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Honours Thesis

Optimal in ation measures for targeting under sectoral heterogeneity

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Declaration

I declare that this thesis is my own work and that, to the best of my knowledge, it contains no material that has been published or written by another person(s) except where due acknowledgement has been made. This thesis has not been submitted for award of any other degree or diploma at the University of New South Wales or at any other educational institution. I declare that the intellectual content of this thesis is the product of my own work except to the extent that assistance from others is acknowledged.

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Cameron Dark
November 2, 2015

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Abstract

This thesis investigates the extent of sectoral heterogeneity in Australian consumer prices and examines how an inflation targeting central bank can best address this issue when formulating policy. An approximate factor model is used to decompose sectoral inflation into its common and idiosyncratic components. Stylised facts on the dynamic behaviour of sectoral inflation and its components are established, which motivate the use of a multisector model with infrequent price-adjustments to summarise price-setting behaviour in Australian consumer prices.

A multisector New-Keynesian model is then used to examine how underlying inflation performs as the inflation target in the central bank's policy rule. The optimal measure inflation of underlying inflation reduces the welfare loss associated with sticky prices by 12 per cent. Under an optimal policy rule with underlying inflation, welfare is only marginally better than when the central bank follows an optimal policy rule with headline inflation. I conclude that formulation of good policy is of far greater importance than the particular inflation measure targeted.

1 Introduction

The existence of heterogeneity in the price-setting behaviour of firms has been well documented in the economics literature. Particular attention is applied to the frequency at which prices change, due to the crucial role this plays in explaining the real effects of monetary policy. This heterogeneity also creates a trade-off for the inflation targeting central bank when formulating policy. The numerical inflation target and its composition must be explicitly announced, and the central bank must assign a major role to the target in guiding policy actions.

Should the central bank target headline inflation, effectively ignoring the underlying sectoral heterogeneity, or should another inflation measure be constructed? If another measure of inflation is to be targeted, how significant is addressing this underlying sectoral heterogeneity, and what trade-offs need to be made in terms of the central bank's communicability and credibility with the public?

Monetary policy in Australia is conducted by the Reserve Bank of Australia (RBA). The RBA has been operating as an independent central bank since 1960 and formally adopted inflation targeting in 1993. The objectives of the RBA are as follows: (i) the stability of the currency of Australia; (ii) the maintenance of full employment in Australia; and (iii) the economic prosperity and welfare of the people of Australia. Since 1993 these objectives have been expressed in a target for consumer price inflation of 2 to 3 per cent. However, consumer price inflation is an aggregate measure across a representative basket of goods and services. This aggregate measure is often referred to as headline inflation and the frequency at which prices change for the contents of the basket are believed to differ remarkably. Many international studies have identified the frequency at which the prices of these goods and services change. However, the price quotations that form the basis of the consumer price index in Australia remain unavailable to researchers.

This thesis investigates the relationship between heterogeneity in consumer prices and the construction of an optimal measure of underlying inflation. I make two key contributions to the literature. The first is the decomposition of disaggregated consumer price inflation (hereafter sectoral inflation) for Australia into a common and idiosyncratic component. I use this decomposition to estimate volatility and persistence for each component, and motivate a model with heterogeneous sectors subject to infrequent price-adjustments.

A microdata founded study does not yet exist for Australia. This is because conventional estimates will considerably overstate the degree of aggregate price stickiness. Furthermore, the presence of roundabout production leads to a false conclusion that prices are indexed to past inflation.

The impact of sectoral heterogeneity on monetary policy is further developed by

2.3 Optimal Inflation Measures

Aoki (2001) uses an optimising model with a flexible-price and sticky-price sector to analyse how inflation fluctuations are affected by relative price changes. Finding that it is optimal to target inflation in the sticky-price sector, Aoki (2001) also concludes that stabilising inflation in the sticky-price sector is sufficient to stabilise relative prices around their efficient level.

Benigno (2004) extends the framework to a two-region model with monopolistic competition and price stickiness. Using a welfare criterion, the optimal outcome is obtained by targeting a weighted average of regional inflation rates. Where both regions faced a uniform level of price stickiness, these weights were the relative share of the economy held by each region. However, when the price stickiness differed between regions, the optimal policy was where the higher weight was given to the region with the greater level of price stickiness.

Producer prices are added to the optimal inflation framework by Huang & Liu

3 Dynamic Behaviour of Sectoral Inflation

This section outlines the framework used to decompose sectoral inflation into a common and an idiosyncratic component. I use the framework of Boivin et al. (2009), Maćkowiak et al. (2009), and Kaufmann & Lein (2013) to establish stylised facts about the dynamic behaviour of each component, before drawing conclusions on the price-adjustment mechanism of sectoral inflation.

3.1 Empirical framework

Under a static factor structure, if x_t is an $N \times 1$ vector of time series then it may be decomposed into K common factors and some series-specific noise. The relationship between x_t and these components may be exBTe b bBi2013) to1 to1 b B29552 Tf e1 to1K

3.1.1 Data

Volatility is measured by the sample standard deviation. Persistence is measured by fitting an autoregressive process with p lags of the form

$$y_{it} = \sum_{m=1}^{p} \rho_m y_{it-m} + \varepsilon_{it}; \tag{3.5}$$

where p is the optimal number of lags chosen by the finite sample adjusted Akaike information criterion and y_{it} is the corresponding time series (π_{it}; $\lambda_i F_t$; e_{it}).

Following Fuhrer (2010), I measure the persistence of each process as

$$\rho(y_{it}) = \sum_{m=1}^{p} \rho_m; \tag{3.6}$$

so persistence is the sum of AR terms. I measure the variation in sectoral inflation π_{it} explained by the common component $\lambda_i F_t$ with the R^2 from an OLS regression.

3.2 Statistical properties of sectoral inflation

Table 3.1 shows the standard deviation, persistence and R^2, for all groups inflation and the 11 expenditure groups. These expenditure groups form the highest level of disaggregation in the consumer price index, and the statistics presented are calculated from the statistics of the underlying expenditure classes, as a weighted mean using expenditure share weights. The average and median statistics are drawn from the 72 expenditure classes included in the factor model.

The standard deviation of all groups inflation is 0.57 percentage points, which is significantly lower than the standard deviation of sectoral inflation in each expenditure group at 0.96 to 2.52 percentage points. Similarly, the persistence of aggregate inflation (0.37) is higher than the persistence of sectoral inflation in each expenditure group, with the exception of housing (0.60), and insurance and financial services (0.44). The lower volatility and higher persistence found in all groups inflation is broadly explained by the aggregation process, and this finding is

Common component

Frequency

Percentage points

Following Maćkowiak et al. (2009) I define the speed of response in sector i as

$$speed_i = \frac{\sum_{q=0}^{2} |resp_{i;q}|}{\sum_{q=5}^{7} |resp_{i;q}|}; \qquad (3.7)$$

where $resp_{i,q}$ is the impulse response to a standardised shock after q quarters for sector i. The speed of response takes a value close to 1 when the component has very high persistence, and a value close to zero when the component has very low persistence. The tightness in distribution of the speed of response mirrors that of the impulse responses, and the correlation of the speed of responses of macroeconomic and idiosyncratic shocks is positive (Table 3.2).

	$sd(\;_{it})$	$sd(\;_i\;_t)$	$sd(e_{it})$	$\frac{sd(e_{it})}{sd(\;_i\;_t)}$	$speed_i^{macro}$	$speed_i^{idio}$
$sd(\;_{it})$	1.00					
$sd(\;_i\;_t)$	0.32	1.00				
$sd(e_{it})$	0.99	0.26	1.00			
$\frac{sd(e_{it})}{sd(\;_i\;_t)}$	0.46	-0.45	0.49	1.00		
$speed_i^{macro}$	-0.10	-0.09	-0.10	0.38	1.00	
$speed_i^{idio}$	0.09	0.01	0.10	-0.01	0.08	1.00

Table 3.2: Correlations of descriptive statistics

Stylised facts are established for sectoral inflation, for which we observe:

1. a slower response to macroeconomic shocks than to idiosyncratic shocks,
2. positive correlation between the speed of responses to macroeconomic and idiosyncratic shocks,
3. cross-sectional variation of the sectoral speeds of responses to macroeconomic shocks is tighter than to sector-specific shocks.

3.3 Informing a model of price-adjustment

The slower response to macroeconomic shocks than idiosyncratic shocks observed in Australian sectoral inflation motivates two popular models of price-adjustment. First, the multisector model with infrequent price adjustments of Carvalho (2006) and second, the rational-inattention model of Maćkowiak et al. (2009).

The multisector model with infrequent price adjustments argues that the frequency at which prices change is associated with nominal rigidities within the economy in the form of sticky prices. These nominal rigidities often take the form of Taylor (1979) pricing, where prices are adjusted according to the length of contracts, or Calvo (1983) pricing, where firms have a particular probability of being able to reset their price in each period. In contrast, the rational-inattention model argues that if idiosyncratic shocks are large relative to macroeconomic shocks, then it is rational for firms to direct their attention to the former. Idiosyncratic shocks cause firms to adjust their prices frequently, and macroeconomic shocks are incorporated into prices slowly.

