CAES Working Paper Series

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WP-2012-001

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In pursuit of monetary econometric systems for New Zealand under inflation targeting policy

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February 7, 2012

Abstract

This paper aims to obtain data-congruent monetary econometric representations of New Zealand under inflation targeting policy starting in the early 1990s. The study analyzes a battery of quarterly time series data associated with the money market, monetary policy and expected inflation in the economy. Two cointegrated vector autoregressive systems, baseline and extended, are estimated to reveal that information on expected inflation available in a business survey plays a critical role in deriving a satisfactory representation of the dynamics of the underlying monetary policy rule. The overall empirical analysis indicates the existence of three cointegrating relationships, all of which are interpretable from the viewpoint of monetary economics. Both of the cointegrated systems are reduced to vector equilibrium correction systems, which are judged to be reliable econometric models representing the data. The preferred systems shed useful light on inflation dynamics as well as the workings of monetary policy in New Zealand.

JEL classification**:** C32; E41; E52

Keywords**:** Monetary econometric systems; Inflation targeting policy; Taylor rule; Expected inflation; Cointegrated vector autoregressive analysis

1. Introduction

New Zealand is recognized as the first economy that adopted the now well-known inflation targeting policy in the early 1990s. This paper, performing a thorough econometric analysis, aims to estimate data-congruent monetary empirical systems for New Zealand under the regime of inflation targeting policy. The study assigns importance to the roles of inflation, an interest rate spread, real aggregate money and expected inflation in the economy. It should be noted that New Zealand's monetary

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authority has been regularly releasing a number of time series data of expected inflation, which are compiled using information from a comprehensive quarterly-basis survey of business managers. See the website of the Reserve Bank of New Zealand (the RBNZ, hereafter) for details. The availability of such quantitative information on expected inflation allows us to conduct a detailed time series analysis of the workings of monetary policy. The introductory section briefly reviews the empirical literature on money demand and monetary policy rules, and also explains what we pursue in our empirical investigation of New Zealand's economy.

Money demand plays a major role in macroeconomic analysis, especially in selecting appropriate monetary policy actions. An empirical investigation of money demand functions is therefore important. A cointegrated vector autoregressive (CVAR) analysis, pioneered by Johansen (1988, 1996), enables us to pursue various objectives in economic research such as the estimation of money demand relationships. Johansen and Juselius (1990), using a CVAR analysis, examine money demand in Denmark and Finland. Hafer and Jansen (1991), and Hoffman and Rasche (1991), among others, find a stable relation for M1 and M2 in the US; Hendry and Mizon (1993) as well as Hendry and Doornik (1994) attain data-congruent representations of the UK M1. For New Zealand's economy, Orden and Fisher (1993) find a stable long-run relationship among M3, the gross domestic product (GDP) deflator and the real GDP over the period of 1965-1989, by incorporating a deterministic shift parameter, which accounts for the effects of financial deregulation in the 1980s. Fisher *et al.* (1995) come to the same conclusion over a period of 1965-1992. Siklos and Eckhold (1997), incorporating measures of institutional changes, find a stable M3 money demand function in New Zealand for the period of 1981-1994. One of the primary purposes of this paper is not merely to examine if any stable money-demand-type relationship exists in New Zealand's time series data, but also to explore how the observed relationship interacts with the rates of realized and anticipated inflation.

With regard to monetary policy rules, it is well known that Taylor (1993) has started an ongoing discussion about them. See, for example, Ball (1997), Clarida *et al.* (1998, 2000), and Ball and Tchaidze (2002). Clarida *et al.* (1998) find that each of the G3 (Germany, Japan, and the US) central banks has pursued an implicit form of inflation targeting since 1979. Christensen and Nielsen (2009), employing a CVAR analysis, reveal a stable long-run relationship between the Federal funds rate, unemployment and the bond rate; the relationship is interpretable as a policy target. Huang *et al.* (2001) investigate the early ten-year performance of inflation targeting and show that a Taylor rule with the standard parameters used in the US describes New Zealand's monetary policy. Plantier and Scrimgeour (2002) estimate a Taylor rule for New Zealand, and show it could be an alternative interest rate path to the inflation forecast based rule of the RBNZ. The Taylor or Taylor-type rule can thus be viewed as a representative way to implement inflation targeting. Another purpose of this paper is to explore the possibility of policy rules like the Taylor rule in the operation of monetary policy in New Zealand, coupled with the aim of revealing the interactions between the identified monetary policy rule and the rates of expected as well as actual inflation.

It seems, as reviewed above, that money demand and monetary policy rules functions are often treated as separate research themes in the literature, despite the possibility that both of them are deeply associated with the primary monetary aspects of economies under study. Brűggemann (2003) and Choo and Kurita (2011), which simultaneously investigate money demand and monetary policy in Germany and South Korea, respectively, may be counted as exceptional. This paper, in principle, pursues the same objective with respect to the New Zealand economy as these two articles. We note that it would be essential, in order to evaluate the workings of monetary policy, to have a good comprehension of the underlying interactions between money demand and monetary policy rule.

Furthermore, it appears that the recent literature on monetary policy analysis has a tendency to place less importance to monetary aggregates than before. See Nelson (2003) and Woodford (2008), *inter alia*. However, there is a possibility that aggregate money still matters. Hence, it is also an important research purpose of this paper to inspect whether or not aggregate money plays a significant part in empirical macroeconomic systems for New Zealand.

In this paper, we pursue data-congruent monetary econometric representations of New Zealand under inflation targeting policy. Employing CVAR methodology, we analyze a battery of quarterly time series data associated with the money market, monetary policy, and expected inflation in the New Zealand economy. Two CVAR systems, baseline and extended, are estimated in order to shed light on an important role played by expected inflation in deriving a satisfactory representation of New Zealand's monetary policy rule. The overall empirical analysis suggests that there exist three cointegrating relationships, which are interpretable in terms of the economics of money demand and monetary policy rules as briefly reviewed above. Both of the CVAR systems are reduced to vector equilibrium correction systems congruent with the underlying data generating mechanism. The preferred systems allow us to have a data-based understanding of both inflation dynamics and monetary policy in New Zealand. The estimated systems can, therefore, be seen as useful empirical references to the monetary aspects of the economy.

The rest of this paper is organized as follows. Section 2 provides a historical review of New Zealand's monetary policy, and Section 3 briefly reviews a CVAR analysis. Section 4 then presents a canonical model focusing on money demand function, monetary policy rule, and expected inflation. Section 5 and Section 6 perform a rigorous econometric analysis of the data in order to explore monetary interaction in New Zealand's economy. Section 5 reveals two cointegrating relationships on inflation and monetary policy rules, while Section 6 reveals one more cointegrating relationship on expected inflation in an extended model. The overall summary and conclusion are given in Section 7. This paper uses *OxMetrics/PcGive* (Doornik and Hendry, 2007) to conduct numerical analyses and create graphics.

2. Historical review of New Zealand's monetary policy

In New Zealand, which began quite early to institute social legislation in the late nineteenth century, government regulation was pervasive and government's business ownership was widespread until recently when it launched economic reforms in 1984. During the preceding decade prior to the economic reforms its economic performance was unsatisfactory. The real GDP grew very slowly at an annual rate of below 2 percent, the public debt increased from 5 percent to 32 percent of GDP, and the annual inflation rate remained in double digits. The government's financial deficit amounted to above 6 percent of GDP in the 1983/84 fiscal year, and the current account deficit was more than 8 percent of GDP in 1984.

Since 1984 the government undertook a wide range of economic liberalization and restructuring measures such as removal of capital and interest rate controls, privatization, deregulation of the industry and labor market, liberalization of international trade, increased institutional independence for the central bank, floating of the exchange rate, and a drive to reduce both government's financial deficit and inflation rate. Specifically, in the reform process the RBNZ started in 1987 to forecast inflation publicly one quarter to three years ahead. See more details in Evans *et al.* (1996).

The economic performance improved early in the 1990s, with an exception of a brief stagnation in late 1992 in the aftermath of the crisis of the European Exchange Rate Mechanism. The annual GDP growth rate stood above 3 percent, the government's deficit turned into surplus, the current account deficit substantially decreased to less than 3 percent of GDP, and consumer price inflation reached the 0-2 percent target range. It is interesting to note a significant drop in actual and expected inflation, although Johnson (2002) and Ball and Sheridan (2004) claim that inflation targeting did not contribute to reducing actual and expected inflation in comparison to non-inflation targeting.

Previously, since the 1960s, monetary policy pursued multiple targets of strong GDP and trade, full employment and price stability according to the RBNZ Act of 1964, but it lacked accountability and transparency. It was undertaken in a framework of controlling bank lending until 1984, and then monetary aggregates were managed under monetary targeting until 1988.

