The M1 Vector-Error-Correction Model: Some Extensions and Applications

Charleen Adam and Scott Hendry

> Conducting monetary policy . . . is akin to driving without full vision—perhaps like driving in a rainstorm with defective windshield wipers. It can be done, but only very carefully. (John Crow, Eric J. Hanson Memorial Lecture, 1988)

> The Fed's dilemma is like that of a tugboat captain pushing a long string of barges in a dense fog; the awkward load is difficult to pilot. He needs to start his turn half a mile before the bend. But he can't see the bend until it's too late. (Allan Murray, *The Wall Street Journal*, 1989)

Introduction

Monetary policy-makers face a difficult task when evaluating the current state of the economy and deciding what actions are needed to achieve their objectives, such as keeping inflation within a given range. Because long and variable lags exist between a monetary policy action and its effects on economic variables, policy-makers need a way to assess whether their actions are having, or indeed will have, the desired effect.

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Economists at the Bank of Canada use inflation forecasts, in addition to other variables considered to have leading-indicator properties, to inform policy-makers' views on the current and future state of the economy. Some of these variables are new orders and shipments, housing market activity, inflation, and various money and credit aggregates. Since no one single indicator is superior to all others, a good strategy is to monitor many variables to try to ensure that the best signals about the economy are being considered. This strategy also extends to models. Given that a model is simply a collection of assumptions or behavioural rules about the way an economy works, economists maintain several models for forecasting or conditional projections.[1]

Economists at the Bank have pursued modelling strategies along a continuum anchored at one end by purely theoretical approaches and at the other end by purely empirical approaches.[2] The model we use in this paper is an M1 vector-error-correction model (VECM), which could be described as lying somewhere between the middle of the continuum and the purely empirical end. At the heart of this model is a long-run money-demand function. Several extensions have been made to the basic model Hendry (1995) presented to add more theory (or structure) to it in order to make it more useful for conducting counter-factual analysis: for asking "what if" questions.

Sections 1 and 2 provide some background and context for the M1 VECM and discuss the changes made to Hendry's original model. Section 3 details why gross M1 is no longer the preferred measure of narrow money for the VECM and outlines how adjusted M1, the preferred measure, is constructed. Section 4 discusses the identification of policy shocks in the VECM, and section 5 lays out the framework for using information from models to inform policy. Section 6 provides some direction for future work.

1 Background

Inflation is essentially a monetary phenomenon. In the long run an excess creation of money is bound to lead to inflation. In the short run the links may not be as tight. After an unsuccessful attempt at using money-growth targets to reduce inflation in the 1970s both here in Canada and in the United States, many models now used to guide policy advice assume that money plays only a passive role and may be ignored for all practical purposes because the

1. Engert and Selody (1998) and Berk (1997) made excellent arguments for the use of multiple models in formulating monetary policy. No single model can capture all aspects of the economy, so it is useful for policy-makers to have several different models summarizing different views or aspects of the economy.
2. Thanks are due to Kevin Moran and Jack Selody for suggesting this analogy.

central bank and commercial banks are assumed to simply supply money passively in accordance with agents' demand. Consequently, no causal role is given to money in these models of inflation. This paper uses an active-money paradigm in which money causes inflation. However, in this model, money's causal effect on inflation does not depend on using money as the instrument of monetary policy, as is the case in many theoretical models. A very short-term interest rate such as the overnight rate can be considered to be the instrument of monetary policy, consistent with the Bank of Canada's operating procedure. In responding to changes in the overnight rate, financial intermediaries make loans to agents in the economy and hence create deposits. These agents then transact with other agents using the newly created balances, leading to changes in the level of aggregate activity and prices. The underlying premise is that agents have a long-run demand for money, and the amount of money an agent actually holds fluctuates around these desired money holdings. For the purposes of the discussion below, the difference between actual money supply and estimated long-run money demand (using the long-run parameters but evaluated at the current values of the variables in the long-run demand function) is called the money gap.[3]

Laidler (1999) discussed the passive- and active-money views, drawing on the buffer-stock theory to explain why people may temporarily be off their long-run money-demand function.[4] For example, suppose an agent receives an unanticipated lump sum of money. Information and transaction costs are involved in deciding what to do with the money and then doing it. Hence, it is optimal to take some time to arrive at a decision, and consequently at any time an agent's actual holdings of transactions money might differ from his or her desired long-run holdings of money. That is, actual money holdings fluctuate around the desired level (i.e., long-run demand for money), much as a firm's inventories fluctuate around some level of desired inventory holdings. A firm or individual with money holdings exceeding the desired level of money balances will act to get rid of these excess balances by transacting with other agents in the economy. An excess aggregate supply of money can translate into inflationary pressure in much the same way that an excess demand for goods does; too much money chases too few goods. Hence, a positive money gap, where the stock of money exceeds the aggregate long-run demand for money, is associated with

3. In this sense, what is being evaluated is the difference between actual money and today's value of the long-run demand for money. The long-run money-demand function could also be evaluated at the long-run values of the variables in the long-run demand function, but doing so causes the money gap to lose most of its predictive power. This is likely because rather than evaluating money supply at its actual value, the model should include some notion of long-run supply. Identifying the money-supply process is an area for future work.
4. Laidler's (1999) discussion focuses on narrow, or transactions, money.

periods of rising inflationary pressure, and a negative gap, where the stock of money is less than long-run demand for money, is associated with disinflationary pressures.

The adjusted-M1 VECM presented in this paper is an extension of work done by Hendry (1995), who estimated a unique long-run cointegrating vector between M1, output, prices, and a short-term interest rate. The vector can be thought of as a long-run money-demand function. Since money demanded does not have to be equal to money supplied at each point in time (though they must be equal in the steady state), the error-correction term of the VECM can be thought of as a money gap, which has been shown to have predictive power for inflation.[5]

2 Details of the VECM

The model used in this paper is similar to Hendry's original model in that it estimates a unique and stable long-run cointegrating vector between quarterly data for nominal M1, real output, the consumer price index, and a short-term interest rate. This vector can be also considered to be a long-run money-demand function. (See the appendix for more details on the model.)

The Johansen-Juselius (1990) methodology was used to estimate the long-run cointegrating vector from a VECM of the form

$$\Delta X_t = \Gamma(L)\Delta X_t + DZ_t + \alpha\beta'[X_{t-1}], \tag{1}$$

where X_t is a vector of endogenous variables (i.e., money, output, prices, and interest rates), $\Gamma(L)$ is a matrix of parameters for a fourth-order lag process, Z_t is a vector of stationary exogenous variables including seasonal dummies, and D is the matrix of parameters associated with the exogenous variables. The α parameters measure the speed at which the variables in the system adjust to restore a long-run equilibrium, and the β vectors are estimates of the long-run cointegrating relationships between the variables in the model.

