calvo parameters (ω_1 and ω_2), at $\omega_1 = 0.71$ and $\omega_2 = 0.08$, these parameters are in-line with the values in the actual data. In line with the empirical evidence (see Boivin et al. (2009)), the shocks in the flexible sector appear to be more volatile than the shocks in the sticky-sector. The standard deviation of sector specific price shocks in the flexible sector is 1.15% , while it is 0.58% for the sticky sector.

The estimates of the other parameters fall within plausible range and are in-line with the typical estimates of the parameters (e.g. SW). The column (2) of Tables 2 and 3 reports the estimation results from an alternative model in which the core inflation is targeted, while Column (3) plots the results from the model in which headline inflation is targeted. The parameter estimates are almost identical.

4.3. Robustness

Given that the main focus of the paper is the estimation of policy rules, the robustness of the benchmark results are assessed by relaxing the priors on the policy rule parameters. The interest-rate smoothing parameter (ρ) is assumed to follow a uniform distribution with a mean zero and a variance one. The prior means and variances of other response coefficients (r_π, r_y and $r_{\Delta y}$) are increased. While, with these changes, the posterior estimates of ρ

is the same as before, the posterior estimates of the other 3 parameters are higher. However, the data are informative, as the posterior estimates of these parameters are different from their prior mean. The posterior estimates of the other model parameters remain more or less the same. Finally, while the marginal densities reported in Figure 1 deteriorate with these changes, the ranking of the models do not change. The finding that the best performing model is the one with $\bar{\alpha_1} = 0.075$ and $\bar{\alpha_2} = 0.925$ appears robust.

Thus far, food and energy inflation is defined as inflation in the flexible-price sector. BKM also provide series specifically for food and energy inflation. This series is plotted in Figure 2 along with the inflation rate in the flexible-price sector. As the figure shows, the two series are almost exactly the same [4]. As a result, using the series for food and energy prices would not change the results.

Finally, I also estimate the model with an alternative specification of the interest rate rule. Policymakers emphasise that monetary policy should be forward-looking. Given this concern, I re-estimate the model with the following forecast based rule suggested by Orphanides (2003)

$$r_t = \rho r_{t-1} + (1-\rho)\left(r_\pi E_t \pi_{t+1}^{index} + r_y \tilde{y}_t\right) + r_{\Delta y} \Delta E_t \tilde{y}_{t+1} + \varepsilon_t^m \tag{7}$$

This rule reacts to changes in the expected inflation index, rather than the current period inflation index. The rule also replaces the current output gap growth rate with its forecast. Orphanides (2003) shows that doing so improves the fit of the rule.

[4] Both series are seasonally adjusted by using seasonal dummies. The presence of fluctuations in the series reflect the highly volatile nature of food and energy prices.

The results suggest that the model with the forecast-based targeting rule fits the data better than the model with the benchmark rule. This finding provides support to the idea that the U.S. monetary policy is forward-looking. While this is true, the main finding of the paper still holds. In this specification too, the rule that mainly targets core inflation but does not completely ignore food and energy prices fits the U.S. data better than core inflation targeting and headline inflation targeting rules.

5. Summary and Conclusions

I have estimated a two-sector version of the multi-sector New Keynesian model proposed by Kara (2015) to evaluate the fit of alternative Taylor rules. The sectors are subject to sector-specific shocks and differ in their contract length and in their share in the economy. In one of the sectors prices are more flexible than the other. Consistent with the micro-evidence on prices and common assumption in the literature, it is assumed that the flexible-price sector represents energy and food prices, while core inflation is defined as the inflation rate in the sticky sector. I have then used appropriate sectoral price data, complied by Bils et al. (2012), along with commonly used macroeconomic data to estimate the model.

As emphasised by Lubik and Schorfheide (2007), one of the main advantages of using New Keynesian models to estimate policy reaction functions is that it helps to overcome identification problems faced when single-equation estimation methods are used.

One of the main findings of the paper is that a Taylor-type rule that reacts to an inflation index that puts substantial weight on core inflation but does not completely ignore food and energy prices fits the U.S. data better than otherwise identical rules.

The results suggest that using micro-level price data gives new insights for monetary policy. While I use data up to October 2009, it would be interesting to redo the same analysis beyond this period. This would be especially interesting since, after this period, the U.S. monetary policy has changed and oil and food prices have experienced large fluctuations. However, the price data used in estimation is not available after this date. The sectoral price data provided by Bils et al. (2012) is based on the BLS's CPI Research Database. This is a confidential dataset. While there is more micro-level price data available than ever before, as surveyed by Klenow and Malin (2011), the lack of the data beyond 2009 highlights the need for follow-up studies that focus on heterogeneity in price stickiness.

