Felipe Alduino Alves

Underlying Inflation in a DSGE Model

DISSERTAÇÃO DE MESTRADO

DEPARTAMENTO DE ECONOMIA
Programa de Pós–graduação em Economia

Rio de Janeiro
March 2014

Pontifícia Universidade Católica do Rio de Janeiro

Felipe Alduino Alves

Underlying Inflation in a DSGE Model

Dissertação de Mestrado

Dissertation presented to the Programa de Pós-Graduação em Economia of the Departamento de Economia, PUC-Rio as partial fulfillment of the requirements for the degree of Mestre em Economia.

Advisor: Prof. Carlos Viana de Carvalho

Rio de Janeiro
March 2014

Pontifícia Universidade Católica do Rio de Janeiro

Felipe Alduino Alves

Underlying Inflation in a DSGE Model

Dissertation presented to the Programa de Pós-Graduação em Economia of the Departamento de Economia do Centro de Ciências Sociais da PUC– Rio as partial fulfillment of the requirements for the degree of Mestre em Economia.Approved by the following commission:

Prof. Carlos Viana de Carvalho
Advisor
Departamento de Economia — PUC–Rio

Prof. Eduardo Zilberman
Department of Economics — PUC–Rio

Prof. Marco Antonio Cesar Bonomo
Department of Economics — Insper

Prof. Tiago Couto Berriel
Department of Economics — PUC–Rio

Prof. Monica Herz
Coordenadora Setorial do Centro de Ciências Sociais – PUC–Rio

Rio de Janeiro, March 21th, 2014

Felipe Alduino Alves

B.A., Economics, Insper, 2008-2011 (São Paulo, Brazil).

Bibliographic data

Alves, Felipe Alduino

Underlying Inflation in a DSGE Model / Felipe Alduino Alves; advisor: Carlos Viana de Carvalho. — Rio de Janeiro : PUC–Rio, Departamento de Economia, 2014.

v., 58 f: il. ; 29,7 cm

1. Dissertação (Mestrado em Economia) - Pontifícia Universidade Católica do Rio de Janeiro, Departamento De Economia.

Inclui Bibliografia.

1. Economia – Dissertação. 2. underlying inflation. 3. sectoral heterogeneity. 4. price stickiness. 5. monetary policy. I. Carvalho, Carlos Viana de. II. Pontifícia Universidade Católica do Rio de Janeiro. Departamento de Economia. III. Título.

CDD: 330

Acknowledgments

I want to thank my family for the unconditional support during these 24 years. And counting...

I want to thank Piruca (Maria) for actually making all these things meaningful.

I would like to thank my adviser, Prof. Carlos Carvalho, for all the support and guidance.

I want to specially thank Joca and Josu for these two special years of home sharing. And Pepeu... Pepeu and your stories. I am sure they helped us during the most difficult times.

To all my other colleagues and professors from PUC-Rio, I am thankful for all the effort we have put into our work together over the past couple years. Financial support from CNPq, PUC-Rio and VINCI are gratefully acknowledged.

Abstract

Alves, Felipe Alduino; Carvalho, Carlos Viana de (Advisor). **Underlying Inflation in a DSGE Model**. Rio de Janeiro, 2014. 58p. Dissertação de Mestrado — Departamento de Economia, Pontifícia Universidade Católica do Rio de Janeiro.

We use a multi-sector sticky-price DSGE model to study the effects of a monetary rule that responds to changes in the underlying measure of inflation as opposed to headline inflation. We discuss the difficulties of including the underlying measure in our DSGE model and present a feasible solution. Using a stylized version of the model, we show that headline/underlying volatilities can experience significant changes under a policy rule that reacts to the underlying measure. The results are interpreted on the basis of the relevance of aggregate and sectoral shocks to headline and underlying inflation. We then conduct a quantitative exercise focused on Australia. The interest in the latter comes from our belief that monetary authority actually started to react to underlying inflation around 2007. We find that the calibrated model is not able to reproduce the behavior of headline/underlying inflation after 2007.

Keywords

underlying inflation; sectoral heterogeneity; price stickiness; monetary policy;

Resumo

Alves, Felipe Alduino; Carvalho, Carlos Viana de. **Medidas de Núcleo de Inflação em um modelo DSGE**. Rio de Janeiro, 2014. 58p. Dissertação de Mestrado — Departamento de Economia, Pontifícia Universidade Católica do Rio de Janeiro.

Nesse trabalho usamos um modelo DSGE de preços rígidos para estudar os efeitos de uma regra monetária que reage a mudanças no núcleo de inflação ao invés da inflação cheia. Começamos discutindo as dificuldades de inclusão das medidas de núcleo em nosso modelo DSGE e apresentamos uma solução viável. Com base em uma versão estilizada do modelo, mostramos que as volatilidades do núcleo e inflação cheia podem variar bastante dependendo da regra monetária adotada. Os resultados são interpretados em função da contribuição de choques agregados e setoriais na variância do núcleo e inflação cheia. A seguir conduzimos um exercício quantitativo com foco na Austrália. O interesse no último deriva da nossa percepção de que a autoridade monetária australiana começou a responder aos movimentos do núcleo de inflação por volta de 2007. Entretanto, nosso modelo calibrado não é capaz de reproduzir o comportamentos das medidas de inflação depois de 2007.

Palavras–chave

núcleo de inflação; heterogeneidade setorial; rigidez de preços; política monetária;

Contents

1
Introduction

Quaterly or monthly data from inflation are quite noisy. The short-term volatility in the data poses a challenge for the monetary authority, since the noise makes it more difficult for the policy maker to correctly assess the inflationary pressures in the economy. So central banks spend a lot of time trying to distinguish between permanent and transitory movements of inflation and, as result, produce a variety of the so-called measures of “underlying” or “core” inflation. Even those central banks that state its target in terms of headline inflation usually monitor a number of underlying measures and use these as an “operational guide”[1].

The rationale for focusing on alternative measures of inflation is that some prices may be more informative than others about the state of the economy, and, therefore, more relevant for the purposes of monetary policy. As Eusepi et al. (2009) point out, this argument has been formally articulated in the literature in at least two ways.

The first one argues that current measures of underlying inflation are a better predictor of future headline inflation than current headline inflation itself.[2] This is a statistical statement of the idea that some prices are mainly driven by a volatile and transient idiosyncratic component. If true, central banks attempting to stabilize headline inflation at any cost might end up increasing, rather than reducing, inflation volatility due to the lagged nature of monetary policy’s effects on the economy. Specifically, this could be the case if the shocks hitting the economy with an effect on inflation tend to dissipate faster than the time it takes for monetary policy to affect overall prices.

The second argument in favor of the measures of underlying inflation as a guide for monetary policy comes from New Keynesian theory and is known in the literature as the “stickiness principle”. It states that in an economy in which prices change only infrequently, and do so at different rates for different goods, the central bank should concentrate more on the stabilization of inflation in the goods with stickier prices, since it is in their production that

[1]Examples include the Bank of Canada, Reserve Bank of Australia and European Central Bank. For a clear evidence of this statement given directly from the perspective of a policymaker see Mishkin (2007).

[2]This statistical property of the measures of underlying inflation has been a point of much debate in the literature: Blinder and reis (2005), Rich and Steindel (2007), Crone et al. (2008), Earlier contributions include Bryan and Cecchetti (1994), Quah and Vahey (1995), Clark (2001) and Cogley (2002).

the real distortions caused by price dispersion are larger. Originally proposed by Goodfriend and King (1997), this intuiton was formalized by Aoki (2001) in a two-good economy in which one good has perfectly flexible prices. In this case, the optimal policy is to focus solely on stabilizing inflation in the sticky price good. Benigno (2004) extends Aoki's result to a multi-good economy with an arbitrary distribution of price stickiness across goods and finds that the optimal monetary policy can be approximated by an inflation targeting policy in which a higher weight is given to the inflation in the good with a higher degree of nominal rigidity.

Yet, despite all the attention given by the central banks to the various measures of underlying inflation, the New Keynesian literature tipically focuses only on the headline inflation when assessing the ability of sticky prices models to reproduce the facts observed in the data[3]. In its initial developments, the discussion of different measures of inflation was limited by the simplifying assumption that the economy consisted of just one sector operating under monopolistic competition. In this case, the measure of inflation was pretty much limited to the change in price of the composite good. However, the growing multi-sector sticky price models literature provides a natural laboratory to address the importance of these underlying measures in the management and effects of monetary policy.

In this paper, we focus on answering the specific question: "How do aggregate dynamics change if monetary policy responds to changes in the underlying as opposed to the headline measure of inflation"? In particular, we are interested in the following exercise: if one substitutes the headline from a Taylor rule with a underlying measure, what happens with the headline and underlying volatility? To answer the question we rely on a multi-sector sticky price model, adapted from Carvalho and Lee (2011), to be our laboratory.

Our first and perhaps main contribution is incorporating the underlying measure in the environment of the model. Although some of the previous cited papers discuss underlying measures in the context of DSGE models[4], their approach usually consists of looking to an optimal measure and not the actual measures computed by central banks. We discuss the difficulties of incorporating the measures proposed in the literature, and elect one which we argue is both viable and informative: the volatility-weighted measure. The measure is a weighted-average of sectoral inflation rate where more volatile items receive less weight.

[3]A notable exception is given by Bodenstein et al. (2008), which introduces an energy sector in the stylized New Keynesian model and distinguishes the headline from the core *ex*-energy inflation.

[4]See Aoki (2001), Benigno (2004) and Eusepi et al. (2009).

Although the volatility-weighted measure is a linear function of sectoral inflations, introducing it in our DSGE model is not straightforward. When the central bank responds to the volatility-weighted measure, its weights, which depend on the variance of the sectoral inflations, are both an input and an output of the rational expectation equilibrium. This defines a fixed point which is not solved by usual solution methods for linear rational expectations models. In the specific context of our model, we were able to find the fixed point by combining usual methods with an iterative procedure.

We then show that the model is able to deliver significantly different aggregate volatilities under a policy rule that reacts to the underlying measure. The direction of the result seems to depend on the relative importance of aggregate and sectoral shocks in the headline inflation. When headline inflation is mainly driven by sectoral shocks, its volatility tends to be equal or even higher under the monetary rule that responds to underlying measure. By contrast, when aggregate shocks accounts for a reasonable share of headline variance, headline volatility tends to be smaller under the monetary rule that responds to underlying measure.

The second contribution of this paper is a quantitative assessment of our model focused on the Australian economy. Since the mid 1990s the Reserve Bank of Australia has been accompanying a selection of underlying inflation measures and using them as an "operational guide", just like many other central banks in the world. More recently, however, we believe that the central bank actually started to respond more intensely to the movements of underlying inflation than to movements in CPI itself, the exact same policy change we are interested in. In particular, central bank has been focusing on a specific underlying measure: the trimmed mean. Unfortunately, incorporating a policy rule that reacts to the trimmed mean in our model would be impractical given the common procedure in the literature, and followed here, of linearizing the model equilibrium conditions[5]. Nevertheless, we show that the volatility-weighted measure is in fact a good proxy for the trimmed mean both in the data and the model. Simulating the change in policy inside a calibrated model with the volatility-weighted, we find that the headline inflation is slightly less volatile under the rule that reacts to underlying inflation instead of headline.

The paper proceeds as follows. Section 2 discusses the concept of underlying inflation, the approaches used to measure it and the difficulties to include them in a DSGE model. Section 3 presents the model while section 4 examines its ability to deliver different headline/underlying configurations in a stilized setup. Section 5 presents the quantitative exercise for the Australian

[5]We discuss this point in more detail in section 2.

economy. Section 6 concludes the article.

2
Underlying measures

Until now we have not been specific about what we mean by underlying inflation rate. This is not unintentional. The reason is that, although the idea of a underlying inflation has been accepted by policy makers and academics, there are many controversies concerning how to define and measure it.

In an abstract sense, the idea is that the concept of inflation that ought to be of concern to monetary policy makers is different from the change in the cost of living, and, thereafter, is not adequately captured by the standard price statistics [Wynne (2008)]. In pratical terms, it is well known that monthly and quaterly measures of CPI contain significant noise, and may not be indicative of the broader trend in inflation. That said, the underlying inflation is usually thought of as the *persistent* or the *generalised* component of inflation. Three main approaches have been used to measure it.

The first one applies smoothing and filtering methods to eliminate temporary disturbances in headline inflation[1]. The second approach involves assigning weights to the price changes of individual goods in terms of their volatility and/or persistence, in which case the underlying inflation is simply a different weighted-average of the inflation of individual goods. This method describes the majority of methods used by central banks including the exclusion, weighted-median, trimmed-mean[2] and the volatility-weighted method[3]. The third approach usually assumes that there is a common dynamic factor among the price changes of all individual goods, which represents the common trend in the price changes[4].

Given so many possibilities, which measure should we elect as the underlying inflation in our model? The first thing to notice is that the chosen measure needs to be incorporated in our model, that is, a multi-sector New-Keynesian model solved by log-linearizing the equilibrium conditions. Hence, if we want the policy rule to react to the underlying inflation, we need not only to be able to compute the measure in the model, but also the measure to be a linear function of of the endogenous variables. This condition clearly restricts the measures we are able to consider.

For instance, the first and third approaches offer no simple closed

[1]Cogley (2002).
[2]Bryan and Pike (1991), Bryan and Cecchetti (1994), and Bryan et al. (1997).
[3]Diewert (1995).
[4]Bryan and Cecchetti (1993), Reis and Watson (2010).

expression for the underlying inflation, rendering specially troubling the task to specify a monetary policy that targets them in a multi-sector DSGE model. Even within the measures in the second approach, the trimmed mean, for example, involves different weights each period, a kind of non-linearity that is also hard to incorporate in our log-linear New-Keynesian model.

A natural and simple possibility is the "excluding food and energy" measure - also known as core inflation. However, the core inflation lacks of both theoretical and empirical support. On the theoretical side, although energy and food prices are indeed more flexible, they are not completely flexible and, by the "stickiness principle", shouldn't be completely excluded. Regarding its empirical performance, the measure tends to be dominated by alternative measures[5]. Not only that, but specifically in the case of Australia, our environment for the quantitative analysis of the model, the exclusion measure is considered a poor underlying measure by the monetary authority itself.

Another option the volatility-weighted measure[6]. In an economy with K different goods, volatility-weighted measure is given by:

$$\pi_t^* = \sum_{k=1}^{K} n_k^* \pi_{k,t}, \text{ where } n_k^* = \frac{n_k/\sigma^2_{\pi_k}}{\sum_k n_k/\sigma^2_{\pi_k}}$$

where n_k is the headline expenditure weight of sector k and $\sigma^2_{\pi_k}$ is the variance of sectoral inflation. The measure is actually a revision of headline weights where more volatile items, which may give a less informative signal about underlying inflation, are downplayed. In some sense, the measure is a middle option between the core inflation and the trimmed mean measure. To our future purposes the volatility-weighted has also the benefit to be a better proxy for the preferred underlying measure of monetary authority in Australia, the trimmed mean.

