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A Distant-Early-Warning Model of Inflation Based on M1 Disequilibria

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Abstract

A vector error-correction model (VECM) that forecasts inflation between the current quarter and eight quarters ahead is found to provide significant leading information about inflation. The model focusses on the effects of deviations of M1 from its long-run demand but also includes, among other things, the influence of the exchange rate, a simple measure of the output gap and past prices.

In out-of-sample forecasts of the eight-quarter inflation rate from 1978 on, the VECM had a mean absolute error of just over one percentage point, and a root-mean-squared error of just under two. From the early 1980s on, mean absolute errors and root-mean-squared errors were both less than one percentage point. In addition, except for 1982, the model performed well around the turning points in out-of-sample experiments.

An interpretation of these results is that monetary disequilibria — represented here as deviations of M1 from its long-run demand — are part of the inflation process. That is, in this model, a “money gap” precedes inflation, and an aggregate money gap persists until prices change to help restore monetary equilibrium.

Résumé

Les auteurs de la présente étude sont parvenus à la conclusion qu’un modèle de correction des erreurs qui prévoit l’évolution du taux d’inflation entre le trimestre de la prévision et les huit trimestres subséquents fournit d’importants renseignements avancés sur l’évolution de l’inflation. Les auteurs se concentrent sur les effets des déviations de M1 par rapport à son niveau de long terme, mais ils incorporent également au modèle, entre autres variables, l’influence du taux de change, une mesure simple de l’écart de production et le niveau des prix antérieurs.

Dans les prévisions hors échantillon qui sont faites depuis 1978 sur l’évolution de l’inflation dans un intervalle de huit trimestres, le modèle de correction des erreurs affichait une erreur moyenne absolue à peine supérieure à un point de pourcentage et une erreur quadratique moyenne à peine inférieure à deux points de pourcentage. Depuis le début des années 80, les erreurs moyennes absolues et les erreurs quadratiques moyennes étaient les unes comme les autres inférieures à un point de pourcentage. Sauf pour 1982, le modèle s’est par ailleurs bien comporté aux points de retournement lors des expériences menées en dehors de la période d’estimation.

Une interprétation possible de ces résultats est que les déséquilibres monétaires — représentés ici comme des déviations de M1 par rapport à son niveau de long terme — font partie intégrante du processus inflationniste. Cela signifie que, dans le présent modèle, un «déséquilibre monétaire» précède l’inflation et persiste à l’échelle globale jusqu’à ce qu’un changement de prix intervienne pour rétablir l’équilibre monétaire.

CONTENTS

1. Introduction

Monetary policy actions affect prices only after a considerable lag, generally thought to be about six to eight quarters. As a result, the Bank of Canada makes its policy decisions with a view to the future. That is, decisions on the appropriate track for monetary conditions are influenced predominantly by the Bank's outlook for inflation over the next two years. Thus, forecasts of inflation are an important part of the forward-looking policy-making process. In this paper, we consider a vector error-correction model (VECM) that forecasts inflation eight quarters into the future — what we call a distant-early-warning (DEW) model of inflation.

This inflation-forecasting model follows from recent work by Hendry (1995) on the long-run demand for the monetary aggregate M1. That work estimates a four-equation VECM for M1, prices, output and interest rates. The model is based on a conventional view of the transmission mechanism in which inflation is a monetary phenomenon. More specifically, the VECM focusses on the effects of deviations of M1 from its long-run demand on the inflation rate. However, the model also includes, in addition to lagged endogenous variables, a short-term U.S. interest rate, the exchange rate and a simple measure of the output gap.

The empirical results indicate that the VECM provides significant leading information about inflation. In out-of-sample forecasts of the eight-quarter inflation rate from 1978, the model had a mean absolute error of just over one percentage point, and a root-mean-squared error of just under two. From the early 1980s on, the VECM had mean absolute errors and root-mean-squared errors both less than one percentage point. In addition, except for 1982, this model performed well around the turning points in our out-of-sample experiments.

An interpretation of these results is that monetary disequilibria — represented here as deviations of M1 from its long-run demand — are part of the inflation process. That is, in this model, a "money gap" precedes inflation, and an aggregate money gap persists until prices change to help restore monetary equilibrium.