Should the rational-inattention model of price-setting be present in the Australian sectoral inflation, we would expect that if the idiosyncratic component is on average more volatile than the common component, then the distribution of speed of responses to idiosyncratic shocks will be tighter than to macroeconomic shocks. The statement on volatility holds for Australian sectoral inflation, however the speed of response to macroeconomic shocks has the tighter distribution. This is consistent with the multisector model with infrequent price adjustments. Moreover, the Carvalho (2006) model suggests that relatively flexible sectors will response quickly to macroeconomic shocks. This requires that there be a positive correlation between the speed of responses to macroeconomic and idiosyncratic shocks, which I find holds for Australian sectoral inflation (Table 3.2).

There are limitations when applying the frameworks of Boivin et al. (2009), Maćkowiak et al. (2009), and Kaufmann & Lein (2013) to the Australian economy. First, many of the conclusions that lead to a model of price-setting rely on knowing the frequency of price changes for each sectors. These are often taken from microdata founded studies of the price quotations that form the basis of national consumer price indices (See Bils & Klenow (2004) as a well-cited study of the U.S. economy, and Kaufmann (2009) for the Swiss economy).

The analysis of Australian sectoral inflation has been limited by the unavailability of price quotation microdata. This prevents four additional stylised facts from being presented. In the multisector model with infrequent price adjustments the sectoral frequencies of price adjustments are expected to have a positive correlation with, (i) the size of response to a macroeconomic shock, (ii) the speed of response to a macroeconomic shock, (iii) the standard deviation of the common component, and (iv) the standard deviation of the idiosyncratic component. To move forward towards a model of price-setting, I draw on the results of a survey conducted by the Reserve Bank of Australia on the price-setting behaviour of firms (Park et al. 2010). The long average duration of prices, and the focus of firms when forming a pricing strategy supports the multisector model with infrequent price adjustments. The frequent price-adjustment behaviour supported by the rational-inattention model is not observed by Park et al. (2010).

Industry	Average duration[a]	Dominant pricing strategy (%)		
		Cost-focus	Demand-focus	Other
Agriculture	4	18	82	-
Construction	$1\frac{1}{3}$	71	27	2
Manufacturing	2	47	46	6
Mining	4	18	71	11
Utilities	4	18	27	55
Wholesale and retail	1	44	50	7
Transport and storage	4	57	30	13
Business services	4	55	44	1
Household services	4	35	30	35
Tourism	4	20	80	-

Source: Park, Rayner and D'Arcy (2010)
[a] in quarters

Table 3.3: Average duration of prices and dominant pricing strategy

The stylised facts from the approximate factor model and the survey of price-setting behaviour both point toward a multisector model with infrequent price adjustments appropriately summarising the heterogeneous price-setting behaviour in Australian sectoral inflation.

4 A Multisector New-Keynesian Model

The model utilised in this thesis is an extension of the multisector New-Keynesian model of Cagliarini et al. (2011). The Cagliarini et al. (2011) model draws on Carvalho (2006) and Nakamura & Steinsson (2010), incorporating heterogeneity in the average duration of prices across sectors, within a roundabout production framework where technology parameters differ across sectors.

In extending the model I consider a measure of underlying inflation that takes the form of a weighted sum of sectoral inflation rates. The monetary authority responds to this underlying measure according to its policy rule, while economy-wide inflation is determined endogenously within the model. The specifications imposed for underlying inflation draw on those measures commonly used in practice by central banks, along with others that are functions of the structural parameters.

4.1 Overview

4.1.1 Agents

The economy consists of a unit interval of identical households, N final-goods producers, a continuum of intermediate-goods producers and a monetary authority.[1]

Households

Households are identical, obtaining utility from consumption c_t and real money holdings $H_t = P_t^c$, and disutility from supplying labour l_t^s, according to

$$U_t = a_t \ln c_t + \ln \frac{H_t}{P_t^c} \quad \frac{1}{1+\frac{1}{}} (l_t^s)^{1+\frac{1}{}}; \qquad (4.1)$$

where a_t is the household preference for consumption and is the Frisch elasticity of labour supply. Households maximise intertemporal utility

$$E_0 \sum_{t=0}^{\infty} {}^t \left[a_t \ln c_t + \ln \frac{H_t}{P_t^c} \quad \frac{1}{1+\frac{1}{}} (l_t^s)^{1+\frac{1}{}} \right]; \qquad (4.2)$$

subject to

$T_t + V_t + H_{t\ 1} +$ B]TJ/F28 7.9701 Tf 9e 0 Td w 0l S 0[(t)]TJ/F31 7.9701 Tf 3.0

Taking wages W_t and the price of the aggregate intermediate good P_t^m as given, intermediate-goods producing firms minimise cost

$$W_t l_{i;t}^d + P_t^m m_{i;t}^d; \qquad (4.7)$$

subject to

$$y_t(i) \leq z_{j;t} \left(z_t l_{i;t}^d\right)^{\alpha_j} \left(m_{i;t}^d\right)^{1-\alpha_j}; \qquad (4.8)$$

where $y_t(i)$, l_t^d and m_t^d are the output, demand for labour and demand for intermediate inputs for firm i, $z_{j;t}$ and α_j are the sector-specific productivity and the factor share of labour in sector j, and z_t is the state of aggregate productivity. As the factor shares of labour are sector-dependent, the steady-state labour cost shares, marginal costs and prices faced by firms will also be sector-dependent.

Monetary authority

The monetary authority follows a policy rule, setting the nominal interest rate I_t according to its prior period value, the growth in final-goods consumption g_t and the rate of underlying inflation π_t^U in the economy

$$I_t = I_{t-1}^{\rho_i} \left(\frac{1}{\beta} e^{(1-\sigma_g)\gamma_z} \left(\pi_t^U\right)^{\phi_\pi} g_t^{\phi_g} \right)^{1-\rho_i} e^{\varepsilon_{i;t}}; \qquad (4.9)$$

where ρ_i, ϕ_π, ϕ_g are policy rule parameters, γ_z is the average growth rate of aggregate technology and $\varepsilon_{i;t}$ is the monetary policy shock.

4.1.2 External shocks

There are four driving forces within the model, a consumption preference shock $\varepsilon_{a;t}$, an aggregate technology shock for intermediate-goods producers $\varepsilon_{z;t}$, sector-specific technology shocks for intermediate-goods producers $\varepsilon_{z;j;t}$ and a monetary policy shock $\varepsilon_{i;t}$. The preference and technology shock processes evolve as follows

$$a_t = a_{t-1}^{\rho_a} e^{\varepsilon_{a;t}}; \qquad (4.10)$$

$$z_t = z_{t-1} e^{\gamma_z + \varepsilon_{z;t}}; \qquad (4.11)$$

$$z_{j;t} = z_{j;t-1}^{\rho_{z;j}} e^{\varepsilon_{z;j;t}}; \qquad (4.12)$$

while the monetary policy shock is incorporated into the policy rule (4.9).

4.1.3 Market clearing

The N markets for N final goods, market for intermediate goods, a labour market, a bond market and a money market, all clear according to

$$c^d_{j,t} = c^s_{j,t} \quad \text{for } j = 1, \ldots, N; \tag{4.13}$$

$$y_t(k) = c^d_t(k) + \int_0^1 m^d_t(k)\, di \qquad \text{for } k \in (0,1]; \tag{4.14}$$

$$l^s_t = \int_0^1 l^d_{i,t}\, di; \tag{4.15}$$

$$B_t = 0; \tag{4.16}$$

$$H_t = H_{t-1} + T_t. \tag{4.17}$$

Aggregation across firms and sectors yields

$$y_t = c_t + m^d_t; \tag{4.18}$$

$$m^d_t = \sum_{j=1}^N m^d_{j,t}; \tag{4.19}$$

$$l^d_t = \sum_{j=1}^N l^d_{j,t}. \tag{4.20}$$

4.2 Underlying inflation

Ideally, a measure of underlying inflation should abstract from price changes that are not influenced by monetary factors. Measures used in practice can be categorised as either an exclusion-based measure or statistical measure (Roberts 2005).

I consider measures of underlying inflation that take the form

$$\pi^U_t = \sum_{j=1}^N \omega_j \pi_{j,t}; \tag{4.21}$$

where the weights assigned to sectoral inflation are subject to the constraints

$$\omega_j \geq 0 \;\; \forall j \quad \text{and} \quad \sum_{j=1}^N \omega_j = 1;$$

with underlying inflation equal to headline inflation when $\omega_j = \alpha_j$ for all j.

4.2.1 Exclusion-based measures of underlying in ation

Exclusion-based measures exclude price changes in sectors that are believed most likely to influence headline inflation for reasons not related to monetary factors. In

Calvo-share

In the first of the other measures I weight each sector according to the normalised product of its Calvo probability $_j$ and share $_j$. This specification seeks to retain the economic importance of each sector through its share, as emphasised in Diewert (1995), while incorporating the response to monetary factors through its stickiness.

Optimal

In the second of the other measures I construct the weights for sectoral inflation by numerically maximising the objective function of the monetary authority. I consider two objectives for the monetary authority. First, following Woodford (2003) I use a utility-based objective function derived from the household period utility function, and second, I use an objective function that is consistent with the mandate of the monetary authority. Further detail is provided in Chapter 5.

