ESTIMATING AN OPTIMAL MACROECONOMIC UNCERTAINTY INDEX FOR AUSTRALIA

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Abstract

In this article, an optimal macroeconomic uncertainty index is constructed for the Australian economy. This index is derived from a small structural macroeconomic model. The structural model is first estimated using GMM to extract the parameter estimates, which are then used to initialise maximum likelihood techniques in order to obtain the optimal coefficient values for the relevant variables. The relevant variables are then weighted by the obtained optimal coefficients and, finally, are aggregated to produce the optimal macroeconomic uncertainty index for Australian economy. The empirical results show that the uncertainty index constructed is a good indicator of the optimal economic conditions in Australia, providing a useful tool to assist the Reserve Bank of Australia in its decision-making process.

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1. Introduction

The concept of economic uncertainty is quite a crucial one for the field of Economics because it affects the decision-making process of every agent in an economy. In particular, if decisions need to be made in an economy where great economic uncertainty exists, then such decisions undertaken can be incorrect, resulting in the consumer, producer or policymaker, attaining misleading and detrimental outcomes.

There are a number of definitions and methodological issues that are inherent in the concept of economic uncertainty, with many practitioners suggesting that economic uncertainty cannot be measured, while others suggesting that it can be. Furthermore, many practitioners base their formulation of economic uncertainty around the rules of probability. Lawson (1988) classifies economic uncertainty within four basic paradigms, which are: 1). the rational expectations hypothesis; 2). the expected utility hypothesis; 3). the Keynesian approach, and 4). the Knightian approach. According to the rational expectations hypothesis, economic uncertainty is a measurable probability, and that this probability is a means of reaching the knowledge of the outside world. The expected utility hypothesis also uses a numerically measurable probability value. However, this probability value meets expectations. On the other hand, the Keynesian approach espouses that economic uncertainty is not measurable, and that the associated probability value is independent of uncertainty, while meeting expectations. Finally, the Knightian approach suggests that economic uncertainty has both a measurable and an immeasurable component. The measurable component is defined as 'risk', while the immeasurable component is defined as 'uncertainty'. Keynes' (1936) view of uncertainty is the same as Knight's (1921), however, his view of probability differs from that of Knight's (1921) view.

No matter what the definition of economic uncertainty used, the onset of the Global Financial Crisis and the Great Recession have galvanised the resolve of practitioners to obtain a measure of economic uncertainty. The use of such a measure allows practitioners and policymakers to implement appropriate policies to mitigate the effects of adverse economic conditions that may occur in the future. Many practitioners have attempted to derive an empirical measure of economic uncertainty, yet there is no single approach that is generally accepted as providing an appropriate measure. Most measures of economic uncertainty are derived from a single macroeconomic variable that is considered to be the most important by the practitioner, as opposed to deriving a measure of uncertainty from a composite of macroeconomic variables. For instance, Price (1995) applies a GARCH-M model to the real GDP of the United Kingdom, to derive a measure of economic uncertainty, and assess its impact on manufacturing investment. The rationale for employing real GDP is that it serves as an index for aggregate demand, which will affect demand in the manufacturing sector. Goel and Ram (2001) derive a measure of economic uncertainty using the inflation rate for a panel of nine OECD countries, to assess the impact that this has on the share of investment as a proportion of GDP. They find that the greater the level of uncertainty, the lower the proportional level of investment. Bredin and Fountas (2005) apply a GARCH-M model to the inflation rate and to the output levels of the G7 nations separately, to derive a measure of inflation uncertainty and output uncertainty and assess their effects on growth and inflation. They find that, in general, greater inflation uncertainty leads to higher inflation, while greater output uncertainty leads to lower output. Cronin et al. (2011) fit a GARCH-M model to the real money stock of the US to derive a measure of economic uncertainty. Kumo (2006) derives single-variable estimates of economic uncertainty from the real effective exchange rate, the real interest rate, producer price inflation, the terms of trade, and the GDP growth rate respectively, for South Africa, to analyse the effect that uncertainty has on aggregate private fixed investment. Other practitioners, however, derive a composite measure of economic uncertainty using multiple variables. For instance, Servén (1998) derives a composite index of uncertainty using the first principal component of the conditional variances of inflation, the terms of trade, the real exchange rate, the relative price of capital, and the GDP growth rate, derived from a GARCH model, to analyse the effect of uncertainty on investment for a panel of 60 countries. Atta-Mensah (2004) analyses the impact of economic uncertainty on the demand for money in Canada using a general equilibrium model. He constructs a composite index of economic uncertainty by extracting the conditional volatilities of the Canadian the stock market, the bond market, the money market, the Canadian dollar *vis-à-vis* US dollar exchange rate, and Canadian real GDP. He finds that greater economic uncertainty leads to a reduction in the amount of risky assets held, an increase in the level of money held for precautionary reasons, and an increase in the holdings of real assets. Gan (2014) criticises the lack of normative analysis in the construction of an economic uncertainty index, suggesting that normative analysis cannot be used to refute the precision of the economic uncertainty index. He suggests that the lack of precision in an uncertainty index is simply the outcome of a commonly used misspecified model and a complex data collection process. Gan (2014) shows that using conditional variances instead of optimal uncertainty measures as an indicator of economic uncertainty can lead to major welfare losses. As such, he recommends that economic uncertainty should be modelled within a system and measured as an index. Furthermore, Atta-Mensah (2004) and Gan (2014) highlight the flaws of measuring uncertainty using a single variable rather than basing it on a general index. In particular, they show that using a single variable to measure uncertainty instead of using an optimal uncertainty index can lead to major welfare losses.