The currently so-called inflation targeting policy was introduced in 1989 and took effect in 1990 for the purpose of containing the inflation. Key factors of the newly instituted monetary policy in New Zealand include (1) announcement of official target range for the inflation rate, (2) increased communication with the public about the objectives of policy, and (3) increased accountability of the central bank for attaining the objectives. The RBNZ is mandated to publicly lower inflation to a certain range. Policy Targets Agreement, which is made periodically between the RBNZ and the Ministry of Finance, spells out the objective of price stability. In 1990 New Zealand started to have a changing target range and in 1993 it started to have a generally unchanging target range—it widened the target range a bit in 1997. For more details see Evans *et al.* (1996), and Bernanke and Mishkin (1997), among others.

In regard to the single target of inflation we should note that in practice, monetary policy takes real sector influences into account to the extent that inflationary pressures react to the state of the economic cycle although it does not attempt to achieve particular short-term real sector objectives. Actually in 1999 the monetary policy of New Zealand qualified the single focus on price stability by adding stability in output, interest rates and the exchange rate.

The RBNZ has not adopted any explicit interest rate target, although it affects short-term interest rates in order to meet its inflation target. In the early 1990s it adopted a quantity target for "overnight (settlement) cash" and changed the target if it wished to affect interest rates. Until the late 1990s it used a 90 day bank bill rate as an information variable, publicizing what it wanted for market conditions through specifying the bank bill rate which would be consistent with price stability. In 1999 it changed its principal instrument of policy from managing the quantity of overnight cash to setting the interest rate for it (Official Cash Rate, i.e., overnight call rate; OCR in short); such a movement might indicate some change in policy, possibly towards a Taylor rule. Thus in effect the 90 day bank bill rate was also replaced by the OCR. Meanwhile there has been a change in the computation of inflation. In 1997 the RBNZ moved from targeting its own computation of "underlying inflation" to a consumer price index (CPI) adjusted by excluding the cost of credit services. The adjusted CPI is denoted as CPIX by the RBNZ.

In summary the inflation targeting policy in New Zealand can be said to be a checkered framework; see Svensson (2001), among others, for an assessment of a decade of monetary policy. Thus there might be some problems in selecting the correct variables for a study on the monetary phenomenon in New Zealand.

3. Econometric methodology

In this section we provide a brief review of econometric methodology adopted in this paper; that is, a review of likelihood-based analysis of CVAR systems as well as a procedure for the pursuit of parsimonious econometric representations. Most economic time series data show non-stationary trending behavior, so that they should be perceived as processes integrated of order 1, denoted as $I(1)$ henceforth. A likelihood-based CVAR analysis, introduced by Johansen (1988, 1996), has thus played a key role in modeling integrated economic time series data. See Crowder *et al.* (1999), Juselius (2006) and Kurita (2007), *inter alia*, for empirical illustrations employing the CVAR methodology.

Let us introduce an unrestricted VAR(k) system for a p-dimensional time series $X_{-k+1},\cdots,X_T$ as follows:

$$\Delta X_t = (\Pi,\Pi_l)\binom{X_{t-1}}{t} + \sum_{i=1}^{k-1}\Gamma_i\,\Delta X_{t-i} + \mu + \varepsilon_t, \text{ for } t = 1,\cdots,T, \tag{1}$$

where the errors $\varepsilon_1,\cdots,\varepsilon_T$ have independent and identical normal $N(0,\Sigma)$ distributions conditional on the initial values $X_{-k+1},\cdots,X_0$, the parameters $\Pi,\Gamma_i,\Sigma \in \mathbf{R}^{p\times p}$ and $\Pi_l,\mu \in \mathbf{R}^p$ vary freely, and Σ is a positive definite matrix.

With a view to conducting the CVAR analysis of $I(1)$ time series data, three regularity conditions need to be observed. The first condition is that a set of characteristic roots obeys an equation $|P(z)| = 0$, which is defined as

$$P(z) = (1-z)I_p - \Pi\, z + \sum_{i=1}^{k-1}\Gamma_i\,(1-z)z^i,$$

such that the roots satisfy either $|z| > 1$ or $z = 1$. It is ensured, due to this condition, that the process is neither explosive nor seasonally cointegrated. The second condition is

$$rank(\Pi,\Pi_l) \le r \quad \text{or} \quad (\Pi,\Pi_l) = \alpha(\beta',\gamma),$$

where $\alpha,\beta \in \mathbf{R}^{p\times r}$ and $\gamma \in \mathbf{R}^r$ for $r < p$. Let us define $\beta^{*\prime} = (\beta',\gamma)$ and $X_{t-1}^* = (X_{t-1}',t)'$ for future reference. A set of vectors α is called adjustment vectors, β^* is referred to as cointegrating vectors, while the index r denotes cointegrating rank. The second condition means that there exist at least $p-r$ common stochastic trends and cointegration is observed when $r \ge 1$. The third condition is given by

$$rank(\alpha_\perp'\Gamma\beta_\perp) = p - r,$$

where $\Gamma = I_p - \sum_{i=1}^{k-1} \Gamma_i$, and $\alpha_\perp, \beta_\perp \in \mathbf{R}^{p\times(p-r)}$ are orthogonal complements such that $\alpha'\alpha_\perp = 0$ and $\beta'\beta_\perp = 0$ with $(\alpha, \alpha_\perp)$ and $(\beta, \beta_\perp)$ being of full rank. The final condition precludes the process from being $I(2)$ or of higher order. Provided that these conditions are fulfilled, an $I(1)$ CVAR system is defined as a sub-system of equation (1) and thus we find

$$\Delta X_t = \alpha\beta^{*\prime} X_{t-1}^* + \sum_{i=1}^{k-1} \Gamma_i \, \Delta X_{t-i} + \mu + \varepsilon_t, \tag{2}$$

which lays the foundation for subsequent cointegration analysis and model reduction.

The cointegrating rank r is usually unknown to researchers modeling the data in question, so the rank needs to be determined based on an empirical study. A test statistic composed of a log-likelihood ratio ($\log LR$), given by the null hypothesis of r cointegration rank $\mathrm{H}(r)$ against the alternative hypothesis $\mathrm{H}(p)$, is expressed as $\log LR(\mathrm{H}(r)|\mathrm{H}(p))$ and utilized for the choice of r in this paper. The asymptotic quantiles of the test statistic are supplied by Johansen (1996, Ch.15); see also Nielsen (1997) and Doornik (1998) for the method of gamma approximations to calculate the limiting quantiles. Choosing the cointegrating rank in (2) then enables us to test various restrictions on α and β^*. Cointegrating relationships, $\beta^{*\prime} X_{t-1}^*$, represent a class of stationary linear combinations, working as equilibrium correction mechanisms in equation (2). The relationships are deemed to be empirical representations of the underlying long-run economic linkages of variables in equation (2); it is thus essential to check whether or not interpretable restrictions may be imposed on β^* estimated from the data.

Furthermore, let us review a partial CVAR system and the procedure of model reduction. Equation (2) above is decomposed as $X_t = (Y_t', Z_t')'$ for $Y_t \in R^m$ and $Z_t \in R^{p-m}$, and $r \le m < p$. Both the parameters and errors are expressed in a conformable way as

$$\alpha = \begin{pmatrix} \alpha_y \\ \alpha_z \end{pmatrix}, \; \Gamma_i = \begin{pmatrix} \Gamma_{y,i} \\ \Gamma_{z,i} \end{pmatrix}, \; \mu = \begin{pmatrix} \mu_y \\ \mu_z \end{pmatrix}, \; \varepsilon_t = \begin{pmatrix} \varepsilon_{y,t} \\ \varepsilon_{z,t} \end{pmatrix}, \; \Sigma = \begin{pmatrix} \Sigma_{yy} & \Sigma_{yz} \\ \Sigma_{zy} & \Sigma_{zz} \end{pmatrix}.$$

Suppose that $\alpha_z = 0$ holds, so that equation (2) is decomposed into a partial CVAR system for Y_t conditional on Z_t and a marginal system for Z_t as follows:

$$\Delta Y_t = \omega \Delta Z_t + \alpha_y \beta^{*\prime} X_{t-1}^* + \sum_{i=1}^{k-1} \Gamma_{y,i}^* \, \Delta X_{t-i} + \mu_y^* + \varepsilon_{y,t}^*, \tag{3}$$
$$\Delta Z_t = \sum_{i=1}^{k-1} \Gamma_{z,i} \, \Delta X_{t-i} + \mu_z + \varepsilon_{z,t}, \tag{4}$$

where

$$\omega = \Sigma_{yz}\Sigma_{zz}^{-1}, \; \Gamma_{y,i}^* = \Gamma_{y,i} - \omega\Gamma_{z,i}, \; \mu_y^* = \mu_y - \omega\mu_z, \; \varepsilon_{y,t}^* = \varepsilon_{y,t} - \omega\varepsilon_{z,t}.$$

Note that equation (4) is free from $\beta^{*\prime} X_{t-1}^*$. If the condition $\alpha_z = 0$ is fulfilled, Z_t is then said to be weakly exogenous for the parameters in equation (3). This means that, under the condition $\alpha_z = 0$, the parameters of the partial system or equation (3) can be estimated without any reference to the marginal system or equation (4). As a result, it is unnecessary to estimate the parameters of equation (4). The condition $\alpha_z = 0$, hence, allows us to focus on the analysis of the partial system, provided the parameters of interest are contained in those of the partial system. See Johansen (1992) and Urbain

(1992) for details of weak exogeneity in CVAR systems. It is thus of much importance, in empirical investigations, to check whether or not $\alpha_z = 0$ holds in the joint system given by equation (2). If the condition is empirically satisfied, we can reduce the joint system to the partial system; the partial system may, by adopting a general-to-specific modeling approach, be further reduced to a parsimonious vector equilibrium correction system. See Hendry (1995) and Campos *et al.* (2005) for details of the approach. The equilibrium correction system can represent the underlying data generating structure and thus provide useful information from the viewpoint of economic policy and forecasting.