This system was found to have a unique stable long-run cointegrating relationship between money, inflation, output, and interest rates. Unitary price elasticity is imposed (i.e., prices move one for one with changes in money), and the long-run coefficient on output is around 0.5 while that on the interest rate is about –0.04, both of which are consistent with previous work.[6]

5. Armour et al. (1996) and Engert and Hendry (1998) found the VECM to be a good inflation-forecasting model at horizons of one to two years. As well, Fung and Kasumovich (1998) found that following an expansionary monetary policy shock, a positive money gap opens up, followed by an increase in prices.

6. The restriction of unitary price elasticity in an unrestricted regression was not rejected.

However, the estimated short-run parameters of Hendry's original model (i.e., the α parameters as well as the coefficients on the lagged endogenous variables) were unstable in that they varied greatly over the sample period. Consequently, a number of exogenous variables were added to improve the estimates. One of the exogenous variables included is a measure of the output gap calculated using potential output from the Bank's Quarterly Projection Model (QPM), which measures potential using an extended multivariate filter (see Butler 1996 for details on this approach). Other exogenous variables added are the Can$/US$ spot exchange rate, the U.S. 90-day commercial paper rate, the U.S. inflation rate, the change in non-personal notice deposits post-1980, and a permanent shift dummy for the early 1980s. The 1980s shift variable is interpreted as a proxy for the financial innovations that occurred at chartered banks at that time.[7] Many other variables, such as daily-interest account rates and dollar values, the yield curve, and the volatility of long-term rates were also tried as proxies for these innovations; however, none of them successfully eliminated the need for the 1980s dummy variable.

Including non-personal notice deposits in the model as an exogenous variable was an attempt to internalize the shift between demand and notice deposits that has been occurring over the 1990s. Reserve requirements on demand and notice deposits were eliminated in the early 1990s, leading to some redistribution of funds on the part of agents (mainly business customers) out of notice deposits and into demand deposits. The redistribution has increased the growth rate of M1 in recent years; however, while the increase in M1 growth has been associated with some acceleration of real GDP growth, it has not spilled over into increased inflation to date. The shift between notice and demand deposits is not the only innovation to affect the M1 aggregate,[8] and this is why adjusted M1, rather than gross M1, is used in the model. The construction of adjusted M1 is discussed in section 3.

Some equilibrium conditions have been imposed on the model to force it to a particular steady state. In the steady state, potential output growth is assumed to be 2.3 per cent, inflation is 2 per cent, and money growth is 3.2 per cent, as implied by the long-run money-demand parameters and the assumptions on output and price growth. The steady-state overnight rate is about 4.9 per cent and is based on the historical relationship with U.S. interest rates.

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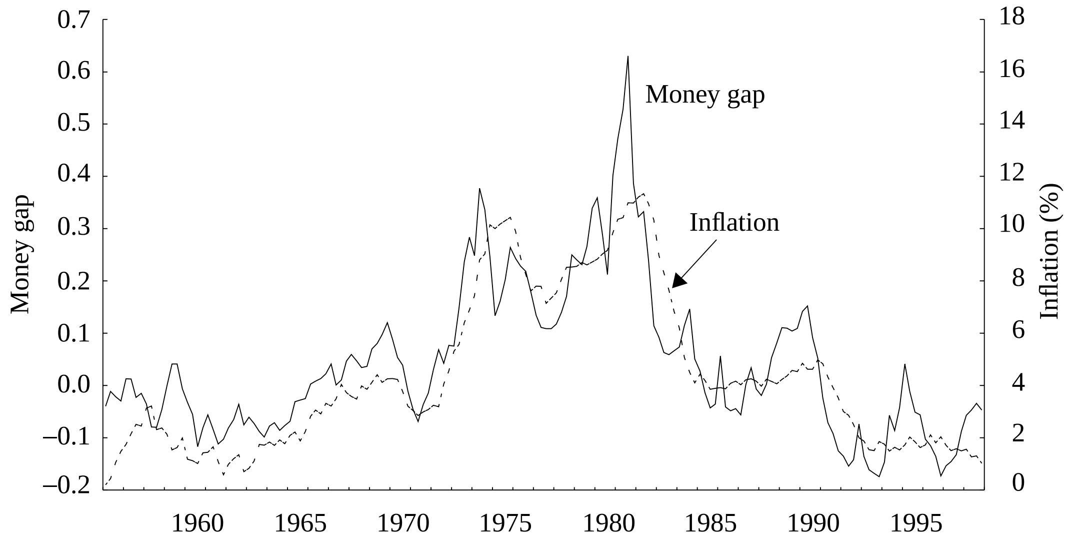
7. See Freedman (1983), Gomme (1998), and Aubry and Nott (2000) for discussions of some of these innovations.
8. See Bank of Canada (1998), Atta-Mensah and Nott (1999), and Aubry and Nott (2000) for discussions of the innovations affecting M1 in the 1990s.

Figure 1
Money gap vs. 8-quarter inflation rate



As discussed in section 1, the difference between actual money supply and estimated long-run money demand is called the money gap. The money gap has moved very closely with actual inflation over the last 40 years (see Figure 1) and helps the model to predict inflation.

The main differences between the M1 VECM presented in this paper and Hendry's original are that the current model uses adjusted M1 (discussed in section 3) rather than gross M1, and the overnight interest rate rather than the 90-day commercial paper rate. The overnight rate has been the policy instrument in Canada since 1994, and there is evidence that the overnight rate provides a good way to measure monetary policy in Canada over a much longer period (see Armour, Engert, and Fung 1996). Moreover, because the overnight rate is highly correlated with the 90-day commercial paper rate (the correlation since 1956 is 0.98), changing the short-term interest rate used in the model had no significant effects on the estimated money-demand function or the model's forecasting performance.

3 Dealing with Financial Innovations in Narrow Money

In Canada, changes in real M1 growth are correlated with changes in real GDP growth about two quarters in the future.[9] M1 growth is also correlated with changes in prices about eight quarters in the future.[10] However, in the 1990s the relationship between money and other economic variables appears

9. See, for instance, Bank of Canada (1999, 29).
10. As discussed in Hendry (1995) and Armour et al. (1996).

to have shifted, possibly in relation to the "restructuring" of the Canadian economy after the 1990–91 recession. This shift could also be related to the change in monetary policy to a regime of explicit inflation targeting. A last explanation could be that the many financial innovations in the 1990s appear to have changed the nature of deposit accounts.

Given this last possibility, the definition of narrow money for use in the VECM was re-examined.[11] Narrow money is generally considered to be money used in transactions for goods and services. In Canada, narrow money is currently defined as M1, which comprises currency, personal chequing accounts, and current accounts. Over the period 1992 to 1994, reserve requirements on accounts were phased out, reducing the distinction between notice and demand accounts.[12] Also, the improvement in electronic financial services in recent years and the increased popularity of debit cards, ATMs, and telephone/PC banking have led agents to economize on their cash balances and enabled them to more easily access non-M1 accounts for transactions purposes. These technological improvements seem to have increased the degree of substitutability between cash and demand or notice deposit accounts, and consequently a broader definition of transactions money might be more appropriate in an electronic world. As well, most of the products financial institutions currently offer have joint transactions and savings characteristics. Thus, some proportion of these balances does not really belong in a transactions money measure and should be excluded. The problem is to come up with a reasonable way of approximating this proportion.