Despite the recent developments of constructing a number of important indices that highlight the degree of uncertainty in an economy, they are quite costly to construct because of the amount of data and computational methods required. In this study, quarterly observations for the period 2000:1 to 2018:1 are used to create an optimal macroeconomic uncertainty index for Australia, which is based on a central bank loss function and is derived from a structural macroeconomic model, to provide valuable information to practitioners and policymakers alike. In generating an optimal uncertainty index for Australia, there are three main benefits that this study will contribute. First, the creation of the index will provide additional information to aid the Reserve Bank of Australia and the Australian Government in implementing both monetary and fiscal policy. Second, the optimal macroeconomic uncertainty index constructed in this study will highlight which policy should be implemented to eliminate the negative effects of uncertainty in the Australian economy. Finally, the construction of this index will be less costly than other indices because of the data employed and the computational methods used.

The remainder of this paper is organised as follows. Section 2 provides a definition of uncertainty from an individual perspective and a social based perspective, with the concept of aggregated uncertainty being a key focus of the discussion. The next section presents the data used and provides a short discussion of the econometric methodology employed. Section 4 presents the empirical results, while the next section provides some concluding remarks.

2. The Concept of Uncertainty

The concept of uncertainty in an economy takes shape within the framework of both an individual's and a policymaker's decision making process about the future. As a result, the concept of uncertainty can be analysed from an individual-based and an aggregate-based perspective. Under an individual-based perspective of uncertainty, the decision-making process of individuals under the presence of uncertain economic conditions is explained by 'expected utility' and 'subjective expected utility'. These two hypotheses evaluate and interpret the concept of uncertainty within the bounds of probabilities. The expected utility hypothesis is based on objective probability conditions, where as the subjective expected utility hypothesis is based on subjective probability conditions.[1] The concept of uncertainty on an aggregated basis is a core feature of this study. Uncertainty on an aggregated basis is explained by three important econometric approaches, these being 'additive uncertainty', 'multiplicative uncertainty', and 'model uncertainty'.

Additive uncertainty is a derivable uncertainty that is different from the individual-based uncertainty. This type of uncertainty is reflected by the effect that the explanatory variables have on the dependent variable of a model but cannot be explicitly included in the model for various reasons. One such type of uncertainty is that of the effect of external random factors that cannot be quantified or measured, and so this type of uncertainty is implicitly captured by including a residual term in a regression model term that is assumed to include a variety of errors. Theil (1964) goes on to create the concept of 'certainty equivalence' in the presence of additive uncertainty. Certainty equivalence here implies that a policymaker whose economic expectations are certain behaves optimally for any decision that they take. The policymaker takes the most economically appropriate model into consideration and tries to optimise their behaviour accordingly in any policy decision that they make because if there is a case of uncertainty in the economy, the policymaker is able to eliminate the additive uncertainty that is present and reach economic certainty equivalence only through an appropriate economic model (Hall et al., 1999, p. 8). Additive uncertainty becomes an important issue when the residual terms are not random because the

[1] For more on the expected utility hypothesis, see von Neumann and Morgenstern (1947), Bernoulli (1954), Shoemaker (1982) and Camerer and Weber (1992). For more on the subjective expected utility hypothesis, see Savage (1954) and Enç (1998).

policymakers have knowledge about the transmission mechanism among the variables and so restrict the additive errors that move within the framework of certainty equivalence. In spite of this, there will still be a situation of uncertainty if the structure of the residual term is not stochastic. This will lead to a situation of additive uncertainty, as indicated by the variance of the error terms (Dow, 2004).