The next section of this paper discusses the measure of inflation that we consider, the eight-quarter inflation rate. Section 3 provides an overview of the model, while Section 4 examines the ability of the VECM to fit the inflation data. Out-of-sample forecasting performance is assessed in Section 5. Section 6 provides an interpretation of the model, and concluding remarks are in Section 7.

2. The measure of inflation

Transitory, short-term changes in the inflation rate will reverse without the central bank's intervention. On the other hand, persistent or permanent changes in inflation require a response from the central bank. Accordingly, the focus of our model is the general direction that prices are taking, or put differently, the medium-term trend in inflation. More specifically, we forecast the annual average inflation rate over the next eight quarters, that is, the rate of change between the price level today (t) and eight quarters later (t+8), expressed at an annual rate. For simplicity, we call this the "eight-quarter inflation rate."

The specific index of prices on which we focus is the consumer price index (CPI), for two reasons. First, the focus of Bank of Canada policy is the inflation-control targets, which are in terms of the CPI. Second, this paper builds on previous work that is based on the CPI.

The DEW model that we consider is a VECM that was developed by Hendry (1995) to estimate the long-run demand for M1. In that work, the most plausible long-run money-demand function was found when non-seasonally adjusted data were used in the estimation. Since we use that function here, our VECM forecasts non-seasonally adjusted CPI inflation. Note, however, that the non-seasonally adjusted eight-quarter CPI inflation rate is almost perfectly correlated with the seasonally adjusted rate over our sample, and in assessing the forecast accuracy of the VECM, we compare its forecasts to the seasonally adjusted CPI inflation rate.

3. A vector error-correction DEW model

As noted above, our DEW model is a VECM developed by Hendry (1995) to estimate the long-run demand for M1. Accordingly, in this section, we provide a summary of that work. We begin with a brief overview of the Johansen-Juselius approach to cointegration, which is used to estimate the VECM.

3.1 An overview of the Johansen-Juselius methodology

In the last several years, there has been growing interest in estimating cointegration relationships in a systems-of-equations framework to make better use of all the information available in the long- and short-run fluctuations of the variables. Johansen (1988) outlined a method, which was later expanded by Johansen and Juselius (1990), that tests for more than one cointegration vector in the data and calculates maximum-likelihood estimates of these vectors.

The Johansen-Juselius (JJ) methodology begins with a statistical model of the following form:

$$X_t = \Pi_1 X_{t-1} + \ldots + \Pi_k X_{t-k} + \mu + \Psi D_t + \varepsilon_t \qquad (1)$$

where X_t is a vector of p variables, ε_t is a vector of disturbances such that $\varepsilon_1, \ldots, \varepsilon_T$ are IINp(0,Λ), μ is a constant, and D_t is a vector of exogenous variables including seasonal dummies. Many economic variables are nonstationary, so a first-difference operator is often applied to equation (1) to ensure that the variables are stationary. However, this can lead to a loss of valuable long-run information. Thus, JJ use some simple algebra to rewrite equation (1) as a VECM:

$$\Delta X_t = \Gamma_1 \Delta X_{t-1} + \ldots + \Gamma_{k-1} \Delta X_{t-k+1} + \Pi X_{t-k} + \mu + \Psi D_t + \varepsilon_t \qquad (2)$$

where $\Gamma_i = -(I - \Pi_1 - \ldots - \Pi_i)$ (3)

and $\Pi = -(I - \Pi_1 - \ldots - \Pi_k)$. (4)

The JJ technique decomposes the matrix Π (pxp) to discover information about the long-run relationships among the variables in X.

In particular, Π can be written as $\Pi = \alpha\beta'$, where β' is an rxp matrix of r cointegration vectors (so that the r variables $\beta'_i X_t$ are stationary) and α is a pxr matrix. Thus, the JJ technique provides maximum-likelihood estimates of α and β'. The β vectors represent estimates of the long-run cointegration relationships among the variables in the system. The α parameters, referred to as the loadings, measure the speed at which the variables adjust to restore long-run equilibrium. Since $\beta'_i X_t$ measures the disequilibrium for a particular vector i, it follows from equation (2) that, given $\Pi = \alpha\beta'$, the α parameters will determine the size of the contemporaneous changes as the economy moves back towards equilibrium.

3.2 The long-run demand for M1

Hendry (1995) uses the JJ methodology to study long-run relationships among M1, the price level, output and interest rates, with a view to determining if there is a stable cointegration relationship that can be interpreted as long-run money demand. In particular, that work estimates a four-equation VECM for M1, the price level, output and interest rates from 1956 to 1993, like the system set out in equation (2).