In Canada over the period 1980 to 1982, another series of financial innovations introduced instability into the parameters of the model's cointegrating vector. However, the 1980s innovations tended to simply move money from (M1) demand deposits to (M2) notice deposits. In order to deal with an environment of high interest rates and changing reserve requirements, banks offered customers incentives to move their accounts from ones that were costly for the banks to maintain (demand deposits) to ones that were more cost-effective for the banks (notice deposits). Banks introduced innovations such as daily-interest savings and daily-interest chequing accounts to motivate consumers to switch from non-interest-

11. Aubry and Nott (2000) examined the conceptual issues of what should be included in a measure of narrow money.

12. Reserve requirements were higher on demand deposits included in M1 than on notice deposits excluded from M1. As a consequence, beyond the essentially irrelevant withdrawal-notice requirement, the distinction between demand and notice accounts has become meaningless. So far, this innovation seems to have affected mainly business accounts. Banks have begun to pay more attractive rates of interest on current accounts, and businesses have shifted some of their funds into those accounts.

bearing demand accounts to interest-bearing notice accounts. The shift in the 1990s has not only been related to a switch back from notice to demand accounts owing to the reduction and eventual removal of reserve requirements for demand accounts, but also to the advent of technological changes, as more types of accounts now have the characteristics of transactions money.

Adjusted M1 is a model-based measure of money that was constructed for this paper specifically to correct the VECM instability and estimate the size of the distortion in M1. This was done in two steps.

First, the money-forecasting equation from a gross-M1 VECM (estimated from 1956 to 1993) was used to forecast M1 growth from 1992Q1 to 1999Q1, using actual values for all other variables in the model. It yielded a time series we called "distortion-free" money. This series is an estimate of what M1 would have been had the data-generating process not changed in the 1990s.

Second, in order to relate the distortion-free money series to the observable money data, it was regressed on all the components of M1++ (gross M1 plus all notice deposits). Because the coefficients were similar on some components that could reasonably be thought of as having the same sort of characteristics or users, these components were grouped together to reduce the number of parameters to estimate in order to improve efficiency, given the small sample size.

3.1 Calculating adjusted M1

Adjusted M1 is calculated as follows:

adjusted M1 = 1.58 (*currency*) + 0.28 (*non-personal*)
for 92Q1 to 94Q3

adjusted M1 = 1.19 (*currency*) + 0.22 (*non-personal*)
+ 0.15 (*personal*) for 94Q4 to 99Q1,

where *non-personal* is the sum of current accounts and non-personal notice deposits, and *personal* is all personal notice deposits.[13]

Adjusted M1 differs from M1 in two respects:

1. Choice of components: Adjusted M1 includes notice accounts but not personal chequing accounts (PCAs) because the latter include investment dealer accounts (which today represent more than half of PCAs). The investment dealer accounts appear to be held predominantly to purchase

13. The sample was divided into two subperiods to reflect the fact that the parameter estimates after 1994Q3 are substantially different from those prior to it.