4.3 Calibration of parameters

The heterogeneity in intermediate-goods producing firms price-setting behaviour is a key distinction from the standard New-Kenyesian framework. The choice of sectors for which the model is calibrated must reflect the availability of information on price-setting behaviour. In the previous chapter, I discussed the current state of microdata availability for the price quotations that form the basis of the consumer price index in Australia. This information is currently unavailable to researchers, preventing the analysis of price-setting behaviour for the elementary goods that form the basis of expenditure classes in the consumer price index.

To arrive at a calibration that remains realistic but is also attainable, I follow the approach of Cagliarini et al. (2011), and draw on their calibration for ten broad sectors of the Australian economy. I use the results from a survey of firms conducted by the Reserve Bank of Australia on price-setting behaviour from June 2000 to April 2006 (Park et al. 2010). The average duration of prices (in quarters) and the corresponding Calvo probability $_j$ are detailed in Table 4.1.

The size of each sector $_j$ is drawn from the share of gross revenue from the input-output tables of the Australian national accounts. The steady-state shares of sectors' labour $\frac{l_j}{l}$ and intermediate inputs $\frac{m_j}{m}$ are drawn from their share of hours worked and estimates of multifactor productivity. The technology parameters for each sector are drawn from experimental estimates of multifactor productivity, and include: (i) persistence of the technology shock process $_j$, (ii) standard deviation of the technology shock process $_{z_j}$, and (iii) labour income share $_j$. These calibrated parameters are detailed in Table 4.2.

Sector	Average duration (quarters)	Calvo probability ($_j$)
Agriculture	4	0:75
Construction	$1\frac{1}{3}$	0.25
Manufacturing	2	0.50
Mining	4	0.75
Utilities	4	0.75
Wholesale and retail trade	1	0:10[(a)]
Transport and storage	4	0.75
Business services	4	0.75
Household services	4	0.75
Tourism	4	0.75

[a] Calibrated at 0.10 as the sector is empirically close to a exible price sector.

Table 4.1: Calvo probabilities by sector

Market sector multifactor productivity is used to calibrate the standard deviation of the aggregate technology shock $_z$. Average growth in aggregate technology $_z$ is calibrated to from the growth in GDP per-capita over the period 1993Q1 to 2007Q4 and set to 1.0061, which equals 2.46% on an annualised basis. The household discount factor   is set to 0.99, which implies an steady-state annualised interest rate of 3.52%. The Frisch elasticity of labour supply   is set to one-half following Carvalho (2006), and the elasticity of substitution " is set to four, representing a one-third mark-up following Nakamura & Steinsson (2010).

Sector	Shares			Technology		
	$_j$	$l_j = l$	$m_j = m$	$_j$	z_j	$_j$
Agriculture	0.06	0.05	0.06	0.83	3.91	0.29
Construction	0.15	0.10	0.17	0.88	1.46	0.24
Manufacturing	0.29	0.25	0.30	0.86	0.60	0.29
Mining	0.05	0.03	0.05	0.80	1.71	0.24
Utilities	0.03	0.02	0.03	0.93	0.53	0.24
Wholesale and retail trade	0.19	0.26	0.17	0.88	0.50	0.39
Transport and storage	0.08	0.07	0.09	0.87	0.61	0.29
Business services	0.07	0.12	0.06	0.91	0.61	0.44
Household services	0.05	0.06	0.05	0.79	0.69	0.35
Tourism	0.02	0.03	0.02	0.91	0.80	0.39

Notes: Share values are for the period 1995-2003 and do not sum to one because of rounding errors. The sectoral share parameters imply a steady-state share of value added in gross output($\frac{C}{Y}$) of 0.48.

Table 4.2: Calibration of sectoral shares and technology parameters

The monetary policy rule parameters $_i$;   and $_g$, persistence of the preference shock $_a$ and standard deviations of the remaining aggregate shocks $_a$ and $_i$ are estimated. Cagliarini et al. (2011) use the Kalman filter to estimate these parameters from growth in GDP per capita, the overnight cash rate and headline inflation in consumer prices (excluding taxes and volatile items) over the period 1993Q1 to 2007Q4. Values for the behavioural parameters are detailed in Table 4.3.

	Description	Parameter value	Standard error
	Household discount factor	0.99	
"	Elasticity of substitution	4.00	
	Frisch elasticity of labour supply	0.50	
z	Standard deviation of aggregate technology shock	0.44	
i	Persistence of the nominal interest rate	0.71	0.04
	Policy rule response to in ation	1.16	0.13
g	Policy rule response to growth in value added	0.21	0.11
a	Persistence of preference shock	0.89	0.07
i	Standard deviation of monetary policy shock	0.12	0.02
a	Standard deviation of preference shock	0.40	0.11

Table 4.3: Calibration and estimation of behavioural parameters

As there is growth in aggregate technology I detrend some variables in order to make them stationary. The log-linearised rational expectations model is then solved using the development release of Dynare 4.5 in MATLAB 2014b.[2]

[2] The development release was used as constrained minimisation is not available in Dynare 4.4.

5 Welfare Approaches to Optimality

Stickiness in prices is the nominal rigidity introduced to the model economy through the price-setting behaviour of intermediate-goods producing firms. This nominal rigidity allows the monetary authority to influence the real economy, however it also causes ine□ciency as the economy is prevented from reaching equilibrium in the short-run.

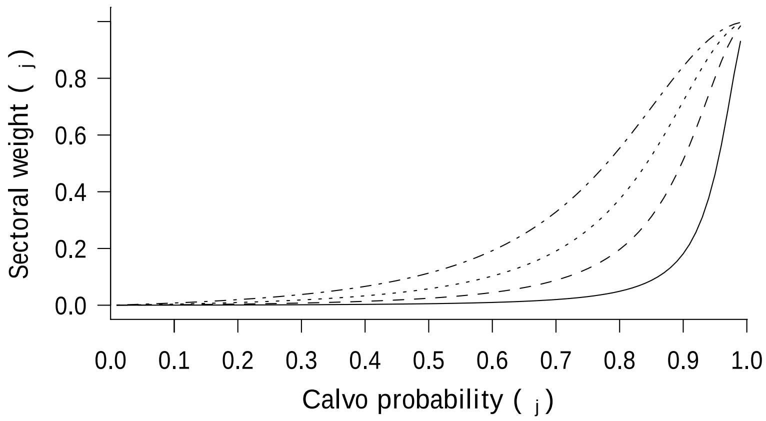
I evaluate the relative performance of di□erent compositions for underlying inflation with two approaches. First, I use a social welfare approach, where the monetary authority maximises a utility-based objective function, and second, I use a simple mandate approach, where the monetary authority maximises a objective function chosen to achieve the monetary authority's mandate.[1] This chapter outlines the relative merits and empirical foundations of each approach.

5.1 Social welfare approach

The social welfare loss is calculated using the method outlined in Woodford (2003) j where the period loss function is an approximation of the discounted sum of utility for the representative household. I generalise Woodford's (2003) two-sector model with Calvo pricing, and following a second order approximation around the e□cient steady-state, the social welfare loss function is of the form

$$L_t^{SW} = \sum_{j=1}^{N} {}_j \hat{}^2_{jt} + {}_c \hat{c}_t^2; \tag{5.1}$$

where $\hat{}_{jt}$ is the log-deviation from trend for inflation in sector j and $\hat{c}_t$ is the log-
t



Sectoral weight (j)
0.0
0.2
0.4
0.6
0.8
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0
Calvo probability (j)

5.2 Simple mandate approach

In the simple mandate approach, the monetary authority seeks to maximise an objective function drawn from its operating mandate, which is often set out in legislation or regulation from the executive government. Using the simple mandate approach has two particular advantages over the social welfare approach in practice. First, the loss-function weights are not derived from the structural parameters of the economy, which are unobserved, and second, it allows the monetary authority to operate in a fashion that is far more communicable to the public.

5.2.1 Headline in ation and value-added output

In forming the simple mandate, I assume that the monetary authority is concerned with stabilising headline inflation and value added output around their steady states. The simple mandate loss function is defined as

$$L_t^{SMi} = \hat{\ }_t^2 + {}_c\hat{C}_t^2$$

6 Performance of Underlying Inflation

In this chapter I compare the performance of headline inflation with four alternative measures of underlying inflation, within the welfare framework outlined in the previous chapter. The weights for the optimal measure of underlying inflation are calculated, then the relative welfare loss of the four alternative measures are compared. Finally, I consider how targeting the optimal measure of underlying inflation impacts on the transmission of monetary policy.

6.1 Optimal measures of underlying in ation

The social welfare (SW) and simple mandate (SM1, SM2) approaches both calculate welfare as a weighted sum of the variances of value added output $\hat{c}_t$ and sectoral inflation $\hat{\ }_t$. The welfare loss will therefore be minimised when the variances are minimised. I calculate the optimal measure of underlying inflation by numerically minimising the welfare loss by choosing sectoral inflation weights ${}_j$ subject to

$$ {}_j \quad 0; \qquad \text{and} \qquad \sum_{j=1}^{N} {}_j = 1: \qquad (6.1) $$

The objective function for each approach is highly non-linear in the underlying parameterisation and there is a risk of the numerical minimiser becoming stuck within the valley of a local minimum. I address this by generating 500 random sets of starting parameters for the sectoral weights, subject to the constraints in Equation 6.1. The set of sectoral weights that minimises the welfare loss is consistent across many of these sets of starting parameters. I also conduct optimisation of the sectoral weights using a pattern search approach. The results are consistent with those from the constrained minimisation procedure.