However, as we pointed out in the introduction, incorporating the volatility-weighted measure in the DSGE model is not as easy as it sounds. Under a policy rule that reacts to it, the weights, defined as a function of the variance of the sectoral inflation, are both an input and an output of the rational expectation equilibrium. Our first contribution is offering an iterative method that allows us to compute the rational expectation solution under

[5]See Rich and Steindel (2007) and Crone et al. (2008) for the US,Roberts (2005) and Brischetto and Richards (2006) for Australia, Vega and Wynne (2001) for the euro area.

[6]For a theoretical motivation see Diewert (1995). The volatility-weighted measure is also widely used by central banks in Canada [see Lafèche and Armour (2006)] and Brazil [see Silva Filho and Figueiredo (2011)]. Note, however, that in the case of these two the measure is computed using the standard deviation instead of the variance of the sectoral inflation.

these circunstaces, enabling us to use the volatility-weighted as our underlying measure. The method along with the description of the model is presented next section.

3
Model

The model is based on Carvalho and Lee (2011). It is a variant of the standard New Keynesian model, from which we make the following departures: i) add multiples sectors with subsectors that are subject to idiosyncratic demand and supply shocks, and that differ in the degree of price stickiness; ii) assume that firms' varieties are also used as intermediate inputs in production; and iii) assume that labor markets are sector-specific. We follow Woodford (2003) in working with the cashless limit of monetary economy.

The economy is divided into a finite number of sectors indexed by $k \in \{1, 2, \ldots, K\}$, each of which is contains S_k subsectors. There is a continuum of firms indexed by $i \in [0, 1]$ and each firm belongs to one subsector s in sector k and produces a differentiated good that is used for consumption and as an intermediate input. We refer to firm i that belongs to subsector s in sector k as "firm ik_s". We also use $\mathcal{I}_k$ and $\mathcal{I}_{k_s}$ to denote, respectively, the set that contains the indices of firms that belong to sector k and to subsector s in sector k (so that $\cup_{s=1}^{S_k} \mathcal{I}_{k_s} = \mathcal{I}_k$ and $\cup_{k=1}^{K} \mathcal{I}_k = [0, 1]$). The mass of firms in each sector and subsector are given by n_k and n_{k_s}.

3.1
Representative Household

The representative consumer derives utility from a composite consumption good, supplies different types of labor to firms in different sectors, and has access to complete set of state-contingent claims. Subject to the budget constraint presented below, she maximizes

$$E_0 \left[\sum_{t=0}^{\infty} \beta^t \Gamma_t \left(\frac{C_t^{1-\sigma}}{1-\sigma} - \frac{N_t^{1+\phi}}{1+\phi} \right) \right]$$

where C_t denotes the household's consumption of the composite good, $N_t = \sum_{k=1}^{K} \omega_k \frac{H_{k,t}^{1+\varphi}}{1+\varphi}$ and $H_{k,t}$ denotes the hours of labor services supplied to sector k. Labor is fully mobile within each sector, but immobile across sectors. The parameters β and $\{\omega_k\}_{k=1}^{K}$ are, respectively, the discount factor and the relative disutilities of supplying hours to sector k. Γ_t denotes the aggregate preference shock.

The flow budget constraint of the household is given by

$$P_tC_t + E_t[Q_{t,t+1}B_{t+1}] = B_t + \sum_{k=1}^{K} W_{k,t}H_{k,t} + \sum_{k=1}^{K}\sum_{s=1}^{S_k}\int_{\mathcal{I}_{k_s}} \Pi_{k_s,t}(i)di$$

where P_t denotes the aggregate price level to be defined below, $W_{k,t}$ is the wage rate in sector k, and $\Pi_{k_s,t}(i)$ denotes profits of firm ik_s. Households can trade nominal securities with arbitrary patterns of state-contingent payoffs. B_{t+1} denotes household's holding of one-period state-contingent nominal securities and $Q_{t,t+1}$ is the nominal stochastics discount factor.

The aggregate consumption composite is

$$C_t = \left(\sum_{k=1}^{K}(n_k)^{1/\eta}C_{k,t}^{(\eta-1)/\eta}\right)^{\eta/(\eta-1)}$$

where η is the elasticity of substitution between the sectoral consumption composites to be defined below. The underlying aggregate price index is

$$P_t = \left(\sum_{k=1}^{K} n_k P_{k,t}^{1-\eta}\right)^{1/(1-\eta)}$$

where $P_{k,t}$ is the sectoral price index associated with the sectoral consumption composite $C_{k,t}$. Given aggregate consumption C_t, and the price levels $P_{k,t}$ and P_t, the optimal demand for the sectoral composite goods, which minimizes total expenditure P_tC_t, is given by

$$C_{k,t} = n_k\left(\frac{P_{k,t}}{P_t}\right)^{-\eta}C_t$$

Sectoral consumption composites, in turn, are given by

$$C_{k,t} = \left(\sum_{s=1}^{S_k}\left(\frac{n_{k_s}}{n_k}D_{k_s,t}\right)^{1/\epsilon}C_{k_s,t}^{(\epsilon-1)/\epsilon}\right)^{\epsilon/(\epsilon-1)}$$

with corresponding sectoral price indices

$$P_{k,t} = \left(\sum_{s=1}^{S_k}\left(\frac{n_{k_s}}{n_k}D_{k_s,t}\right)P_{k_s,t}^{1-\epsilon}\right)^{1/(1-\epsilon)}$$

where $D_{k_s,t} > 0$ is a relative demand shock satisfying $\sum_{k=1}^{K}\sum_{s=1}^{S_k} n_{k_s}D_{k_s,t} = 1$.

Analogously, the optimal demand for subsectoral composite goods is given by

$$C_{k_s,t} = \frac{n_{k_s}}{n_k} D_{k_s,t} \left(\frac{P_{k_s,t}}{P_{k,t}}\right)^{-\epsilon} C_{k,t}$$

At the last level, the subsectoral consumption composites t given by

$$C_{k_s,t} = \left(\left(\frac{1}{n_{k_s}}\right)^{1/\theta} \int_{\mathcal{I}_{k_s}} C_{k_s,t}(i)^{(\theta-1)/\theta} di\right)^{\theta/(\theta-1)}$$

with corresponding subsectoral price indices

$$P_{k_s,t} = \left(\frac{1}{n_{k_s}} \int_{\mathcal{I}_{k_s}} P_{k_s,t}(i)^{1-\theta} di\right)^{1/(1-\theta)}$$

where θ denotes the within-sector elasticity of substitution between consumption varieties. Given $C_{k_s,t}$, the optimal demand for firm ik_s's good, $C_{k_s,t}(i)$, is

$$C_{k_s,t}(i) = \frac{1}{n_{k_s}} \left(\frac{P_{k_s,t}(i)}{P_{k_s,t}}\right)^{-\theta} C_{k_s,t}$$

The two remaining first-order conditions for the household's problem are:

$$Q_{t,t+1} = \beta \left(\frac{\Gamma_t}{\Gamma_{t+1}}\right) \left(\frac{C_t}{C_{t+1}}\right)^{\sigma} \left(\frac{P_t}{P_{t+1}}\right)$$
$$\frac{W_{k,t}}{P_t} = \omega_k N_t^{\phi} H_{k,t}^{\varphi} C_t^{\sigma}$$

3.2 Firms

Firms use sector-specific labor and other (intermediate) good to produce according to the following technology:

$$Y_{k_s,t}(i) = A_t A_{k_s,t} H_{k_s,t}(i)^{1-\delta} Z_{k_s,t}(i)^{\delta}$$

where $Y_{k_s,t}(i)$ is the production of firm ik_s, A_t is economy-wide productivity, $A_{k_s,t}$ is subsectoral-specific productivity, $H_{k_s,t}(i)$ denotes hours of labor that firm ik_s employs, $Z_{k_s,t}(i)$ is firm ik_s's usage of other goods as intermediate inputs, and δ is the elasticity of output with respect to intermediate inputs.

Firms combine the variaties of goods to form composites of subsectoral intermediate inputs through a Dixit-Stiglitz aggregator. The subsectoral intermediate inputs are further assembled into the sectoral and aggregate composite intermediate input that can be used for production. The total quantity of intermediate inputs employed by the firm ik_s is a Dixit-Stiglitz aggregator of sectoral intermediate inputs with the same across-sector elasticity of substitution as the one between consumption varieties (η):

$$Z_{k_s,t}(i) = \left(\sum_{k'=1}^{K} (n_{k'})^{1/\eta} Z_{k_s,k',t}(i)^{(\eta-1)/\eta} \right)^{\eta/(\eta-1)}$$

where the sectoral intermediate input, $Z_{k_s,k',t}(i)$, denotes the amount of firm ik_s's usage of sector-k' goods as intermediate inputs, and is similarly given by

$$Z_{k_s,k',t}(i) = \left(\sum_{s'=1}^{S_{k'}} \left(\frac{n_{k'_{s'}}}{n_{k'}} D_{k'_{s'},t} \right)^{1/\epsilon} Z_{k_s,k'_{s'},t}(i)^{(\epsilon-1)/\epsilon} \right)^{\epsilon/(\epsilon-1)}$$

with

$$Z_{k_s,k'_{s'},t}(i) = \left(\left(\frac{1}{n_{k'_{s'}}} \right)^{1/\theta} \int_{\mathcal{I}_{k'_{s'}}} Z_{k_s,k'_{s'},t}(i,i')^{(\theta-1)/\theta} di' \right)^{\theta/(\theta-1)}$$

where $Z_{k_s,k'_{s'},t}(i,i')$ denotes the quantity of good that firm ik_s purchases from firm $i'k'_{s'}$.

Taking the prices $P_t, P_{k',t}, P_{k'_{s'},t}, P_{k'_{s'},t}(i)$ and $W_{k,t}$ as given, firm ik_s decides how much of each input to employ in production. The cost minimization problem yields the foolowing optimality conditions

$$\begin{aligned}
Z_{k_s,t}(i) &= \frac{\delta}{1-\delta} \frac{W_{k,t}}{P_t} H_{k_s,t}(i), \\
Z_{k_s,k',t}(i) &= n_{k'} \left(\frac{P_{k',t}}{P_t} \right)^{-\eta} Z_{k_s,t}(i), \\
Z_{k_s,k'_{s'},t}(i) &= \frac{n_{k'_{s'}}}{n_{k'}} D_{k'_{s'},t} \left(\frac{P_{k'_{s'},t}}{P_{k',t}} \right)^{-\epsilon} Z_{k_s,k',t}(i), \\
Z_{k_s,k'_{s'},t}(i,i') &= \frac{1}{n_{k'_{s'}}} \left(\frac{P_{k'_{s'},t}(i')}{P_{k'_{s'},t}} \right)^{-\theta} Z_{k_s,k'_{s'},t}(i)
\end{aligned}$$

Prices are sticky as in Calvo (1983). A firm in subsector k_s adjusts its price with probability $1 - \alpha_{k_s}$ each period. Thus, the subsectoral price level P_{k_s} evolve as:

$$\begin{aligned}
P_{k_s,t} &= \left[\frac{1}{n_{k_s}} \int_{\mathcal{I}^*_{k_s,t}} {P^*_{k_s,t}}^{1-\theta} di + \frac{1}{n_{k_s}} \int_{\mathcal{I}_{k_s}-\mathcal{I}^*_{k_s,t}} P_{k_s,t-1}(i)^{1-\theta} di \right]^{1/(1-\theta)} \\
&= \left[(1-\alpha_{k_s}) {P^*_{k_s,t}}^{1-\theta} + \alpha_{k_s} P^{1-\theta}_{k_s,t-1} \right]^{1/(1-\theta)}
\end{aligned}$$

where $P^*_{k_s,t}$ is the common price chosen by the firms that adjust at time t.

These firms are grouped into the set $\mathcal{I}^*_{k_s,t} \subset \mathcal{I}_{k_s}$ which is a randomly chosen subset with measure $n_{k_s}(1-\alpha_{k_s})$.

Firms that adjust their price at time t maximize expected discounted profits:

$$\max_{P_{k_s,t}(i)} E_t \sum_{\tau=0}^{\infty} \alpha_{k_s}^{\tau} Q_{t,t+\tau} \Pi_{k_s,t+\tau}$$

where $Q_{t,t+\tau}$ and $\Pi_{k_s,t+\tau}$ are respectively the stochastic discount factor between time t and $t+\tau$ and firm ik_s's nominal profit at time $t+\tau$ given that the price chosen at time t is still being charged

$$Q_{t,t+\tau} = \beta^{\tau} \left(\frac{\Gamma_t}{\Gamma_{t+\tau}}\right) \left(\frac{C_t}{C_{t+\tau}}\right)^{\sigma} \left(\frac{P_t}{P_{t+\tau}}\right)$$
$$\Pi_{k_s,t+\tau}(i) = D_{k_s,t} \left(\frac{P_{k_s,t}(i)}{P_{k_s,t}}\right)^{-\theta} \left(\frac{P_{k_s,t}}{P_{k,t}}\right)^{-\epsilon} \left(\frac{P_{k,t}}{P_t}\right)^{-\eta} Y_{t+\tau} \left[P_{k_s,t}(i) - MC_{k_s,t+\tau}\right]$$

where $MC_{k,t+\tau} = P_{t+\tau} A^{-1}_{t+\tau} A^{-1}_{k_s,t+\tau} \frac{1}{1-\delta} \left(\frac{\delta}{1-\delta}\right)^{-\delta} \left(\frac{W_{k,t+\tau}}{P_{t+\tau}}\right)^{1-\delta}$ is the nominal marginal cost of firm ik_s at time $t+\tau$.

3.3 Equilibrium

Equilibrium is characterized by an allocation of quantities and prices that satisfy the households' optimality conditions and budget constraint, the firm's optmality conditions, the monetary policy rule (described later), and finally the market clearing conditions:

$$B_t = 0$$
$$H_{k,t} = \sum_{s=1}^{S_k} \int_{\mathcal{I}_{k_s}} H_{k_s,t}(i) di \ \forall k$$
$$Y_{k_s,t}(i) = C_{k_s,t}(i) + \sum_{k'=1}^{K} \sum_{s'=1}^{S_{k'}} \int_{\mathcal{I}_{k'_{s'}}} Z_{k'_{s'},k_s,t}(i',i) di' \ \forall i,k$$

The first equation is the asset market clearing condition. The second is the labor market clearing condition for each sector. The last condition equates supply and demand for each good, and indicates that firm ik_s's output can be either consumed by the household or employed as inputs by other firms.