Figure 2
Income elasticity from rolling regression

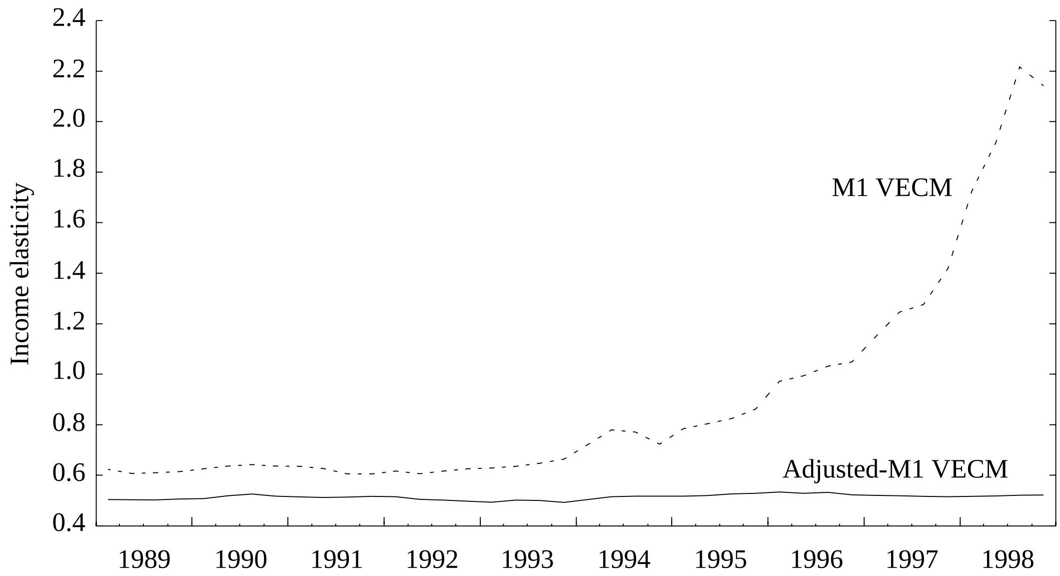


Figure 3
Interest rate semi-elasticity from rolling regression

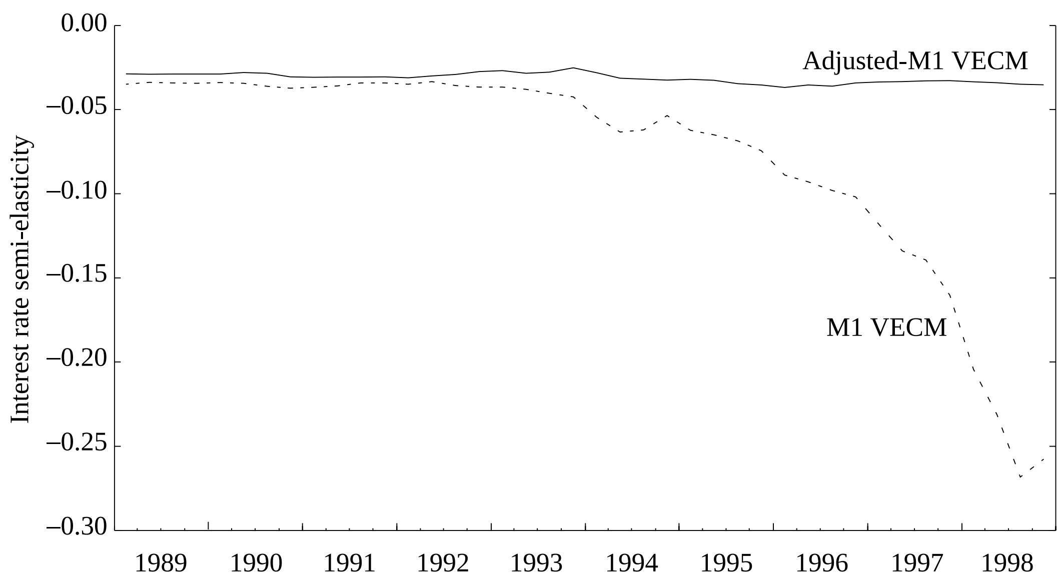


Figure 4
Year-over-year growth rate of gross M1 vs. adjusted M1

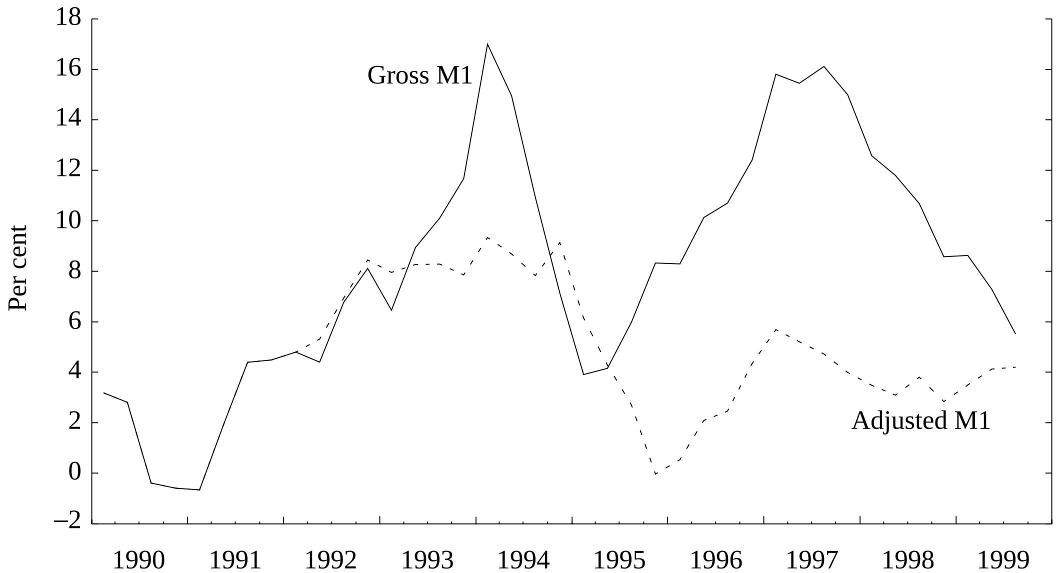
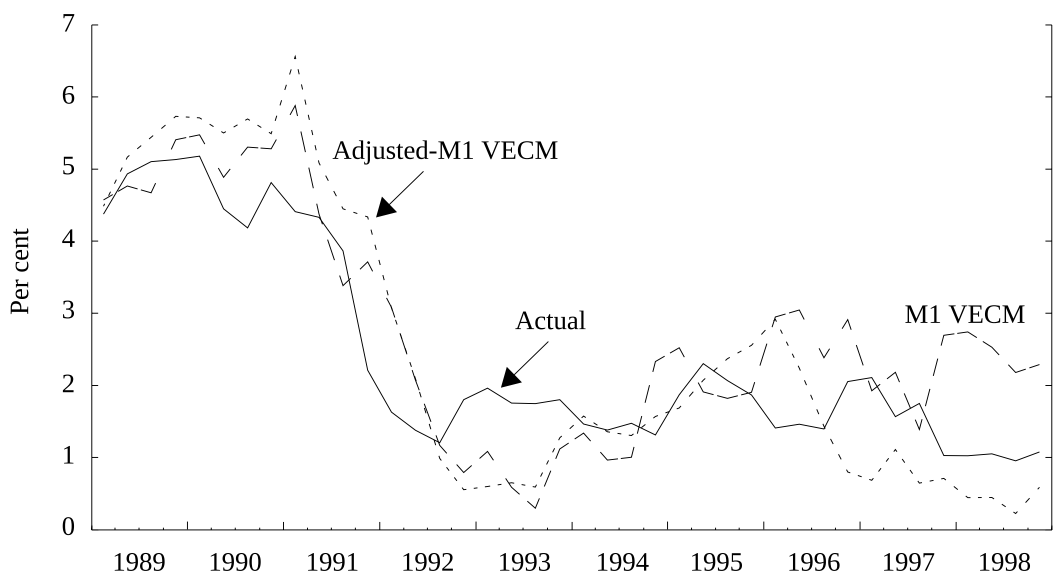


Figure 5
Forecast and actual 4-quarters-ahead 4-quarter inflation rate



financial assets such as mutual funds, stocks, and bonds, rather than to buy goods and services, and therefore should probably be classified within some broader aggregate that is defined as store-of-wealth money rather than in our measure of transactions money.

2. Choice of weights: M1 uses fixed weights of 1 on each of its components, whereas the weights of adjusted M1 differ from 1 based on the estimation results. Adjusted M1 also permits the weights to change at discrete points in the sample.

Given the small size of the sample, as well as the extent to which the parameters have shifted over time, the weights reported here should be treated with caution. This issue will be discussed in more depth later.

The primary purpose of this exercise was to correct the VECM instability, and Figures 2 and 3 clearly show that the adjusted-M1 VECM has more stable parameters, by design, than the original M1 VECM.

Figure 4 shows that the growth rate of adjusted M1 has been much weaker than that of gross M1 over much of the 1990s. However, by design, adjusted M1 is more consistent with the actual movements of prices, output, and interest rates.

In spite of this lower growth rate the inflation forecasts of the adjusted-M1 VECM are similar to those of Hendry's original M1 VECM (see Figure 5). This is likely because the M1 VECM version had shifted parameters to offset the high M1 growth and still obtained moderate inflation forecasts. The adjusted-M1 VECM uses lower money growth but more-stable parameters to obtain a reasonably similar forecast through most of the sample, with a root-mean-squared error (RMSE) of 0.91 compared to an RMSE of 0.94 for the original M1 VECM.

3.2 Why choose this approach?

The instability in the long-run parameters in Hendry's model could have been corrected with dummy variables, but this would not have provided any information about the sources of the instability.[14] The approach taken in our paper is also more flexible than the dummy-variable approach in that it is not necessary to impose a priori when the distortion should end. As Figure 4 shows, the distortion to M1 (the difference between the growth rate of gross M1 and adjusted M1) has been about 6 to 7 per cent per year over the last three years. In this volume's paper by Aubry and Nott (2000), distortions

14. One problem with the dummy-variable approach is that it would treat the distortion in all components as equal. Our approach allows for the possibility that the amount of distortion in the components is different.

related to specific institutional events were examined (the substitution of funds from notice accounts to current accounts at some banks, the effects of dealer accounts in PCAs, and the introduction of the $2 coin), and the estimate of the size of the distortion was found to be only about 2 per cent per year.[15]

It can probably be assumed that these numbers provide upper- and lower-bound estimates of the size of the distortion. Since Aubry and Nott's work examined only three institutional events, it seems reasonable to conclude that their estimate of the size of the distortion would be considered as a lower bound. Adjusted M1 can be considered as an upper bound because all possible sources of instability are attributed to distortions in M1. Hence, it can be argued that our approach might provide too much of a correction, as the methodology may also be attributing structural changes in the economic relationship between M1 and output and inflation to distortions in M1 related to financial innovations.