I report the optimised sectoral weights ${}_j^{SW}$, ${}_j^{SM1}$, ${}_j^{SM2}$, sectoral share weights ${}_j$, steady-state shares of labour and intermediate inputs $l_j = l$, $m_j = m$, sectoral Calvo probabilities ${}_j$ and standard deviation of the sectoral technology shocks ${}_{z_j}$ in Table 6.1. For the social welfare measure of underlying inflation a surprising result is that five of the ten sectors have a weight of zero. Three of these sectors are those with the smallest Calvo probabilities, wholesale and retail trade, construction, and manufacturing. The construction of the social welfare loss function heavily penalises sectors that have a Calvo probability lower than the equivalent uniform Calvo probability. In the previous section I found that this equivalent Calvo probability was 0.65, so the sectoral weights in these three sectors are not unexpected.

Sector	$^{SW}_j$	$^{SM1}_j$	$^{SM2}_j$	$_j$	$l_j = l$	$m_j = m$	$_j$	$_{z_j}$
Agriculture	0.00	0.00	0.00	0.06	0.05	0.06	0.75	3.91
Construction	0.00	0.08	0.03	0.15	0.10	0.17	0.25	1.46
Manufacturing	0.00	0.42	0.21	0.28	0.25	0.30	0.50	0.60
Mining	0.07	0.00	0.00	0.05	0.03	0.05	0.75	1.71
Utilities	0.30	0.00	0.00	0.03	0.02	0.03	0.75	0.53
Wholesale and retail	0.00	0.02	0.00	0.20	0.26	0.17	0.10	0.50
Transport and storage	0.23	0.00	0.10	0.08	0.07	0.09	0.75	0.61
Business services	0.00	0.05	0.08	0.08	0.12	0.06	0.75	0.61
Household services	0.35	0.34	0.49	0.05	0.06	0.05	0.75	0.69
Tourism	0.04	0.09	0.09	0.01	0.03	0.02	0.75	0.80

Table 6.1: Underlying in ation sectoral weights

6.1.1 Response to sectoral technology shocks

The two other sectors with a zero weight are agriculture and business services. The agriculture sector has a sectoral technology shock process with a high standard deviation (3.91), and relatively uniform shares of gross revenue (0.06), labour inputs (0.05) and intermediate inputs (0.06). As roundabout production is a feature of this economy, Intermediate-goods producing firms use the output of other intermediate-goods producing firms as an input. This transmits technology shocks that originate in one sector into the others, according to their share of steady-state intermediate inputs. The response of sectoral inflation and sectoral value added output to three sectoral technology shocks with di ering standard deviations is shown in Figure 6.1.

Here I compare the response of sectoral inflation and sectoral value output added to technology shocks originating in the agriculture ($_{z_j}$ = 3:91), mining ($_{z_j}$ = 1:71) and household services ($_{z_j}$ = 0:69) sectors. These three sectors are approximately equal in size and their use of labour and intermediate inputs. I omit the within-sector responses to allow comparisons across di erent shocks using the same scale. The impulse response functions for each shock show a slight di erence in profile, but a remarkable di erence in magnitude.

A positive sectoral technology shock temporarily decreases the marginal cost faced by intermediate-goods producing firms in that sector, and as prices are sticky, these firms can only reset their prices according to their Calvo probability. The intermediate-goods producing firms in the three sectors highlighted in Figure 6.1 have very sticky prices ($_j$ = 0:75), which is equivalent to a 25% chance of being able to reset their prices within a given period. The firms that are unable to decrease their prices respond by increasing their production. The market for intermediate goods clears, so the increase in intermediate-goods production in one sector will increase production by intermediate-goods producing firms in other sectors.

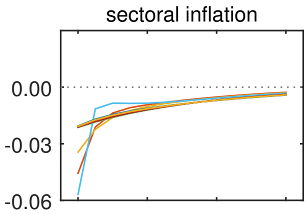


Figure 6.1: Impulse responses: Sectoral technology shocks
Baseline: Monetary authority responds to headline in ation

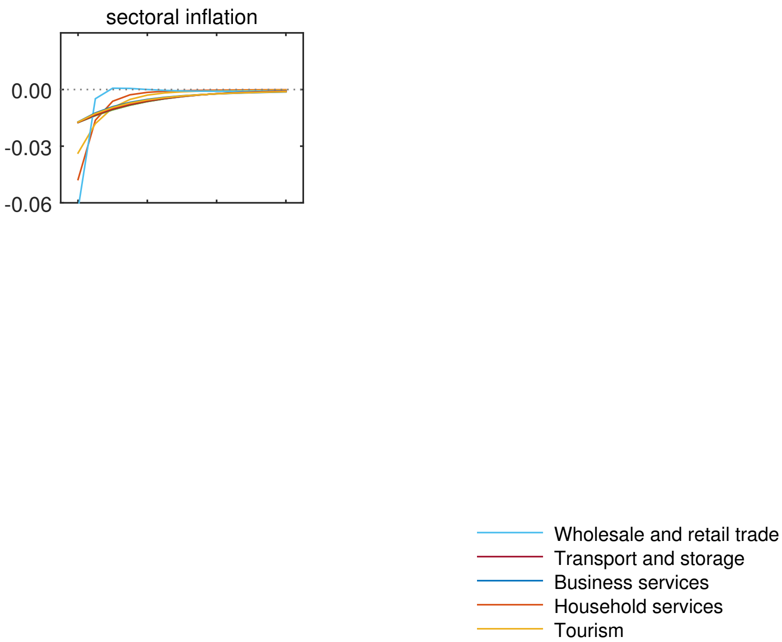


Figure 6.2: Impulse responses: Sectoral technology shocks
Optimal: Monetary authority responds to underlying in ation

Consequently, the production of final goods also increases and the economy

The optimal measure of underlying inflation maximises social welfare. It is optimal only in an aggregatecontext so the net welfare improvement can be comprised of an improved response to some shocks, and a worsened response to others. Figure 6.3 shows the response of the nominal interest rate, inflation, growth and value added output to the same set of sectoral technology shocks.

At the outset, note that the observations made around the aggregate response improving or worsening holds. Responding to the optimal measure of underlying inflation: (i) improves the response to a technology shock in the agriculture sector; (ii) has little to no net effect on the response to a technology shock in the mining sector; and (iii) worsens the response to a technology shock in the household services sector. The magnitude of response in k ivonseusT2nssectIng in-27(onse)]TJ 0 -17.devi07(sT2n

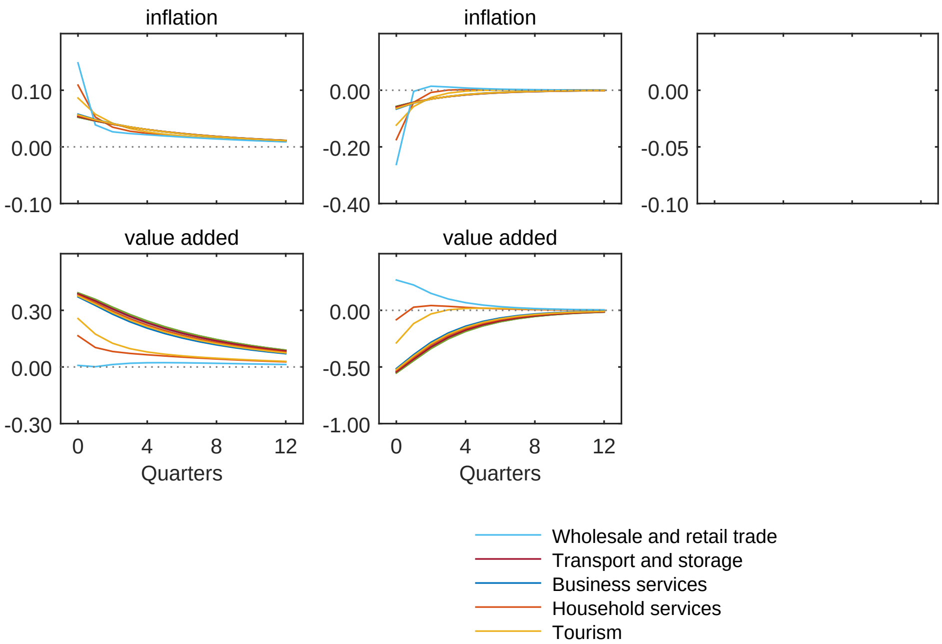


Figure 6.4: Impulse responses: Aggregate shocks
Baseline: Monetary authority responds to headline in ation