For lates use, we define aggregate wage and hours indices as follows:

$$W_t \equiv \sum_k n_k W_{k,t}$$
$$H_t \equiv \sum_k H_{k,t}$$

3.4 Log-Linear approximate Model

We solve the model by log-linearizing the equilibrium conditions around the deterministic zero-inflation steady-state. Here we only present the equations necessary to characterize the equilibrium of the variables of interest:

$$\{c_t, \pi_t, i_t, m_t, h_t, (w_t - p_t)\} \text{ and } \{c_{k_s,t}, \pi_{k_s,t}\}_{s=1}^{S}$$

where lowercase letters denote log-deviation from their steady state counterparts, and $\pi_t \equiv p_t - p_{t-1}$ denotes inflation. The following $5 + (2 \times S)$ equations describe the equilibrium conditions for the private sector:

$$c_t = E_t[c_{t+1}] - \frac{1}{\sigma}[(i_t - E_t[\pi_{t+1}]) + (\gamma_t - E_t[\gamma_{t+1}])] \tag{3-1}$$

$$w_t - p_t = [\phi(1+\varphi) + \varphi]h_t + \sigma c_t \tag{3-2}$$

$$(1-\psi)c_t + \psi z_t = a_t + \sum_k \sum_s n_{k_s} a_{k_s,t} + (1-\delta)h_t + \delta z_t \tag{3-3}$$

$$w_t - p_t = z_t - h_t \tag{3-4}$$

$$\pi_{k_s,t} = \beta E_t[\pi_{k_s,t+1}] + \frac{1-\alpha_{k_s}}{\alpha_{k_s}(1-\alpha_{k_s}\beta)^{-1}} \begin{bmatrix} \left(\frac{(1-\delta)(\sigma-\psi\varphi)}{1+\delta\varphi} - \frac{1}{\eta}\right) c_t + \frac{(1-\delta)\varphi}{1+\delta\varphi} c_{k,t} + \frac{1}{\eta} c_{k_s,t} + \frac{(1-\delta)\psi\varphi}{1+\delta\varphi} z_t \\ \frac{\phi(1-\delta)(1+\varphi)}{(1+\delta\varphi)} h_t - \frac{1+\varphi}{1+\delta\varphi} a_t - \frac{(1-\delta)\varphi}{1+\delta\varphi} a_{k,t} - a_{k_s,t} - \frac{1}{\eta} d_{k_s,t} \end{bmatrix} \tag{3-5}$$

$$\pi_t = \sum_k \sum_s n_{k_s} \pi_{k_s,t} \tag{3-6}$$

$$\Delta(c_{k_s,t+1} - c_{t+1}) = -\eta(\pi_{k_s,t+1} - \pi_{t+1}) + \Delta d_{k_s,t+1} \tag{3-7}$$

where $\psi \equiv \delta(\theta - 1)/\theta$. The first equation is the household's consumption Euler equation, often referred as the intertemporal IS equation; (2) is obtained by aggregating the household's intratermporal optimality conditions over sectors, and can be interpreted as an aggregate labor supply schedule; (3) is obtained by integrating the production functions over all firms; (4) results from the aggregation of cost minimization conditions; (5) gives the subsectoral Phillips curves and (6) delivers aggregate inflation; the demand function for sectoral consumption goods is given by (7). Note that we have not yet determined how monetary policy is conducted. That is the objective of the next section.

3.5 Monetary Policy

In order to close the model, we assume that the monetary policy is explicitly characterized by a Taylor-type interest-rate rule. As mentioned in the introduction, we want to study the different effects between a monetary policy that responds to underlying inflation rate as opposed to the traditional Taylor rule with the headline inflation. To do that, we specify two different rules for i_t. If the central bank targets headline inflation:

$$i_t = (1 - \rho_i)(\phi_\pi \pi_t + \phi_c c_t) + \rho_i i_{t-1} + \mu_t \tag{3-8}$$

where μ_t is a monetary policy shock. In the case the central bank targets the underlying inflation, we have:

$$i_t = (1 - \rho_i)(\phi_\pi \pi_t^* + \phi_c c_t) + \rho_i i_{t-1} + \mu_t \tag{3-9}$$

where π_t^* is the volatility-weighted measure:

$$\pi_t^* = \sum_k \sum_s n_{k_s}^* \pi_{k_s,t}, \text{ where } n_{k_s}^* = \frac{n_{k_s}/\sigma_{\pi_{k_s}}^2}{\sum_k \sum_s n_{k_s}/\sigma_{\pi_{k_s}}^2}$$

As already noticed, the weights of underlying measure are both an input - they enter as coeficients in the Taylor rule - and an output - they are the variance of the solution - of the rational expectation equilibrium. To the best of our knowledge there is no work in the literature that has already dealt with this kind of situation.

In the case of our model, we were able to find a fixed-point that solves the indetermination of the rational expectation problem. We start by solving the model under headline Taylor rule and computing the sectoral inflations variances. Next, we change policy to the underlying Taylor rule, using the weights of the first model to construct the underlying measure. But, as we have also changed the policy rule, the sectoral variances will not be the same of the first model. So we update our weights and repeate the last step. By doing this enough times, we were able to converge to the fixed point.

3.6 Exogenous shocks

We also make distributional assumptions on the exogenous shocks. We assume they follow AR(1) processes:

$$\gamma_{t+1} = \rho_\Gamma \gamma_t + \sigma_\Gamma \varepsilon_{\Gamma,t+1}$$
$$a_{t+1} = \rho_A a_t + \sigma_A \varepsilon_{A,t+1}$$
$$\mu_{t+1} = \rho_\mu \mu_t + \sigma_\mu \varepsilon_{\mu,t+1}$$
$$a_{k_s,t+1} = \rho_{A_{k_s}} a_{K_s,t} + \sigma_{A_{k_s}} \varepsilon_{A_{k_s},t+1}$$
$$d_{k_s,t+1} = \tilde{d}_{k_s,t+1} - \sum_k \sum_s n_{k_s} \tilde{d}_{k_s,t=1}, \tilde{d}_{k_s,t+1} = \rho_{D_{k_s}} \tilde{d}_{k_s,t} + \sigma_{D_{k_s}} \varepsilon_{D_{k_s},t+1}$$

with every innovation being standard Gaussian white noise.

4
Stylized Setup

Let's begin by considering the model in a stylized setup. This will consist of two 15-sectors economies with one subsector *per* sector. In both, there are only three types of sectors, which share the same specifications. So, hereafter, we will discuss the specification of these 3 kind of sectors, but keep in mind that we have five of each kind in the economy.

The types differ in their sizes, price stickiness and idiosyncratic shocks. In the first economy, the distribution of price stickiness and sectoral weights between the sectors types, $\{\alpha_k, n_k\}$, is set to $\{0.01, 0.02\}$ for the first, $\{0.50, 0.06\}$ in the second and $\{0.84, 0.12\}$ for the third type of sector. Note that we have parameterized our economy so that we have a very sticky-price sector type that adds up to 60% of the economy, and an almost flexible sector type that taken altogether represents only 10% of the economy. In the second economy, we exchange the Calvo coefficient between the first and second sector. So we have $\{\alpha_k, n_k\}$ set to $\{0.50, 0.02\}$ for the first sector type and $\{0.01, 0.06\}$ for the second. The third sector type is identical to the one specified in the first economy. Note that the economy is identical to the first, except that now the almost flexible sector type adds up to a much more significative size of 30%.

We consider two values for the elasticity of output with respect to intermediate inputs, δ, one high (0.7) and one low (0.2). The coefficient captures the interdependency of sectors. That is, the higher δ is, more important the intermediate inputs are in the production function and, as a result, higher the degree of strategic complementarity between the price-setting decisions across-sectors.[1]

We set the other non-sectoral parameters to conventional values found in the literature. The discount factor, β, equals 0.9855, corresponding to a 6% annual steady-state interest rate. The parameter φ is set equal to 2 and ϕ is set to 0, so that the (Frisch) elasticity of labor supply is 0.5. We set the within-sector elasticity of substitution between different varieties, θ, to 6, which implies a 20 percent steady-state mark-up for the firms. The across-sector and subsector elasticity of substitution, η, ϵ, is set equal to 2.

Standard deviation of aggregate productivity and preference shocks are set to 0.5%; for the monetary shock we assume 0.125%. As for the sectoral

[1]See Carvalho and Lee (2011) for an instructive discussion of pricing strategic relations in a multi-sector sticky-price model.

shocks, they are likely larger than aggregate shocks. So sectoral demand shocks variance are set to $\sigma_{D_k} = 2\%$.

For sectoral productivity shock we also assume two specifications: one where the standard deviations are set to the same values of demand shocks, $\sigma_{A_k} = 2\%$; other which has $\sigma_{A_k} = \{5\%, 2\%, 0\%\}$ in the case of the first economy and $\sigma_{A_k} = \{2\%, 5\%, 0\%\}$ for the second. In the first case, the heterogeneity in price stickiness is the only factor making the sectoral aggregates differ in their volatility. Inflation volatility is higher in the less sticky sector and lower in the stickest. This case intends to isolate the "stickness principle" argument. The second specification tries to incorporate the notion that some prices are mainly driven by a volatile and transient idiosyncratic component. Particularly, we assume that the effect adds to the stickiness argument, that is, we increase the productivity shock variance of the less sticky sectors. For the stickiest sector, we set the productivity shock variance to zero, so that its variability comes mainly from the aggregate shocks. In every case considered, we set the autoregressive coefficient to 0.7.

Given this setup, is the model capable of producing meaninful headlines differences under the two different monetary rules? If so, what are the underlying mechanisms? We attack this question in the following section.

4.1 Results

We now solve the rational expectation equilibrium given by equation (3-1) to (3-7) under the two alternative policy rules, the headline inflation and the underlying inflation Taylor rule - equations (3-8) and (3-9). Table 4.1 presents the results for our different model specifications.

TABLE 4.1: QUANTITATIVE EXERCISE I - STYLIZED SETUP

Series	Economy 1		Economy 2	
	shock 1	shock 2	shock 1	shock 2
Headline inflation under ($\delta = 0.2$)				
Headline rule	0.33	0.37	0.37	0.62
Underlying rule	0.31	0.36	0.38	0.66
Headline inflation under ($\delta = 0.7$)				
Headline rule	0.40	0.48	0.54	1.00
Underlying rule	0.36	0.44	0.52	1.00

Note: The table presents the second moments of the headline under two monetary policy rules specification. Headline rule refers to (3-8) and underlying rule to (3-9). Model 1 and 2 refers to the different price stickiness and sectoral weights specifications, and shock 1 and 2 refers to the different parameterization for the sectoral productivity shock.

The model is able to deliver almost any combination of headline variance under headline and underlying rule. Under the first economy, we usually find that the variance of headline inflation under underlying rule is smaller than under the headline rule. The difference is particularly significative when δ is equal to 0.7, where the headline inflation is 10% lower under the underlying inflation rule.

As for the second model, we find that conclusion depends on the value of δ. In the case δ equals 0.7, inflation's variance is about the same under the two monetary rules. However, if δ is set to 0.2, we find that headline is more volatile under the underlying rule. For the second sectoral productivity shock specification, the difference reaches 6%.

Figure 4.1: Inflation Simulated Series

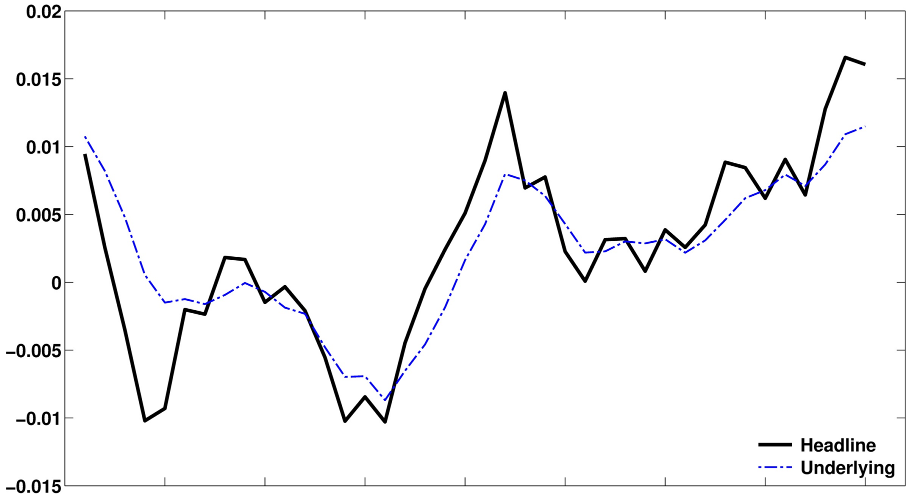


Figure 4.A: Simulated series of inflation - Parametrization 1

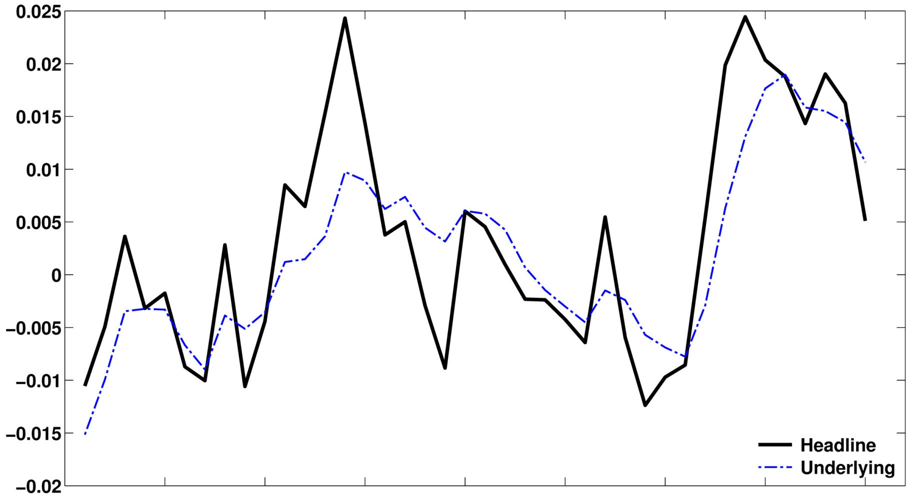


Figure 4.B: Simulated series of inflation - Parametrization 2

Note: The figure presents the simulated series of 4 quarter cumulative headline inflation and underlying inflation under headline Taylor rule. We use the 15 per cent trimmed mean, as the RBA, and our underlying inflation measure is given by the volatility weighted measure, described in subsection 2.2.