As a result of the JJ technique used, all of the information available in the short-run dynamics and the long-run movements of the variables is exploited to estimate the coefficients of the long-run money-demand equation. As well, a number of exogenous variables are included to help model the short-run dynamics of the system, and to help identify a unique cointegration vector among M1, prices, output and interest rates. These exogenous variables are the change in a short-term U.S. interest rate, the change in the Canada–U.S. exchange rate, a simple measure of the output gap, a GST dummy, and a permanent shift dummy for the early 1980s to account for the financial innovations that occurred at that time.[1]

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1. The shift dummy is zero before 1980:1 and one after 1982:4, and it increases linearly between those dates. This is designed to approximate the slow introduction and dissemination of financial innovations. As regards the output gap, the measure used in the VECM is the residual from a regression of GDP on linear and quadratic time trends.

Money-demand relationships were estimated for a number of different data definitions, including raw and seasonally adjusted, nominal and real, and monthly and quarterly series. The best results were found with raw, quarterly data for nominal gross M1: equation (5) defines a stable and unique long-run (cointegration) relationship among the natural logarithm of nominal M1, the CPI, real GDP and the level of the 90-day commercial paper rate (R90).

$$M1_t = -0.503 - 0.141 D80_t + 0.930 CPI_t + 0.597 GDP_t - 0.038 R90_t \quad (5)$$

The variable D80 is the dummy that accounts for financial innovations or other factors causing a permanent negative shift in the M1 demand function in the early 1980s. The hypothesis of long-run unitary price elasticity was easily accepted for this equation with little change in the other coefficients. The income elasticity is reasonably close to one-half, as it would be in a simple Baumol-Tobin type model, but the hypothesis of unitary income elasticity was rejected. With a restriction of unitary price elasticity, equation (5) becomes

$$M1_t = 0.031 - 0.178 D80_t + 1.0 CPI_t + 0.524 GDP_t - 0.035 R90_t . \quad (6)$$

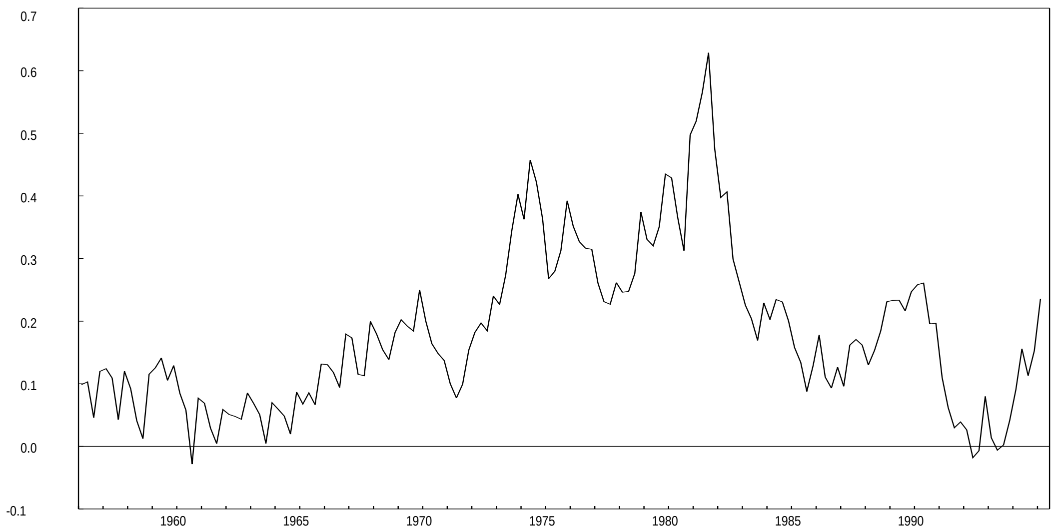
The coefficients on the deviation of money from its long-run equilibrium in the VECM — the speeds of adjustment — also conformed to theory. In particular, when M1 is above its long-run demand, money will decrease and prices will increase to restore long-run equilibrium. The effects on output and interest rates of such a deviation are insignificant, implying the "weak exogeneity" of these two variables. Thus, the adjustment to return the economy to monetary equilibrium comes from fluctuations in money and prices. However, this does not preclude the possibility that changes in the stock of money can have short-run real effects. In fact, the short-run dynamic coefficients indicate that lagged values of ΔM1 do affect $\Delta M1_t$, ΔGDP_t, and $\Delta R90_t$, but not ΔCPI_t.[2] In sum, M1 seems to be important for short-term changes in

2. These short-run dynamic results are consistent with the findings of previous research conducted at the Bank of Canada on the short-term effects of changes to M1. See Muller (1990), for example.

output and for the longer-term trend or movement in prices, but less so for short-run fluctuations of inflation.