Multiplicative uncertainty was first analysed by Holt (1962). He finds that when parameters of a model are uncertain, there may be a disturbance at a significant level in the outcomes of policies implemented by policymakers. Brainard (1967) further develops the concept of multiplicative uncertainty by measuring the optimal reaction of a policymaker against the uncertainty of a model's parameters. This is why multiplicative uncertainty is also known as parameter uncertainty. Brainard (1967) shows that it is optimal for policymakers to behave more carefully when the effects of a policy are uncertain compared to when there is no uncertainty. The key issue here is how policymakers can behave optimally. Those who set policy do not expect the gap between the targeted and actual value of a variable to be eliminated completely when there is economic uncertainty or when there is uncertainty in the relationship between economic variables. However, they behave in such a way as to either minimise or close the gap between the targeted and actual value, and in so doing, encourages policymakers to behave more carefully. As such, policymakers behave more carefully and implement more optimal policies accordingly, when there is a situation of uncertainty. They can therefore implement policies that focus on reducing the gap between the targeted and actual values in a moderate way (Hall et al., 1999, p. 8-9).

Although the amount of additive uncertainty is derived from the cumulative total of the residual terms, this is not its only source. Uncertainty can also arise from the indecisiveness of policymakers about the parameter values in the multiplicative type of uncertainty, as stated previously. Aksoy and Sahin (2009) argue that multiplicative uncertainty reveals the possible effects of the policies that are to be implemented when the policymakers are indecisive about the parameter values. As a result, they claim that the presence of multiplicative uncertainty forces policymakers to behave more carefully.

Model uncertainty is the type of uncertainty that policymakers have about which model is the best to analyse the outcomes of a particular policy. According to Hall et al. (1999), model uncertainty may arise because of misspecifying an equation or a system of equations, omitting variables from an equation or a system of equations, or from having the incorrect functional form of an equation or equations based on incorrect assumptions of the model to be applied. To summarise, Dow (2004) shows that cumulative uncertainty is generated by the variance of the residual term in a regression equation, while multiplicative uncertainty is created by the uncertainty of the parameters. Model uncertainty, on the other hand, is measured by the spectral density of the non-random error terms when there is uncertainty about the specification of the appropriate model.

3. The Data, Model and Econometric Methodology

3.1. Data Description

The data used in this study consists of quarterly observations for the period 2000:1 to 2018:1. The inflation rate, INF_t, is derived from the Consumer Price Index (CPI), while the inflation gap, INF_t^G, is measured as the difference between this period's inflation rate and the potential inflation rate, obtained by applying the HP filter. Real output, $RGDP_t$, is measured by real Gross Domestic Product (GDP), while the real output gap, $RGDP_t^G$, is given by the difference in the value of current real output and potential real output, obtained by applying the HP filter. The real output gap is multiplied by 100. The real exchange rate, REX_t, is measured by the CPI based real effective exchange rate, while the real exchange rate gap, REX_t^G, is given by the difference between the current real effective exchange rate and the potential real effective exchange rate, obtained by applying the HP filter. The real interest rate, RIR_t, is proxied by the money market rate, while the real interest rate gap, RIR_t^G, is the difference between this period's real interest rate and its potential value obtained by applying the HP filter. The term U_t represents the optimal macroeconomic uncertainty index. All variables are expressed in natural logarithms, except for interest rates, and are extracted from the International Monetary Fund's *International Financial Statistics* database.

