Optimal inflation measures for targeting under sectoral heterogeneity

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4 December 2015

Background

Motivation

The price-setting behaviour of firms has been studied extensively with consumer price index microdata for Europe and the U.S.

For Australia, much of what we know about price-setting behaviour is based on surveys and the analysis of disaggregated price indices.

This presents a problem when attempting to use structural multisector models, as we need the frequency of price changes in each sector to examine the transmission of monetary policy.

Overview

I present my analysis for the Australian economy in three parts.

1. Approximate factor model
   - Establish an empirical case for heterogeneous sectors with sticky prices.
2. Multisector New-Keynesian DSGE model
   - Simulate sectoral inflation processes with varying characteristics, including frequency of price changes.
3. Discriminant analysis
   - Estimate the stickiness in consumer price index expenditure classes.

Approximate Factor Model

Overview

The approximate factor model is given by

$$\mathbf{X}_t = \boldsymbol{\Lambda}\mathbf{C}_t + \mathbf{e}_t \tag{1}$$

- $\mathbf{X}_t$ is a large panel of macroeconomic and sectoral variables.
- $\boldsymbol{\Lambda}$ is a matrix of factor loadings.
- $\mathbf{C}_t$ is a matrix of K static factors.
- $\mathbf{e}_t$ is a vector of error terms.

Approximate factor model

Data

The data in the large panel $\mathbf{X}_t$ covers the period 1989Q3-2014Q4 and is comprised of

1. 146 macroeconomic variables
   - Real output, labour market, housing, inventories, stock market, exchange rates, foreign sector, interest rates, money and credit.
2. 72 expenditure class price indices
   - 77.1% of the CPI by expenditure weight

Seasonally adjusted data is used when available.

Variables are transformed to induce stationarity where required.

Approximate factor model

Estimation

The factor model is estimated with principal components techniques.

A structural break is found in the factor loadings at 2001Q3. Analysis using the Quandt-Andrews unknown break point test shows that this is related to the introduction of the Goods and Services tax in 2000Q3.

I correct for this breakpoint by estimating the factor loadings in each regime separately.

The number of common factors is chosen based on the information criterion of Bai & Ng (2002). This results in 3 common factors that explain 21.8% of the variation in $\tilde{\mathbf{X}}_t$.

Approximate factor model

Estimation

Sectoral inflation (x_{it}) is decomposed into a common ($\lambda_i \mathbf{C}_t$) and idiosyncratic component (e_{it}).

$$x_{it} = \lambda_i \mathbf{C}_t + e_{it}$$

Volatility of sectoral inflation and its components are estimated by their standard deviation.

The dynamic behaviour of each is estimated with an AR model, with lags chosen by information criterion. The sum of AR terms provides a measure of the persistence in each sectoral inflation process.

Approximate factor model

Heterogeneity and sticky prices

I claim that consumer prices:

- are heterogeneous across expenditure classes, and
- are subject to infrequent price adjustments (prices are sticky).

If true, we would expect to see the following in the data:

- substantial cross-sectional variation in volatility and persistence,
- a slower response to macroeconomic shocks than to idiosyncratic shocks, and
- tighter cross-sectional variation of the sectoral speed of response to macroeconomic shocks than to sector-specific shocks.