The alternative measures of money M1+ (M1+ is M1 plus chequable notice deposits) and M1++ were also tried as the money variable in VECMs, but a stable money-demand function could not be estimated using either definition. This result probably reflects the fact that neither M1+ nor M1++ adequately measures transactions money over history. To address this, "extended M1+" and "extended M1++" series were constructed using the level of M1 up to 1990 and then using the growth rate of M1+ (or M1++) to calculate the level of "extended M1+" (or "extended M1++") post-1990. However, even the extended definitions did not lead to a stable money-demand function, probably because the added components are not completely transactions-oriented, but also include some money held as a liquid store of value.

Since the weights on the components of adjusted M1 have changed because of financial innovations that occurred over time and not within a single quarter, assuming fixed weights on the components could be problematic. A time-varying parameter model with Kalman filtering may seem appropriate, but estimating such a model has proven difficult given the small data sample available. The results are quite sensitive to the initial assumptions, and we do not have a ready technique to restrict the weights to be positive in this environment. As a compromise, the single break in the weights is allowed.

To sum up, adjusted M1 can be thought of as the money growth that should have been observed over the last few years if the relationship between money, output, interest rates, and prices had remained unchanged

15. See Bank of Canada (1998), Atta-Mensah and Nott (1999), and Aubry and Nott (2000).

from the past. Of the three possible reasons for the observed instability in money's relationship with other economic variables in the 1990s, the first reason has to do with institutional changes and difficulties with our current data-reporting system that imply we may no longer be measuring the appropriate data. The second reason has to do with the changing nature of money demand in an electronic world. Finally, the instability may reflect the economy's structural changes that are not specifically related to financial innovations. The M1 distortion estimated using the VECM incorporates all of these elements, so even though adjusted M1 can be related to a measure of transactions money, one should be careful about making inferences based on this aggregate. In fact, we consider adjusted M1 to be an interim step on the path to finding a new narrow aggregate. However, given that some economic interpretation can be put on the components of adjusted M1 and its relation to distortion-free M1, adjusted M1 is, by design, the best aggregate now available for use in the VECM.

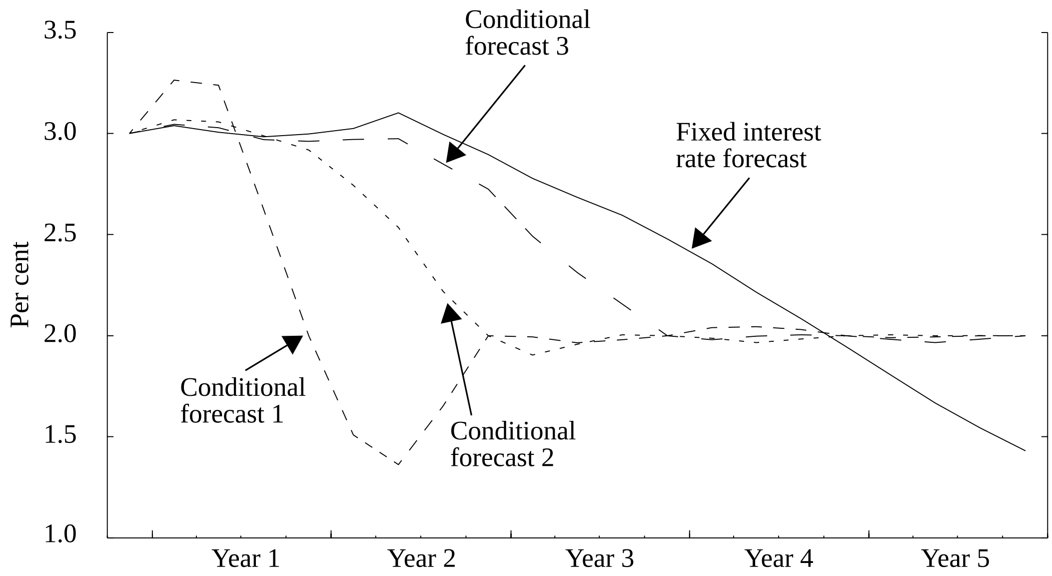
4 Identifying Policy Shocks

Another change from the original VECM Hendry described is that policy shocks have now been identified in our model as the structural shocks to the interest rate equation as derived from a Choleski decomposition.[16] That is, policy shocks are identified as unanticipated innovations to the overnight interest rate.

Previously the models were generating a "price puzzle," in that a policy-induced increase in the nominal interest rate was accompanied by a rise in inflation. The puzzle arose because an increase in the interest rate caused a decline in the estimated long-run demand for money, and the decreased demand in turn created a positive money gap that led to a persistent inflation bubble. One possible explanation for this outcome is that changes in the interest rate have been more closely correlated over history with changes in expected inflation rather than with monetary policy shocks, and the model has not yet properly identified all of the movements in expected inflation. However, it seems reasonable that long-run money demand should be based on a smoother measure of the opportunity cost of money. It is unlikely that the long-run demand for money will move substantially with every transitory change in the interest rate. Consequently, an "unanticipated policy-free" interest rate series was computed by removing the model's estimated structural policy shocks from the overnight rate, basing its removal on the argument that agents would not immediately

16. The ordering of the variables in the decomposition is: U.S. interest rate, U.S. prices, overnight rate, adjusted M1, non-personal chequable accounts, output, prices, and the exchange rate.

Figure 6
Inflation forecasts



adjust their long-run money demand to the latest interest rate policy shock. In a world with limited information regarding policy shocks, agents would respond slowly to policy innovations as they learned about the nature of the latest change in interest rates. It is this unanticipated policy-free rate that enters into the calculation of the long-run money-demand parameters and the money gap.

Using our unanticipated policy-free interest rate implies that a policy tightening will leave money demand unchanged in the quarter of the shock, thereby removing the price puzzle from the model. As well, in the first few quarters following the monetary policy tightening, the interest rate increase slows money growth by more than money demand, causing an excess demand for money, and that in turn causes inflation to fall.

The Bank is also continuing to investigate how best to measure the output and interest rate variables used in calculating money demand. Empirically the money gap that is calculated from current values of output and interest rates is the best predictor of inflation. Theoretically, however, long-run money demand calculated from long-run measures of output and interest rates—for instance, potential output and equilibrium interest rates—makes more sense (see Gerlach and Svensson 1999). We hope to examine these issues in future work.