Figure 1 plots the deviation of M1 from its long-run demand, that is, the "money gap," from 1956 to 1994 from equation (5).[3]

Figure 1: Money gap from equation (5)



This money gap series is highly correlated with inflation. As well, much of the volatility in the money gap seems to be caused by movements in interest rates. For example, most of the increase in the money gap shown in Figure 1 for 1994 is the result of increases in interest rates, which decreased estimated long-run money demand. Similarly, the spike in the money gap in 1981 appears to be related to a sharp increase in short-term interest rates around that time. Nevertheless, this work suggests that M1 disequilibria could be a significant determinant of future inflation.

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3. The M1 gap shown in Figure 1 is from a system in which a constant is restricted to appear only in the cointegration vector and not in the short-run dynamics of the VECM, a restriction that was accepted by the data. As shown in Hendry (1995), it is possible to apportion an unrestricted constant to both the cointegration vector and the short-run dynamics so that the M1 gap series is centered on zero, instead of on a non-zero value as in Figure 1.

In sum, Hendry (1995) has identified a unique, stable and well-specified long-run demand function for M1, represented as a cointegration vector among M1, GDP, the CPI and R90. The results suggest that changes in M1 lead short-term changes in output, and that deviations of M1 from its long-run demand — M1 disequilibria or money gaps — lead changes in prices.

4. In-sample fit of the eight-quarter inflation rate

As noted above, the VECM was estimated with a number of exogenous variables, that is, the changes in the Canada–U.S. exchange rate and a short-term U.S. interest rate, a shift-dummy variable, a GST-dummy variable, and a simple measure of the output gap. Accordingly, to generate either in-sample or out-of-sample predictions with this model, we need to specify the behaviour of these exogenous variables over the prediction horizon.

For example, in Figure 2, one of the fitted eight-quarter inflation rate series (the “random walk” model) is based on the VECM as estimated over the entire sample period, 1956 to 1994, but each fitted eight-quarter inflation rate is conditioned only on information available at the beginning of each eight-quarter horizon. Accordingly, for each eight-quarter prediction horizon we assume that the exchange rate and the U.S. treasury bill rate follow a random walk (that is, the levels of these variables are kept unchanged at their most recent values). We include the two dummy variables as if we knew them in advance — of course, forecasting these shocks is beyond the scope of this (or any other) model. Thus, in this case, we treat both the shift in money demand and the GST shock as truly exogenous and presumably unique events, or at least very infrequent events.[4] The output gap, which is measured simply as the residual from a regression of output against linear and quadratic time trends, is updated endogenously through the simulation period, given the predicted values of GDP from the VECM.

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4. In this regard, note that Hendry (1995) found evidence of only one shift in M1 demand over the almost 40 years covered in his study. (In comparison, indirect tax shocks, for example, have been much more frequent in the last 40 years.)

Figure 2 shows that the VECM, under the “random-walk” assumptions, fits the inflation experience of the last 25 years reasonably well: the mean absolute error of the fitted eight-quarter inflation rate is 1.3 percentage points and the root-mean-squared error is 1.7 percentage points from 1972 to 1994 — a period characterized by large swings in the inflation rate.[5] However, it makes some substantial errors, especially in the early 1970s and the early 1980s. Also, it may appear that the fitted eight-quarter inflation rates might in general be simply following the actual (lagged) inflation experience: note, for example, the model’s performance in 1976 and 1983-84. However, examining Figure 1 suggests that what is driving the peak of the VECM inflation prediction in early 1976 and in early 1983 (shown in Figure 2) is not simply lagged inflation, but the (lagged) M1 gap.