Approximate factor model

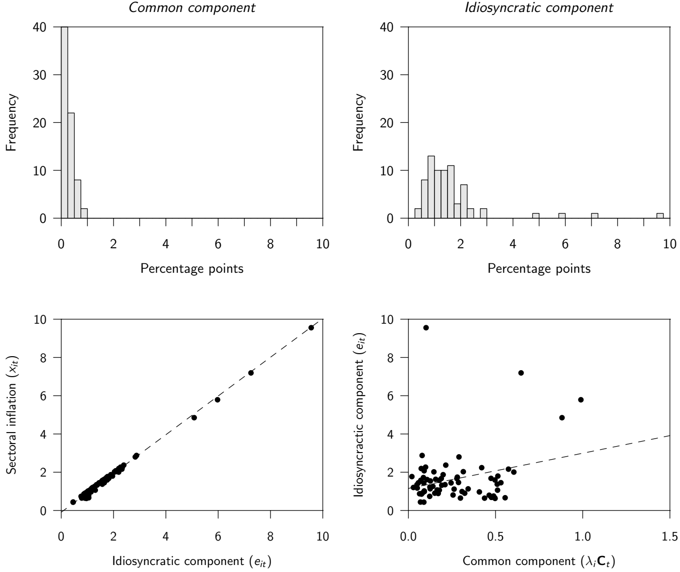
Descriptive statistics

	Standard deviation			Persistence			R^2
	x_{it}	$\lambda_i \mathbf{C}_t$	e_{it}	x_{it}	$\lambda_i \mathbf{C}_t$	e_{it}	
All groups	0.57	0.24	0.45	0.37	0.5	0.27	0.43
Food and non-alcoholic beverages	2.52	0.28	2.40	0.04	0.48	0.03	0.22
Alcohol and tobacco	1.27	0.36	1.15	0.38	0.49	0.35	0.23
Clothing and footwear	1.50	0.50	1.29	-0.20	0.50	-0.28	0.31
Housing	0.96	0.26	0.85	0.60	0.48	0.60	0.21
Furnishings, household equipment	1.48	0.30	1.38	0.15	0.48	0.14	0.16
Health	2.21	0.25	2.18	-0.02	0.50	-0.09	0.05
Transport	2.31	0.36	2.21	0.19	0.45	-0.02	0.09
Communication	1.15	0.40	0.98	0.16	0.50	0.09	0.31
Recreation and culture	2.12	0.20	2.09	-0.07	0.45	-0.02	0.04
Education	-	-	-	-	-	-	-
Insurance and financial services	1.52	0.25	1.41	0.44	0.47	0.38	0.18
Average	1.74	0.27	1.65	0.13	0.47	0.07	0.14
Median	1.37	0.20	1.35	0.17	0.50	0.11	0.07

Notes: I report the standard deviation and persistence of inflation (x_{it}), the common component ($\lambda_i \mathbf{C}_t$) and the idiosyncratic component (e_{it}). The standard deviation is measured in percentage points and the R^2 gives the share of variation in inflation explained by the common component. Sectors are reported as weighted means.

Approximate factor model

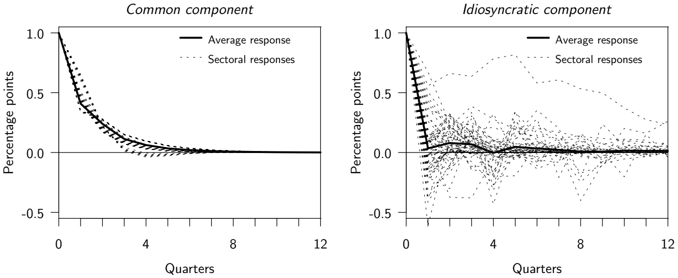
Volatility



Standard deviation of components (percentage points)

Approximate factor model

Speed of Response



Response of components to standardised shock

Approximate factor model

However, without information on the frequency of price changes, this is not a strong result.

In particular, Kaufmann & Lein (2013) state that we should expect to find a positive correlation between the frequency of sectoral price changes and the

- speed of response to a macroeconomic shock,
- standard deviation of the common component, and
- standard deviation of the idiosyncratic component.

Despite this, the factor model does present evidence that significant heterogeneity does exist across sectors, and that sectoral prices are likely to be sticky.

To simulate sectoral inflation processes that resemble those decomposed in the approximate factor model I use a multisector New-Keynesian DSGE model, with agents

- households,
- final goods producing firms,
- intermediate goods producing firms, and
- a monetary authority.

Cagliarini, Robinson and Tran (2011)

Multisector New-Keynesian DSGE Model

Agents

Households:

- Identical representative household,
- obtain utility from consumption, real money holdings and leisure,
- maximise utility subject to a budget constraint.

Final goods producing firms:

- N firms, one representing each sector,
- are perfectly competitive making zero profits in equilibrium,
- produce final goods using inputs from within-sector intermediate goods producers.

Multisector New-Keynesian DSGE Model

Agents

Intermediate goods producing firms:

- N sectors containing monopolistically competitive firms,
- can change prices with Calvo probability $\theta_j : j \in N$,
- produce goods for their within sector final goods firms, and other sector intermediate goods firms.

Monetary authority:

- sets the nominal interest rate according to a policy rule, responding to aggregate inflation and aggregate growth in value-added.

Multisector New-Keynesian DSGE Model

Shocks

Four shocks drive the model:

- a household preference shock,
- an aggregate technology shock for intermediate goods producers,
- a within-sector technology shock for intermediate goods producers,
- a monetary policy shock.