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Appendix

A. The rest of the SW Model

This section summarises the remaining equations of the model, which, as noted above, are identical to a special case of the SW model with logarithmic consumption utility, no discounting and no wage indexation. Since SW provide detailed derivations of the equations, the discussion here is kept brief. The consumption Euler equation with habit formation is given by

$$c_t = c_1 c_{t-1} + (1 - c_1) E_t c_{t+1} - c_2 \left(r_t - E_t \pi_{t+1} + \varepsilon_t^b \right) \tag{A.1}$$

with $c_1 = \frac{\lambda/\gamma}{1+\lambda/\gamma}$ and $c_2 = \frac{1-\lambda/\gamma}{(1+\lambda/\gamma)}$. c_t is consumption, r_t is the interest rate, ε_t^b is the exogenous risk premium process and λ is the habit persistence parameter. The following equation gives the investment Euler equation

$$i_t = i_1 i_{t-1} + (1 - i_1) E_t i_{t+1} + i_2 q_t + \varepsilon_t^i \tag{A.2}$$

where $i_1 = \frac{1}{2}$, $i_2 = \frac{i_1}{\gamma^2 \varphi}$, φ is the elasticity of the capital adjustment cost function, i_t is investment, q_t is the current value of capital and ε_t^i is the investment specific technology shock. The arbitrage equation is given by

$$q_t = q_1 E_t q_{t+1} + (1 - q_1) E_t r_{t+1}^k - \left(r_t - E \pi_{t+1} + \varepsilon_t^b \right) \tag{A.3}$$

where $q_1 = \frac{1-\delta}{\gamma}$, r_{t+1}^k is the capital rental rate and δ is the depreciation rate. Capital (k_t) evolves according to the following equation:

$$k_t = k_1 k_{t-1} + (1 - k_1) i_t + k_2 \varepsilon_t^i \tag{A.4}$$

with $k_1 = \frac{(1-\delta)}{\gamma}$ and $k_2 = \frac{1-k_1}{i_2}$. The aggregate production function is given by

$$\begin{aligned} y_t &= \phi_p \left(\alpha k_t^s + (1-\alpha)\, l_t + \varepsilon_t^a\right) &\text{(A.5)} \\ &= c_y c_t + i_y i_t + z_y z_t + \varepsilon_t^g &\text{(A.6)} \end{aligned}$$

where y_t is output, l_t denotes labour and ε_t^g represents the government spending shock. c_y and i_y are respectively the steady state consumption-output ratio and investment-output ratio. z_t denotes the degree of capital utilization. z_y is the steady state rental rate of capital $\left(r_t^k\right)$. k_t^s is given by

$$k_t^s = k_{t-1} + z_t \tag{A.7}$$

with

$$z_t = \frac{1-\psi}{\psi} r_k^t \tag{A.8}$$

where r_k^t is given by

$$r_t^k = -\left(k_t - l_t\right) + w_t \tag{A.9}$$

The wage setting equation is given by

$$w_t = w_1 w_{t-1} + (1-w_1)(E_t w_{t+1} + E_t \pi_{t+1}) - w_2 \pi_t - w_3 \mu_t^w + \varepsilon_t^w \tag{A.10}$$

where $w_1 = w_2 = \frac{1}{2}$ and $w_3 = \frac{1}{2} \frac{(1-\xi_w)^2}{\xi_w((\phi_w - 1)\varepsilon_w + 1)}$. $(1-\xi_w)$ is the Calvo hazard rate, ε_w is the Kimball aggregator for the labour market, $(\phi_w - 1)$ is the steady state labour market mark-up and ε_t^w is the mark-up shock. μ_t^w is the difference between the real wage (w_t) and the marginal rate of substitution between labour and consumption. It is given by

$$\mu_t^w = w_t - \left(\sigma_l l_t + \frac{(c_t - \lambda c_{t-1})}{1-\lambda}\right) \tag{A.11}$$