Figure 2 also shows the VECM’s in-sample predictions of the eight-quarter inflation rate under more generous (but perhaps less relevant) assumptions with respect to knowledge about the exchange rate and the U.S. interest rate over the prediction horizon. In this case, instead of assuming that these variables follow a random walk over the prediction horizon, we use their actual values. Thus, under these circumstances (the “future information” case), the VECM performs somewhat better, most notably at the end of the 1970s and in the first part of the 1980s, which is not surprising. In the late 1970s and first few years of the 1980s, the exchange rate and short-term U.S. rates were both very volatile, so that the random-walk assumption is misleading for these years. However, in general, giving the VECM future information about the behaviour of the exchange rate and short-term U.S. rates does not really alter its performance much from that in the random-walk case. As well, note that the errors in the early to mid-1970s might be related to the first oil shock; however, efforts to account for this by using dummy variables did not improve the model’s performance.

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5. The Rbar^2 statistic is not an appropriate goodness-of-fit measure in this case, because the variable that we are fitting, the eight-quarter inflation rate, is not the dependent variable of the VECM. The VECM forecasts the price level, from which we calculate the eight-quarter inflation rate. (As a result, the Rbar^2 statistic is not necessarily bounded by zero and one.)

5. Out-of-sample performance of the VECM

In this section, out-of-sample inflation forecasts of the VECM are presented. That is, we provide eight-quarter inflation forecasts based on recursive estimations of the VECM over a series of subsamples.

5.1 Out-of-sample eight-quarter inflation forecasts

We start by estimating the model over subsamples beginning in 1956 and forecasting the (annualized) inflation rate over the next eight quarters. Then we add a quarter of data, re-estimate the VECM and forecast the next eight-quarter inflation rate. Another quarter of data is then added to our sample, we again re-estimate the model, and the next eight-quarter inflation rate is forecasted. In this way, we generate a quarterly series of dynamic, out-of-sample, eight-quarter inflation forecasts.

As noted above, Hendry (1995) found that the cointegration vector β (among M1, GDP, the CPI and R90), which underpins the VECM, is unique and stable. Accordingly, in the period-by-period re-estimation of the VECM, we keep the cointegration vector fixed for this forecasting exercise. Put differently, in terms of equation (2), we keep β fixed. However, for each subsample, we re-estimate all the other parameters of the system, including the speeds of adjustment to long-run monetary equilibrium. That is, we re-estimate the Γ parameters, which are the coefficients on the lagged, differenced variables, and the α parameters, which are the speeds of adjustment to long-run money disequilibrium.[6] (We re-estimate the VECM in each subsample with ordinary least squares estimation, while Hendry's work was based on maximum-likelihood estimation.)

As regards the exogenous variables in the VECM, again, we assume that the exchange rate and the short-term U.S. interest rate follow a random walk over the forecast horizon. Our measure of the

6. One extension of the present work could be to re-estimate the cointegration vector for each subsample relevant to the out-of-sample forecast. However, one drawback of this is that shorter time series lead to less reliable estimates of long-run relationships in the data, like cointegration, especially when the equilibrating process is a slow one (Hendry 1986, Perron 1989 and Siklos 1993).

output gap is updated through the forecast period by the forecasted values of GDP from the VECM. Finally, we include the shift dummy as if we knew of this particular shock in advance; however, we do not include a GST-dummy variable.

The first case presented in Table 1 shows the mean absolute error and the root-mean-squared error for the 17-year out-of-sample period from 1978 to 1994 inclusive. That is, the VECM is initially estimated from 1956 to 1978:1. This estimation is used to provide an out-of-sample forecast for the inflation rate over the eight quarters following 1978:1, that is, 1978:2 to 1980:1 inclusive. (This forecast is shown in Figure 3 at 1980:1.) Then we add a quarter of data, in this case, 1978:2, and repeat the process: Re-estimate the VECM, keeping (only) the cointegration vector fixed, and forecast the eight-quarter inflation rate following 1978:2, that is, the inflation rate over 1978:3 to 1980:2 inclusive. This process is repeated until we generate a quarterly series of out-of-sample, eight-quarter forecasts of CPI inflation from 1978 to 1994 inclusive. The other cases shown in the table consider shorter out-of-sample forecast periods.