Underlying inflation

Name	Specification	Sectors
Headline	$\pi_t^U = \sum_j \frac{\gamma_j}{\sum_j \gamma_j} \pi_{j,t}$	$j = 1, \dots, N$
Exclusion 1		$j = 1, \dots, N \mid \theta_j > 0.10$
Exclusion 2		$j = 1, \dots, N \mid \theta_j > 0.25$
Exclusion 3		$j = 1, \dots, N \mid \theta_j > 0.50$
Calvo-share	$\pi_t^U = \sum_{j=1}^{N} \frac{\gamma_j \, \theta_j}{\sum_{j=1}^{N} \gamma_j \, \theta_j} \pi_{j,t}$	$j = 1, \dots, N$
Optimal	$\pi_t^U = \sum_{j=1}^{N} \phi_{\pi_j} \, \pi_{j,t}$	$j = 1, \dots, N$

Note: γ_j and θ_j are the share and Calvo probability of sector j.

ϕ_{π_j} are the weights assigned when numerically maximising an objective function.

The new (log-linearised) policy rule of the monetary authority.

$$\hat{i}_t = \rho_i \hat{i}_{t-1} + (1 - \rho_i)(\phi_\pi \pi_t^U + \phi_g g_t) + \varepsilon_{it}$$

The construction of aggregate inflation, and the equilibrium relationships for sectoral and aggregate inflation remain.

The monetary authority is the only agent that acts on movements of the underlying measures, leaving aggregate inflation to evolve according to the actions of households and firms.

Multisector New-Keynesian DSGE Model

Calibration

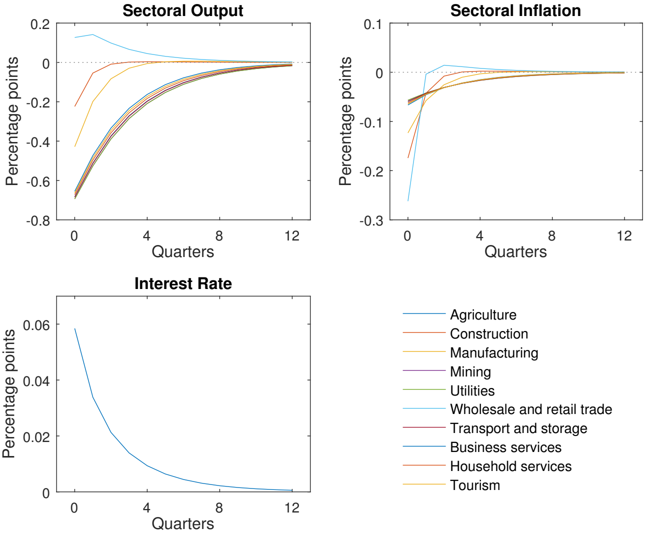
In its original form the model is calibrated for ten broad sectors of the Australian economy. Whilst informative on the interaction between the sectors, there is no correspondence with consumer price expenditure groups or classes.

Sector	Average duration[a]	Calvo probability	Share	Calvo-share weight
Agriculture	4	0.75	0.06	0.04
Construction	$1\frac{1}{3}$	0.25	0.15	0.04
Manufacturing	2	0.50	0.28	0.14
Mining	4	0.75	0.05	0.03
Utilities	4	0.75	0.03	0.02
Wholesale and retail trade	1	0.10[b]	0.20	0.02
Transport and storage	4	0.75	0.08	0.06
Business services	4	0.75	0.08	0.06
Household services	4	0.75	0.05	0.04
Tourism	4	0.75	0.01	0.01

Sources: Park et al. (2010), Cagliarini et al. (2011), Author's calculations.
[a] Measured in quarters.
[b] Calibrated at 0.10 as the sector is empirically close to a flexible price sector.

Multisector New-Keynesian DSGE Model

Monetary Policy Shock



Multisector New-Keynesian DSGE Model

Objective of the monetary authority

Following Woodford (2003) the monetary authority seeks to maximise social welfare.