4. Model for money demand, monetary policy rule and expected inflation

This section, relying on recent developments in macro and monetary economics, provides a canonical model for money demand, monetary policy rule, and expected inflation. The model paves the way for long-run econometric analyses conducted in the following sections.

4.1 Equilibrium in the money market

Imposing price homogeneity, a real broad money demand model may be postulated as follows:

$$m_t - p_t = \gamma_0 + \gamma_1 y_t + \gamma_2 i_t^s - \gamma_3 i_t^l - \gamma_4 \pi_t, \tag{5}$$

where m_t is the logarithm of desired holdings of real money balances; p_t is the logarithm of price level; y_t is the logarithm of real GDP; i_t^s is a short-term interest rate and measures the own rate of money; i_t^l is a long-term interest rate represented by yields on government bonds; π_t is an annual inflation rate, which is a proxy for the change in the nominal value of physical assets held; and $\gamma_i > 0$ for $i = 1,\cdots,4$. Equation (5) is thus seen as a log-linear representation of the equilibrium condition for the money market.

Let us turn our attention to the financial market opportunity costs of holding money embedded in equation (5). It is of interest to test the two interest rates, i_t^s and i_t^l, for equal coefficients with opposite signs. We may find it possible to further take unity for the income elasticity, that is, $\gamma_1 = 1$. As a result of these restrictions, equation (5) leads to

$$m_t - p_t = \gamma_0 + y_t + \gamma_2 \left(i_t^s - i_t^l\right) - \gamma_4 \pi_t.$$

In addition, we are interested in testing $\gamma_2 = \gamma_4$ so that we can obtain

$$m_t - p_t = \gamma_0 + y_t - \gamma_2 \left(i_t^l - i_t^s + \pi_t\right), \tag{6}$$

or, if it turns out that the interest rates do not play a critical role, we may observe $\gamma_2 = 0$ and $\gamma_4 \neq 0$ as in the following equation:

$$m_t - p_t = \gamma_0 + y_t - \gamma_4 \pi_t.$$

Thus,

$$-(m_t - p_t - y_t) = -\gamma_0 + \gamma_4 \pi_t. \quad (7)$$

Hence, we find that the equilibrium condition (5) can be expressed as a positive relationship between the velocity of money and inflation rate. It is known that the velocity of money and inflation rate can show a co-movement, with other things given (see Gylfason and Herbertsson, 2001). In the empirical analysis performed in this paper, we regard the money market function (6) or (7) as a candidate for one of the underlying long-run economic linkages in the data.

4.2 Interest-rate-based monetary policy

Next, let us turn to a monetary policy rule. Taylor (1993) points out that the monetary policy process can be summarized by a simple policy rule, in which the short-term policy rate responds to deviations of output and inflation from their respective policy targets as follows:

$$i_t^s = \pi_t + \eta_0 + \eta_1 (y_t - y_t^*) + \eta_2 (\pi_t - \pi_t^*), \quad (8)$$

where y_t^* is the natural logarithm of a potential output; π_t and π_t^* denote the inflation and its monetary policy target, respectively; and η_0 is interpretable as the target real short-term interest rate, and $\eta_i > 0$ for $i = 0,1,2$.

Note that it is possible to reckon the above Taylor rule as a way to implement inflation targeting. While inflation targeting itself yields a medium-run plan, the Taylor rule may be seen as a short-run operating procedure for a medium-run inflation target. The rule also responds to the output gap, which can be counted as a measure of inflation pressure. Suppose that the potential output is assumed to show a log linear deterministic trend, *i.e.* $y_t^* = \theta_1 + \theta_2 t$ with $\theta_i > 0$ for $i = 1,2$. Furthermore, if we could simply assume that the inflation target is time-varying, approximated as $\pi_t^* = \theta_3 + \theta_4 t$ with $\theta_3 > 0$ and $\theta_4 \neq 0$, equation (8) is then reduced to

$$i_t^s = \mu_0 + \mu_1 y_t + (1 + \mu_2) \pi_t + \mu_3 t, \quad (9)$$

where $\mu_i = \eta_i$ for $i = 1,2$, $\mu_0 = \eta_0 - \mu_1 \theta_1 - \mu_2 \theta_3$, and $\mu_3 = -\mu_1 \theta_2 - \mu_2 \theta_4$. According to Laurent (1988) as well as Bernanke and Blinder (1992), the spread between the Federal funds rate and yield on long-term government bonds is viewed as a useful indicator of the stance of monetary policy. The reasons for this are summarized as follows: (i) the long-term rate should incorporate inflation expectations of all interest rates but is relatively insensitive to short-run variations in monetary ease or tightness and (ii) a conceivable predominant force underlying the long-term rate behavior comes from expected inflation. Bernanke and Blinder (1992) further note that the Federal funds rate, not the bond rate, dominates movements in the spread. The same holds for the interest rates and spread in New Zealand; the correlation coefficient between $(i_t^s - i_t^l)$ and i_t^s is 0.807, while that between $(i_t^s - i_t^l)$ and i_t^l is just 0.273, as shown in Appendix B. Mehra (2001) and Christensen and Nielsen (2009) also include the bond rate as an additional variable in the Taylor rule function. Assuming that the long-term interest rate moves along with inflation and noting that inflation is already present in equation (9), we add to equation (9) the information as measured by the real long-term interest rate, $i_t^l - \pi_t$ to find

$$\begin{aligned} i_t^s &= \mu_0 + \mu_1 y_t + (1+\mu_2)\pi_t + \mu_3 t + \mu_4\left[\left(i_t^l - \pi_t\right) - \bar{r}^l\right] \\ &= \mu_0^* + \mu_1 y_t + (1+\mu_2-\mu_4)\pi_t + \mu_4 i_t^l + \mu_3 t, \end{aligned} \tag{10}$$

where $\bar{r}^l$ is the mean of the real long-term interest rate, assumed to be time-invariant, and $\mu_0^* = \mu_0 - \mu_4\bar{r}^l$; it is simply assumed that the factor productivity of the economy, which may directly affect the real long-term interest rate, grows along a long-term trend over the period. If there is a one-to-one effect from the long-term interest rate to the short-term interest rate, then $\mu_4 = 1$, and we obtain:

$$i_t^s = \mu_0^* + \mu_1 y_t + \mu_2\pi_t + i_t^l + \mu_3 t.$$

It follows from $\mu_3 = -\mu_1\theta_2 - \mu_2\theta_4$ that

$$i_t^s = \mu_0^* + \mu_1(y_t - \theta_5 t) + \mu_2\pi_t + i_t^l, \tag{11}$$

that is,

$$i_t^s - i_t^l = \mu_0^* + \mu_1(y_t - \theta_5 t) + \mu_2\pi_t, \tag{12}$$

where $\theta_5 = \theta_2 + (\mu_2/\mu_1)\theta_4$. Thus equation (12) shows a monetary policy target expressed in terms of the interest rate spread, $i_t^s - i_t^l$. Note that the last terms $\mu_2\pi_t + i_t^l$ in equation (11) show the combined influence of inflation and expected inflation (embedded in the long-term interest rate) on the short-term policy rate, whose magnitude is near $\mu_2 + 1$. In the empirical analysis conducted in this paper, we consider the monetary policy rule function (12) as a candidate for one of the long-run economic relationships embedded in the data. In an open economy like New Zealand the exchange rate could play a role in the monetary policy. See Svensson (2000) and Taylor (2001); both consider the existence of the real exchange rate in the implementation of monetary policy. However, the time lags for the influence of the exchange rate on inflation, among others, cannot be examined in the cointegration model, and thus it is not considered in this paper.

4.3 Expected inflation

Lastly, let us consider the formation of expected inflation. As mentioned above, the monetary authority of New Zealand has regularly made public the survey-based data of business managers' expected inflation since the late 1980s. By attaching importance to information on inflation at present, we may possibly be justified in simply postulating that expected inflation is positively related with current inflation:

$$\varphi_t^e = \rho_0 + \rho_1\pi_t, \tag{13}$$

where φ_t^e denotes one-year-ahead ($t+4$ in a quarterly model) expected inflation made at time t by the monetary authority and $\rho_1 > 0$. We also regard the above equation (13) as a candidate for one of the underlying long-run economic linkages in the data. If both $\rho_0 = 0$ and $\rho_1 = 1$ are observed in the estimated cointegrating linkage, we can infer that there exists a long-run one-for-one relationship between the expected and current inflation rates; the relationship may be interpreted as a type of random walk long-run forecast.