3.2. Econometric Model

In order to obtain the loss function for a central bank, a linear structure of the economy is established through the private sector and policymakers. Following Svensson and Woodford (2003), equation (1) gives the linear model:

$$\begin{bmatrix} H_{t+1} \\ \omega_{x_{t+1|t}} \end{bmatrix} = K^1 \begin{bmatrix} H_t \\ h_t \end{bmatrix} + K^2 \begin{bmatrix} H_{t|t} \\ h_{t|t} \end{bmatrix} + Si_t + \begin{bmatrix} \varepsilon_{t+1} \\ 0 \end{bmatrix} \tag{1}$$

where H_t is a vector of n_H predetermined variables in period t, h_t is a vector of n_H forward-looking variables, i_t is a vector of the central bank's n_i policy instrument, ε_t is a vector of n_H independently and identically shocks, with a zero mean and a covariance matrix given by $\sum \varepsilon\varepsilon$, while K^1, K^2, S, and ω are matrices of appropriate dimension.

For any variable x_t, the term $x_{\tau|t}$ denotes the use of the rational expectations operator, such that $x_{\tau|t} = E[x_\tau | I_t]$, implying that $x_{\tau|t}$ is the rational expectations of x_t, given all of the information available to the central bank at time t, I_t. Equation (2) is therefore given by:

$$M_t = B^1 \begin{bmatrix} H_t \\ h_t \end{bmatrix} + B^2 \begin{bmatrix} H_{\tau|t} \\ h_{\tau|t} \end{bmatrix} + Bi_t \tag{2}$$

where M_t represents a vector of n_M target variables, and B^1, B^2 and B are matrices with appropriate dimensions. The quadratic form of the central bank's loss function is given by:

$$L_t = M_t^{'} A M_t \tag{3}$$

where A is a positive semi-definite matrix. Equation (4) is given by:

$$C_t = E^1 \begin{bmatrix} H_t \\ h_t \end{bmatrix} + E^2 \begin{bmatrix} H_{\tau|t} \\ h_{\tau|t} \end{bmatrix} + u_t \tag{4}$$

where C_t is a vector of n_C observable variables, u_t is a vector of n_C independently and identically shocks, with a zero mean and a covariance matrix given by $\sum uu$. The information set, I_t, available to the central bank in period t is given by:

$$I_t = \left[C_\tau, K^1, K^2, S, B^1, B^2, B, i_t, E^1, E^2, \omega, A, \vartheta, \sum \varepsilon\varepsilon, \sum uu\right] \tag{5}$$

where $\tau \leq t$ and ϑ is a discount factor that lies between 0 and 1.

The expectations term $h_{\tau|t}$ in the second block of equations is conditional on the information set, I_t. It can be easily shown that the information is symmetric, as both the central bank and the public have the same information. In the case of asymmetric information, the expectations generating mechanism is replaced by the expectations of the private sector, $E\left[h_\tau \middle| I_t^P\right]$, in which the private sector information set, I_t^P, differs from the information set available to the central bank, I_t. It is assumed that the central bank acts under its discretion, assuming that there is no commitment to a rule. In each period t, the central bank tries to minimise the expected current and future discounted values of the intertemporal loss function:[2]

[2] For more details, see Svensson and Woodford (2003).

$$\text{Minimise} \quad E_t \sum_{\tau=0}^{\infty} \beta^{\tau} L_{t+\tau} \tag{6}$$

subject to:

$$m_{i_t} = \beta_1 h_{1,i_t} + \beta_2 h_{2,i_t} + \ldots + \beta_{k-1} h_{k-1,i_t} + \mu_{i_t} \tag{6a}$$

and:

$$U_t = \gamma_k m_{i_t} + \overline{\mu}_t \tag{6b}$$

where β and γ are a vector of coefficients, μ and $\overline{\mu}$ are stochastic terms, and U_t is the economic uncertainty index. The loss function approaches zero as the economy approaches its long run equilibrium. As such, there is a balance of certainty as the central bank and private sector have the same information set (Gan, 2014).