- Social welfare is defined as the sum of all household's utility.
- I generalise Woodford's two-sector result for the N sector economy, and the social welfare loss function is

$$L_t = -\left[\sum_{j=1}^{N} \lambda_j \hat{\pi}_{jt}^2 + \lambda_c \hat{c}_t^2\right] \tag{2}$$

Multisector New-Keynesian DSGE Model

Objective of the monetary authority

$$L_t = -\left[\sum_{j=1}^{N} \lambda_j \hat{\pi}_{jt}^2 + \lambda_c \hat{c}_t^2\right] \tag{3}$$

where

$$\lambda_j = \frac{\gamma_j \theta_j}{(1-\theta_j)(1-\beta\theta_j)} \left[\sum_{j=1}^{N} \frac{\gamma_j \theta_j}{(1-\theta_j)(1-\beta\theta_j)}\right]^{-1} \tag{3}$$

and

$$\lambda_c = \frac{1}{\varepsilon} \left[\sum_{j=1}^{N} \frac{\gamma_j \, \theta_j}{(1-\theta_j)(1-\beta\theta_j)}\right]^{-1} \tag{4}$$

Multisector New-Keynesian DSGE Model

Welfare analysis

- By responding to inflation in the comparatively stickier sectors, the monetary authority can reduce the social welfare loss.
- The welfare improvement is around 13% when using the calibrated rule, and around 50% when optimising the policy rule parameters.

	Welfare loss		Optimal rule parameters		
	Calibrated	Optimal rule	ρ_i	ϕ_π	ϕ_g
Headline	-7.532	-3.973	0.491	6.839	1.140
Exclusion 1	-7.337	-4.045	0.551	4.270	0.732
Exclusion 2	-7.072	-3.879	0.999	8.108	0.941
Exclusion 3	-6.814	-3.989	0.999	6.713	0.666
Calvo x share	-6.866	-3.882	0.864	8.165	1.072
Optimal	-6.539	-3.723	0.999	19.907	1.033

Multisector New-Keynesian DSGE Model

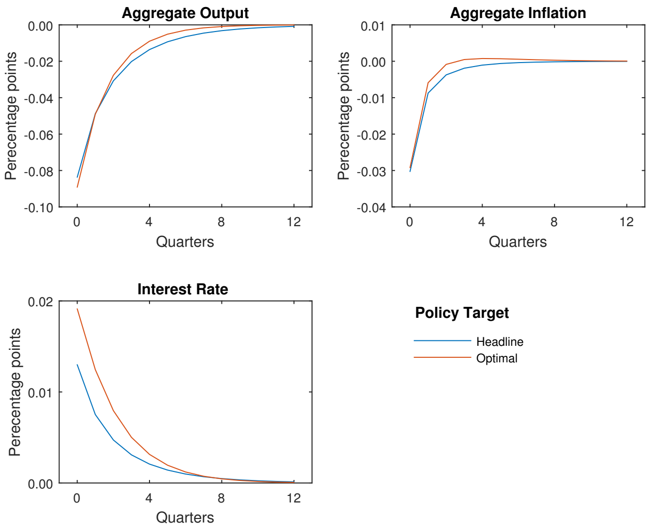
Optimal weights

Sector	ϕ_j^{SW}	γ_j	l_j / l	m_j / m	θ_j	σ_{z_j}
Agriculture	0.00	0.06	0.05	0.06	0.75	3.91
Construction	0.00	0.15	0.10	0.17	0.25	1.46
Manufacturing	0.00	0.28	0.25	0.30	0.50	0.60
Mining	0.07	0.05	0.03	0.05	0.75	1.71
Utilities	0.30	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	0.23	0.08	0.07	0.09	0.75	0.61
Business services	0.00	0.08	0.12	0.06	0.75	0.61
Household services	0.35	0.05	0.06	0.05	0.75	0.69
Tourism	0.04	0.01	0.03	0.02	0.75	0.80

Underlying inflation sectoral weights

Multisector New-Keynesian DSGE Model

Monetary policy shock



Multisector New-Keynesian DSGE Model

So targeting underlying inflation is welfare improving, often allowing a more rapid return to steady-state following a shock.

However in practice, central banks place a focus on inflation in the CPI. The ten broad sectors as calibrated before do not translate well to the expenditure groups that comprise the CPI.

In an attempt to apply these findings to the CPI, I turn to a classification technique from the multivariate statistics literature.

Discriminant Analysis

Overview

Discriminant analysis is a statistical technique to predict a categorical variable by one or more continuous or binary variables.

I consider the estimates of volatility, persistence and R^2 from the approximate factor model as observations, and use discriminant analysis to classify their price stickiness.