With policy shocks as they are now identified in our model, it is possible to back out the shocks to interest rates that will move inflation to

Figure 7
Money-growth forecasts

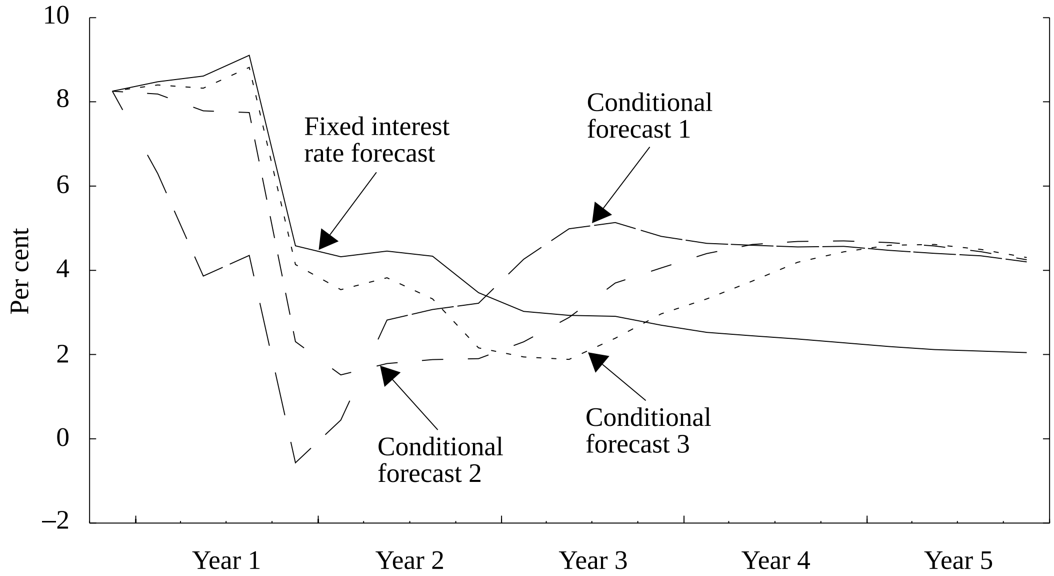
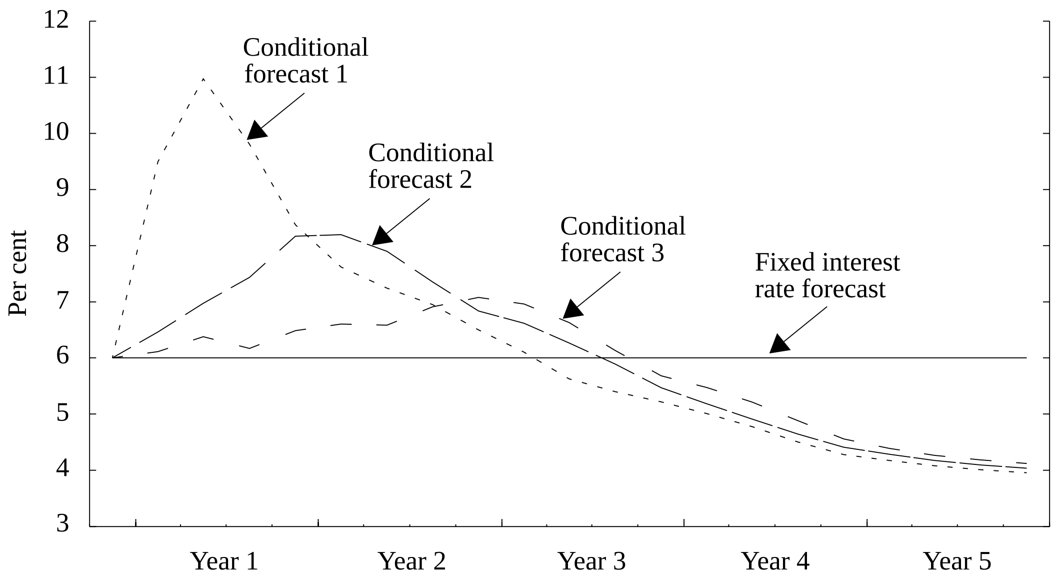


Figure 8
Overnight interest rate forecasts



the midpoint of the Bank's inflation-control target range over a given horizon.

5 Using the Adjusted-M1 VECM for Forecasting

As an example of how the adjusted-M1 VECM could be a useful model for policy-makers, assume a set of initial conditions with 3 per cent inflation, 8 per cent money growth, 3.5 per cent output growth, and 6 per cent interest rates. These conditions were also chosen so that when the interest rate was held fixed at 6 per cent, the inflation rate would be stable around 3 per cent for the first two years out of sample.

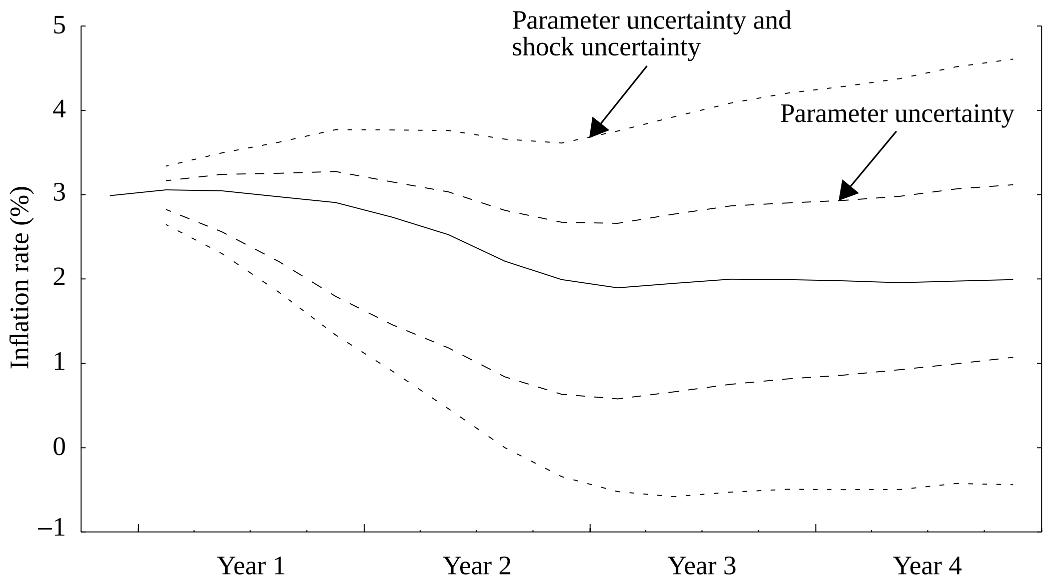
Four separate forecasts could be provided with this model given these initial conditions. The first is a fixed interest rate forecast. The other three are conditional forecasts in which we estimated the series of interest rate shocks necessary to move the 4-quarter inflation rate to the midpoint of the inflation-control target range over 4, 8, or 12 quarters, and maintain inflation at 2 per cent in the fourth quarter of each year thereafter.