The shock processes are as follows: ε_t^m is a monetary policy shock. Wage mark-up shocks (ε_t^w), price shocks in the flexible sector ($\varepsilon_t^{p_1}$), price shocks in the sticky sector ($\varepsilon_t^{p_2}$), sampling error in inflation (ε_t^p), government spending shocks (ε_t^g), monetary policy shocks (ε_t^m), risk premium shocks (ε_t^b), investment shocks (ε_t^i) and productivity shocks (ε_t^a) evolve according to the following processes:

$$\varepsilon_t^{p_1} = \rho_{p_1}\varepsilon_{t-1}^{p_1} + \eta_t^{p_1} \tag{A.12}$$

$$\varepsilon_t^{p_2} = \rho_{p_2}\varepsilon_{t-1}^{p_1} + \eta_t^{p_2} \tag{A.13}$$

$$\varepsilon_t^{p} = \rho_{p}\varepsilon_{t-1}^{p} + \eta_t^{p} \tag{A.14}$$

$$\varepsilon_t^{w} = \rho_{w}\varepsilon_{t-1}^{w} + \eta_t^{w} \tag{A.15}$$

$$\varepsilon_t^{g} = \rho_{g}\varepsilon_{t-1}^{g} + \eta_t^{g} + \rho_{ga}\eta_t^{a} \tag{A.16}$$

$$\varepsilon_t^{r} = \rho_{r}\varepsilon_{t-1}^{r} + \eta_t^{r} \tag{A.17}$$

$$\varepsilon_t^{b} = \rho_{b}\varepsilon_{t-1}^{b} + \eta_t^{b} \tag{A.18}$$

$$\varepsilon_t^{i} = \rho_{i}\varepsilon_{t-1}^{i} + \eta_t^{i} \tag{A.19}$$

$$\varepsilon_t^{a} = \rho_{z}\varepsilon_{t-1}^{a} + \eta_t^{a} \tag{A.20}$$

where $\rho-$ variables denote persistence parameters in the shocks processes. η_t- variables denote innovations to the shocks and are i.i.d with zero mean and finite variance. These shock processes are the same in the SW model, with two exceptions. Price shocks and wage shocks follow the following process:

$$\varepsilon_t^{p} = \rho_{p}\varepsilon_{t-1}^{p} + \eta_t^{p} - \mu_p\eta_{t-1}^{p} \tag{A.21}$$

$$\varepsilon_t^w = \rho_w \varepsilon_{t-1}^w + \eta_t^w - \mu_w \eta_{t-1}^w \tag{A.22}$$

B. Data and Priors

Nine observables are used in the estimation. Seven of them are the same as in the SW: real output growth, consumption growth, investment growth, hours worked, wage inflation, price inflation and the federal funds rate. Two of them are sectoral price series constructed by BKM. Since the micro data on prices used to construct sectoral prices are bi-monthly, as in BKM, the models in this paper are estimated using bimonthly data compiled by BKM. The estimation sample is from January − February 1990 to September − October 2009. The first six observations are used o initialise the estimation. BKM provide a detailed discussion as to how they modify SW's quarterly series to construct bimonthly series and therefore, the description of the data is kept brief. For a detailed discussion about the dataset, the reader is referred to Bils, Klenow and Malin(2012).

The other seven series used in estimation are the same as in the SW: real output growth, consumption growth, investment growth, hours worked, wage inflation, price inflation and the federal funds rate. The rest of the measurement equations are the same as in the SW and are repeated here for convenience.

$$
\begin{array}{lcl}
\text{Output growth} & = & \bar{\gamma} + y_t - y_{t-1} \\
\text{Consumption growth} & = & \bar{\gamma} + c_t - c_{t-1} \\
\text{Investment growth} & = & \bar{\gamma} + i_t - i_{t-1} \\
\text{Wage inflation} & = & \bar{\gamma} + w_t - w_{t-1} \\
\text{Hours worked} & = & \bar{l} + l_t \\
\text{Federal Funds Rate} & = & \bar{r} + r_t
\end{array}
\tag{B.1}
$$

where $\bar{\gamma} = 100(\gamma - 1)$, $\bar{r} = 100(\Pi_\star - 1)$ and $\bar{l} = 0$. $\bar{\gamma}$ is the trend growth rate of real GDP, $\bar{r}$ captures the steady-state short-term nominal interest rate and $\bar{l}$ denotes the mean of hours, which is normalised to zero.

Tables 2 and 3 provide a summary of the priors. The assumed prior distributions for most of the parameters are the same as those in SW. All of the remaining parameters have been fixed. The depreciation rate is set at 0.017. The government spending−GDP ratio is calibrated at 0.18. Following SW, the curvature of the Kimball labour and product markets aggregators (ϵ_p and ϵ_w) are fixed at 10. β is the discount factor and σ_c denotes the degree of the relative risk aversion. For notational simplicity and without significant loss of generality, these parameters are set to 1.