5. Estimating a baseline monetary econometric system

In this section, a comprehensive CVAR analysis of quarterly time series data in New Zealand is performed in order to obtain a baseline monetary econometric system. Consistent with the theoretical model developed in Section 4, we introduce a set of variables to be analyzed as follows:

$$X_t = \left(\pi_t, i_t^s - i_t^l, m_t - p_t, y_t\right)',$$

which leads to a four-dimensional VAR system formulated as equation (1). See Appendices A and B for details of the data and their overview, respectively. Let us stress that a real broad money measure, $m_t - p_t$, is included in the set of variables so as to estimate an econometric model that belongs to a class of monetary models. Also note that the GDP deflator is adopted as the empirical measures of both p_t and π_t. The reason why the GDP deflator is chosen is that the deflator, consisting of individual prices of all goods and services produced in the overall economy, is considered as the most general measure of price level among all price indices available. With regard to the *ex-ante* expected inflation, φ_t^e, which is introduced in the empirical analysis in Section 6, we have no choice but to use the survey-based CPIX inflation expectation as a reliable quantitative measure of anticipated inflation; thus the measures of *ex-post* and *ex-ante* inflation do not coincide in terms of goods and services coverage. It is nonetheless interesting, in our extended analysis in Section 6, to investigate how the comprehensive *ex-post* inflation rate and the consumption-oriented *ex-ante* expected inflation interact with each other.

This section consists of four sub-sections. Section 5.1 estimates an unrestricted VAR system to choose an appropriate cointegrating rank. Section 5.2 conducts tests for weak exogeneity, which then lead to the identification of a set of long-run economic relationships in Section 5.3. In Section 5.4, based on the results in Section 5.3, the reduction of the system is pursued, so that a baseline econometric system is estimated conditional on a set of weakly exogenous variables.

5.1 Tests for cointegrating rank

In this sub-section we estimate an unrestricted VAR system for X_t using a set of quarterly data in New Zealand in order to explore the underlying cointegrating rank. The sample period for estimation runs from the second quarter in 1991 to the second quarter in 2011, denoted as 1991.2-2011.2 hereafter, covering the era of inflation targeting policy being explicitly adopted in New Zealand. The number of observations is therefore 81. We start the analysis by setting the lag length of the system to 4, then finding that the choice of the lag length 3 seems to be appropriate in terms of statistical significance, although there is some evidence for residual autocorrelation in the inflation equation. Thus we choose the lag length 3 or $k = 3$ and also employ the method of short-run dynamics adjustment suggested by Kurita and Nielsen (2009). That is, lagged second-order dynamic terms for inflation, $\Delta^2\pi_{t-3}$ and $\Delta^2\pi_{t-4}$, are added to the VAR(3) system unrestrictedly, so that the problem of autocorrelation is remedied while the log LR test for cointegrating rank remains intact asymptotically. In addition, there is an outlier in the data for y_t in 1992.3, possibly due to the aftermath of the European Exchange Rate Mechanism crisis, as mentioned in Section 2. Thus a dummy variable taking 1 in 1992.3 and 0 otherwise is also included in the VAR system.

Table 1 displays a set of mis-specification tests for the residuals of the adjusted VAR(3) system. Most of the test results are provided in the form $F_j(k, T-l)$, which denotes an approximate F test against the alternative hypothesis j: kth-order autocorrelation (F_{ar}: see Godfrey, 1978, Nielsen, 2006), kth-order autoregressive conditional heteroskedasticity or ARCH (F_{arch}: see Engle, 1982), heteroskedasticity (F_{het}: see White, 1980). In addition, a chi-square test for normality (χ^2_{nd}: see Doornik and Hansen, 2008) is reported. All these diagnostic test statistics are insignificant at the 5% level, indicating that the VAR(3) system is viewed as a satisfactory representation of the data. We therefore conclude that the VAR(3) system can be used for subsequent cointegration analysis and model reduction.

Table 1: Mis-specification tests for the VAR(3) system

	π_t	$i_t^s - i_t^l$	$m_t - p_t$	y_t
Autocorr.[$F_{ar}(5,59)$]	1.33[0.26]	1.23[0.31]	1.82[0.12]	1.56[0.19]
ARCH [$F_{arch}(4,56)$]	0.18[0.95]	2.51[0.05]	0.26[0.90]	0.91[0.47]
Hetero.[$F_{het}(26,37)$]	0.75[0.77]	0.90[0.60]	1.19[0.31]	0.93[0.57]
Normality [$\chi^2_{nd}(2)$]	2.12[0.35]	0.97[0.62]	1.31[0.52]	1.20[0.55]

Note: The figures in the square brackets are p-values.

The well-formulated VAR system then enables us to address the issue of choosing an appropriate cointegrating rank. Testing for the choice of cointegrating rank is conducted, leading to a set of empirical results reported in Table 2.

Table 2: Tests for cointegrating rank in the VAR(3) system

	$r = 0$	$r \leq 1$	$r \leq 2$	$r \leq 3$
$\log LR\{\mathrm{H}(r)\vert\mathrm{H}(p)\}$	93.16[0.00]**	54.31[0.00]**	28.89[0.02]*	6.27[0.44]

mod ($r = 2$)	1	1	0.80	0.80	0.67	0.67

Notes: The figures in the square brackets are p-values.
** and * denote significance at the 1% and 5% level, respectively.

The first panel in the table reports a set of log LR test statistics for the choice of cointegrating rank. The test statistics reject the null hypotheses of $r = 0$ and $r \leq 1$ at the 1% level of significance, while the null hypothesis of $r \leq 2$ is not rejected at the same level but rejected at the 5% level. It is known that the rank tests tend to over-reject the null in small samples; see Cheung and Lai (1993), *inter alia*. Thus we can state that the likelihood-based tests in Table 2 are in favor of $r = 2$. For the purpose of verifying the choice of $r = 2$, the second panel in Table 2 presents the modulus (denoted as *mod*) of the six largest eigenvalues of a companion matrix of the CVAR system, which is estimated under the restriction of $r = 2$. All the eigenvalues, apart from the imposed two unit roots, are distinct from 1, indicating that the choice of $r = 2$ is appropriate for the data description. We thus arrive at the conclusion that the cointegrating rank is set at 2 or $r = 2$. As a result of choosing the cointegrating rank, we are able to proceed to the next stage of CVAR analysis.

5.2 Tests for weak exogeneity

The determination of the cointegrating rank ($r = 2$) allows us to conduct hypothesis tests on the estimates of α and β^*, based on standard χ^2-based asymptotic inferences. This sub-section carries out a set of tests for weak exogeneity with a view to providing a basis for model reduction. It is possible, as discussed in Section 3, to examine weak exogeneity by checking zero restrictions on all adjustment coefficients for a variable in question. If both $m_t - p_t$ and y_t are judged weakly exogenous for the parameters of a partial system for π_t and $i_t^s - i_t^l$, we are then justified in focusing on the analysis of the partial system conditional on the set of weakly exogenous variables. The modeling scheme centering on such a partial system, in principle, seems to agree with the canonical economic model in Section 4, and also reduces the modeling efforts required in the econometric study.

Likelihood-based test statistics for weak exogeneity are reported in Table 3. According to the table, the null hypothesis of weak exogeneity is highly rejected with regard to π_t and $i_t^s - i_t^l$ at the 5% level; in stark contrast, the hypothesis is not rejected for $m_t - p_t$ and y_t even at the 10% level. These test results suggest that $m_t - p_t$ and y_t can be treated as weakly exogenous for the parameters of the partial system for π_t and y_t. It is therefore possible, without loss of information, to proceed to the investigation of the partial system, from which further model reduction may be pursued. Before launching the exploration of the model reduction, we find it useful to seek the identification of long-run relationships interpretable from economic models presented in Section 4. This issue is addressed in the next sub-section.

Table 3: Tests for weak exogeneity in the CVAR(3) system

π_t	$i_t^s - i_t^l$	$m_t - p_t$	y_t
8.9 [0.01]*	9.25[0.01]**	2.74[0.25]	2.54[0.28]

Note: The figures in the square brackets are *p*-values.
** and * denote significance at the 1% and 5% level, respectively.