In order to obtain an economic uncertainty index, a small structural model is developed. The structural model is given by:

$$RGDP_t^G = \alpha_1 RGDP_{t-1}^G - \lambda_1 RIR_t^G - \delta_1 REX_{t-1}^G + \varepsilon_t \tag{7}$$

$$INF_t^G = \alpha_2 RGDP_{t-1}^G + \beta_1 INF_{t-1}^G - \delta_2 REX_{t-1}^G + \eta_t \tag{8}$$

$$REX_t^G = \lambda_2 RIR_t^G + \upsilon_t \tag{9}$$

$$U_t = \alpha_3^{Optimal} RGDP_t^G + \beta_2^{Optimal} INF_t^G - \delta_3^{Optimal} REX_t^G - \lambda_3^{Optimal} RIR_t^G + \overline{\omega}_t \tag{10}$$

$$RIR_t^G = \alpha_4 RGDP_{t-1}^G + \beta_3 INF_{t-1}^G - \delta_4 REX_{t-1}^G + U_{t-1} + \varsigma_t \tag{11}$$

where α_1, λ_1, δ_1, α_2, β_1, δ_2, λ_2, α_4, β_3 and δ_4 are coefficients to be estimated, ε_t, η_t, υ_t, $\overline{\omega}_t$ and ς_t are the associated residuals of the respective equations, and $\alpha_3^{Optimal}$, $\beta_2^{Optimal}$, $\delta_3^{Optimal}$ and $\lambda_3^{Optimal}$ are the optimal coefficients of the variables that go into constructing the optimal uncertainty index, U_t. Equation (7) represents an economy's total level of real output. Equation (8) represents an aggregate supply relationship in an open economy (or an open economy version of the Phillips curve). Equation (9) shows the relationship between the real exchange rate and the real interest rate. Equation (10) shows the optimal and simultaneous uncertainty function, while the monetary policy reaction function is given by equation (11). The quadratic loss function of the central bank is given by:

$$L_t = \mu_{RGDP_t^G}\left(RGDP_t^G\right)^2 + \mu_{INF_t^G}\left(INF_t^G\right)^2 + \mu_{RIR_t^G}\left(RIR_t^G\right)^2 \tag{12}$$

where the weights, $\mu_{RGDP_t^G}$, $\mu_{INF_t^G}$ and $\mu_{RIR_t^G}$ stabilise the variables $RGDP_t^G$, INF_t^G and RIR_t^G, respectively. Equation (12) can be rewritten using the unconditional variances of the relevant variables, which suggests that the loss function becomes:

$$L_t = \mu_{RGDP_t^G} V_t^{RGDP^G} + \mu_{INF_t^G} V_t^{INF^G} + \mu_{RIR_t^G} V_t^{RIR^G} \tag{13}$$

where $V_t^{RGDP^G}$, $V_t^{INF^G}$ and $V_t^{RIR^G}$ are the unconditional variances of $RGDP_t^G$, INF_t^G and RIR_t^G, respectively. As a result, the optimal uncertainty index is determined by the optimal combination of the real output gap, inflation gap, real exchange rate gap, and the real interest rate gap as the loss function of the central bank is minimised.

3.3. Econometric Methodology

In order to derive the macroeconomic uncertainty index for Australia, the parameters α_1, λ_1, δ_1, α_2, β_1, δ_2, λ_2, α_4, β_3 and δ_4 are first estimated using the Generalised Method of Moments (GMM) technique. The values of the estimated coefficients are then used as the starting values to estimate the structural model using maximum likelihood techniques, in order to obtain parameter values for the optimal coefficients. The variables INF_t^G, $RGDP_t^G$, REX_t^G, and RIR_t^G that go into the construction of the uncertainty index are then weighted using the estimated optimal parameters, $\alpha_3^{Optimal}$, $\beta_2^{Optimal}$, $\delta_3^{Optimal}$ and $\lambda_3^{Optimal}$. The macroeconomic uncertainty index is then constructed along the lines shown in Erdem and Yamak (2016).

4. The Data, Model and Econometric Methodology

Before the macroeconomic uncertainty index can be derived for Australia, the univariate properties of the variables must be analysed to ensure that the variables are stationary. For this purpose, two unit root tests are used, these being the augmented Dickey-Fuller (ADF) test and the Phillips-Perron (PP) test. Table 1 reports the results of these tests for the variables in levels and their first differences. They show that all the gap variables are stationary in levels.

[Insert Table 1 about here].

Table 2 presents the results of estimating the small structural model using GMM. The results of estimating equation (7) show that all of the parameters have the hypothesised sign, except for the coefficient on the lagged interest rate, which is insignificant. The estimates of the open economy Phillips curve shows that the current inflation gap depends positively on the lagged inflation gap. Finally, the monetary policy reaction function shows that all of the estimated coefficients have the hypothesised signs, except for the lagged real exchange rate gap. In all of the estimated equations, the null hypothesis that the overidentifying restrictions are orthogonal to the error terms cannot be rejected by the estimated *J*-statistic.