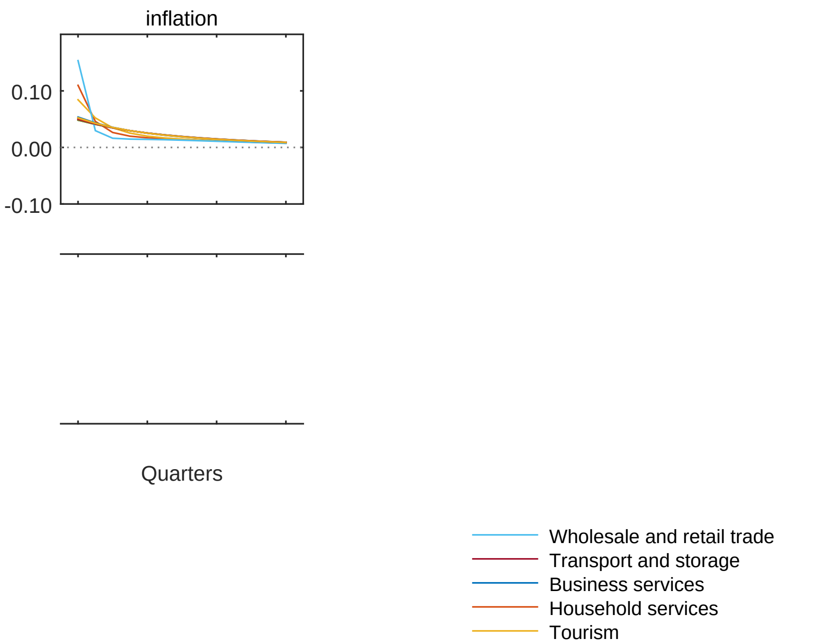


Figure 6.5: Impulse responses: Aggregate shocks
Optimal: Monetary authority responds to underlying in ation

the nominal interest rate. Inflation returns to its steady state at a quicker pace, while the response of growth in value added output and value added output are relatively unchanged. More notable is that by responding to underlying inflation, the intervention by the monetary authority returns inflation to its steady state quicker, but is smaller. The difference in the size of the response is reasonably small, approximately 6 basis points on an annualised basis.

Monetary policy shock

A positive shock to the nominal interest rate decreases the relative price level in each sector, which decreases the marginal costs faced by intermediate-goods producing firms. Intermediate-goods producing firms reset their prices in line with their Calvo probability, and those that cannot reset their price adjust their output. The monetary policy shock decreases inflation, growth in value added output, and value added output. When responding to underlying inflation the monetary authority can increase the nominal interest rate by an additional 12 basis points (annualised).

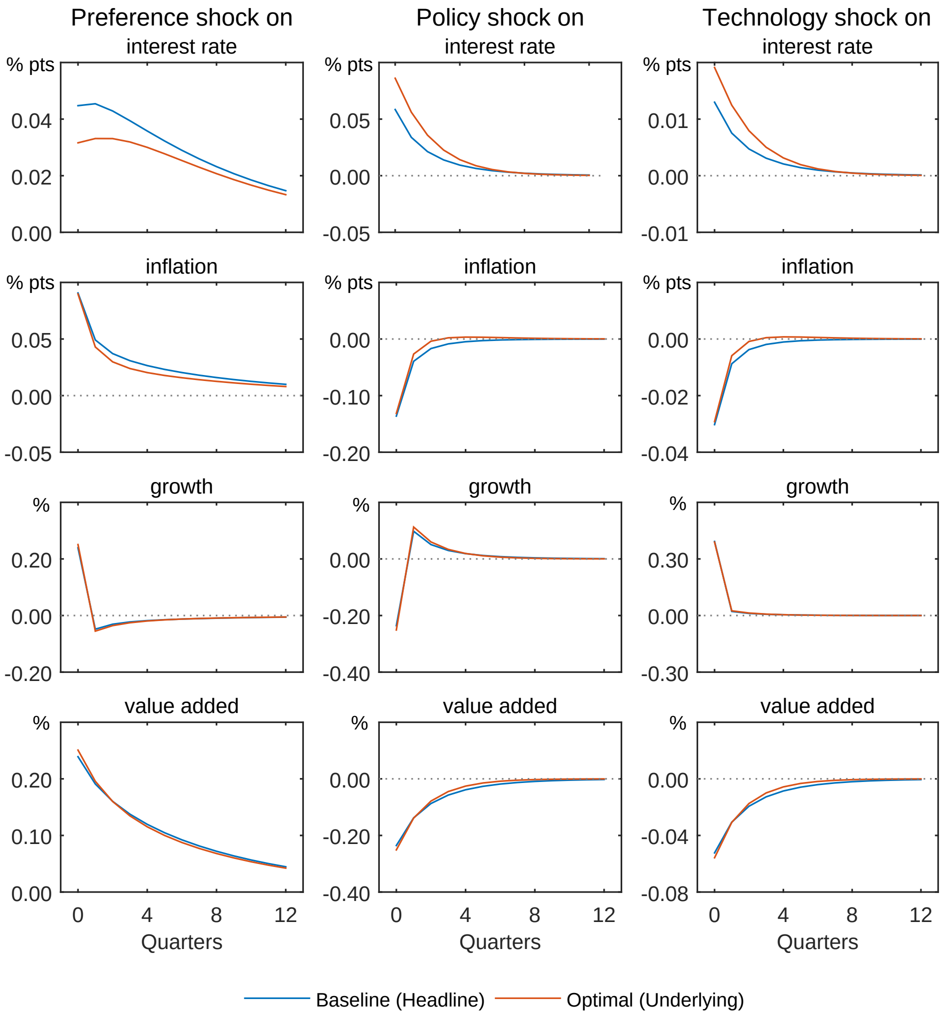


Figure 6.6: Impulse responses: Aggregate shocks

Inflation will then return to its steady state at a quicker pace. The larger shock when responding to underlying inflation has a minor positive effect on growth in value added output, and value added output.

Technology shock

A positive shock to aggregate technology increases growth in value added output and decreases inflation. This rather unintuitive response needs to be framed in terms of detrended variables. The positive shock is permanent, which increases the steady-state level of value added output. Intermediate-goods producing firms respond to the shock according to their Calvo probability, and because prices are sticky, actual value added does not immediately increase. This causes value added output to fall below its new steady-state value. When responding to underlying inflation the monetary authority can increase the nominal interest rate by an additional 2 basis points on an annualised basis, and inflation will return to its steady state at a quicker pace. The larger shock when responding to underlying inflation has a minor positive effect on growth in value added output, and value added output.

Underlying in ation measure	Welfare loss		
	L_t^{SW}	$L_t^{SM\ 1}$	$L_t^{SM\ 2}$
Headline	100.0	100.0	100.0
Exclusion 1	97.4	99.9	99.7
Exclusion 2	93.9	100.1	99.4
Calvo-share	94.8	100.1	99.5
Optimal			
Social welfare	87.3	100.2	98.9
Simple mandate 1	94.5	99.3	98.9
Simple mandate 2	90.0	99.5	98.6

Notes: I report normalised losses where the welfare loss of headline in ation is equal to 100.00. Values less than 100.00 represent an improvement in welfare.

Table 6.2: Welfare loss by underlying measure of in ation

welfare. All alternative measures of underlying reduce the social welfare relative loss. Excluding the least sticky sector, wholesale and retail trade, reduces the social welfare loss by 2.6 per cent. Excluding the two least sticky sectors, wholesale and retail trade, and construction, reduces the social welfare loss by 6.1 per cent. Weighting each sector by the product of its share and Calvo probability reduces the social welfare loss by 5.2 per cent. Choosing sectoral weights to minimise the social welfare loss results in a reduction of 12.7 per cent.

The relative welfare loss from the simple mandates are less definitive in their improvement. Excluding the wholesale and retail trade sector reduces the simple mandate relative losses by 0.1 and 0.3 per cent. Excluding wholesale and retail trade, and construction, increases the relative welfare loss for simple mandate 1 by 0.1 pere 5elfare loss for simple mandate 1 by

Underlying in ation measure	Variance				
	$\hat{\pi}_t$	$\hat{\pi}^U_t$	$\hat{i}_t$	$\hat{c}_t$	$\hat{g}_t$
Headline	0.058	0.058	0.029	0.542	0.320
Exclusion 1	0.056	0.046	0.030	0.543	0.325
Exclusion 2	0.054	0.035	0.028	0.546	0.325
Calvo-share	0.054	0.038	0.028	0.545	0.324
Optimal					
Social welfare	0.050	0.019	0.026	0.551	0.327
Simple mandate 1	0.055	0.039	0.027	0.541	0.322
Simple mandate 2	0.052	0.026	0.026	0.545	0.324

Table 6.3: Variance by underlying measure of in ation

Examination of the theoretical variances is perhaps a better method of identifying the relative improvement. The theoretical variances from the rational expectations solution are calculated for each measure of underlying inflation, and reported for headline inflation $\hat{\pi}_t$, underlying inflation $\hat{\pi}^U_t$, the nominal interest rate $\hat{i}_t$, value added output $\hat{c}_t$ and growth in value added output $\hat{g}_t$ in Table 6.3.

Through its policy rule, the monetary authority responds to a measure of inflation and to growth in value added output. By responding to a measure of underlying inflation, the monetary authority can reduce the variability in headline inflation. This often reduces the variability in the nominal interest rate, but increases the variability in value added output and growth in value added output. This trade-off appears why such little relative improvement in welfare is observed when following a simple mandate.

6.3 Selecting a measure of underlying in ation

amount of information on the economy and financial markets, there are notable gaps. The lack of detailed price-adjustment information prevents use of the price stickiness faced by a sector. While we have used survey responses across ten broad sectors here, the reality of consumer price inflation is that the disaggregated expenditure classes are highly heterogeneous. With the requirement to be transparent and accountable comes the issue of communicability. In practice, the verbal and written communications of central banks are widely circulated and highly scrutinised. For an inflation targeting central bank to remain credible, the measure of underlying inflation chosen must be disclosed. Measures of underlying inflation that are derived from mathematical methods, either statistical or optimisation-based, suffer heavily in this respect. Most agents within the economy have little to no formal training in economics or mathematics, so the communicability of these measures is reduced.