5.3 Identification of long-run economic relationships

Combined with zero restrictions imposed on the adjustment vectors, we are able to inspect the validity of various restrictions on the cointegrating vectors, using χ^2-based asymptotic inferences. This sub-section, testing a battery of restrictions on β^*, aims to obtain the empirical expressions of the underlying long-run economic linkages in the

New Zealand data. Let us recall the vector of variables in level appearing in both equations (2) and (3):

$$X_{t-1}^{*} = \left(\pi_{t-1}, i_{t-1}^{s} - i_{t-1}^{l}, m_{t-1} - p_{t-1}, y_{t-1}, t\right)'.$$

The test results in Table 3 permit us to impose zero restrictions on the adjustment coefficients for $m_{t-1} - p_{t-1}$ and y_{t-1}; under these zero restrictions, we normalize the cointegrating vectors for π_{t-1} and $i_{t-1}^{s} - i_{t-1}^{l}$, respectively, and examine additional restrictions on the cointegrating vectors with the restricted adjustment vectors normalized consistent with that of the cointegrating vectors. After a series of trials, we arrive at an identified structure of the cointegrating and adjustment spaces as follows:

$$\hat{\alpha}\,\hat{\beta}^{*\prime} = \begin{pmatrix} \underset{(0.083)}{-0.481} & \underset{(-)}{0} \\ \underset{(-)}{0} & \underset{(0.077)}{-0.433} \\ \underset{(-)}{0} & \underset{(-)}{0} \\ \underset{(-)}{0} & \underset{(-)}{0} \end{pmatrix} \begin{pmatrix} \underset{(-)}{1} & \underset{(-)}{0} & \underset{(0.075)}{0.165} & \underset{(-)}{-0.165} & \underset{(0.00044)}{-0.00109} \\ \underset{(-)}{0} & \underset{(-)}{1} & \underset{(-)}{0} & \underset{(0.06)}{-0.342} & \underset{(0.00048)}{0.00273} \end{pmatrix}, \quad (14)$$

where the figure in the parenthesis under each coefficient is a standard error. The log LR test statistic for the restrictions in equation (14) is 6.52, with its p-value according to $\chi^2(8)$ given by 0.59; the null hypothesis is thus not rejected even at the 10% level. The restricted cointegrating linkages, revealed in equation (14), play the roles of equilibrium correction mechanisms in the partial system pursued in the next sub-section.

Let us have a close look at the restricted cointegrating linkages in equation (14). The first cointegraing linkage is denoted as $c_{1,t-1}$, which is approximately expressed as

$$c_{1,t-1} \approx \pi_{t-1} + 0.17(m_{t-1} - p_{t-1} - y_{t-1}) - 0.001t,$$

which may be interpreted as an empirical representation of equation (7) in the theoretical model. As a demonstration of a possible causality flow in support of $c_{1,t-1}$, Gylfason and Herbertsson (2001) show that the greater the velocity is, the higher the inflation rate. It is, therefore, justifiable to rewrite equation (7) as

$$\pi_{t-1} = -(1/\gamma_4)(m_{t-1} - p_{t-1} - y_{t-1}) + \gamma_0/\gamma_4\,, \quad (15)$$

which agrees with the estimated cointegrating relation above, if we reckon the linear trend as a proxy for some unspecified economic factors such as institutional and behavioral changes influencing the long-run behavior of the velocity. As revealed in the adjustment structure in equation (14), $c_{1,t-1}$ acts as an equilibrium correction mechanism in the equation for inflation.

Next, let us consider economic interpretations of the second cointegrating linkage in equation (14), denoted as $c_{2,t-1}$, which is approximately given by

$$c_{2,t-1} \approx i_{t-1}^{s} - i_{t-1}^{l} - 0.34y_{t-1}^{*},$$

where $y_{t-1}^{*} = y_{t-1} - 0.008t$. Judging from the identified structure of $c_{2,t-1}$ and adjustment vectors above, we may reason that this long-run relationship corresponds to equation (12) derived from the underlying Taylor rule, although the inflation rate does not play any significant role in $c_{2,t-1}$ beyond that contained in the expected inflation via the long-term interest rate; that is, the expected inflation is conceived to be present in $c_{2,t-1}$ with a coefficient of unity via i_{t-1}^{l}. It is true that, for the RBNZ, the focus is on price stability; according to Archer (1997), inflation targeting in New Zealand has been set in place in order to prohibit monetary policy from active consideration of output and employment as objectives in their own right. However, an empirical measure of the output gap should remain relevant to the implementation of monetary policy, reflecting the recognition that the gap is an important contribution to the generation of inflationary pressures. Our finding shows that the empirical output gap has indeed played a significant role in the underlying inflation targeting rule in New Zealand. For the interpretation of a major role played by the output gap in the monetary policy rule, see Svensson (1997) and Fazzari *et al.* (2010), *inter alia*. It is demonstrated by Svensson (1997) that the weight on output stabilization determines how quickly the inflation forecast is adjusted towards the inflation target. Fazzari *et al.* (2010) show that a strong response to output is more effective than a strong response to inflation in stabilizing economic fluctuations.

5.4 A baseline monetary econometric system

We are now in a position to pursue an $I(0)$ econometric system conditional on $\Delta(m_t - p_t)$ and Δy_t, a set of weakly exogenous variables. Our primary interest lies in estimating a parsimonious system centering on inflation dynamics influenced by the underlying monetary policy rule. Thus, the partial system should be composed of equations for the inflation rate π_t and interest rate spread $(i_t^s - i_t^l)$ conditional on the set of weakly exogenous variables. First, mapping the data to $I(0)$ space by differencing and using the cointegrating relationships derived above, we move on to a bivariate equilibrium correction system given the set of weakly exogenous variables. It is then inspected whether or not any contemporaneous correlations exist in the data; a number of insignificant lagged regressors are also eliminated from the model, step by step. As a consequence of model reduction, we arrive at a baseline monetary econometric system as follows:

$$\begin{aligned}
\Delta\pi_t &= -\underset{(0.042)}{0.102}\Delta(m_t - p_t) - \underset{(0.076)}{0.369}c_{1,t-1} + \underset{(0.085)}{0.208}\Delta\pi_{t-2} + \underset{(0.157)}{0.371}\Delta\left(i_{t-2}^s - i_{t-2}^l\right) \\
&\quad + \underset{(0.07)}{0.157}\Delta^2\pi_{t-3} - \underset{(0.072)}{0.154}\Delta^2\pi_{t-4} + \underset{(0.014)}{0.068} + \hat{\varepsilon}_{1,t}, \\
\Delta\left(i_t^s - i_t^l\right) &= -\underset{(0.066)}{0.39}\,c_{2,t-1} + \underset{(0.095)}{0.32}\,\Delta\left(i_{t-1}^s - i_{t-1}^l\right) + \underset{(0.024)}{0.044}\Delta(m_{t-1} - p_{t-1}) \\
&\quad - \underset{(0.073)}{0.152}\Delta y_{t-2} - \underset{(0.121)}{0.721} + \hat{\varepsilon}_{2,t},
\end{aligned} \tag{16}$$

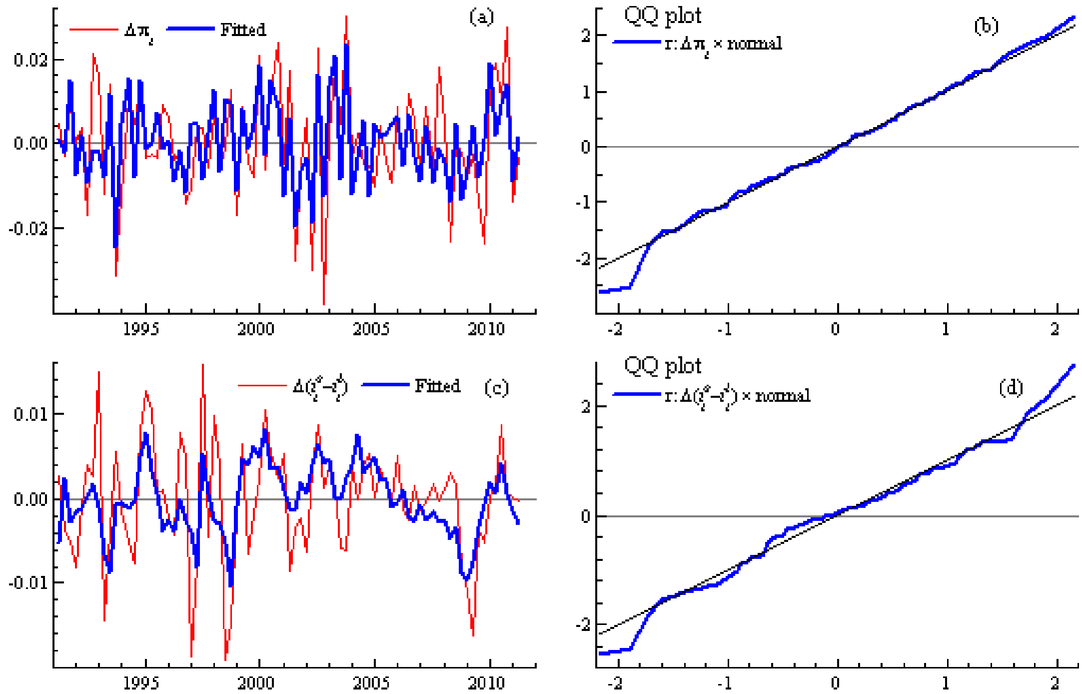
for

$$c_{1,t-1} = \pi_{t-1} + 0.165(m_{t-1} - p_{t-1} - y_{t-1}) - 0.0011t,$$
$$c_{2,t-1} = i_{t-1}^s - i_{t-1}^l - 0.342y_{t-1} + 0.0027t,$$

Autocorr. $[F_{ar}(20{,}128)] = 1.21\ [0.26]$,
Hetero. $[F_{het}(84{,}132)] = 1.31\ [0.08]$,
Normality$[\chi_{nd}^2(4)] = 1.83\ [0.77]$,

where the figure in the parenthesis under each coefficient denotes a standard error. Various system mis-specification tests are reported below the equation, together with their p-values; all of the tests are insignificant at the 5% level. Figure 1 (a) and (c) display a set of fitted values derived from equation (16), coupled with the corresponding actual values; the overall data tracking seems to be good. Figure 1 (b) and (d) show quantile-quantile (QQ) plots of scaled residuals from equation (16) based on the standard normal distribution; there is no strong evidence against normality in the residuals. It is, therefore, justifiable to conclude that equation (16) is judged a satisfactory data-representation from a statistical point of view.