[Insert Table 2 about here].

Table 3 reports the estimates of the optimal coefficients along with the unconditional variances of the variables that are required to estimate the loss function of the Reserve Bank of Australia. The results show that an increase in the current real output and inflation gaps leads to an increase in economic uncertainty, while an increase in the real exchange rate and real interest rate gaps leads to a fall in economic uncertainty. Furthermore, the loss function of the Reserve Bank of Australia is relatively close to zero, suggesting that the Australian economy is operating close to its long-run equilibrium. Figure 1 plots the optimal macroeconomic uncertainty index for Australia for the sample period under consideration. A positive value for the uncertainty index implies that policymakers must implement contractionary monetary and fiscal policy, where as in the periods where the uncertainty index is negative, policymakers must implement expansionary monetary and fiscal policy. The periods of positive uncertainty correspond to the following time periods: 2000:3, 2001:1, 2001:04-2003:1, 2006:2, 2006:3, 2007:2, 2007:4-2009:4, 2013:3-2014:1, 2015:1-2016:4, and 2018:01.

[Insert Figure 1 about here].

5. Concluding Remarks

In this paper, a five-equation structural macroeconomic model is estimated to derive an optimal uncertainty index for Australia, using quarterly data for the period 2001:1-2018:1. The structural model is first estimated using GMM to extract the parameter estimates, which are then used to initialise maximum likelihood techniques in order to obtain the optimal coefficient values for the relevant variables that go into constructing the optimal macroeconomic uncertainty index. The relevant variables are then weighted by these optimal coefficients.

The optimal macroeconomic uncertainty index indicates a number of periods in which macroeconomic uncertainty was positive, suggesting that policymakers should implement more contractionary economic policy to reduce greater economic uncertainty. On the other hand, policymakers should implement expansionary economic policies when there is negative macroeconomic uncertainty.

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Table 1: Results of Testing for Unit Roots

	Dickey-Fuller Test			Phillips-Perron Test		
	$\hat{\tau}$	$\hat{\tau}_{\mu}$	$\hat{\tau}_{\tau}$	$Z(\hat{\tau})$	$Z(\hat{\tau}_{\mu})$	$Z(\hat{\tau}_{\tau})$
INF_t^G	-5.978***[2]	-5.945***[2]	-5.940***[2]	-10.465***[8]	-10.344***[8]	-10.006***[7]
ΔINF_t^G	-7.950***[3]	-7.882***[3]	-7.830***[3]	-22.833***[12]	-22.720***[12]	-22.940***[12]
$RGDP_t^G$	-4.833***[0]	-4.805***[0]	-4.783***[0]	-5.032***[3]	-5.003***[3]	-4.968***[3]
$\Delta RGDP_t^G$	-10.440***[0]	-10.368***[0]	-10.328***[0]	-10.393***[2]	-10.320***[2]	-10.273***[2]
REX_t^G	-3.996***[1]	-3.969***[1]	-3.945***[1]	-3.696***[1]	-3.675***[1]	-3.687**[2]
ΔREX_t^G	-7.469***[0]	-7.414***[0]	-7.359***[0]	-7.802***[9]	-7.716***[9]	-7.620***[9]
RIR_t^G	-5.932***[1]	-5.893***[1]	-5.852***[1]	-2.998***[1]	-2.984**[1]	-2.969[1]
ΔRIR_t^G	-5.612***[1]	-5.571***[1]	-5.546***[1]	-4.209***[5]	-4.172***[5]	-4.010***[6]

Notes: An ***, **, * indicates a rejection of the null hypothesis at the 1, 5, and 10 per cent levels of significance respectively. Δ is the difference operator.