We choose to take a closer look at the two extreme cases, hereafter

Table 4.2: Quantitative Exercise II - Stylized Setup

Series	"Flexible" sector	Aggregate shocks
Parametrization 1		
Headline variance decom under		
Headline rule	37.0	41.0
Underlying rule	39.8	39.6
Underlying variance decom under		
Headline rule	16.5	63.3
Underlying rule	8.8	78.3
Parametrization 2		
Headline variance decom under		
Headline rule	77.1	21.0
Underlying rule	81.2	16.2
Underlying variance decom under		
Headline rule	61.3	37.5
Underlying rule	24.3	74.0

Note: The table presents the variance decomposition of the headline and underlying inflation under two monetary policy rules specification. Headline rule refers to (3-8) and underlying rule to (3-9). Parametrization 1 and 2 refers to the different specifications chosen from 4.1.

Parametrization 1 and 2: the economy 1 with second shock specification and $\delta = 0.7$; the economy 2 with second shock specification and $\delta = 0.2$.

Figure 4.1 presents the simulated series of headline inflation and our volatility-weighted measure under Taylor rule (3-8) for the two parameterized models. As we can see, the simulated series seem consistent with what we should expect. The underlying inflation is less volatile than the headline, but follows the measure on average. Given that the dynamics of headline and underlying inflation are both plausible, we proceed to understand why headline volatility reduces (increases) under underlying taylor rule in the first (second) parametrization?

As discussed in the introduction, the rationale for focusing on alternative measures of inflation is that some prices may be more informative than others about the state of the economy. In the context of our model, the information contained in headline and underlying inflation can be assessed by their variance decomposition under our two parametrizations. Table 4.2 presents the results.

The decomposition is summarized in two components: the variance due to sectoral shocks in the almost flexible sector and due to aggregate shocks (a_t, μ_t, γ_t). What immediatly calls our attention is the importance of the "flexible" sector in both parametrizations. Consider first the results under headline inflation taylor rule. In the first parametrization - where the "flexible" sector represents 10% of the economy - the shocks in the almost flexible sector account for 37% of the variance for headline inflation and 16.5% for underlying inflation. For the second parametrization - where the “flexible” sector adds to 30% of the economy - the almost flexible sector contributes in 77.1% for the variability in headline and 61.3% for the underlying. Also worth noticing, under headline inflation taylor rule the underlying inflation is much more informative about the aggregate shocks than the headline inflation.

When we change the monetary policy to respond to the underlying inflation, some interesting things happen. The aggregate shocks contribution to the underlying measure variability is even bigger - in the first parametrization it grows from 68.3% to 78.3%; in the second it goes from 37.5% to 74%. In contrast, the headline inflation variance decomposition shows a slightly increase participation for the shocks in the almost flexible sector.

In both cases, underlying inflation is working as we would expect, that is, the measure is less subject to idyiosincratic and trasient sectoral shocks and carries more information about the aggregate shocks. If headline inflation also significantly depends on aggregate shocks, as in parametrization 1, a monetary rule that responds to the underlying measure tends to reduce headline volatility by better responding to its aggregate component. However, if the headline is dominated by sectoral shocks, as in parametrization 2, a monetary rule that responds to the underlying inflation tends to increase headline volatility by ignoring the main source of inflationary pressures in the headline.

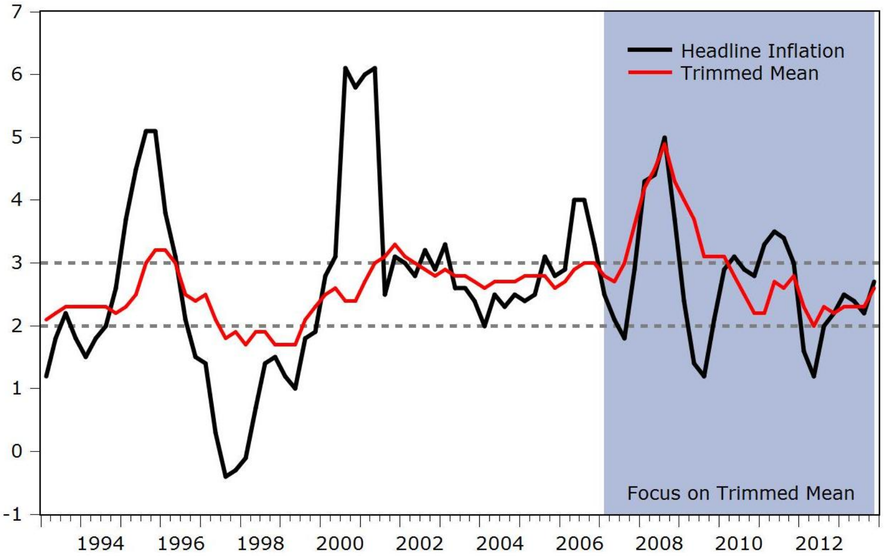
In the next section, we move from this stylized environment to an real-life example, which took place in Australia.

5
Quantitative analysis - Australia

The choice of Australia as the focus of our quantitative analysis comes from the belief that the experiment we are interested in, that is, the change from a monetary policy that reacts to headline to one that responds to underlying inflation, actually occurred.

Next section discusses the monetary policy framework in Australia, and gives a description of its historical evolution. In particular, we argue for the view that the change in monetary policy took place around 2007. We then move to the calibration exercise, where we use Australian sectoral data in order to generate a reliable laboratory for our research question.[1]

FIGURE 5.1: CHANGE IN PREFERRED MEASURE IN AUSTRALIA



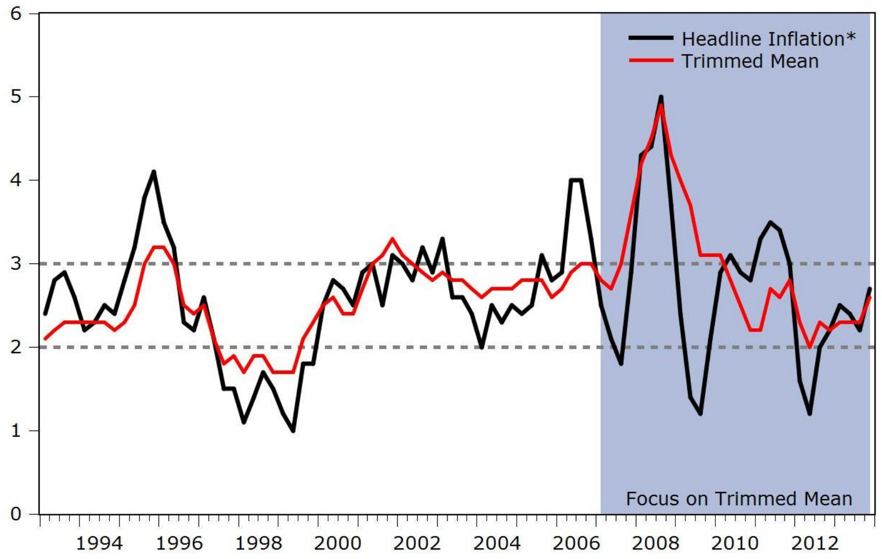
Note: RBA estimates of headline and trimmed mean inflation.

5.1
Monetary Policy in Australia

Since 1993, the Reserve Bank of Australia (RBA) has targeted headline inflation between 2 and 3 per cent, on average, over the course of the business cycle. Given the flexible nature of this target, the monetary authority is not

[1]Initially, we tried to estimate the model using full information methods as it is usually done in the literature. However, the estimation results struggle to reproduce the qualitative features of the cross-section of inflation series and the dynamics of headline versus underlying inflation. We discuss this with more detail in the Appendix C.

Figure 5.2: Change in Preferred Measure in Australia



Series	Volatility		
	All Sample	93-06	07-13
Headline Inflation	0.395	0.344	0.485
Trimmed Mean	0.197	0.154	0.253
Relative volatility (Headline/Trimmed)	2.004	2.235	1.921

Note: RBA estimates of headline and trimmed mean inflation, excluding interest charges prior to September quarter 1998 and adjusted for the tax changes of 1999/2000. The Table presents the standard deviation of series in percentages.

required to respond to all movements in the consumer price index (CPI), and has focused on medium-term inflationary trends. So, although the objective is clearly in terms of the overall CPI, measures of underlying inflation are often used so as to help the bank achieve its objective. Accordingly, since the mid 1990s the RBA has incorporated a selection of underlying inflation measures into its analysis of the economy.

Particular attention is given to the trimmed mean measure. The trimmed-mean rate of inflation is defined as the average rate of inflation after "trimming" away a certain percentage of the distribution of price changes at both ends of that distribution. These measures are calculated by ordering the seasonally adjusted price changes for all CPI components in any period from lowest to highest, trimming away those that lie at the two outer edges of the distribution of price changes for that period, and then calculating an average inflation rate from the remaining set of price changes. In practice, the RBA has tended to focus on two particular trims: the 15 per cent trimmed mean and the weighted median (which is the price change at the 50th percentile by weight of the distribution of price changes).

Although the RBA has been accompanying the underlying measures for a long time, we believed that the policy rule actually started responding to trimmed mean only around 2007. This belief is based on two facts: prior to 2007 the Reserve Bank of Australia produced a series of articles highlighting the virtues of the trimmed mean as an underlying inflation measure [Heath et al. (2004); Roberts (2005); Brischetto and Richards (2006)]; the Bureau of Statistics started publishing the trimmed mean as a preferred measure of the Central Bank around 2007.

Figure 5.1 plots the consumer price index inflation with the 15 per cent trimmed mean measure for the inflation target period. The shaded region marks the period in which we belive that the central bank started responding to changes in the underlying as opposed to the headline inflation. Looking at the figure, our first impression is that headline volatility has fallen during period with focus on the trimmed mean measure.

However, it is not true that this CPI inflation series has always been the reference target for the policymakers at RBA. Actually, from 1993 to late 1998 the RBA focused on its own headline measure, which removed interest rate charges (included in the CPI over that period), thereby precluding a mechanical relationship between changes in monetary policy and targeted inflation. Another important episode is the peak we see in headline measure around 2000. The movement was ultimately disregard by the monetary authority, since it was an one time only lift in the price level induced by a tax reform. In this sense, any assessment made based on the behaviour we observe in Figure 5.1 is misleading about the true objectives of RBA.

Figure 5.2 plots the own RBA estimates of headline inflation adjusted for interest charges and tax changes with the same 15 per cent trimmed mean measure. To our knowledge, this is the series that best reflects the RBA true objective. Below the figure we present the variances for the whole sample, the period prior to the change in policy (1993-2006), and the period with focus in the trimmed mean. Unlike last figure, what we now observe is an increase, instead of a reduction, in volatility for both series after 2007. However, if the shocks hiting the economy are heteroscedastic, looking at the absolute value can be misleading. If the shaded periodwas hit by higher shocks[2], we can mistake an overall rise in volatility for an effect of the policy change. Therefore we choose, instead, to look at relative volatility. In this case, the period after 2007 is characterized by a reduction in volatility of headline over trimmed mean. We take this as the fact our model should reproduce.

[2]As we are led to believe, since the period coincides with the beginning of the financial crisis.

5.2 Calibrated Model

We now turn to the calibration exercise for Australia using the volatility-weighted as a proxy to the trimmed mean measure[3]. Next subsection gives a brief description of our data. Subsection 5.2.2 discusses the calibration itself, while Subsection 5.2.3 conducts the quantitative exercise of changing the preferred inflation measure of the central bank from the headline to the underlying inflation.

5.2.1 Data

The observables in our model are given by: nominal interest rate (i_t), hours (h_t), sectoral inflation observed at the subsector level $\{\pi_{k_s}\}$ and consumption at the sector level $\{c_k\}$. We use total hours from industry sector as a measure of hours, and the effective federal funds rate as the nominal interest rate. Consumption is given by household personal consumption expenditures (HPCE), while the price measure is taken from the consumer price index (CPI).[4]

Total hours are normalized by the total labour force. We also detrend the real variables using a linear trend, and demean the nominal interest rate and the sectoral inflation rates. The sectoral weights are set to the expenditure weights of the last revision in CPI. The data are quaterly, and the sample period is 2000:Q4 to 2006:Q4. The sample is limited both from the tax peak in 2000 and the date where we believed there was a change in the monetary policy rule. In Appendix C we present details of the sectors and subsectors.

Notice that we observe inflation at a more detailed level than consumption. This poses a potential problem for our model. Since we only observe the inflation at a subsectoral level, it can be the case that we no longer can identity both of the subsectoral shocks - demand and productivity. To see that, if we rewrite equation (3-7) in the observed level:

$$\Delta(c_{k,t+1} - c_{t+1}) = -\eta \left(\sum_s \frac{n_{k_s}}{n_k} \pi_{k,t+1} - \pi_{t+1} \right) + \sum_s \frac{n_{k_s}}{n_k} \Delta d_{k_s,t+1}$$

[3]Ideally, the underlying measure for this quantitative exercise would be the trimmed mean. However, for the reasons discussed in section 2, this wouldn't be feasible. So we are left to show that the volatility-weighted measure is a good proxy. Figure D.1 in Appendix D plots the trimmed mean, the volatility-weighted and the usual exclusion measure in Australia. As we can see, the volatility-weighted measure is more correlated with the trimmed mean measure, making it a better proxy.

[4]Since CPI and HPCE doesn't have a perfect match in their categories definitions, we had to associate some sectors based on our own judgement.

the equation depends only on the sum of demand shocks in each subsector, which makes the parameters of the subsectoral shocks not identifiable.[5]. So, in face of the restriction on the data, we choose to model the demand shock only at a sectoral level, keeping the productivity shock at the subsectoral level.

5.2.2 Model Calibration

In this subsection, we turn to calibration exercise. The parameters $\beta, \varphi, \phi, \theta, \epsilon, \eta, \delta$ will be set to the same values used in the previous section. In the case of the distribution of price stickiness and sectoral weights, $\{\alpha_{k_s}, n_{k_s}\}_{s=1}^{S}$, these are set in accordance with the Australian CPI[6].

The remaining parameters are set to match in the moments that proved essential to our exercise, that is, the variance and autocorrelation of observable series. The moments of the data and the calibrated model are presented in Tables 5.1 and 5.2. The value of the parameters are shown in Appendix D.

If we take a look at Figure 5.3, we can see that the dynamics of the trimmed mean and headline inflation for the calibrated model is much similar of that in the data. Also important for our exercise, the volatility weighted measured seems to be a very good *proxy* for the trimmed mean measure. The distance of the headline from trimmed mean is twice the distance of the volatility-weighted from trimmed mean.

But, the calibration exercise is not without its costs. Table 5.1 presents the likelihood evaluated at the calibrated coefficiens. The low value signalizes that, as we focus on just some moments, we are possibly ignoring important aspects of the data. Nevertheless, we prefer to rely on the calibrated model, since it was able to replicate the essential dynamics of headline and underlying inflation. Next section conducts the experiment of changing the monetary policy rule.

5.2.3 Quantitative exercise

The steps here are the same as those described in subsection 4.1. Before we turn to the results, what should we expect based on our earlier discussion?

[5]Although the statement makes sense, note that we didn't actually prove that the model suffers from under-identification. In order to do that, we verify identification using the identification method suggested by Iskrev (2010). Using his method we find that the model is in fact not identified when consumption is observed only at sectoral level.