Figure 1: Graphic analysis of the baseline system



With regard to the equation for $\Delta\pi_t$, the term $c_{1,t-1}$ has a negative and highly significant coefficient. Similarly, the coefficient for $c_{2,t-1}$ is also negative and highly significant in the equation for $\Delta(i_t^s - i_t^l)$. Both of these findings indicate the presence of strong equilibrium correction mechanisms in the system (16).

Furthermore, it is noteworthy that neither $\Delta\pi_t$ nor its past values are significant in the equation for $\Delta(i_t^s - i_t^l)$; let us recall the inflation rate does not play any significant part in $c_{2,t-1}$ beyond that contained in the expected inflation by way of the long-term interest rate. This finding may convey negative connotations for the existence of an empirically relevant monetary policy rule that focuses on inflation targeting. Note, however, the baseline model above does not explicitly take account of expected inflation. Incorporating a measure of expected inflation in the model may lead to such an empirical outcome as sheds useful light on the workings of monetary policy. This possibility motivates an extended analysis conducted in the next section.

In addition, it should be noted that information on the real money appears to play some roles in the equation for $\Delta\pi_t$. The results seem to suggest aggregate money may still be counted as a factor that can account for inflation dynamics. This point needs further investigation using an extended model in the next section.

Overall, we are justified in referring to a set of equations in system (16) as a *baseline monetary econometric system*, the extension of which is pursued in the next section by allowing for expected inflation.

6. An extended analysis incorporating expected inflation

The empirical analysis in the previous section successfully reveals two long-run relationships interpretable from economic theories. The analysis then leads to a baseline monetary economic model describing the dynamics of $\Delta\pi_t$ and $\Delta(i_t^s - i_t^l)$. These empirical results are surely informative for the comprehension of the underlying structure of the New Zealand economy. However, the finding that information on the inflation rate is irrelevant to the dynamics of $\Delta(i_t^s - i_t^l)$, apart from the conceivable role played by expected inflation hidden in the long-term interest rate, seems to be a bit puzzling and would not be satisfactory from the viewpoint of monetary policy centering on inflation targeting. As pointed out above, the finding may be due to a lack of explicit information on expected inflation in the baseline model. This section thus performs an extended analysis including a quantitative measure of expected inflation.

The set of variables to be analyzed in this section is given by

$$X_t = \left(\pi_t, i_t^s - i_t^l, m_t - p_t, y_t, \varphi_t^e\right)',$$

where φ_t^e denotes the rate of survey-based expected CPIX inflation. An unrestricted VAR(3) system is formulated using X_t above, in which both the short-run adjustment terms and the dummy variable are included in the same way as the baseline model. Mis-specification analysis of the extended five-dimensional VAR(3) model for X_t above leads to a set of fairly satisfactory results in line with those of the baseline model, although there is some evidence for ARCH effects in the residuals. It is known that the cointegrated VAR analysis is robust to such ARCH-type effects, as demonstrated by Rahbek, Hansen and Dennis (2002). Overall, we are justified in conducting a cointegration analysis using this extended VAR system.

Table 4: Tests for cointegrating rank in the extended VAR(3) system

	$r = 0$	$r \leq 1$	$r \leq 2$	$r \leq 3$	$r \leq 4$
$\log LR\{\mathrm{H}(r)\|\mathrm{H}(p)\}$	125.72[0.00]**	84.56[0.00]**	51.42[0.00]**	26.54[0.04]*	6.1[0.46]

mod $(r = 3)$	1	1	0.81	0.81	0.78	0.69

Notes: The figures in the square brackets are *p*-values.

** and * denote significance at the 1% and 5% level, respectively.

The first panel in Table 4 records a battery of log *LR* test statistics for choosing cointegrating rank based on the extended VAR model. According to the table, the null hypotheses of $r = 0$, $r \leq 1$ and $r \leq 2$ are rejected at the 1% level, whereas the null hypothesis of $r \leq 3$ fails to be rejected at the same level, but rejected at the 5% level.

Using the same argument as in Section 5.1, we can infer that the test statistics support the choice of $r = 3$. The second panel in the table displays the modulus of the six largest eigenvalues of a companion matrix of the CVAR system under the restriction of $r = 3$. In line with the argument in Section 5.1, the inspection of the eigenvalues allows us to conclude that the cointegrating rank is 3, or $r = 3$.

Next, Table 5 records log LR test statistics for weak exogeneity in the extended CVAR system with $r = 3$. Consistent with the results in Table 3 in the previous section, we observe that both $m_t - p_t$ and y_t are judged weakly exogenous with respect to the parameters of a partial model for π_t, $i_t^s - i_t^l$ and φ_t^e. Again, we find it possible to focus on the econometric analysis of the partial system without any loss of information.

Table 5: Tests for weak exogeneity in the extended CVAR(3) system

π_t	$i_t^s - i_t^l$	$m_t - p_t$	y_t	φ_t^e
10.54 [0.01]*	9.24[0.03]*	3.58[0.31]	3.22[0.36]	15.22 [0.002]**

Note: The figures in the square brackets are p-values.
** and * denote significance at the 1% and 5% level, respectively.

We proceed to the identification of cointegrating relations embedded in the CVAR system. Let us recall a set of variables in level in the system is as follows:

$$X_{t-1}^* = \left(\pi_{t-1}, i_{t-1}^s - i_{t-1}^l, m_{t-1} - p_{t-1}, y_{t-1}, \varphi_{t-1}^e, t\right)'.$$

Paying attention to the structure of the cointegrating and adjustment spaces in the baseline model as well as the results of the weak exogeneity tests reported in Table 5, we arrive at a set of identified cointegrating relations, which are reported below in the same fashion as equation (14):

$$\hat{\alpha}\hat{\beta}^{*\prime} = \begin{pmatrix} \underset{(-)}{0} & \underset{(-)}{0} & \underset{(0.092)}{0.47} \\ \underset{(0.154)}{0.328} & \underset{(0.089)}{-0.434} & \underset{(0.148)}{0.289} \\ \underset{(-)}{0} & \underset{(-)}{0} & \underset{(-)}{0} \\ \underset{(-)}{0} & \underset{(-)}{0} & \underset{(-)}{0} \\ \underset{(0.066)}{-0.348} & \underset{(-)}{0} & \underset{(0.066)}{-0.355} \end{pmatrix} \begin{pmatrix} \underset{(-)}{1} & \underset{(-)}{0} & \underset{(0.024)}{0.108} & \underset{(-)}{-0.108} & \underset{(-)}{0} & \underset{(0.00014)}{-0.00079} \\ \underset{(-)}{0} & \underset{(-)}{1} & \underset{(-)}{0} & \underset{(0.058)}{-0.336} & \underset{(-)}{0} & \underset{(0.00047)}{0.00269} \\ \underset{(-)}{-1} & \underset{(-)}{0} & \underset{(-)}{0} & \underset{(-)}{0} & \underset{(-)}{1} & \underset{(-)}{0} \end{pmatrix}. \quad (17)$$