Table 2: GMM estimates of the Structural Model

	$RGDP_t^G$	INF_t^G	REX_t^G	RIR_t^G
$RGDP_{t-1}^G$	0.8691***	0.1045		0.1226***
	(0.0827)	(0.0643)		(0.0242)
INF_{t-1}^G		0.2727***		0.1759***
		(0.0777)		(0.0474)
REX_{t-1}^G	-1.3168*	-0.6831		6.0381***
	(0.7482)	(0.6356)		(0.3786)
RIR_{t-1}^G	0.0858		0.0186**	
	(0.0539)		(0.009)	
$\overline{R}^2$	0.4266	0.0069	0.1209	0.2839
$\hat{\sigma}$	0.3796	0.3399	0.0364	0.3139
$Q-Stat$	0.0505	0.1472	0.7384	1.4896
	[0.822]	[0.701]	[0.39]	[0.222]
$Norm$	3.1945	0.061	211.68	160.0436
	[0.2025]	[0.9699]	[0.0000]	[0.0000]
$J-Stat$	9.7314	10.4579	9.162	12.089
	[0.4644]	[0.5759]	[0.3288]	[0.9789]

Notes: The set of instruments includes different lags of the real output gap, the inflation gap, the real interest rate gap, and the real exchange rate gap. The Q-statistic is the Ljung-Box (1978) test for serial correlation, the test for Normality is the Jarque-Bera (1980) test, and the J-statistic is the Hansen (1982) statistic for testing the null hypothesis that the over-identifying restrictions are valid. All the values reported in parenthesis are the Newey-West (1987) robust standard errors. The values reported in square brackets are the marginal levels of significance. An ***, ** and * indicates statistical significance at the 1, 5 and 10 per cent levels, respectively.

Equations (9) and (11) were estimated using the Cochrane-Orcutt iterative procedure to correct for the presence of autocorrelations problem.

Table 3: Results of estimating the Optimal Coefficients and Loss Function

Optimal Coefficient	Parameter Estimates
$\alpha_3^{Optimal}$	6.174***
	(2.116)
$\beta_2^{Optimal}$	9.7435***
	(3.07)
$\delta_3^{Optimal}$	134.0276***
	(29.24)
$\lambda_3^{Optimal}$	2.24112**
	(1.1389)
Unconditional Variances	**Estimates**
$V_t^{RGDP^G}$	2.81016
	(1.7585)
$V_t^{INF^G}$	0.9017**
	(0.4575)
$V_t^{RIR^G}$	1.900
	(1.3189)
Loss Function, L_t	4.190

Notes: All the values reported in parenthesis are the Newey-West (1987) robust standard errors. An *** and ** indicates statistical significance at the 1 and 5 per cent levels, respectively. This study uses the preference parameters, $\mu_{RGDP_t^G}=1$, $\mu_{INF_t^G}=1$ and $\mu_{RIR_t^G}=0.25$, and calculates the loss function along the lines of Gan (2015).

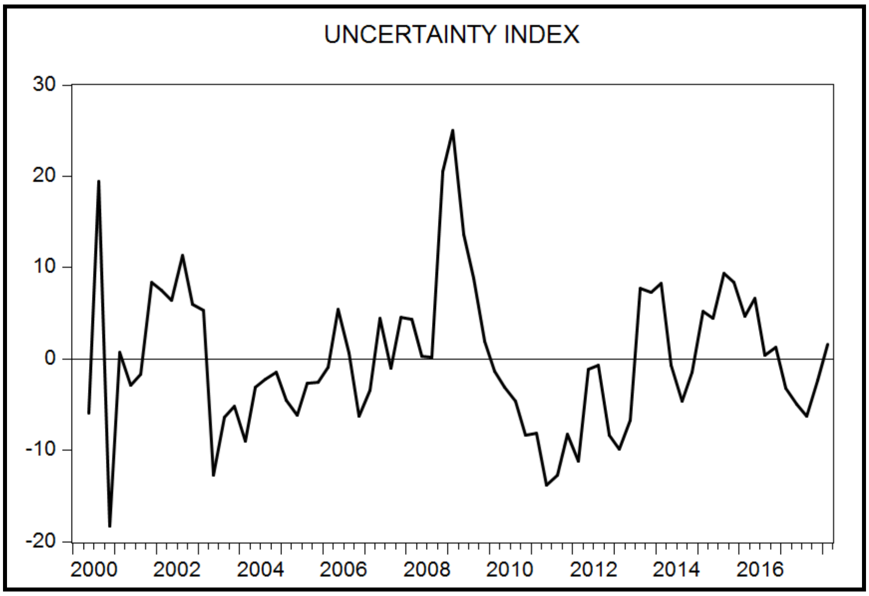

Figure 1: The Macroeconomic Uncertainty Index for Australia, 2000:1 to 2018:1.