However, the social welfare optimal measure of underlying inflation provided a key insight which may address the issues outlined above. The optimal measure heavily penalised those sectors where the sectoral technology shock has a high standard deviation. The empirical findings from Chapter 3 established that the standard deviation of sectoral inflation is mostly driven by the idiosyncratic component. It should then be possible to use sectoral volatility in forming sectoral inflation weights for a measure of underlying inflation. Placing less emphasis on the sectors that have relatively volatile prices, which fluctuate independently of monetary factors, is a far more communicable concept. To test this hypothesis I construct a measure of underlying using a neo-Edgeworthian approach (Diewert 1995).

The neo-Edgeworthian measure is

$$\hat{\pi}_t^U = \frac{\sum_{j=1}^{N} \frac{\hat{\pi}_{j,t}}{\sigma_j}}{\sum_{j=1}^{N} \frac{1}{\sigma_j}} \qquad (6.2)$$

and its performance is reported in Table 6.4 and Table 6.5. The neo-Edgeworthian measure of underlying inflation reduces the relative social welfare loss by 7 per cent, and the relative simple mandate welfare loss by 0.2 and 0.9 per cent. The improvement is comparable to the unoptimised measures of underlying inflation. However, the new-Edgeworthian approach is not without its detractors. It is certainly arguable that excluding (or re-weighting) sectoral inflation using volatility is no more communicable than a statistical procedure such as the trimmed mean. Heath, Roberts & Bulman (2004) also found that for Australian consumer price inflation, the neo-Edgeworthian index: (i) was difficult to calculate, as the weights of sectoral inflation change from time to time; and (ii) exhibited significant bias.

Underlying in ation measure	Welfare loss		
	L_t^{SW}	$L_t^{SM\,1}$	$L_t^{SM\,2}$
Headline	100.0	100.0	100.0
Exclusion 1	97.4	99.9	99.7
Exclusion 2	93.9	100.1	99.4
Calvo-share	94.8	100.1	99.5
Optimal			
Social welfare	87.3	100.2	98.9
Simple mandate 1	94.5	99.3	98.9
Simple mandate 2	90.0	99.5	98.6
neo-Edgeworthian	93.0	99.8	99.1

Exclusion 2 94.8 Optimal 7364e

Social 98.9

Notes: I report normalised losses where the welfare loss of headline in ation is equal to 100.00. Values less than 100.00 indicate a welfare gain.

Table 6.4: Welfare loss by underlying measure of in ation (NE)

The volatility of sectoral inflation is important in formulating policy responses. This result is derived from a structural model, supported by the empirical results of Chapter 3. Given the importance of volatility in sectoral inflation, the construction and use of volatility themed analytical inflation series' by national statistical agencies and central banks is comforting.

However, as we have seen volatility in a very sticky sector should not be treated the same as volatility in a relatively flexible sector. Moreover, the unavailability of detailed price-adjustment information for the consumer price index remains an important issue that separates Australia from many other developed economies where item level price stickiness can be incorporated into policy.

Underlying in ation measure	Variance		
	$\hat{\pi}_t$	$\hat{\pi}_t^U$	[illegible]

id--326(b)]T2038 Tf 5.679 -1.495 Td [(t765n6ah4)

97.4 99.9 99.7

7 Alternative Monetary Policy Rules

In this chapter, I investigate if the reduction in welfare loss from responding to a measure of underlying inflation can instead be obtained with an alternative monetary policy rule. I begin by introducing the family of monetary policy rules under investigation, then minimise the social welfare loss by adjusting the response of the monetary authority to aggregate inflation and growth in value added output. Finally, I examine how the optimal policy rule impacts the transmission of shocks.

7.1 The optimal monetary policy rule

I consider three specifications for the monetary policy rule, in the form of a generalised Taylor rule that contains a lagged interest rate term

$$\hat{i}_t = \rho_i \hat{i}_{t-1} + \phi_\pi \hat{\pi}^U_t + \phi_g \hat{g}_t + \hat{\varepsilon}_{i;t} \tag{7.1}$$

where the nominal interest rate $\hat{i}_t$ is determined by its previous period value, underlying inflation $\hat{\pi}_t$, growth in value added output $\hat{g}_t$, and the policy shock $\hat{\varepsilon}_{i;t}$

(iii) Rule C restricts $_i = 1$ and chooses and $_g$, and

Sector	$^{sw}_{j}$	$_j$	$l_j = l$	$m_j = m$	$_j$	z_j
Agriculture	0.01	0.06	0.05	0.06	0.75	3.91
Construction	0.00	0.15	0.10	0.17	0.25	1.46
Manufacturing	0.02	0.28	0.25	0.30	0.50	0.60
Mining	0.03	0.05	0.03	0.05	0.75	1.71
Utilities	0.26	0.03	0.02	0.03	0.75	0.53
Wholesale and retail	0.00	0.20	0.26	0.17	0.10	0.50
Transport and storage	0.22	0.08	0.07	0.09	0.75	0.61
Business services	0.17	0.08	0.12	0.06	0.75	0.61
Household services	0.20	0.05	0.06	0.05	0.75	0.69
Tourism	0.09	0.01	0.03	0.02	0.75	0.80

Table 7.2: Underlying in ation sectoral weights

The source of welfare improvement is well-observed through the theoretical variances reported in Table 7.3. Rather remarkable is the reduction in variance across all key variances from optimising the monetary policy rule. Rule B retains the decaying period-to-period behaviour of Rule A, but takes a particularly strong stance on fluctuations in inflation and growth in value added output. Under Rule B the response to inflation and growth in value added output by the monetary authority is approximately six times greater than under Rule A. The variance of headline inflation has decreased by an order of magnitude. The variance of the nominal interest rate has decreased by half. Value added and growth in value added output both show reduced variances, although the improvement is not as remarkable.

The reduction in variance of the nominal interest rate for Rule B is equivalent to a 27 basis point reduction in its standard deviation. Rule D improves on this further, by trading a high variance of headline inflation for a low variance of the nominal interest rate, value added output and growth in value added output. Under Rule D the standard deviation of the nominal interest rate is 37 basis points lower than under Rule A.

Policy rule	Variance				
	$\hat{}_t$	$\hat{}^U_t$	$\hat{i}_t$	$\hat{c}_t$	$\hat{g}_t$
Headline in ation					
Rule A	0.0580	0.0580	0.0292	0.5416	0.3200
Rule B	0.0051	0.0051	0.0135	0.4951	0.2101
Rule C	0.0051	0.0051	0.0113	0.4948	0.2118
Optimal in ation					
Rule D	0.0091	0.0005	0.0085	0.4408	0.1960

Notes: Rule A is the baseline model where parameters are calibrated from Chapter 4, and the monetary authority responds to headline in ation.

Table 7.3: Variance for alternative monetary policy rules

7.1.2 Response to aggregate shocks

Figure 7.1 shows the response of the nominal interest rate, inflation, growth in value added output, and value added output under each rule to a preference, policy and technology shock. Here we see the inflation stabilisation effect operating through large values of .

Preference shock

A positive shock to household preferences increases demand for final goods. Final-goods producing firms increase their demand for intermediate goods, which the intermediate-goods producing firms meet by adjusting their prices or output, according to the Calvo probability faced by the firm. Under the alternative policy rules, the response of the monetary authority is of a similar magnitude to the baseline