[6]Since we were not able to find a paper that studies the sectoral price stickiness distribution for Australia, we constructed our measures by suitably matching consumption categories from the Nakamura and Steinsson (2008) price-setting statistics for the US to the sectoral categories in Australian CPI.

Table 5.1: Inflation Moments

Series	Data		Calibration	
	Std (%)	AR(1)	Std (%)	AR(1)
$\pi_{1,1}$	0.94	0.26	0.93	0.00
$\pi_{1,2}$	1.18	0.76	1.18	0.00
$\pi_{1,3}$	0.84	0.25	0.84	-0.18
$\pi_{1,4}$	7.23	0.05	6.68	-0.32
$\pi_{1,5}$	0.59	0.02	0.59	0.10
$\pi_{1,6}$	1.37	-0.26	1.37	-0.14
$\pi_{1,7}$	0.18	-0.27	0.28	0.93
$\pi_{2,1}$	0.46	-0.23	0.43	0.46
$\pi_{2,2}$	0.63	0.57	0.64	0.02
$\pi_{3,1}$	0.97	-0.18	0.99	0.03
$\pi_{3,2}$	1.10	-0.28	1.10	-0.24
$\pi_{4,1}$	0.20	0.49	0.33	0.80
$\pi_{4,2}$	0.29	-0.05	0.33	0.80
$\pi_{4,3}$	0.75	-0.13	0.77	0.17
$\pi_{5,1}$	0.69	-0.24	0.69	-0.02
$\pi_{5,2}$	1.78	-0.50	1.78	-0.15
$\pi_{5,3}$	0.77	-0.18	0.77	0.04
$\pi_{5,4}$	0.74	-0.15	0.74	0.33
$\pi_{5,5}$	1.00	0.04	1.01	0.32
$\pi_{6,1}$	0.91	-0.12	0.91	-0.06
$\pi_{6,2}$	0.57	0.62	0.55	0.74
$\pi_{7,1}$	1.43	-0.16	1.34	0.05
$\pi_{7,2}$	0.65	-0.08	0.65	0.06
$\pi_{8,1}$	0.66	0.32	0.66	0.45
$\pi_{9,1}$	1.87	0.44	1.85	0.30
$\pi_{9,2}$	0.45	-0.11	0.45	0.83
$\pi_{9,3}$	1.97	0.06	1.91	-0.02
$\pi_{9,4}$	0.60	-0.42	0.30	0.89
$\pi_{10,1}$	0.50	0.02	0.30	0.89
$\pi_{11,1}$	0.73	0.09	0.73	0.34
Log Likelihood	-		-6.58×10^{15}	

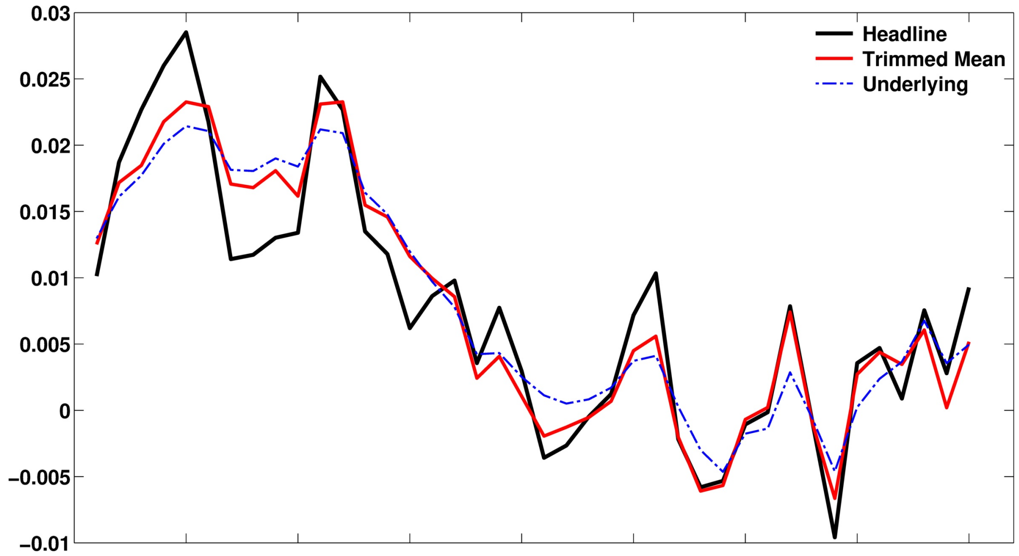
Note: Variance and autocorrelation of the observable series in the data and in the calibrated model.

Table 5.2: Other Moments

Series	Data		Calibration	
	Std (%)	AR(1)	Std (%)	AR(1)
i	0.13	0.74	0.29	0.92
h	0.67	0.67	0.60	0.41
c_1	1.28	0.62	1.98	0.36
c_2	1.59	0.48	1.57	0.97
c_3	3.87	0.88	3.67	0.93
c_4	0.76	0.82	0.64	0.80
c_5	2.30	0.80	2.18	0.94
c_6	3.05	0.21	3.69	0.97
c_7	2.28	0.77	2.96	0.72
c_8	2.64	0.79	2.73	0.92
c_9	2.27	0.78	2.64	0.83
c_{10}	2.09	0.77	2.04	0.11
c_{11}	2.50	0.68	2.48	0.87

Note: Variance and autocorrelation of the observable series in the data and in the calibrated model.

Figure 5.3: Simulated Inflation Series



Note: The figure presents the simulated series of 4 quarter cumulative headline inflation, trimmed mean and underlying inflation under headline Taylor rule. We use the 15 per cent trimmed mean, as the RBA, and our underlying inflation measure is given by the volatility weighted measure, described in subsection 2.2.

TABLE 5.3: QUANTITATIVE EXERCISE - AUSTRALIA

Series	Standard Deviation (%)
Headline inflation under	
Headline rule	0.57
Underlying rule	0.56
Consumption under	
Headline rule	0.95
Underlying rule	0.96
Underlying inflation under	
Headline rule	0.34
Underlying rule	0.31
Interest under	
Headline rule	0.29
Underlying rule	0.24

Note: The table presents the second moments of the aggregates in the model under two monetary policy rules specification. Headline rule refers to equation (3-8) and underlying rule to (3-9).

Repeating the variance decomposition exercise, we find that under headline rule the share of headline variance accounted for the aggreate shocks - in this case, only the preference shock - is of 23%; under the same rule, the share of underlying variance explained by aggregate shocks is of 59%. Notice that we have an underlying inflation very dependent on aggregate shocks (as in Parametrization 1), and a headline inflation dominated by sectoral shocks (as in Parametrization 2). So by responding to the underlying measure, the central bank will reduce the headline volatility component that depends on aggregate shocks and might increase the headline volatility component that depends on sectoral shocks. Since the aggregate/sectoral shocks contribution to inflation lies between the two parametrizations considered in subsection 4.1, the most likely result is that these two forces will offset each other, rendering more or less the same variance under headline or underlying rule. That is exactly what we see in our exercise. Table 5.3 presents the results.

We find that the headline inflation is slightly less volatile under the rule that reacts to underlying inflation if comparared with the headline rule. As for the other variables, the consumption volatility is about the same under either rule, while underlying inflation and the interest rate are 10% and 20% less volatile under the underlying Taylor rule.

What about our empirical fact of a reduction in relative variance when the RBA started reacting to the underlying measure? Is the quantitative exercise able to reproduce it? The anwser is no. Since headline volatility stays the same, and underlying volatility falls, our exercise predicts a rise in relative volatility. But, would the model be able to go the same direction of the data? From the results in section 4, we know that headline volatility can go both directions, but underlying volatility will certainly go down when the policy rule starts to react to it. So, the only way the relative volatility could go up would be if headline inflation is reduced by a larger amount than underlying. However, given the opposite forces acting on headline, it is often the case that underlying volatility falls by a larger amount than the headline volatility. So, for any reasonable setup, we should expect the relative volatility to rise with the policy change, and not to fall as in the data.

6
Conclusion

How do aggregate dynamics change if monetary policy responds to changes in the underlying as opposed to the headline measure of inflation? In this paper we tried to anwser this question using a multi-sector sticky-price DSGE model as our laboratory.

We start by discussing the difficulties of incorporating the underlying measures proposed in the literature into our DSGE model. Out of the available options, we choose the volatility-weighted measure. However, when policy rule was stated in terms of headline, the dependence of the measure on the variance of the sectoral inflations created a fixed point not solved by usual linear rational expectation model solution methods. In this case, we had to combine the latter with an iterative procedure to solve the model. This was, to the best of our knowledge, not previously discussed in the literature.

We then move to a stylized economy, where we show that headline/underlying volatilities can be very different depending if the policy rule is specified in term of headline or underlying inflation. The direction of the result seems to depend essentially on the relevance of aggregate and sectoral shocks.

In our quantitative exercise focused on Australia, our calibrated model fails to replicate the reduction in relative volatility of headline over underlying inflation. Actually, as we argue, the fact seems at odds with the model itself. In absolute terms, the model predicts a slightly decrease in headline volatility under a monetary rule that reacts to underlying measure.

However, a number of issues remain open. The absurdly low value of the likelihood evaluated at the calibrated parameters casts a doubt on our results, and points out the importance of estimation. Clearly, we cannot capture the behaviour of the data just by looking at variances and autocorrelations of the series. On the other hand, as we show in Appendix C, the usual Bayesian estimation fails to generate reasonable second moments, being equally disapointing.

We hope, however, that by stating the challenges of how to include underlying measures in DSGE and putting forward a benchmark, we can motivate future research to come up with better solutions. Ultimately, we would like an estimation procedure that delivers both a good description of the data and a reasonable headline and underlying inflation properties. With that at hand, our definitive test would consist in a comparison of the marginal likelihood of the data in two different arrangements: one that uses the same monetary rule for the entire sample; one that forces the change of focus from headline to underlying around 2007.

7
Bibliography

AOKI, K. **Optimal monetary policy responses to relative-price changes**. *Journal of Monetary Economics*, v. 48, n. 1, p. 55–80, 2001.

BENIGNO, P. **Optimal monetary policy in a currency area**. *Journal of International Economics*, v. 63, n. 2, p. 293–320, July 2004.

BLINDER, A. S.; REIS, R. **Understanding the Greenspan standard**. *Proceedings - Economic Policy Symposium - Jackson Hole*, , n. Aug, p. 11–96, 2005.

BODENSTEIN, M.; ERCEG, C. J.; GUERRIERI, L. **Optimal monetary policy with distinct core and headline inflation rates**. *Journal of Monetary Economics*, v. 55, n. Supplemen, p. S18–S33, October 2008.

BRISCHETTO, A.; RICHARDS, A. **The Performance of Trimmed Mean Measures of Underlying Inflation**. RBA Research Discussion Papers rdp2006-10, Reserve Bank of Australia, Dec. 2006.

BRYAN, M. F.; PIKE, C. J. **Median price changes: an alternative approach to measuring current monetary inflation**. *Economic Commentary*, , n. Dec, 1991.

BRYAN, M. F.; CECCHETTI, S. G. **The Consumer Price Index as a Measure of Inflation**. NBER Working Papers 4505, National Bureau of Economic Research, Inc, Oct. 1993.

BRYAN, M. F.; CECCHETTI, S. G. **Measuring Core Inflation**. In: *Monetary Policy*, NBER Chapters. National Bureau of Economic Research, Inc, 1994. p. 195–219.

BRYAN, M. F.; CECCHETTI, S. G.; II, R. L. W. **Efficient Inflation Estimation**. NBER Working Papers 6183, National Bureau of Economic Research, Inc, Sept. 1997.

CALVO, G. A. **Staggered prices in a utility-maximizing framework**. *Journal of Monetary Economics*, v. 12, n. 3, p. 383–398, September 1983.

CARVALHO, C.; LEE, J. W. **Sectoral price facts in a sticky-price model**. Staff Reports 495, Federal Reserve Bank of New York, 2011.

CLARK, T. E. **Comparing measures of core inflation**. *Economic Review*, , n. Q II, p. 5–31, 2001.

COGLEY, T. **A Simple Adaptive Measure of Core Inflation**. *Journal of Money, Credit and Banking*, v. 34, n. 1, p. 94–113, February 2002.

CRONE, T. M.; KHETTRY, N. N. K.; MESTER, L. J.; NOVAK, J. A. **Core measures of inflation as predictors of total inflation**. Working Papers 08-9, Federal Reserve Bank of Philadelphia, 2008.

DIEWERT, E. **On the Stochastic Approach to Index Numbers**. Discussion Papers 1995-31, University of British Columbia, 1995.

EUSEPI, S.; HOBIJN, B.; TAMBALOTTI, A. **CONDI: a cost-of-nominal-distortions index**. Working paper series, Federal Reserve Bank of San Francisco, 2009.

DA SILVA FILHO, T. N. T.; FIGUEIREDO, F. M. R. **Has Core Inflation Been Doing a Good Job in Brazil?** *Revista Brasileira de Economia*, v. 65, n. 2, p. 207–233, June 2011.

GOODFRIEND, M.; KING, R. **The New Neoclassical Synthesis and the Role of Monetary Policy**. In: *NBER Macroeconomics Annual 1997, Volume 12*, NBER Chapters. National Bureau of Economic Research, Inc, October 1997. p. 231–296.

HEATH, A.; ROBERTS, I.; BULMAN, T. **Inflation in Australia: Measurement and Modelling**. In: KENT, C.; GUTTMANN, S. (Eds.) *The Future of Inflation Targeting*, RBA Annual Conference Volume. Reserve Bank of Australia, 2004.

LAFÈCHE, T.; ARMOUR, J. **Evaluating Measures of Core Inflation**. *Bank of Canada Review*, v. 2006, n. Summer, p. 19–29, 2006.

MISHKIN, F. S. **Headline versus core inflation in the conduct of monetary policy** : a speech at the business cycles, international transmission and macroeconomic policies conference, hec montreal, montreal, canada, oc. Speech 332, Board of Governors of the Federal Reserve System (U.S.), 2007.

DEL NEGRO, M.; SCHORFHEIDE, F. **Forming priors for DSGE models (and how it affects the assessment of nominal rigidities)**. *Journal of Monetary Economics*, v. 55, n. 7, p. 1191–1208, October 2008.

QUAH, D.; VAHEY, S. P. **Measuring Core Inflation?** *Economic Journal*, v. 105, n. 432, p. 1130–44, September 1995.

REIS, R.; WATSON, M. W. **Relative Goods' Prices, Pure Inflation, and the Phillips Correlation**. *American Economic Journal: Macroeconomics*, v. 2, n. 3, p. 128–57, July 2010.