Table 1: Comparison of policy rules

Policy	Marginal Likelihood	KR
(1) Inflation-Index targeting ($\bar{\alpha_1} = 0.075$)	-897	
(2) Core-Inflation targeting ($\bar{\alpha_1} = 0$)	-900	6
(3) Headline-Inflation targeting ($\bar{\alpha_1} = 0.34$)	-903	12

Notes: This table shows the log-marginal likelihood for the relevant policy and the corresponding KR ratio of the policy rules relative to the inflation index targeting. $\bar{\alpha_2}$ is given by $1 - \bar{\alpha_1}$.

Table 2: Prior and Posterior Estimates of Structural Parameters

	Prior Distribution			Posterior Distribution			
				Inflation-Index targeting		Headline-Inflation Targeting	
	type	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev
φ	Normal	4	1.5	6.87	1.15	7.04	1.14
h	Beta	0.7	0.1	0.73	0.04	0.72	0.04
ξ_w	Beta	0.5	0.1	0.84	0.03	0.84	0.04
σ_l	Normal	2	0.75	1.35	0.37	1.21	0.37
ω_1	Beta	0.57	0.15	0.74	0.06	0.71	0.06
ω_2	Beta	0.18	0.15	0.07	0.01	0.08	0.01
ψ	Beta	0.5	0.15	0.61	0.13	0.68	0.12
Φ	Normal	1.25	0.12	1.6	0.09	1.64	0.09
r_π	Normal	1.5	0.25	1.41	0.13	1.35	0.13
ρ	Beta	0.75	0.1	0.94	0.01	0.97	0
r_y	Normal	0.12	0.05	0.16	0.03	0.17	0.04
$r_{\triangle y}$	Normal	0.12	0.05	0.02	0.01	0.04	0.01
α	Normal	0.3	0.05	0.21	0.02	0.22	0.02
$\bar{\Pi}$	Gamma	0.62	0.1	0.34	0.06	0.29	0.06
$\bar{\mathrm{L}}$	Normal	0	2	-2.34	0.81	-1.84	0.88
$\bar{\gamma}$	Normal	0.4	0.1	0.27	0.03	0.25	0.02

Notes: Inflation-Index targeting refers to the model in which the central bank reacts to an inflation index, while Headline-inflation targeting is the case where headline-inflation is targeted. The columns 'Mean' and 'St. Dev.' list the means and the standard deviations of the prior and posterior distributions.

Table 3: Prior and Posterior Estimates of Shock Processes

	Prior Distribution			Posterior Distribution			
				Inflation-Index targeting		Headline-Inflation targeting	
	type	Mean	st. dev.	Mean	st. dev.	Mean	st. dev
σ_a	Invgamma	0.1	2	1.24	0.1	1.21	0.09
σ_b	Invgamma	0.1	2	0.05	0.01	0.05	0.01
σ_g	Invgamma	0.1	2	0.57	0.04	0.59	0.04
σ_I	Invgamma	0.1	2	0.22	0.04	0.23	0.04
σ_r	Invgamma	0.1	2	0.04	0	0.05	0
σ_p	Invgamma	0.1	2	0.58	0.04	0.59	0.03
σ_{p1}	Invgamma	0.1	2	1.11	0.08	1.15	0.03
σ_{p2}	Invgamma	0.1	2	0.41	0.16	0.59	0.03
σ_w	Invgamma	0.1	2	0.48	0.03	0.41	0.05
ρ_a	Beta	0.5	0.2	0.94	0.01	0.94	0.01
ρ_b	Beta	0.5	0.2	0.89	0.03	0.9	0.03
ρ_g	Beta	0.5	0.2	0.96	0.01	0.96	0.01
ρ_I	Beta	0.5	0.2	0.96	0.01	0.97	0.02
ρ_r	Beta	0.5	0.2	0.58	0.06	0.48	0.06
ρ_p	Beta	0.5	0.2	0.25	0.08	0.25	0.06
ρ_{p1}	Beta	0.5	0.2	0.94	0.02	0.88	0.06
ρ_{p2}	Beta	0.5	0.2	0.65	0.07	0.61	0.06
ρ_w	Beta	0.5	0.2	0.09	0.04	0.09	0.16
ρ_{ga}	Beta	0.5	0.2	1.15	0.06	1.17	0.06

Notes: See the description notes in the previous table.