Table 1: Out-of-sample forecast performance of the VECM for the eight-quarter inflation rate

Out-of-sample forecast period	Mean absolute error (percentage points)	Root-mean-squared error (percentage points)
1978:2 to 1994:4 (17 years)	1.2	1.8
1982:2 to 1994:4 (13 years)	0.8	1.1
1983:2 to 1994:4 (12 years)	0.6	0.8
1987:2 to 1994:4 (8 years)	0.6	0.8

As shown in Table 1 and illustrated in Figure 3, the VECM generally performs well out-of-sample. Over the whole 17-year period, the mean absolute error is just over one percentage point, and the root-mean-squared error is just under two. In Figure 3, we see that most of the error comes during the sharp drop in inflation in the early 1980s. Indeed, after the early 1980s, the VECM forecasts the eight-quarter inflation rate with mean absolute errors and root-mean-squared errors both less than one percentage point.

In the out-of-sample period that we are considering, that is, the 17 years from 1978 to 1994, there are four turning points in the inflation data: (i) 1982, when inflation peaked and then fell sharply; (ii) 1984, when inflation stopped falling and plateaued; (iii) 1991, when the gradual run-up of inflation in the late 1980s peaked and fell sharply; and (iv) 1994, when the drop in inflation levelled off. Notably, the VECM calls the last three of these turning points well in advance.

However, the model makes some significant errors forecasting the sharp drop in the eight-quarter inflation rate in the early 1980s; note the brief, although large spike in Figure 3. The forecast of almost 15 per cent for 1983:3 was made at 1981:3, before inflation peaked at 1982:1. By 1982:1, the model was forecasting a very sharp drop in the eight-quarter inflation rate, and the VECM continued to correctly forecast significant declines in inflation. Thus, even though the model made some significant forecast errors in this episode, it still provided some useful advance information about the break in inflation through this period.

5.2 Two qualifications

The preceding analysis suggests that the VECM provides significant leading information about inflation, well in advance. However, as discussed above, the M1 gap is sensitive to movements in short-term interest rates, which can make the M1 gap volatile. Accordingly, inferences from the VECM during periods of sharp interest-rate swings would need to be considered carefully. (The most notable example of this type of episode in our sample is the early 1980s.)

Recently, there have also been changes with respect to the nature of current accounts, one of the components of M1. (The other components of M1 are currency holdings outside financial institutions and personal chequing accounts.) Prior to the early 1990s, current accounts did not pay interest; however, in the last few years these accounts have begun to pay interest in proportion to the size of the account balance (Bank of Canada 1995). Both the interest sensitivity of M1 demand and M1 might be affected by these changes, and this could influence the forecasting ability of our VECM. Accordingly, these developments (along with other financial innovations) and their potential impact on the VECM would need to be monitored.[7]

6. An interpretation

The central construct of the VECM is the cointegration relationship between M1, prices, output and a short-term interest rate. We interpret this relationship as aggregate long-run money demand, following Hendry (1995).

Accordingly, the model is based on the idea that firms and individuals change their expenditure and investment plans when their actual money holdings are different from their desired money holdings, and this reaction affects the inflation rate. That is, in response to the discrepancy between their actual and desired money balances, firms and individuals alter their expenditure and investment flows in an effort to move their money balances back toward levels with which they are more comfortable. For the economy as a whole, a discrepancy between the aggregate money stock and estimated long-run money demand continues until the factors that affect the aggregate supply and demand for money adjust to restore equilibrium. As part of that adjustment process, that is, the process of restoring monetary equilibrium, prices change.[8]

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7. Rolling stability tests of the long-run M1 demand equation from the VECM indicate that the relationship has remained stable (so far), despite the recent innovations to current accounts.

8. As noted in Section 3, Hendry (1995) found that adjustments to M1 and prices were critical to eliminating deviations of M1 from its long-run demand.

Of course, this is fundamentally a traditional, familiar story of the transmission mechanism; see, for example, Friedman (1956, 1970), Johnson (1962) or Laidler (1990). (In a forthcoming study, Kasumovich (1996) explores further the dynamics of this money-gap story in the context of a structural vector autoregression model.)

In sum, an M1 disequilibrium precedes inflation, and a money gap persists until the price level changes to help restore monetary equilibrium.

7. Concluding remarks

Monetary policy actions have their effect on prices only after a considerable lag, generally thought to be about six to eight quarters, so that inflation forecasts are an important part of the policy-making process. In this paper, we considered a VECM that focusses on narrow-money disequilibrium. However, the model also includes, in addition to lagged endogenous variables, a short-term U.S. interest rate, the exchange rate, and a simple measure of the output gap. Our empirical results indicate that the VECM forecasts the eight-quarter inflation rate well. For example, in our out-of-sample forecast exercises from the early 1980s, the VECM had mean absolute errors and root-mean-squared errors both less than one percentage point. As well, this model generally performed well around the turning points in our out-of-sample experiments.