RICH, R.; STEINDEL, C. **A Comparison of Measures of Core Inflation**. *Economic Policy Review*, v. 13, n. 3, p. 19–38, December 2007.

ROBERTS, I. **Underlying Inflation: Concepts, Measurement and Performance**. RBA Research Discussion Papers rdp2005-05, Reserve Bank of Australia, July 2005.

VEGA, J. L.; WYNNE, M. A. **An evaluation of some measures of core inflation for the euro area**. Working Paper Series 0053, European Central Bank, Apr. 2001.

WYNNE, M. A. **Core inflation: a review of some conceptual issues**. *Review Federal Reserve Bank of St. Louis*, , n. May, p. 205–228, 2008.

A
Steady state

As mentioned in the main text, we solve the model by log-linearizing equilibrium conditions around a symmetric non-stochastic zero-inflation steady state, which is detailed here. A non-stochastic steady-state equilibrium is, in fact, not generally symmetric. In particular, it depends on the steady-state levels of subsector-specific productivity $\{A_{k_s}\}_{s=1}^{S}$, and the sector-specific parameters that measure the relative disutilities of supplying hours, $\{\omega_k\}_{k=1}^{K}$. For simplicity, we make two assumptions that deliver a symmetric steady state: i) the steady state levels of sector-specific productivities are the same across sectors (specifically, A_{k_s}=1) for all k, without loss of generality; ii) $\omega_k = n_k^{-\varphi}$ for all k. This last assumption relates the relative disutilies of labor to the size of the sectors, and equalizes steady state sectoral wages.

We solve for $\{Y, C, Z, H, N, \frac{W}{P}, \frac{\Pi}{P}\}$: the steady state valeus of aggregate gross output, aggregate value of added-output (i.e. GDP), aggregate intermediate input usage, aggregate hours, aggregate disutilities of labor, real wage and real profits. Once we obtain these aggregates variables, it is trivial to characterize the steady state values for sectoral, subsectoral and micro variables using the symmetric nature of the steady state (i.e $Y_k = n_k Y, Y_{k_s} = n_{k_s} Y, C_k = n_k C, C_{k_s} = n_{k_s} C, Z_k = n_k Z, Z_{k_s} = n_{k_s} Z, H_k = n_k H, H_{k_s} = n_{k_s} H, \Pi = \Pi_k(i), W_k = W$, and $\frac{P(i)}{P} = \frac{P_k}{P} = 1$).

After exploting the symmetry of market-clearing conditions, the system of equilibrium conditions can be reduced to the following seven equations:

$$C = \frac{W}{P} H + \frac{\Pi}{P} \tag{A-1}$$

$$\Phi \frac{W}{P} = H^{\phi(1+\varphi)+\varphi} C^{\sigma} \tag{A-2}$$

$$Y = H^{1-\delta} Z^{\delta} \tag{A-3}$$

$$Y = C + Z \tag{A-4}$$

$$\frac{\Pi}{P} = Y - \frac{W}{P} H - Z \tag{A-5}$$

$$Z = \frac{\delta}{1-\delta} \frac{W}{P} H \tag{A-6}$$

$$1 = \left(\frac{\theta}{\theta - 1}\right) \chi \left(\frac{W}{P}\right)^{1-\delta} \tag{A-7}$$

where $\chi \equiv \frac{1}{1-\delta} \left(\frac{\delta}{1-\delta}\right)^{-\delta}, \ \Phi \equiv (1+\varphi)^{\phi}$.

First, it is trivial to solve for the real wage from $(A-7)$:

$$\left(\frac{W}{P}\right)=\left(\frac{1}{\chi}\frac{\theta-1}{\theta}\right)^{\frac{1}{1-\delta}}$$

Next, we substitute out Z in $(A-3)$ and $(A-5)$ using $(A-6)$, which gives:

$$Y=H\left(\frac{\delta}{1-\delta}\right)^{\delta}\left(\frac{W}{P}\right)^{\delta}$$
$$\left(\frac{\Pi}{P}\right)=Y-\left(\frac{1}{1-\delta}\right)\left(\frac{W}{P}\right)H$$

Combining the two equation above, we substitute out H and express real profits as a function of the real wage and output:

$$\left(\frac{\Pi}{P}\right)=\left[1-\chi\left(\frac{W}{P}\right)^{1-\delta}\right]Y$$

But $\chi\left(\frac{W}{P}\right)^{1-\delta}=\frac{\theta-1}{\theta}$ from $(A-7)$, and consequently we obtain:

$$\left(\frac{\Pi}{P}\right)=\frac{1}{\theta}Y$$

Equation $(A-1)$ indicates that aggregate value-added output should be equal to the sum of labor income and real profits:

$$\begin{aligned}C&=\left(\frac{W}{P}\right)H+\left(\frac{\Pi}{P}\right)\\&=\frac{1-\delta}{\delta}Z+\frac{1}{\theta}Y\\&=\frac{1-\delta}{\delta}(Y-C)+\frac{1}{\theta}Y\\&=\left[1-\delta\left(\frac{\theta-1}{\theta}\right)\right]Y\end{aligned}$$

From $(A-6)$, total labor hours are given by:

$$\begin{aligned}H&=\frac{1-\delta}{\delta}\left(\frac{W}{P}\right)^{-1}Z\\&=\left(\frac{W}{P}\right)^{-1}(1-\delta)\left(\frac{\theta-1}{\theta}\right)Y\\&=\left[\delta\left(\frac{\theta-1}{\theta}\right)\right]^{-\frac{\delta}{1-\delta}}Y\end{aligned}$$

So far, we have expressed the steady state values of $C, Z, H, \frac{\Pi}{P}$ in terms of Y, which can be obtained using $(A-2)$:

$$\begin{aligned}
\Phi\frac{W}{P} &= H^{\phi(1+\varphi)+\varphi}C^{\sigma} \\
\Phi\frac{W}{P} &= \left[\delta\left(\frac{\theta-1}{\theta}\right)\right]^{\frac{-\delta[\phi\Phi(1+\varphi)+\varphi]}{1-\delta}}\left[1-\delta\left(\frac{\theta-1}{\theta}\right)\right]^{\sigma}Y^{\sigma+\phi(1+\varphi)+\varphi} \\
\left(\frac{1}{\chi}\frac{\theta-1}{\theta}\right)^{\frac{1}{1-\delta}} &= \left[\delta\left(\frac{\theta-1}{\theta}\right)\right]^{\frac{-\delta[\phi(1+\varphi)+\varphi]}{1-\delta}}\left[1-\delta\left(\frac{\theta-1}{\theta}\right)\right]^{\sigma}Y^{\sigma+\phi(1+\varphi)+\varphi} \\
Y^{\sigma+\phi(1+\varphi)+\varphi} &= \Phi\left(\frac{1}{\chi}\frac{\theta-1}{\theta}\right)^{\frac{1}{1-\delta}}\left[\delta\left(\frac{\theta-1}{\theta}\right)\right]^{\frac{\delta[\phi(1+\varphi)+\varphi]}{1-\delta}}\left[1-\delta\left(\frac{\theta-1}{\theta}\right)\right]^{-\sigma} \\
Y &= \left\{\Phi\left(\frac{1}{\chi}\frac{\theta-1}{\theta}\right)^{\frac{1}{1-\delta}}\left[\delta\left(\frac{\theta-1}{\theta}\right)\right]^{\frac{\delta[\phi(1+\varphi)+\varphi]}{1-\delta}}\left[1-\delta\left(\frac{\theta-1}{\theta}\right)\right]^{-\sigma}\right\}^{\frac{1}{\sigma+\phi(1+\varphi)+\varphi}}
\end{aligned}$$

B
Loglinear approximation

Here we present full set of log-linearized equations.

B.1
CES Aggregates, market clearing, and definitions

$$p_t = \sum_k n_k p_{k,t}, \qquad p_{k,t} = \sum_s \frac{n_{k_s}}{n_k} p_{k_s,t}, \qquad p_{k_s,t} = \frac{1}{n_{k_s}} \int_{\mathcal{I}_{k_s}} p_{k_s,t}(i) di$$
$$y_t = \sum_k n_k y_{k,t}, \qquad y_{k,t} = \sum_s \frac{n_{k_s}}{n_k} y_{k_s,t}, \qquad y_{k_s,t} = \frac{1}{n_{k_s}} \int_{\mathcal{I}_{k_s}} y_{k_s,t}(i) di$$
$$c_t = \sum_k n_k c_{k,t}, \qquad c_{k_s,t} = \sum_s \frac{n_{k_s}}{n_k} c_{k_s,t}, \qquad c_{k_s,t} = \frac{1}{n_{k_s}} \int_{\mathcal{I}_{k_s}} c_{k_s,t}(i) di$$
$$h_t = \sum_k n_k h_{k,t}, \qquad h_{k,t} = \sum_s \frac{n_{k_s}}{n_k} h_{k_s,t}, \qquad h_{k_s,t} = \frac{1}{n_{k_s}} \int_{\mathcal{I}_{k_s}} h_{k_s,t}(i) di$$
$$n_t = (1+\varphi) h_t, \qquad y_t = (1-\psi) c_t + \psi z_t, \qquad \psi \equiv \delta \left(\frac{\theta - 1}{\theta} \right)$$

$$z_t = \sum_k \sum_s \int_{\mathcal{I}_{k_s}} z_{k_s,t}(i) di, \qquad z_{k_s,t}(i) = \sum_{k'} n_{k'} z_{k_s,k',t}(i)$$
$$z_{k_s,k',t}(i) = \sum_{s'} \frac{n_{k'_{s'}}}{n_{k'}} z_{k_s,k'_{s'},t}(i), \quad z_{k_s,k'_{s'},t}(i) = \frac{1}{n_{k'_{s'}}} \int_{\mathcal{I}_{k'_{s'}}} z_{k_s,k'_{s'},t}(i,i') di'$$

B.2
Demand functions

$$y_{k,t} - y_t = -\eta (p_{k,t} - p_t)$$
$$y_{k_s,t} - y_{k,t} = -\epsilon (p_{k_s,t} - p_{k,t}) + d_{k_s,t}$$
$$y_{k_s,t}(i) - y_{k_s,t} = -\theta (p_{k_s,t}(i) - p_{k_s,t})$$

If we impose $\epsilon = \eta$, the demand schedule can be reduced to:

$$y_{k_s,t} - y_t = -\eta(p_{k_s,t} - p_t) + d_{k_s,t}$$
$$y_{k_s,t}(i) - y_{k_s,t} = -\theta(p_{k_s,t}(i) - p_{k_s,t})$$

For demand for consumption and intermediate inputs:

$$c_{k_s,t} - c_t = -\eta(p_{k_s,t} - p_t) + d_{k_s,t}$$
$$c_{k_s,t}(i) - c_{k_s,t} = -\theta(p_{k_s,t}(i) - p_{k_s,t})$$
$$z_{k_s,k'_{s'},t}(i) - z_{k_s,t}(i) = -\eta(p_{k'_{s'},t} - p_t) + d_{k'_{s'},t}$$
$$z_{k_s,k'_{s'},t}(i,i') - z_{k_s,k'_{s'},t}(i) = -\theta(p_{k'_{s'},t}(i') - p_{k'_{s'},t})$$

B.3
Households' FOCs

$$c_t = E_t[c_{t+1}] - \frac{1}{\sigma}[(i_t - E_t[\pi_{t+1}]) + (\gamma_t - E_t[\gamma_{t+1}])]$$
$$w_{k,t} - p_t = \phi(1+\varphi)h_t + \varphi h_{k,t} + \sigma c_t$$

B.4
Firms

Production function:

$$y_{k_s,t}(i) = a_t + a_{k_s,t} + (1-\delta)h_{k_s,t}(i) + \delta z_{k_s,t}(i)$$

Cost minimization:

$$w_{k,t} - p_t = z_{k_s,t}(i) - h_{k_s,t}(i)$$

A firm's nominal marginal cost:

$$mc_{k_s,t} = (1-\delta)(w_{k,t} - p_t) - a_{k_s,t} - a_t + p_t$$

Here we provide a little detail on the derivation of the generalized Phillips curvers presented in the text. To derive the Phillips curve, log-linearize the firm's FOC:

$$E_t \sum_{\tau=0}^{\infty} \alpha_{k_s}^{\tau} Q_{t,t+\tau} D_{k_s,t+\tau} \left(\frac{P^*_{k_s,t}}{P_{k_s,t+\tau}}\right)^{-\theta} \left(\frac{P_{k_s,t+\tau}}{P_{t+\tau}}\right)^{-\eta} Y_{t+\tau} \left[P^*_{k,t} - \left(\frac{\theta-1}{\theta} MC_{k_s,t+\tau}\right)\right] = 0$$

It yields:

$$E_t \sum_{\tau=0}^{\infty} (\alpha_{k_s}\beta)^\tau p^*_{k_s,t} = E_t \sum_{\tau=0}^{\infty} (\alpha_{k_s}\beta)^\tau mc_{k_s,t+\tau}$$

Solve for $p^*_{k_s,t}$:

$$p^*_{k_s,t} = (1-\alpha_{k_s}\beta) E_t \sum_{\tau=0}^{\infty} (\alpha_{k_s}\beta)^\tau mc_{k_s,t+\tau}$$
$$p^*_{k_s,t} = (1-\alpha_{k_s}\beta)[mc_{k_s,t}] + \alpha_{k_s}\beta E_t[p^*_{k_s,t+1}]$$

Loglinearizing the price level yields:

$$p_{k_s,t} = (1-\alpha_{k_s})p^*_{k_s,t} + \alpha_{k_s} p_{k_s,t-1}$$

Combining the two delivers the sectoral Phillips curve:

$$\pi_{k_s,t} = \beta E_t[\pi_{k_s,t+1}] + \frac{(1-\alpha_{k_s})(1-\alpha_{k_s}\beta)}{\alpha_{k_s}}[mc_{k_s,t} - p_{k_s,t}]$$

Note that from the two equations:

$$w_{k,t} - p_t = \phi(1+\varphi)h_t + \varphi h_{k,t} + \sigma c_t$$
$$w_{k,t} - p_t = z_{k,t} - h_{k,t}$$

we can obtain:

$$z_{k,t} = \phi(1+\varphi)h_t + (1+\varphi)h_{k,t} + \sigma c_t$$

Also, from the production function, we get:

$$\begin{aligned} y_{k,t} &= a_t + \sum_{s=1}^{S_k} \frac{n_{k_s}}{n_k} a_{k_s,t} + (1-\delta)h_{k,t} + \delta z_{k,t} \\ &= a_t + \underbrace{\sum_{s=1}^{S_k} \frac{n_{k_s}}{n_k} a_{k_s,t}}_{a_{k,t}} + (1-\delta)h_{k,t} + \delta(1+\varphi)h_{k,t} + \phi\delta(1+\varphi)h_t + \delta\sigma c_t \end{aligned}$$