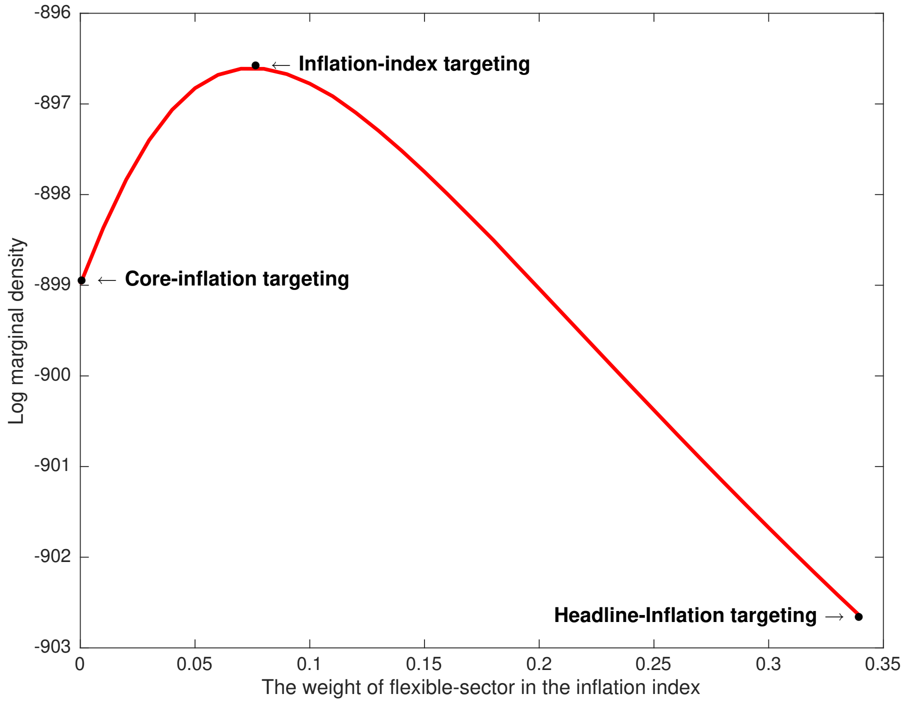

Figure B.1: Log marginal densities for different policy rules

Notes: The figure shows log marginal densities for different policy rules.

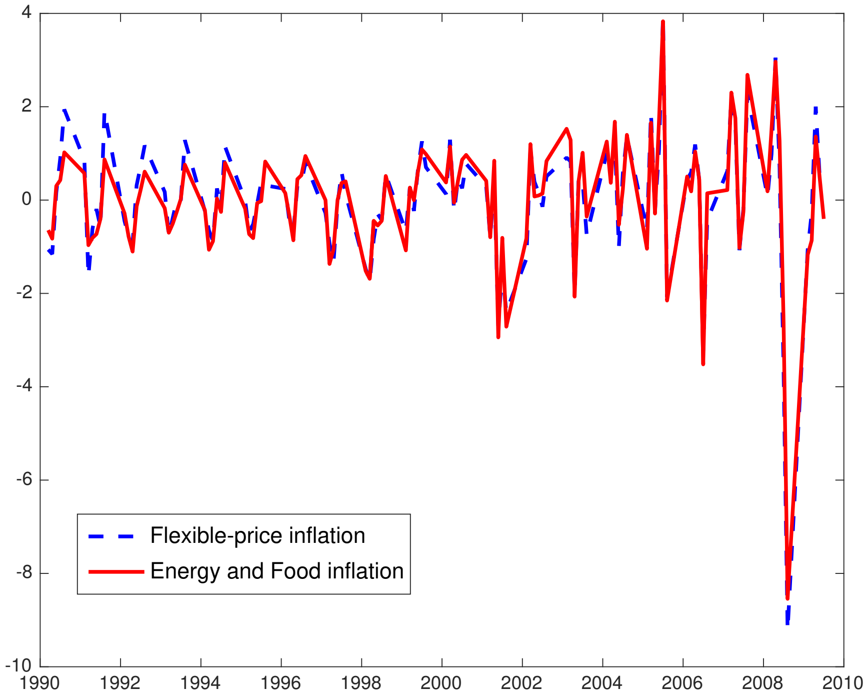

Figure B.2: Food and energy inflation vs. flexible-price sector inflation
Notes: The red solid line is the series for food and energy inflation, while blue dotted line shows the series for inflation in the flexible-price sector.