Discriminant Analysis

Data

To train the model, I recalibrate the multisector New-Keynesian DSGE model and feed the simulated data through the approximate factor model.

To keep the computation feasible, I calibrate over a grid

$\theta_j = \{0.10, 0.25, 0.50, 0.75\}$	Sector price stickiness
$\rho_j = \{0.1, 0.3, 0.5, 0.7, 0.9\}$	Persistence of sector technology shock
$\sigma_{z_j} = \{1, 2, 3, 4, 5, 6\}$	Volatility of sector technology shock

I set the resulting 120 sectors to be equal in other characteristics, then run 150 simulations, each time changing the random seed to obtain a different stochastic shock process.

Discriminant Analysis

Results

In-sample: 100 simulations

The model predicts the correct price stickiness in 79.9% of cases.

Out-of-sample: 50 simulations

The model predicts the correct price stickiness in 79.7% of cases.

The model performs best for the very sticky sectors (95.3%).

Discriminant Analysis

Sector price stickiness

Classification results

Sector	Sector price stickiness			
	0.10	0.25	0.50	0.75
Food and non-alcoholic beverages	20	2	3	-
Alcohol and tobacco	1	-	3	-
Clothing and footwear	3	2	2	-
Housing	1	1	1	1
Furnishings, household equipment	6	3	4	-
Health	2	-	1	1
Transport	3	-	3	-
Communication	1	-	1	-
Recreation and culture	5	-	1	-
Education	-	-	-	-
Insurance and financial services	1	-	-	-
Total	43	8	19	2

Discriminant Analysis

Sector shock persistence

Classification results

Sector	Sector shock persistence				
	0.1	0.3	0.5	0.7	0.9
Food and non-alcoholic beverages	1	3	3	8	10
Alcohol and tobacco	-	-	-	3	1
Clothing and footwear	-	-	-	5	2
Housing	-	-	-	3	1
Furnishings, household equipment	1	-	2	3	7
Health	-	-	2	1	1
Transport	1	-	1	1	3
Communication	-	-	-	1	1
Recreation and culture	-	-	-	5	1
Education	-	-	-	-	-
Insurance and financial services	-	-	-	-	1
Total	3	3	8	30	28

Discriminant Analysis

Sector shock volatility

Classification results

Sector	Sector shock volatility					
	1%	2%	3%	4%	5%	6%
Food and non-alcoholic beverages	-	-	-	1	5	19
Alcohol and tobacco	-	-	-	-	-	4
Clothing and footwear	-	-	-	-	4	3
Housing	-	-	-	-	1	3
Furnishings, household equipment	-	-	-	3	3	7
Health	-	-	-	-	1	3
Transport	-	-	-	1	1	4
Communication	-	-	-	-	1	1
Recreation and culture	-	-	-	-	-	6
Education	-	-	-	-	-	-
Insurance and financial services	-	-	-	-	-	1
Total	0	0	0	5	16	51

Discriminant Analysis

Sector shock volatility

Classification results

Expenditure class	γ_j	θ_j
Cakes and biscuits	0.74	0.50
Carpets and other floor coverings	0.28	0.50
Cleaning, repair and hire of clothing and footwear	0.12	0.50
Garments for women	1.47	0.50
Hairdressing and personal grooming services	0.90	0.50
Maintenance and repair of motor vehicles	1.67	0.50
Maintenance and repair of the dwelling	2.05	0.50
Other household services	0.69	0.50
Restaurant meals	2.81	0.50
Spare parts and accessories for motor vehicles	0.99	0.50
Spirits	0.91	0.50
Take away and fast foods	2.62	0.50
Telecommunication equipment and services	2.93	0.50
Therapeutic appliances and equipment	0.14	0.50
Tools and equipment for house and garden	0.26	0.50
Urban transport fares	0.74	0.50
Veterinary and other services for pets	0.40	0.50
Wine	1.64	0.50
Beer	2.20	0.75
Dental services	0.56	0.75
Rents	6.71	0.75

Conclusion

Findings

1. There is substantial heterogeneity in consumer prices.
2. Sectoral heterogeneity is important, particularly in price stickiness.
3. Excluding less sticky sectors from the policy rule improves welfare.
4. Many of the expenditure classes that comprise the CPI are not particularly sticky, although classification across a grid may not result in the most accurate estimates.

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