Therefore:

$$h_{k,t} = \frac{1}{1+\delta\varphi} y_{k,t} - \frac{\delta\sigma}{1+\delta\varphi} c_t - \frac{\phi\delta(1+\varphi)}{1+\delta\varphi} h_t - \frac{1}{1+\delta\varphi} a_t - \frac{1}{1+\delta\varphi} a_{k,t}$$

Then:

$$
\begin{aligned}
mc_{k_s,t} &= (1-\delta)(w_{k,t}-p_t) - a_{k_s,t} - a_t + p_t \\
&= (1-\delta)\left(\phi(1+\varphi)h_t + \frac{\varphi}{1+\delta\varphi}y_{k,t} - \frac{\varphi\delta\sigma}{1+\delta\varphi}c_t - \frac{\varphi\phi\delta(1+\varphi)}{1+\delta\varphi}h_t \right.\\
&\left. -\frac{\varphi}{1+\delta\varphi}a_t - \frac{\varphi}{1+\delta\varphi}a_{k,t} + \sigma c_t\right) - a_{k_s,t} - a_t + p_t \\
&= \frac{(1-\delta)\varphi}{1+\delta\varphi}y_{k,t} + \frac{(1-\delta)\sigma}{1+\delta\varphi}c_t + \frac{\phi(1-\delta)(1+\varphi)}{1+\delta\varphi}h_t - \frac{1+\varphi}{1+\delta\varphi}a_t \\
&- \frac{(1-\delta)\varphi}{1+\delta\varphi}a_{k,t} - a_{k_s,t} + p_t
\end{aligned}
$$

So the subsectoral Phillips curve can be written as:

$$
\pi_{k_s,t} = \beta E_t[\pi_{k_s,t+1}] + \frac{1-\alpha_{k_s}}{\alpha_{k_s}(1-\alpha_{k_s}\beta)^{-1}}\begin{bmatrix} \frac{(1-\delta)\varphi}{1+\delta\varphi}y_{k,t} + \frac{(1-\delta)\sigma}{1+\delta\varphi}c_t + \frac{\phi(1-\delta)(1+\varphi)}{1+\delta\varphi}h_t - (p_{k_s,t}-p_t) \\ -\frac{1+\varphi}{1+\delta\varphi}a_t - \frac{(1-\delta)\varphi}{1+\delta\varphi}a_{k,t} - a_{k_s,t} \end{bmatrix}
$$

Finally, note that:

$$
\begin{aligned}
y_{k_s,t} &= y_t - \eta(p_{k_s,t}-p_t) + d_{k_s,t} \\
-(p_{k,s,t}-p_t) &= \frac{1}{\eta}(c_{k_s,t}-c_t) - \frac{1}{\eta}d_{k_s,t}
\end{aligned}
$$

$$
\pi_{k_s,t} = \beta E_t[\pi_{k_s,t+1}] + \frac{1-\alpha_{k_s}}{\alpha_{k_s}(1-\alpha_{k_s}\beta)^{-1}}\begin{bmatrix} \left(\frac{(1-\delta)(\sigma-\psi\varphi)}{1+\delta\varphi} - \frac{1}{\eta}\right)c_t + \frac{(1-\delta)\varphi}{1+\delta\varphi}c_{k,t} + \frac{1}{\eta}c_{k_s,t} + \frac{(1-\delta)\psi\varphi}{1+\delta\varphi}z_t \\ \frac{\phi(1-\delta)(1+\varphi)}{(1+\delta\varphi)}h_t - \frac{1+\varphi}{1+\delta\varphi}a_t - \frac{(1-\delta)\varphi}{1+\delta\varphi}a_{k,t} - a_{k_s,t} - \frac{1}{\eta}d_{k_s,t} \end{bmatrix}
$$

C
About the Estimated Model

Here we present the results of the estimated model using Bayesian methods. That is, we incorporate prior information about the structural parameters $\boldsymbol{\theta}$ by specifying a prior distribution $f(\boldsymbol{\theta})$. With data set decribed in subsection 4.2.1, $\mathbf{X}^T$, we can obtain the likelihood function $f(\mathbf{X}^T|\boldsymbol{\theta})$ implied by the model economy. Then, the posterior distribution of $\boldsymbol{\theta}$; $f(\boldsymbol{\theta}|\mathbf{X}^T)$ is then determined by Bayes theorem. We simulate the posterior distribution by Markov Chain Monte Carlo methods.

C.1
Priors and posteriors

We fix some parameters in the estimation, setting them at the same values as in the calibrated version of the model studied in previous subsections.

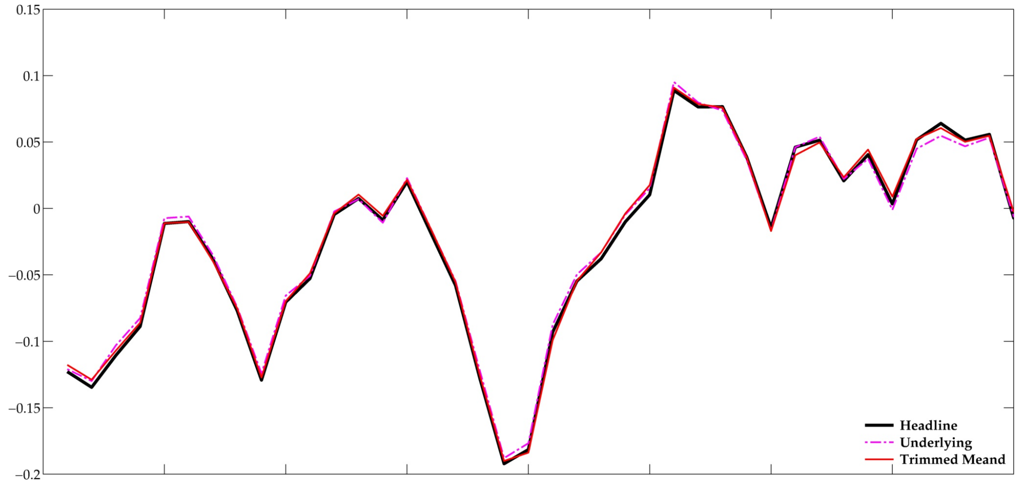
As for the remaining parameters, our prior distribution also mostly follows the convention in the literature on Bayesian estimation of DSGE models. Regarding the Taylor rule coefficients, we select normal distributions. The mean of ϕ_π is set to be 1.5 with standard deviation of 0.25. We set the mean of ϕ_c to be $0.5/4$ and its prior standard deviation to be 0.05. The autoregressive parameter of the monetary shock, ρ_μ has a beta distribution with mean of 0.7 and standard deviation of 0.1, whereas the innovation parameter, σ_μ, has an inverse gamma distribution with mean of 0.0125% and standard deviation of 0.0125%.

We treat the aggregate shocks, γ_t and a_t, symmetrically. The prior mean of ρ_Γ and ρ_A is 0.7, and the standard deviation is 0.1. The standard deviations of the innovations σ_Γ and σ_A are assumed to have mean of 0.1% and standard deviation of 0.1%.

We also treat the sectoral shocks symmetrically in the prior distribution. The autoregressive parameters have the same prior distribution as their counterparts in aggregate shocks. However, due to the likely more volatile nature of sectoral shocks, we set the prior mean of $\sigma_{A_{k_s}}$ and $\sigma_{D_{k_s}}$ to 1% and the prior standard deviation to 2%. Finally, we assume that all parameters are distributed independently.

C.2

Figure C.1: Simulated Inflation Series



Note: The figure presents the simulated series of 4 quarter cumulative headline inflation, trimmed mean and underlying inflation for the estimated model. We use the 15 per cent trimmed mean, as the RBA, and our underlying inflation measure is given by the volatility weighted measure, described in subsection 2.2.

Results

As we stated in the text, the estimated model fails to account for the dynamics of the cross-section of inflation. If we take a look at Figure C.1, the analogous of Figure 5.3 for the estimation results, it is pretty much clear that the behaviour of headline versus underlying inglation in the model is far from what we observe in the data.

But where exactly the estimated model fails? One aspect in which the model does a very poor job is with respect to the variance of the inflation series. The estimated model fails to capture the differences in volatility of the cross-section of inflation series. Actually, all the variances are overestimated - some even by a factor of 10.[1] This pretty much explain the poor perfomance of our underlying measure. We have tried different values for the fixed parameters and different specifications - external habit formation in preferences - without attaining any better results. A potential solution would be to use the prior specification developed by Del Negro and Schorfheide (2008), which does not assume independency between prior distributions. Their proposal is specially interesting for our case, since their method permits to translate priors about reasonable magnitudes for second moments of observables into a joint prior distribution for these parameters.

[1]Note from table C.2 to C.6 that this is not due to our choice of priors, since most estimated standard deviations are above the mean of the distribution.

Table C.1: Sectors and Weights

Categories	Weights (%)	α_{k_s}	Duration (months)
Food and Non-Alcoholic Beverages			
Bread and cereal products	1.71	0.047	3.15
Meat and seafoods	2.29	0.047	3.15
Dairy and related products	1.15	0.047	3.15
Fruits and vegetables	2.95	0.047	3.15
Other food	2.17	0.047	3.15
Non-alcoholic beverages	1.14	0.047	3.15
Meals out and take away foods	5.43	0.842	18.97
Alcohol and Tobacco			
Alcoholic beverages	4.75	0.368	4.75
Tobacco	2.32	0.023	3.07
Clothing and Footwear[1]			
Garments	3.21	0.040	3.12
Footwear	0.78	0.228	3.88
Housing[2]			
Rents	15.38	0.691	9.71
Other housing	3.31	0.691	9.71
Utilities	3.61	0.211	3.80
Furnishings, Household Equipment and Services			
Furniture and furnishings	1.91	0.320	4.41
Household textiles	0.61	0.354	4.64
Household appliances, utensils and tools	1.43	0.102	3.34
Non-durable household goods	2.86	0.354	4.64
Domestic and household services	2.29	0.354	4.64
Health			
Medical products, appliances and equipment	1.32	0.548	6.64
Medical, dental and hospital services	3.97	0.811	15.93
Transport			
Private motoring	10.81	0.386	4.88
Urban transport fares	0.74	0.304	4.31
Communication			
Communication	3.05	0.592	7.35
Recreation and Culture			
Audio, visual and computing equipment and services	2.53	0.637	8.27
Newspapers, books and stationery	1.08	0.817	16.43
Holiday travel and accommodation	4.76	0.119	3.40
Other recreation, sport and culture	4.20	0.782	13.77
Education			
Education	3.18	0.810	15.77
Insurance and Financial Services[3]			
Insurance and Financial Services	5.08	0.757	12.35

Note: [1] Accessories and clothing services was excluded due to data availability; [2] New dwelling purchase by owner-occupiers was added to Rents

Table C.2: Priors and Posteriors -Aggregates shocks

Parameter	Prior			DSGE *posterior*				
	Dist	Mean	Std	Mode	Mean	5%	50%	95%
ϕ_π	Normal	1.50	0.25	0.997	1.139	1.003	1.109	1.377
ϕ_c	Normal	0.5/4	0.05	0.017	0.065	0.018	0.058	0.134
ρ_i	Beta	0.70	0.10	0.809	0.887	0.849	0.888	0.921
σ^*_μ	InvGam	0.0125	0.0125	0.095	0.087	0.072	0.086	0.107
ρ_μ	Beta	0.70	0.10	0.428	0.436	0.336	0.436	0.536
σ^*_A	InvGam	0.10	0.10	0.187	0.267	0.174	0.265	0.369
ρ_A	Beta	0.70	0.10	0.991	0.989	0.982	0.990	0.996
σ^*_Γ	InvGam	0.10	0.10	1.790	2.077	1.689	2.052	2.546
ρ_Γ	Beta	0.70	0.10	0.609	0.643	0.548	0.644	0.732

Note: (*) The standard deviations values are given in percentages.

Table C.3: Priors and Posteriors - Sectoral Productivity shocks

Parameter	Prior			DSGE *posterior*				
	Dist	Mean	Std	Mode	Mean	5%	50%	95%
$\sigma^*_{a_{1,1}}$	InvGam	1.00	2.00	1.323	1.213	1.030	1.204	1.423
$\sigma^*_{a_{1,2}}$	InvGam	1.00	2.00	1.576	1.567	1.335	1.559	1.830
$\sigma^*_{a_{1,3}}$	InvGam	1.00	2.00	1.335	1.364	1.167	1.353	1.596
$\sigma^*_{a_{1,4}}$	InvGam	1.00	2.00	5.576	5.402	4.642	5.374	6.279
$\sigma^*_{a_{1,5}}$	InvGam	1.00	2.00	1.032	1.180	1.006	1.171	1.385
$\sigma^*_{a_{1,6}}$	InvGam	1.00	2.00	1.770	1.768	1.507	1.754	2.079
$\sigma^*_{a_{1,7}}$	InvGam	1.00	2.00	9.238	8.956	7.627	8.877	10.486
$\sigma^*_{a_{2,1}}$	InvGam	1.00	2.00	0.896	0.962	0.816	0.953	1.139
$\sigma^*_{a_{2,2}}$	InvGam	1.00	2.00	1.639	1.690	1.439	1.672	2.011
$\sigma^*_{a_{3,1}}$	InvGam	1.00	2.00	1.131	1.345	1.149	1.330	1.598
$\sigma^*_{a_{3,2}}$	InvGam	1.00	2.00	1.806	1.739	1.490	1.731	2.022
$\sigma^*_{a_{4,1}}$	InvGam	1.00	2.00	2.947	2.790	2.235	2.749	3.459
$\sigma^*_{a_{4,2}}$	InvGam	1.00	2.00	6.344	6.206	4.984	6.160	7.570
$\sigma^*_{a_{4,3}}$	InvGam	1.00	2.00	2.149	1.870	1.575	1.860	2.200
$\sigma^*_{a_{5,1}}$	InvGam	1.00	2.00	1.133	1.366	1.156	1.355	1.623
$\sigma^*_{a_{5,2}}$	InvGam	1.00	2.00	2.825	2.589	2.205	2.571	3.021
$\sigma^*_{a_{5,3}}$	InvGam	1.00	2.00	0.835	0.810	0.681	0.804	0.966
$\sigma^*_{a_{5,4}}$	InvGam	1.00	2.00	1.684	1.594	1.340	1.583	1.888
$\sigma^*_{a_{5,5}}$	InvGam	1.00	2.00	1.570	1.572	1.335	1.558	1.845
$\sigma^*_{a_{6,1}}$	InvGam	1.00	2.00	5.375	5.556	4.660	5.483	6.641
$\sigma^*_{a_{6,2}}$	InvGam	1.00	2.00	21.25	19.21	16.34	19.06	22.59
$\sigma^*_{a_{7,1}}$	InvGam	1.00	2.00	1.975	2.066	1.759	2.052	2.439
$\sigma^*_{a_{7,2}}$	InvGam	1.00	2.00	1.175	1.239	1.056	1.229	1.453
$\sigma^*_{a_{8,1}}$	InvGam	1.00	2.00	3.264	2.711	2.254	2.692	3.229
$\sigma^*_{a_{9,1}}$	InvGam	1.00	2.00	7.542	6.606	5.436	6.559	7.927
$\sigma^*_{a_{9,2}}$	InvGam	1.00	2.00	10.47	10.92	8.373	10.77	14.01
$\sigma^*_{a_{9,3}}$	InvGam	1.00	2.00	1.875	1.990	1.686	1.972	2.359
$\sigma^*_{a_{9,4}}$	InvGam	1.00	2.00	8.483	7.786	6.523	7.758	9.158
$\sigma^*_{a_{10,1}}$	InvGam	1.00	2.00	6.029	6.698	5.513	6.629	8.065
$\sigma^*_{a_{11,1}}$	InvGam	1.00	2.00	5.961	6.077	5.138	6.001	7.288

Note: (*) The standard deviations values are given in percentages.