However, given the interest sensitivity of the M1 gap, inferences from the VECM during periods of sharp interest-rate swings would need to be considered carefully. As well, the potential impact on the VECM of any financial innovations would need to be monitored.

An interpretation of these results is that monetary disequilibria — represented here as deviations of M1 from its long-run demand — are a part of the inflation process. That is, an M1 disequilibrium precedes inflation, and a money gap persists until prices change to help restore monetary equilibrium.

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Figure 2: In-sample fit of VECM: "Random-walk" assumption and "Future information" assumption

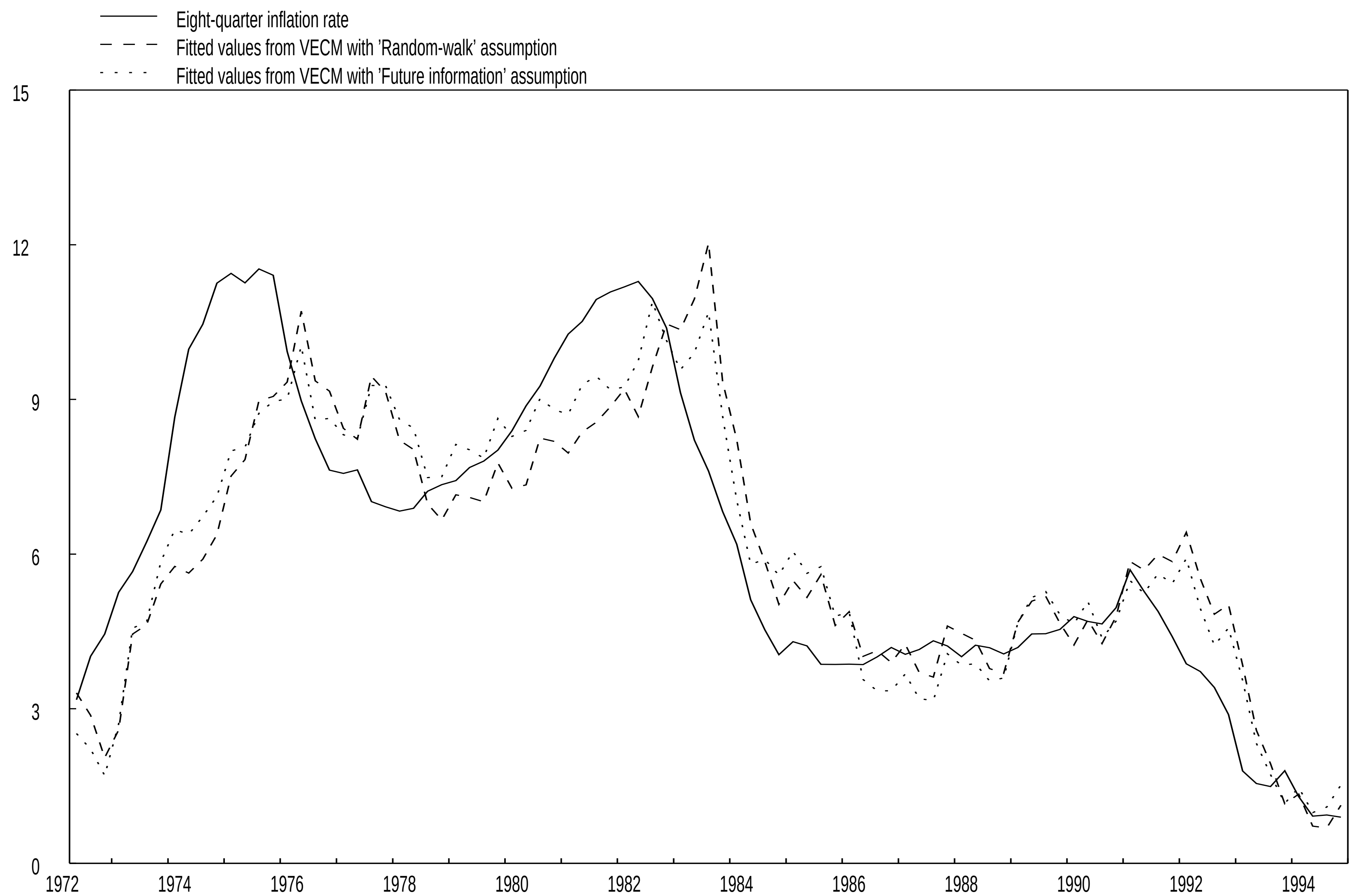
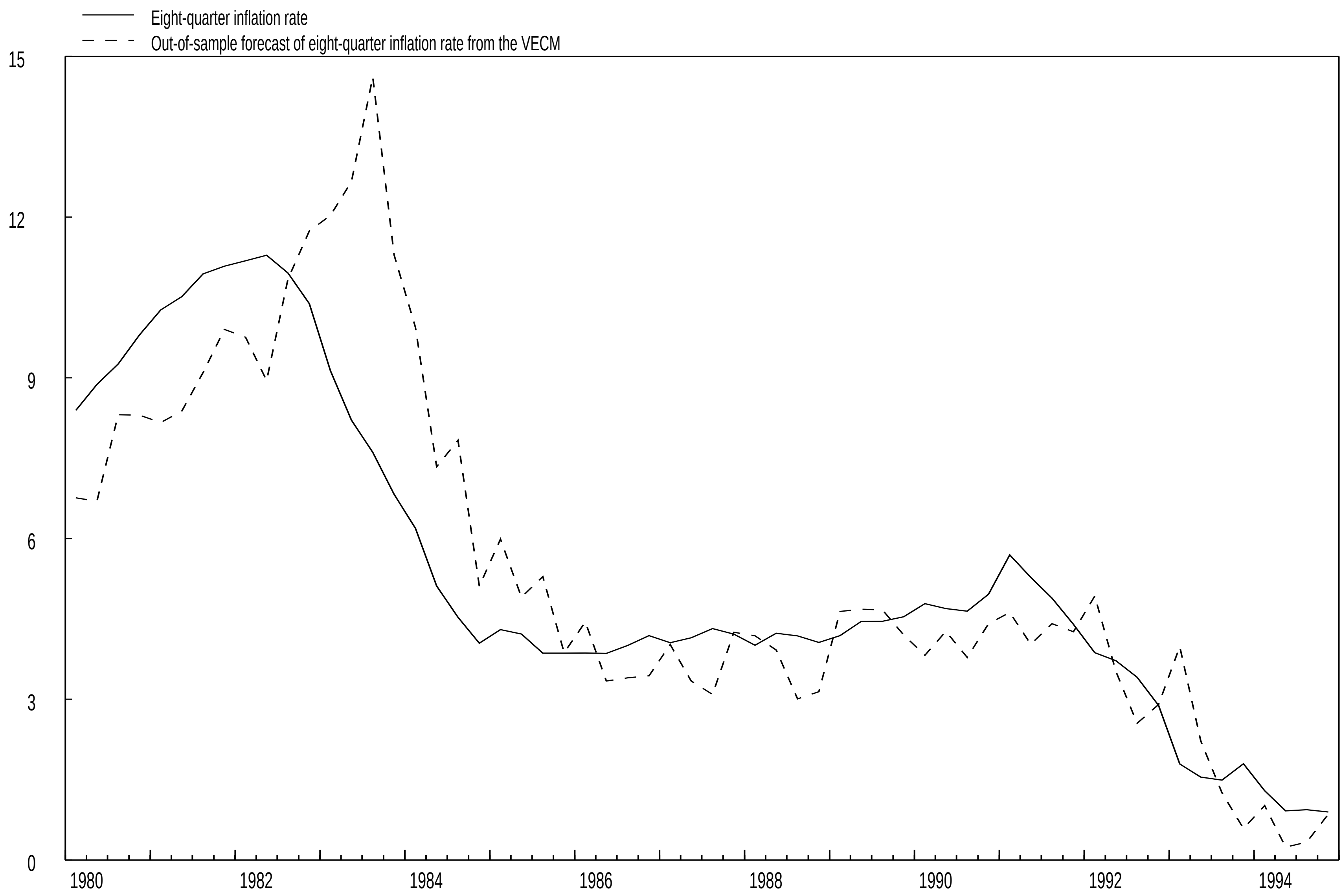


Figure 3: VECM out-of-sample forecasts



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