Figure 6 illustrates these forecasts. In the base case, in which the overnight rate is held fixed at 6 per cent (which is above the model's steady-state value for the overnight rate), inflation will eventually decline to a point below 2 per cent in year 4. Because the overnight rate is fixed above its steady-state value, the inflation rate will converge to some new lower steady state. The line representing conditional forecast 1 shows the forecast in which the overnight rate is increased to move inflation back to 2 per cent in only 4 quarters, and the line representing conditional forecast 2 shows the forecast in which the overnight rate is increased to return inflation to 2 per cent in 8 quarters. Conditional forecast 3 moves the overnight rate to bring inflation back to 2 per cent in 12 quarters.

Figure 7 shows the money-growth forecasts associated with the inflation forecasts shown in Figure 6. In the fixed interest rate forecast, money growth is initially higher than in the forecasts in which inflation is lowered to 2 per cent more quickly. Money growth subsequently falls in the base case because the overnight interest rate is held fixed at a contractionary level above steady state.

Figure 8 plots the path of the overnight rate for the same set of forecasts. Moving inflation to 2 per cent in this example requires tightening policy through an increase in the overnight rate. However, by year 3 the policy tightening is completely reversed to keep inflation from falling below 2 per cent. The closer the target horizon (4 quarters in conditional forecast 1, but 12 quarters in conditional forecast 3), the more the interest rate must be increased to achieve the target. Similarly, money growth is more volatile for

Figure 9
Conditional inflation forecast 2 with error bands



closer target horizons. Choosing the appropriate policy requires considering both the target horizon and the required interest rate or money-growth movements.

Another way of conveying information about the state of the world and possible future outcomes is to provide confidence intervals or probabilities of these outcomes. For instance, a "reference range" or "monitoring range" can be constructed for money growth that is consistent with achieving 2 per cent inflation over a given horizon. This reference range would have some associated probability of inflation remaining within the target range or, alternatively, some tighter bands. As actual money growth becomes known, deviations of growth from the range should then give early warning of any impending deviations of inflation from the target range. One advantage of using a money-growth reference range as an information variable, in addition to the inflation forecasts themselves, is that it helps to gauge the change in inflationary pressures in the months since the reference range was derived.[17] Gerlach and Svensson (1999) found that the information from a money-growth indicator is subsumed by a money gap.

17. The main distinction between an intermediate target and an information variable lies in the degree of correlation between the intermediate target/information variable and the goal variable (GV). An intermediate target (IT) is assumed to have a tight correlation with the GV, whereas the correlation of an information variable with the GV is much looser. A related concern is the degree of controllability between the IT and the GV. If policy-makers are unable to control the IT, it seems unlikely that they would be able to control the GV.

Figure 10
Distribution of the 4-quarter conditional inflation rate forecasts based on parameter uncertainty for conditional forecast 2

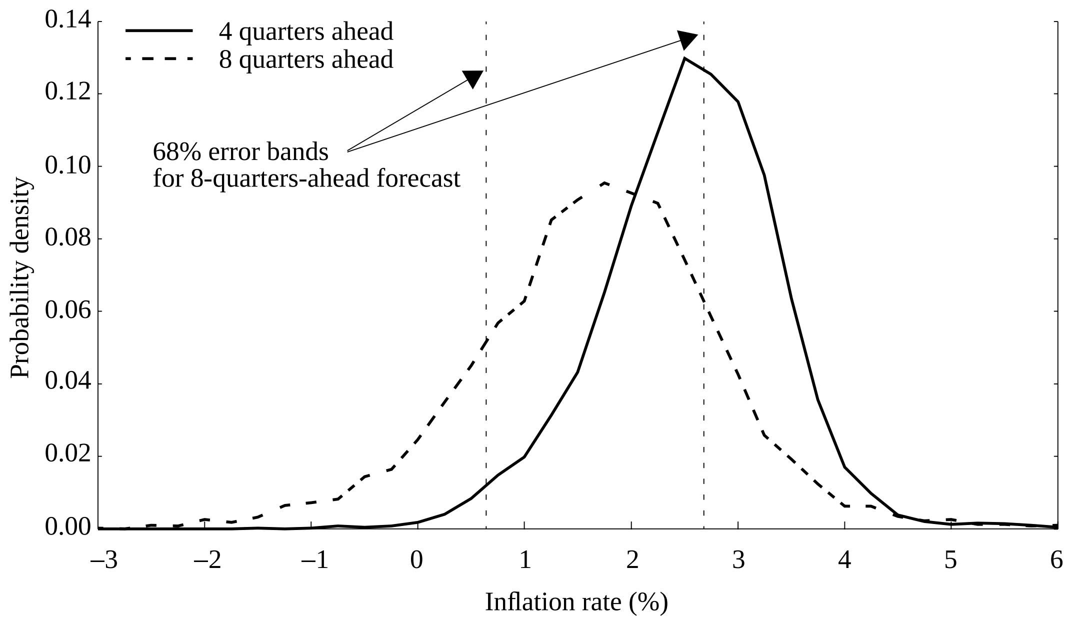


Figure 11
Distribution of the 4-quarter conditional inflation rate forecasts based on parameter and future shock uncertainty for conditional forecast 2

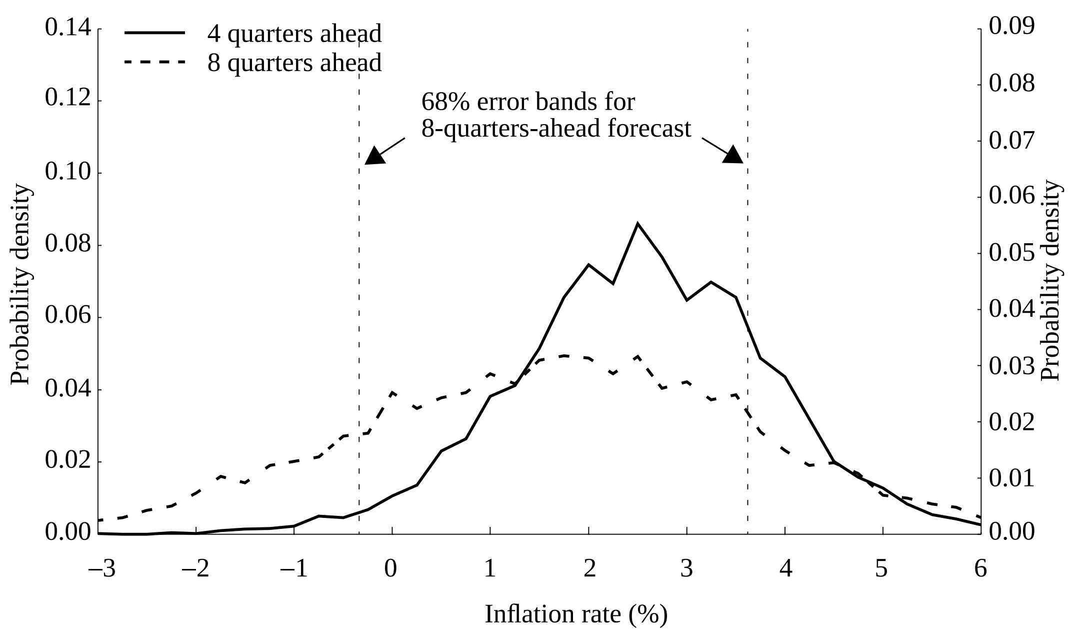


Table 1
Inflation probabilities from conditional forecast 2 with parameter and future shock uncertainty