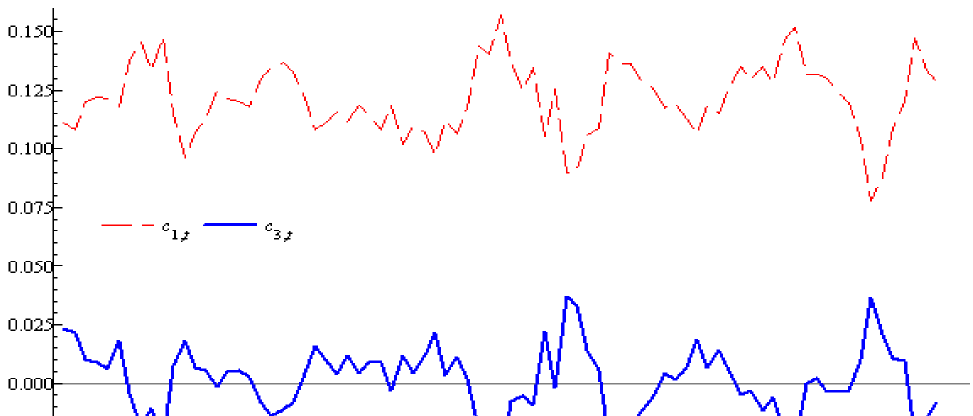
The log LR test statistic for the overall restrictions above is 15.59, the p-value of which is found 0.34 according to $\chi^2(14)$. Thus the joint restrictions in equation (17) are not rejected even at the 10% level. Equation (17) shows the first two equilibrium correction terms are fairly close to $c_{1,t-1}$ and $c_{2,t-1}$ in the baseline model, respectively. We should note that the real money is now perceived as highly significant in the first equilibrium correction term, judging from its coefficient and standard error. In addition, according to equation (17), the third equilibrium correction term is defined as

$$c_{3,t-1} = \varphi_{t-1}^e - \pi_{t-1},$$

which corresponds to equation (13), indicating the presence of a long-run one-for-one relationship between the expected and current inflation rates, although it is necessary to check that $c_{3,t-1}$ is in fact a mean-zero process. The adjustment structure in equation (17) shows that the actual inflation rate is normalized in such a way that it is now driven by $c_{3,t-1}$ instead of $c_{1,t-1}$, while the expected inflation is driven by both $c_{1,t-1}$ and $c_{3,t-1}$. The former finding means that $c_{3,t-1}$ can act as a substitute for $c_{1,t-1}$; as shown in Figure 2, there is a clear countercyclical relationship between $c_{1,t}$ and $c_{3,t}$. It is also observed that $c_{3,t}$ is a mean-zero process, which proves the existence of a long-run one-for-one relationship between φ_t^e and π_t. The finding that $c_{3,t}$ is a mirror image of $c_{1,t}$ indicates that both the rate of expected inflation and the adjusted velocity share a common stochastic trend, which is seen as an empirical characteristic consistent with the shared stochastic trend between the actual inflation rate and the adjusted velocity, as found in the previous section. We are, therefore, able to infer that expected inflation is closely tied to not only realized inflation but also economic fundamentals embodied in the velocity relationship. This evidence may be viewed as an indication that information on expected inflation should be explicitly incorporated in an econometric model for the New Zealand economy, as it is in our analysis.

A further inspection of the adjustment structure in equation (14) allows us to find there is a critical difference between the extended and baseline systems: the interest rate spread $(i_t^s - i_t^l)$ in the extended system is now driven by all the equilibrium correction terms, $c_{1,t-1}$, $c_{2,t-1}$ and $c_{3,t-1}$, in stark contrast to the simple adjustment structure of the baseline system. This finding seems to imply that New Zealand's monetary policy has attached importance to the dynamic interactions among realized inflation, expected inflation and aggregate money. We will examine, using a reduced system estimated below, the details of how the interest rate spread reacts to these three equilibrium errors.

Figure 2: Countercyclical features of $c_{1,t}$ and $c_{3,t}$



Based on the identified structure in equation (14), we seek a parsimonious system for $\Delta\pi_t$, $\Delta(i_t^s - i_t^l)$ and $\Delta\varphi_t^e$ conditional on $\Delta(m_t - p_t)$ and Δy_t. We check whether or not any contemporaneous correlations are present in the data, and then delete a number of insignificant lagged regressors from the model step by step. Imposing restrictions on some of the model's coefficients in order to facilitate their economic interpretations and reduce the number of parameters to be estimated, we arrive at a parsimonious monetary econometric system as follows:

$$
\begin{aligned}
\Delta\pi_t = & \underset{(0.038)}{-0.068}\Delta(m_t - p_t) + \underset{(0.08)}{0.389}c_{3,t-1} + \underset{(0.085)}{0.218}\Delta\pi_{t-2} + \underset{(0.157)}{0.325}\Delta\left(i_{t-2}^s - i_{t-2}^l\right) \\
& + \underset{(0.07)}{0.162}\Delta^2\pi_{t-3} - \underset{(0.072)}{0.148}\Delta^2\pi_{t-4} + \hat{\varepsilon}_{1,t},
\end{aligned}
$$

$$
\begin{aligned}
\Delta\left(i_t^s - i_t^l\right) = & \underset{(0.07)}{0.457}\left(c_{1,t-1} - c_{2,t-1}\right) + \underset{(0.069)}{0.404}c_{3,t-1} + \underset{(0.086)}{0.229}\Delta\left(i_{t-1}^s - i_{t-1}^l\right) \\
& + \underset{(0.172)}{0.371}\Delta\varphi_{t-1}^e - \underset{(0.063)}{0.135}\Delta y_{t-2} - \underset{(0.135)}{0.885} + \hat{\varepsilon}_{2,t},
\end{aligned}
\quad (18)
$$

$$
\begin{aligned}
\Delta\varphi_t^e = & -\underset{(0.049)}{0.32}\left(c_{1,t-1} + c_{3,t-1}\right) + \underset{(0.011)}{0.026}\Delta(m_{t-1} - p_{t-1}) + \underset{(0.083)}{0.338}\Delta\varphi_{t-1}^e \\
& - \underset{(0.081)}{0.232}\Delta\varphi_{t-2}^e + \underset{(0.006)}{0.039} + \hat{\varepsilon}_{3,t},
\end{aligned}
$$

for

$$
\begin{aligned}
c_{1,t-1} &= \pi_{t-1} + 0.108(m_{t-1} - p_{t-1} - y_{t-1}) - 0.00079t, \\
c_{2,t-1} &= i_{t-1}^s - i_{t-1}^l - 0.336y_{t-1} + 0.00269t, \\
c_{3,t-1} &= \varphi_{t-1}^e - \pi_{t-1},
\end{aligned}
$$

$$
\begin{aligned}
&\text{Autocorr.}\,[F_{ar}(45{,}176)] = 1.06\ [0.39], \\
&\text{Hetero.}\,[F_{het}(204{,}221)] = 0.99\ [0.54], \\
&\text{Normality}[\chi_{nd}^2(6)] = 2.93\ [0.82],
\end{aligned}
$$

where standard errors and system mis-specifications tests are recorded in the same way as in equation (16). Figure 3 records a set of fitted values and QQ plots with respect to equation (18), in the same manner as does Figure 1. Again, no evidence is found against the appropriateness of the model in terms of statistical diagnostics.

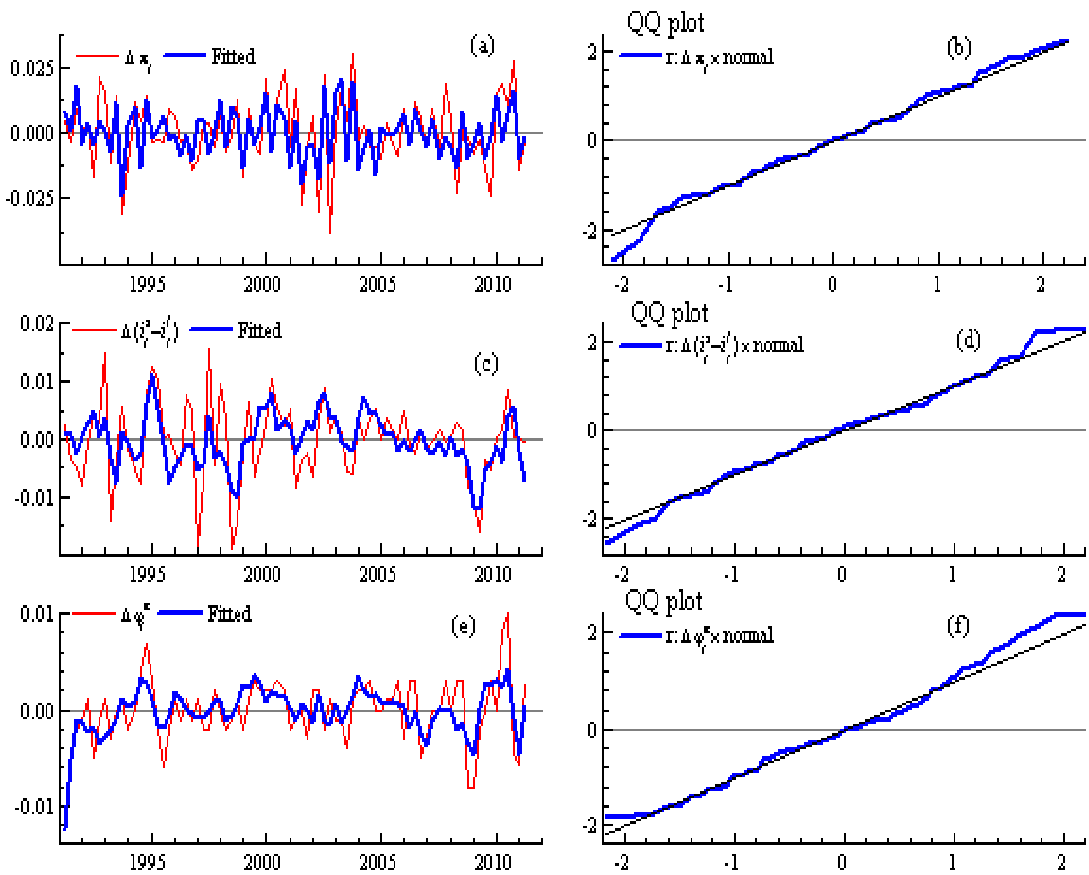
As in line with the adjustment structure in equation (17), $\Delta\pi_t$ reacts to $c_{3,t-1}$ in the first equation, while $\Delta\varphi_t^e$ adjusts to the sum of $c_{1,t-1}$ and $c_{3,t-1}$ in the third equation. The former evidence indicates, as disussed above by referring to (17), the existence of a close linkage between the rates of actual and expected inflation, while the latter implies