Table C.4: Priors and Posteriors - Sectoral Productivity shocks

Parameter	Prior			DSGE *posterior*				
	Dist	Mean	Std	Mode	Mean	5%	50%	95%
$\rho_{a_{1,1}}$	Beta	0.70	0.10	0.737	0.765	0.655	0.766	0.873
$\rho_{a_{1,2}}$	Beta	0.70	0.10	0.735	0.813	0.719	0.816	0.895
$\rho_{a_{1,3}}$	Beta	0.70	0.10	0.854	0.767	0.658	0.772	0.861
$\rho_{a_{1,4}}$	Beta	0.70	0.10	0.817	0.790	0.691	0.794	0.882
$\rho_{a_{1,5}}$	Beta	0.70	0.10	0.773	0.676	0.543	0.678	0.803
$\rho_{a_{1,6}}$	Beta	0.70	0.10	0.972	0.888	0.827	0.889	0.941
$\rho_{a_{1,7}}$	Beta	0.70	0.10	0.938	0.954	0.934	0.955	0.970
$\rho_{a_{2,1}}$	Beta	0.70	0.10	0.718	0.776	0.678	0.780	0.863
$\rho_{a_{2,2}}$	Beta	0.70	0.10	0.909	0.912	0.859	0.915	0.955
$\rho_{a_{3,1}}$	Beta	0.70	0.10	0.846	0.841	0.762	0.843	0.918
$\rho_{a_{3,2}}$	Beta	0.70	0.10	0.925	0.735	0.614	0.734	0.855
$\rho_{a_{4,1}}$	Beta	0.70	0.10	0.705	0.678	0.565	0.682	0.777
$\rho_{a_{4,2}}$	Beta	0.70	0.10	0.655	0.664	0.531	0.661	0.805
$\rho_{a_{4,3}}$	Beta	0.70	0.10	0.978	0.966	0.946	0.967	0.983
$\rho_{a_{5,1}}$	Beta	0.70	0.10	0.920	0.815	0.718	0.817	0.902
$\rho_{a_{5,2}}$	Beta	0.70	0.10	0.813	0.868	0.794	0.870	0.931
$\rho_{a_{5,3}}$	Beta	0.70	0.10	0.828	0.888	0.822	0.890	0.946
$\rho_{a_{5,4}}$	Beta	0.70	0.10	0.790	0.734	0.620	0.738	0.835
$\rho_{a_{5,5}}$	Beta	0.70	0.10	0.827	0.906	0.851	0.908	0.954
$\rho_{a_{6,1}}$	Beta	0.70	0.10	0.485	0.571	0.431	0.573	0.706
$\rho_{a_{6,2}}$	Beta	0.70	0.10	0.955	0.959	0.944	0.959	0.973
$\rho_{a_{7,1}}$	Beta	0.70	0.10	0.808	0.826	0.754	0.828	0.889
$\rho_{a_{7,2}}$	Beta	0.70	0.10	0.662	0.699	0.570	0.700	0.828
$\rho_{a_{8,1}}$	Beta	0.70	0.10	0.809	0.794	0.709	0.795	0.875
$\rho_{a_{9,1}}$	Beta	0.70	0.10	0.815	0.816	0.722	0.818	0.897
$\rho_{a_{9,2}}$	Beta	0.70	0.10	0.696	0.645	0.502	0.648	0.781
$\rho_{a_{9,3}}$	Beta	0.70	0.10	0.896	0.806	0.719	0.808	0.887
$\rho_{a_{9,4}}$	Beta	0.70	0.10	0.881	0.891	0.843	0.894	0.931
$\rho_{a_{10,1}}$	Beta	0.70	0.10	0.680	0.590	0.489	0.601	0.697
$\rho_{a_{11,1}}$	Beta	0.70	0.10	0.889	0.875	0.822	0.877	0.920

Table C.5: Priors and Posteriors - Sectoral Demand shocks

Parameter	Prior			DSGE *posterior*				
	Dist	Mean	Std	Mode	Mean	5%	50%	95%
$\sigma_{d_1}^*$	InvGam	1.00	2.00	2.124	1.926	1.591	1.902	2.329
$\sigma_{d_2}^*$	InvGam	1.00	2.00	1.723	1.462	1.204	1.441	1.790
$\sigma_{d_3}^*$	InvGam	1.00	2.00	2.054	1.868	1.563	1.855	2.215
$\sigma_{d_4}^*$	InvGam	1.00	2.00	0.894	1.060	0.847	1.055	1.298
$\sigma_{d_5}^*$	InvGam	1.00	2.00	2.027	2.045	1.694	2.034	2.428
$\sigma_{d_6}^*$	InvGam	1.00	2.00	4.929	5.194	4.434	5.144	6.106
$\sigma_{d_7}^*$	InvGam	1.00	2.00	2.248	2.622	2.207	2.604	3.097
$\sigma_{d_8}^*$	InvGam	1.00	2.00	2.243	2.724	2.312	2.704	3.190
$\sigma_{d_9}^*$	InvGam	1.00	2.00	3.151	3.306	2.775	3.277	3.954
$\sigma_{d_{10}}^*$	InvGam	1.00	2.00	2.505	2.850	2.426	2.826	3.372
$\sigma_{d_{11}}^*$	InvGam	1.00	2.00	4.293	3.830	3.284	3.795	4.477

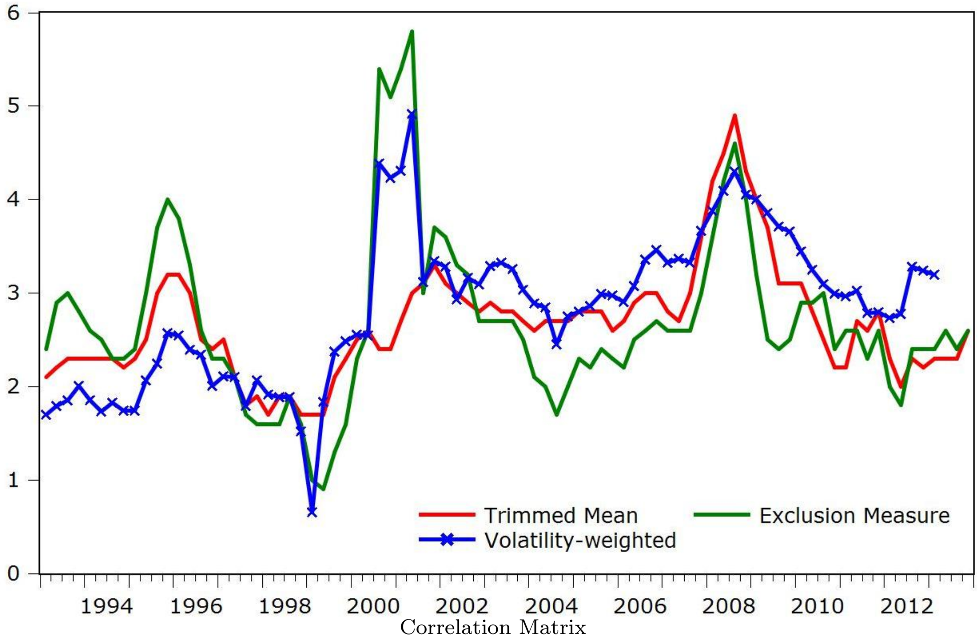
Note: (*) The standard deviations values are given in percentages.

Table C.6: Priors and Posteriors - Sectoral Demand shocks

Parameter	Prior			DSGE *posterior*				
	Dist	Mean	Std	Mode	Mean	5%	50%	95%
ρ_{d_1}	Beta	0.70	0.10	0.905	0.847	0.749	0.853	0.928
ρ_{d_2}	Beta	0.70	0.10	0.898	0.912	0.853	0.916	0.960
ρ_{d_3}	Beta	0.70	0.10	0.920	0.808	0.685	0.814	0.909
ρ_{d_4}	Beta	0.70	0.10	0.967	0.980	0.964	0.981	0.992
ρ_{d_5}	Beta	0.70	0.10	0.884	0.679	0.513	0.680	0.841
ρ_{d_6}	Beta	0.70	0.10	0.936	0.909	0.855	0.911	0.953
ρ_{d_7}	Beta	0.70	0.10	0.720	0.784	0.663	0.789	0.882
ρ_{d_8}	Beta	0.70	0.10	0.857	0.874	0.801	0.877	0.936
ρ_{d_9}	Beta	0.70	0.10	0.939	0.938	0.895	0.941	0.971
$\rho_{d_{10}}$	Beta	0.70	0.10	0.713	0.813	0.707	0.817	0.908
$\rho_{d_{11}}$	Beta	0.70	0.10	0.935	0.928	0.888	0.929	0.962

D
About the Calibrated Model

Figure D.1: Underlying Inflation Measures AUS



Correlation Matrix

Series	Trimmed Mean	Volatility weighted	Exclusion Measure
Trimmed Mean	1.00		
Volatility-weighted	**0.69**	1.00	
Exclusion Measure	0.57	0.67	1.00

Table D.1: Calibrated Parameters -Aggregates shocks

Parameter	Value
ϕ_π	1.05
ϕ_c	0.00
ρ_i	0.80
σ^*_μ	0.00
ρ_μ	0.00
σ^*_A	0.00
ρ_A	0.00
σ^*_Γ	0.43
ρ_Γ	0.97

Note: (*) The standard deviations values are given in percentages.

TABLE D.2: CALIBRATED PARAMETERS - Sectoral Demand shocks

Parameter	Value	Parameter	Value
$\sigma^*_{d_1}$	0.00	ρ_{d_1}	0.00
$\sigma^*_{d_2}$	0.00	ρ_{d_2}	0.00
$\sigma^*_{d_3}$	0.01	ρ_{d_3}	0.00
$\sigma^*_{d_4}$	0.21	ρ_{d_4}	0.00
$\sigma^*_{d_5}$	0.14	ρ_{d_5}	0.37
$\sigma^*_{d_6}$	0.07	ρ_{d_6}	0.00
$\sigma^*_{d_7}$	0.00	ρ_{d_7}	0.00
$\sigma^*_{d_8}$	0.00	ρ_{d_8}	0.00
$\sigma^*_{d_9}$	0.08	ρ_{d_9}	0.00
$\sigma^*_{d_{10}}$	1.98	$\rho_{d_{10}}$	0.00
$\sigma^*_{d_{11}}$	0.00	$\rho_{d_{11}}$	0.00

Note: (*) The standard deviations values are given in percentages.

TABLE D.3: CALIBRATED PARAMETERS - Sectoral Productivity shocks

Parameter	Value	Parameter	Value
$\sigma^*_{a_{1,1}}$	0.72	$\rho_{a_{1,1}}$	0.72
$\sigma^*_{a_{1,2}}$	1.04	$\rho_{a_{1,2}}$	0.83
$\sigma^*_{a_{1,3}}$	0.48	$\rho_{a_{1,3}}$	0.00
$\sigma^*_{a_{1,4}}$	5.79	$\rho_{a_{1,4}}$	0.28
$\sigma^*_{a_{1,5}}$	0.13	$\rho_{a_{1,5}}$	0.00
$\sigma^*_{a_{1,6}}$	1.17	$\rho_{a_{1,6}}$	0.51
$\sigma^*_{a_{1,7}}$	0.00	$\rho_{a_{1,7}}$	0.00
$\sigma^*_{a_{2,1}}$	0.02	$\rho_{a_{2,1}}$	0.99
$\sigma^*_{a_{2,2}}$	0.00	$\rho_{a_{2,2}}$	0.00
$\sigma^*_{a_{3,1}}$	0.89	$\rho_{a_{3,1}}$	0.94
$\sigma^*_{a_{3,2}}$	1.29	$\rho_{a_{3,2}}$	0.00
$\sigma^*_{a_{4,1}}$	0.00	$\rho_{a_{4,1}}$	0.00
$\sigma^*_{a_{4,2}}$	0.00	$\rho_{a_{4,2}}$	0.0-
$\sigma^*_{a_{4,3}}$	0.61	$\rho_{a_{4,3}}$	0.91
$\sigma^*_{a_{5,1}}$	0.87	$\rho_{a_{5,1}}$	0.00
$\sigma^*_{a_{5,2}}$	3.28	$\rho_{a_{5,2}}$	0.20
$\sigma^*_{a_{5,3}}$	0.52	$\rho_{a_{5,3}}$	0.76
$\sigma^*_{a_{5,4}}$	0.89	$\rho_{a_{5,4}}$	0.92
$\sigma^*_{a_{5,5}}$	1.35	$\rho_{a_{5,5}}$	0.94
$\sigma^*_{a_{6,1}}$	3.28	$\rho_{a_{6,1}}$	0.00
$\sigma^*_{a_{6,2}}$	2.35	$\rho_{a_{6,2}}$	0.87
$\sigma^*_{a_{7,1}}$	2.20	$\rho_{a_{7,1}}$	0.51
$\sigma^*_{a_{7,2}}$	0.72	$\rho_{a_{7,2}}$	0.20
$\sigma^*_{a_{8,1}}$	1.50	$\rho_{a_{8,1}}$	0.77
$\sigma^*_{a_{9,1}}$	7.42	$\rho_{a_{9,1}}$	0.57
$\sigma^*_{a_{9,2}}$	1.44	$\rho_{a_{9,2}}$	0.97
$\sigma^*_{a_{9,3}}$	1.93	$\rho_{a_{9,3}}$	0.76
$\sigma^*_{a_{9,4}}$	0.00	$\rho_{a_{9,4}}$	0.00
$\sigma^*_{a_{10,1}}$	0.00	$\rho_{a_{10,1}}$	0.00
$\sigma^*_{a_{11,1}}$	5.55	$\rho_{a_{11,1}}$	0.43

Note: (*) The standard deviations values are given in percentages.