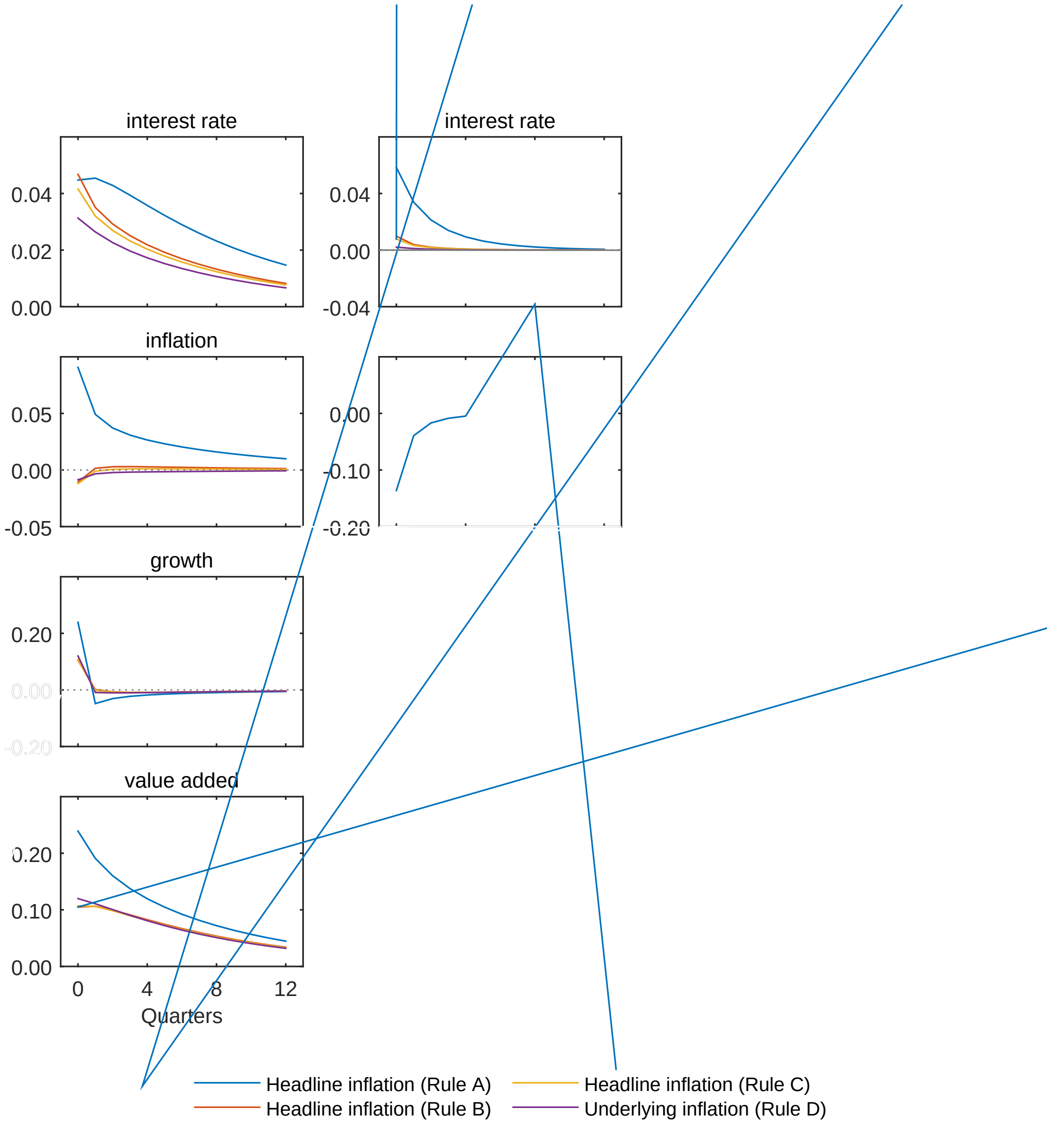


Figure 7.1: Impulse responses: Aggregate shocks
Optimal: Monetary authority responds to underlying inflation

rule. The response of inflation is the same for the stable and explosive alternative policy rules, which shows that the response is driven by the large values of .
Inflation and growth in value added output both return to their steady-states rapidly. Value added returns to its steady state faster than under the baseline policy rule, however it is a gradual rather than rapid return.

This behaviour reflects price-setting decisions of firms seeking to keep the nominal interest rate from entering an explosive path. Instead of adjusting prices according to their Calvo probability as occurs in the baseline case, the intermediate-goods producing firms are particularly sensitive to the expected response of the monetary authority, information which within a rational expectations framework is available to agents.

Monetary policy shock

A positive shock to the nominal interest rate decreases the relative price level in each sector, which decreases the marginal costs faced by intermediate-goods producing firms. Intermediate-goods producing firms reset their prices in line with their Calvo probability, and those that cannot reset their price adjust their output. In the baseline case, the monetary policy shock decreases both inflation and value added output.

The same relative responses are observed for the alternative monetary policy rules, however the magnitude of shock and the subsequent responses are significantly smaller. This again reflects price-setting decisions of firms seeking to keep the nominal interest rate from entering an explosive path. Under the alternative policy framework, the monetary authority is able to influence the behaviour of agents by making much smaller adjustments than in the baseline case. This acts to stabilise inflation around its steady-state with much greater vigour than before.

Technology shock

A positive shock to aggregate technology increases growth in value added output and decreases inflation. This rather unintuitive response needs to be framed in terms of detrended variables. The positive shock is permanent, which increases the steady-state level of value added output. Intermediate-goods producing firms respond to the shock according to their Calvo probability, and because prices are sticky, actual value added output does not immediately increase. This causes value added output to fall below its new steady-state value.

Here the alternative monetary policy rules depart from their previous performance. Instead of returning to the steady-state at a quicker pace, we observe the opposite.

Larger values of $_g$

8 Conclusion

8.1

8.3 Concluding remarks

Overall, the findings of my thesis support the existence of heterogeneity in sectoral inflation, and the incorporation of a measure of underlying inflation into the policy rule of the central bank. However, the policy conclusions arise from a highly stylised

A Data Sources

Table A.1 lists the short name of each series, a brief description, the transformation applied and the data source. Each series begins in 1989Q3 and ends in 2014Q4. After individual series transformations the balanced panel begins in 1989Q4.

Transformation key

Code	Description	Expression
0	None	$X_{it} = Y_{it}$
2	First difference	$X_{it} = \Delta Y_{it}$
5	First difference of logarithm	$X_{it} = \Delta \ln Y_{it}$

Data source key

Code	Source

Real Output

Name	Description	Trans.	Source
RGDP	Gross Domestic Product - Total	5	ABS
RGDP.A	Gross Value Added - Agriculture, forestry and shing	5	ABS
RGDP.B	Gross Value Added - Mining	5	ABS
RGDP.C	Gross Value Added - Manufacturing	5	ABS
RGDP.D	Gross Value Added - Electricity, gas, water and waste services	5	ABS
RGDP.E	Gross Value Added - Construction	5	ABS

DHPS.SA	Number of dwellings - South Australia - Houses - Private Sector (SA)	5	ABS
DHPS.WA	Number of dwellings - Western Australia - Houses - Private Sector (SA)	5	ABS

Households

Name	Description	Trans.	Source
HHE.FOOD	Household expenditure - Food (CVM, SA)	5	ABS
HHE.CAT	Household expenditure - Cigarettes and tobacco (CVM, SA)	5	ABS
HHE.ALC	Household expenditure - Alcoholic beverages (CVM, SA)	5	ABS
HHE.CLO	Household expenditure - Clothing and footwear (CVM, SA)	5	ABS
HHE.RENT	Household expenditure - Rent and other dwelling services (CVM, SA)	5	ABS
HHE.ENG	Household expenditure - Electricity, gas and other fuel (CVM, SA)	5	ABS
HHE.EQP	Household expenditure - Furnishings, household equipment (CVM, SA)	5	ABS
HHE.HEA	Household expenditure - Health (CVM, SA)	5	ABS
HHE.PHV	Household expenditure - Purchase of vehicles (CVM, SA)	5	ABS
HHE.OPV	Household expenditure - Operation of vehicles (CVM, SA)	5	ABS
HHE.TRN	Household expenditure - Transport services (CVM, SA)	5	ABS
HHE.COM	Household expenditure - Communications (CVM, SA)	5	ABS
HHE.REC	Household expenditure - Recreation and culture (CVM, SA)	5	ABS
HHE.EDU	Household expenditure - Education services (CVM, SA)	5	ABS
HHE.HCR	Household expenditure - Hotels, cafes and restaurants (CVM, SA)	5	ABS
HHE.IFS	Household expenditure - Insurance, other nancial services (CVM, SA)	5	ABS
HHE.OTH	Household expenditure - Other goods and services (CVM, SA)	5	ABS
HHE.FCE	Household nal consumption expenditure (SA)	5	ABS

Government

Name	Description	Trans.	Source
GOV.FCE.DEF	Government - National nal consumption expenditure - Defence (SA)	5	ABS
GOV.FCE.NDF	Government - National nal consumption expenditure - Non-defence (SA)	5	ABS
GOV.FCE.TOT	Government - National nal consumption expenditure (SA)	5	ABS
GOV.FCE.STL	Government - State and local nal consumption expenditure (SA)	5	ABS
GOV.FCE	Government - Total nal consumption expenditure (SA)	5	ABS

Inventories

Name	Description	Trans.	Source
INV.MIN	Changes in Inventories - Private - Mining (CVM, SA)	0	ABS
INV.MAN	Changes in Inventories - Private ; Manufacturing (CVM, SA)	0	ABS
INV.WT	Changes in Inventories - Private ; Wholesale trade (CVM, SA)	0	ABS
INV.RT	Changes in Inventories - Private ; Retail trade (CVM, SA)	0	ABS
INV.NF.OTH	Changes in Inventories - Private - Non-farm - Other non-farm (CVM, SA)	0	ABS
INV.NF	Changes in Inventories - Private - Non-farm (CVM, SA)	0	ABS
INV.FM	Changes in Inventories - Farm (CVM, SA)	0	ABS
INV.PA	Changes in Inventories - Public authorities (CVM, SA)	0	ABS

Investment

Name	Description	Trans.	Source
AE.BLD	Actual Expenditure - Buildings and Structures (CVM, SA)	5	ABS
AE.EQP	Actual Expenditure - Equipment, Plant and Machinery (CVM, SA)	5	ABS
AE.MIN	Actual Expenditure - Mining (CVM, SA)	5	ABS
AE.MAN	Actual Expenditure - Manufacturing (CVM, SA)	5	ABS
AE.OSI	Actual Expenditure - Other Selected Industries (CVM, SA)	5	ABS
FCF.ALL	All sectors gross xed capital formation (SA)	5	ABS
FCF.GOV	General government gross xed capital formation (SA)	5	ABS
FCF.PUB	Public corporations gross xed capital formation (SA)	5	ABS
FCF.PRV	Private gross xed capital formation (SA)	5	ABS