$$
\begin{aligned}
c_{1,t-1} + c_{3,t-1} &= \pi_{t-1} + 0.108(m_{t-1} - p_{t-1} - y_{t-1}) - 0.00079t + \varphi_{t-1}^e - \pi_{t-1} \\
&= \varphi_{t-1}^e + 0.108(m_{t-1} - p_{t-1} - y_{t-1}) - 0.00079t,
\end{aligned}
$$

where realized inflation is cancelled out, yielding to a long-run economic relationship between the rate of expected inflation and the velocity of money. We can thus interpret the adjustment of $\Delta\varphi_t^e$ to $c_{1,t-1} + c_{3,t-1}$ as *equilibrium correction* in the standard sense of the words. With reference to the second equation, $\Delta\left(i_t^s - i_t^l\right)$ reacts to $c_{1,t-1}$ and $c_{2,t-1}$ with the same coefficient of different sign (positive and negative), while it is also influenced by $c_{3,t-1}$. All of these results are, in principle, anticipated from equation (17); however, as a result of eliminating insignificant lagged regressors from the system, it is now clearly depicted in equation (18) how the equilibrium correction mechanisms are working in the New Zealand economy.

Let us now have a close look at the second equation for $\Delta\left(i_t^s - i_t^l\right)$, which should be most related to the underlying monetary policy rule. We can see here that, as a consequence of a change in the cointegrating space, the adjustment structure is distinct from that in the baseline model. The presence of $c_{3,t-1}$ in the second equation in equation (18), in particular, indicates one of the critical adjustment mechanisms; that is, if the anticipated one-year ahead inflation rate is greater than the realized inflation rate at present, it then has a significant positive impact on the growth of the interest rate spread, $\Delta(i_t^s - i_t^l)$. This implies that, in the face of anticipated high inflation relative to inflation at the present time, the monetary authority attempts to tighten monetary policy, thus increasing the short-term interest rate relative to the long-term rate. This observation seems to be consistent with inflation-stabilizing policy. Hence, we are able to conceive that quantitative information on inflation, both expected and realized, has played an important role in the conduct of monetary policy in New Zealand. As a result of the existence of $c_{3,t-1}$, the significant role played by $c_{1,t-1}$ in the second equation has also come to light; $c_{1,t-1}$ is acting on $\Delta(i_t^s - i_t^l)$ in combination with $c_{2,t-1}$, which was found in the baseline model in the last section. With regard to the role of $c_{1,t-1}$, it may reasonably be viewed as evidence for some spill-over effects of the money market on the monetary policy rule.

Figure 3: Graphic analysis of the extended system



Furthermore, we should point out that the real money plays critical roles in the overall system (18). Information on monetary aggregates is, therefore, seen as an important factor accounting for the dynamics of anticipated and realized inflation as well as that of monetary policy, even though the New Zealand's monetary authority has basically placed importance to controlling the short-term interest rate, instead of monetary aggregates, since the early 1990s.

Overall, the extended system (18), may be considered as a data-congruent econometric representation capturing the monetary aspects of the New Zealand economy. The preferred system sheds useful light on inflation dynamics as well as the workings of monetary policy in the economy.

7. Summary and conclusion

This paper pursues monetary econometric systems for New Zealand under inflation targeting policy. A thorough CVAR analysis of New Zealand's quarterly time series data not only leads to a baseline monetary econometric system but also results in an extended monetary system, in which an empirical measure of expected inflation plays a critical role. The overall CVAR analysis indicates the presence of three cointegrating linkages in the data, and it turns out that all of these long-run linkages are subject to reasonable interpretations from the viewpoint of monetary economics. It is also demonstrated, in the analysis of the extended system, that information on aggregate money still plays a significant part in the dynamics of expected and realized inflation as well as that of monetary policy. Both the baseline and extended cointegrated systems are reduced to vector equilibrium correction systems, which are seen as satisfactory representations of monetary interactions in the New Zealand economy. We judge that the estimated monetary systems cast much light on inflation dynamics as well as the workings of monetary policy. The systems are, thus, viewed as useful empirical references that can be relied upon to comprehend the monetary aspects of the economy.

Appendix A. Data definitions, sources and notes

A.1. Data definitions

π_t = the percentage change in the GDP deflator index (2005 = 100) over the previous four quarters, *i.e.* $\Delta^4 p_t$,

$m_t - p_t$ = the log of the end-of-period M3 $-$ the log of the GDP deflator index,

y_t = the log of the seasonally-adjusted real GDP,

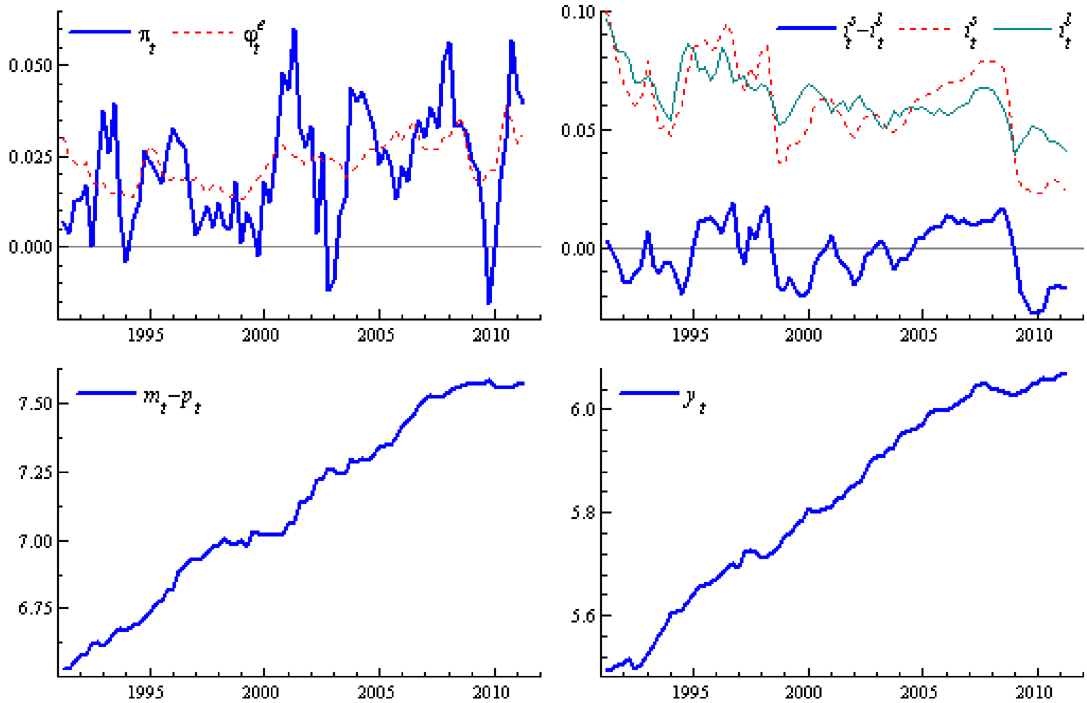
$i_t^s - i_t^l$ = the overnight call rate (OCR) $-$ the yield on 5 year government bond,

φ_t^e = the expected one-year-ahead CPIX inflation based on a survey of business managers.

A.2. Sources and notes

The data of π_t, $m_t - p_t$, y_t and $i_t^s - i_t^l$ are obtained from *International Financial Statistics* (International Monetary Fund), while those of φ_t^e are taken from the website of the Reserve Bank of New Zealand. Each component in the interest rate spread is defined as $i_t^s = log\,(1 + I_t^s/100)$ and $i_t^l = log(1 + I_t^l/100)$, where I_t^s and I_t^l denote the corresponding original series (in percent) available in the data source.

Appendix B. An overview of the data



As shown in the top right figure above, the short-term policy interest rate i^s_t represented by the dotted line, not the long-term government bond rate i^l_t by the thin line, dominates movements in the spread $(i^s_t - i^l_t)$ between the two.

Table A-1: Correlation matrix

	$i^s_t - i^l_t$	i^s_t	i^l_t
$i^s_t - i^l_t$	1.000	0.807	0.273
i^s_t	0.807	1.000	0.789
i^l_t	0.273	0.789	1.000

As shown in Table A-1, the correlation coefficient between $(i^s_t - i^l_t)$ and i^s_t is 0.807, while that between $(i^s_t - i^l_t)$ and i^l_t is just 0.273.

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