Stock Prices

Name	Description	Trans.	Source
ALL.ORD	All Ordinaries Index - Adjusted Close	5	Yahoo

Exchange Rates

Name	Description	Trans.	Source
RTWI	Real trade-weighted index	5	RBA
RMWI	Real import-weighted index	5	RBA
RXWI	Real export-weighted index	5	RBA
R7WI	Real G7 GDP-weighted index	5	RBA
FXR.CNY	Chinese renminbi per Australian dollar	5	RBA
FXR.HKD	Hong Kong dollar per Australian dollar	5	RBA
FXR.IDR	Indonesian rupiah per Australian dollar	5	RBA
FXR.JPY	Japanese yen per Australian dollar	5	RBA
FXR.MYR	Malaysian ringgit per Australian dollar	5	RBA
FXR.TWD	New Taiwan dollar per Australian dollar	5	RBA
FXR.NZD	New Zealand dollar per Australian dollar	5	RBA
FXR.SGD	Singapore dollar per Australian dollar	5	RBA
FXR.KRW	South Korean won per Australian dollar	5	RBA
FXR.GBP	United Kingdom pound sterling per Australian dollar	5	RBA
FXR.USD	United States dollar per Australian dollar	5	RBA

Foreign Sector

Name	Description	Trans.	Source
RGDP.CAN	Real gross domestic product - Canada	5	FRED
RGDP.FRA	Real gross domestic product - France	5	FRED
RGDP.GBR	Real gross domestic product - United Kingdom	5	FRED
RGDP.USA	Real gross domestic product - United States	5	FRED
CPI.CAN	Consumer price index - Canada	5	FRED
CPI.FRA	Consumer price index - France	5	FRED
CPI.GER	Consumer price index - Germany	5	FRED
CPI.ITA	Consumer price index - Italy	5	FRED
CPI.JAP	Consumer price index - Japan	5	FRED
CPI.GBR	Consumer price index - United Kingdom	5	FRED
CPI.USA	Consumer price index - United States	5	FRED
FOR.RATE	Average policy rate of USA, Japan and Eurozone (Germany pre-1999)	5	MK-DR

Interest Rates

Name	Description	Trans.	Source
IR.CASH	Interest rate - Interbank overnight	5	RBA
IR.90D	Interest rate - Bank accepted bills - 90 days	5	RBA
BOND.5Y	Yield - Australian Government bonds - 5 years	5	RBA
BOND.10Y	Yield - Australian Government bonds - 10 years	5	RBA

Money and Credit

Name	Description	Trans.	Source
CR.TH	Credit - Housing - 12-month ended growth (SA)	2	RBA
CR.OP	Credit - Other personal - 12-month ended growth (SA)	2	RBA
CR.BS	Credit - Business - 12-month ended growth (SA)	2	RBA
CR.TO	Credit - Total - 12-month ended growth (SA)	2	RBA
AG.M3	M3 - 12-month ended growth (SA)	2	RBA
AG.BM	Broad money - 12-month ended growth (SA)	2	RBA

Prices

Name	Description	Trans.	Source
CPI.ALL	Consumer price index - Australia (SA)	5	ABS
INFL.EXP	Business in ation expectations - 3-months ahead	2	RBA
INFL.BE	Break-even 10-year in ation rate	2	RBA

COM.SDR	Index of commodity prices - SDR	5	RBA
COM.RU.SDR	Commodity price index - Rural component - SDR	5	RBA
COM.NR.SDR	Commodity price index - Non-rural - SDR	5	RBA
COM.BM.SDR	Commodity price index - Non-rural - Base metals - SDR	5	RBA
COM.BK.SDR	Commodity price index - Non-rural â€“ Bulk commodities - SDR	5	RBA

Sectoral Prices

Name	Description	Trans.	Source
CPI.EC.01	Consumer price index - Bread (SA)	5	ABS
CPI.EC.02	Consumer price index - Cakes and biscuits (SA)	5	ABS
CPI.EC.03	Consumer price index - Breakfast cereals (SA)	5	ABS
CPI.EC.04	Consumer price index - Other cereal products (SA)	5	ABS

CPI.EC.56	Consumer price index - Hairdressing and personal grooming services (SA)	5	ABS
CPI.EC.57	Consumer price index - Other household services (SA)	5	ABS
CPI.EC.58	Consumer price index - Pharmaceutical products (SA)	5	ABS
CPI.EC.59	Consumer price index - Therapeutic appliances and equipment (SA)	5	ABS
CPI.EC.60	Consumer price index - Medical and hospital services (SA)	5	ABS
CPI.EC.61	Consumer price index - Dental services (SA)	5	ABS
CPI.EC.62	Consumer price index - Motor vehicles (SA)	5	ABS
CPI.EC.63	Consumer price index - Spare parts and accessories for motor vehicles (SA)	5	ABS
CPI.EC.64	Consumer price index - Automotive fuel (SA)	5	ABS
CPI.EC.65	Consumer price index - Maintenance and repair of motor vehicles (SA)	5	ABS
CPI.EC.66	Consumer price index - Other services in respect of motor vehicles (SA)	5	ABS
CPI.EC.67	Consumer price index - Urban transport fares (SA)	5	ABS
CPI.EC.68	Consumer price index - Postal services (SA)	5	ABS
CPI.EC.69	Consumer price index - Telecommunication equipment and services (SA)	5	ABS
CPI.EC.70	Consumer price index - Audio, visual and computing equipment (SA)	5	ABS
CPI.EC.71	Consumer price index - Audio, visual, computing media and services (SA)	5	ABS
CPI.EC.74	Consumer price index - Domestic holiday travel, accommodation (SA)	5	ABS
CPI.EC.75	Consumer price index - International holiday travel, accommodation (SA)	5	ABS
CPI.EC.78	Consumer price index - Pets and related products (SA)	5	ABS
CPI.EC.79	Consumer price index - Veterinary and other services for pets (SA)	5	ABS
CPI.EC.85	Consumer price index - Insurance (SA)	5	ABS

B Test for Structural Breaks

I test for structural breaks in the factor loadings using the procedure outlined in Chen et al. (2014). Let F_t be a $N \times 3$ matrix of static factors

$$F_t = \begin{bmatrix} F_{1,t} & F_{2,t} & F_{3,t} \end{bmatrix}.$$

I estimate the following regression using ordinary least squares

$$F_{1,t} = c_1 F_{2,t} + c_2 F_{3,t}. + \varepsilon_t$$

C Model

In this section I provide the transformations, non-linear equations, and log-linearised equations that comprise the multisector New-Kenyesian model. A full derivation of the model can be found in the online appendix of Cagliarini et al. (2011).

C.1 Transformations

As there is growth in aggregate technology z_t, some variables are detrended in order to make them stationary.

$$\tilde{c}_t = c_t$$

For k 2 ($_{j}$ $_{1}$; $_{j}$] and j = 1; : : : ; N:

$$! _{j;t} = \frac{1}{_{j}{}^{j}(1 \quad _{j})^{1 \quad j}} \frac{1}{(z_{j;t}) ^{j}} \frac{\tilde{w}_t ^{j}}{r_{j;t}} \quad (C.8)$$

$$l^d_{j;t} = \frac{_{j} ! _{j;t}}{\tilde{w}_t} \tilde{y}_{j;t} \quad (C.9)$$

$$\tilde{y}_{j;t} = _{j} \quad r^{+}_{j;t} \quad " \tilde{y}_t \quad (C.10)$$

$$m^d_{j;t} = (1$$

411.9552 Tf3396 713.678 Td [(r)]TJ/F28 7.9701 Tf 5.708 -1.793 Td [(j)1(;t)]TJ/F15 10.11452 Tf3396 719.994 Td [(~)]TJ/F27 11.9552 Tf -0.792 0 Td [(y)]TJ/F28 7.9701 T

]TJ/F28 7 7.701 Tf 5.6 1+.916 Td [(m)]TJ/F28 7.8201 Tf 6.586 001 112491 Tf -0.325 -8.012 3 Td [(j.5[(w)]TJ/F281 7.9701 Tf 4.+0 Td [( )]TJ/F28 7.9701 Tf 6.nTd [(j)1(;t)]TJ/F15

Stochastic processes

$$\begin{aligned} a_t &= a_{t-1}^{\rho_a} e^{\varepsilon_{a,t}} \\ z_{j,t} &= z_{j,t-1}^{\rho_j} e^{\varepsilon_{z,j,t}} \end{aligned} \tag{C.24}$$

Market clearing and aggregation

$$\hat{l}_t = \sum_{j=1}^{N} \frac{l_j}{l} \hat{l}_{j;t} \tag{C.39}$$

$$\hat{y}_t = \frac{c}{y} \hat{c}_t + \frac{m}{y} \hat{m}_t \tag{C.40}$$

$$\hat{m}_t = \sum_{j=1}^{N} \frac{m_j}{m} \hat{m}_{j;t} \tag{C.41}$$

$$0 = \sum_{j=1}^{N} {}_j\, r^{1-\varepsilon} \hat{r}_{j;t} \tag{C.42}$$

Stochastic processes

$$\hat{a}_t = {}_a \hat{a}_{t-1} + \varepsilon_{a;t} \tag{C.43}$$

$$\hat{z}_{j;t} = {}_{z;j} \hat{z}_{j;t-1} + \varepsilon_{z;j;t} \tag{C.44}$$

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