Date	Probability of inflation between 1 and 3 per cent	Probability of inflation between 1.5 and 2.5 per cent
Year 1Q1	50%	8%
Year 1Q2	55%	24%
Year 1Q3	58%	30%
Year 1Q4	52%	27%
Year 2Q4	37%	19%
Year 3Q4	32%	17%

Our findings generally support this claim. However, an attraction of money growth rate indicators and reference ranges is that they are perhaps easier to explain than a money gap and thus may help a central bank explain its reasons for a policy action.

The European Central Bank (ECB) uses the 3-month growth rate of the 12-month moving average of M3 growth as one of the pillars of its two-pillar strategy of achieving and maintaining price stability.[18] Although the ECB uses a broad aggregate to allow for the possibility of shifts such as those due to financial innovations, we have explicitly accounted for the shifts that have occurred in Canada in our narrow aggregate.

Alternatively, the probabilities of inflation remaining within the target range can be calculated without using a reference range for money growth. Figure 9 shows the conditional inflation forecast and two possible 68 per cent confidence intervals (about 1 standard deviation) when the interest rate is set as in conditional forecast 2 to achieve 2 per cent inflation in eight quarters. The confidence intervals were calculated from a bias-corrected bootstrap technique proposed by Kilian (1998) and discussed in Sims and Zha (1995).[19] The distribution of inflation forecasts shown by the inner bands is based on uncertainty about the model's parameters. The distribution shown by the outer bands is based on uncertainty about both the model's parameters and possible future exogenous shocks.

The complete distributions for the 4-quarter inflation forecast four and eight quarters ahead are plotted in Figures 10 and 11. The vertical lines

18. The ECB's stability-oriented monetary policy is based on: (i) a prominent role for money and (ii) a broadly based assessment, using financial and other indicators, of both the outlook for price developments and the risks to price stability.

19. This technique requires one bootstrap to first obtain an estimate of the bias in the model's coefficients. Bias-corrected coefficients are calculated and used for a second bootstrap simulation to generate the error bands. We computed 5,000 bootstrap samples at each stage.

Figure 12
Inflation forecasts under alternative decompositions

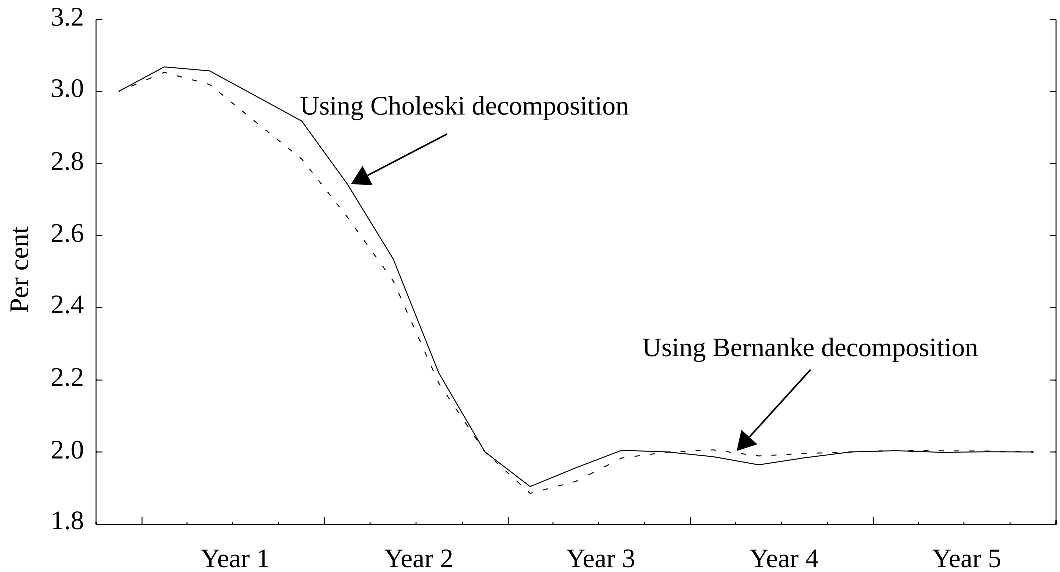


Figure 13
Money-growth forecasts under alternative decompositions

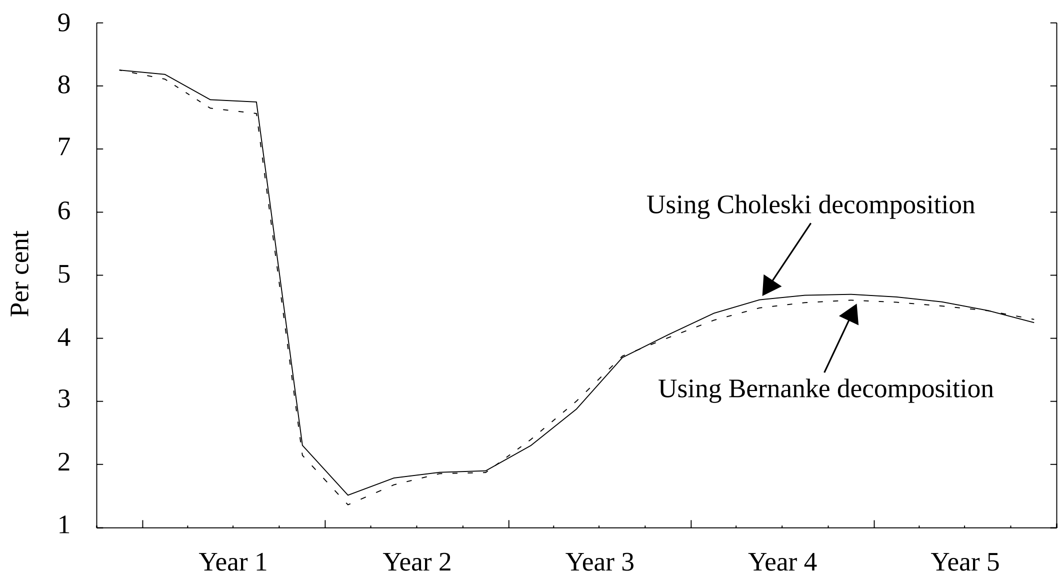
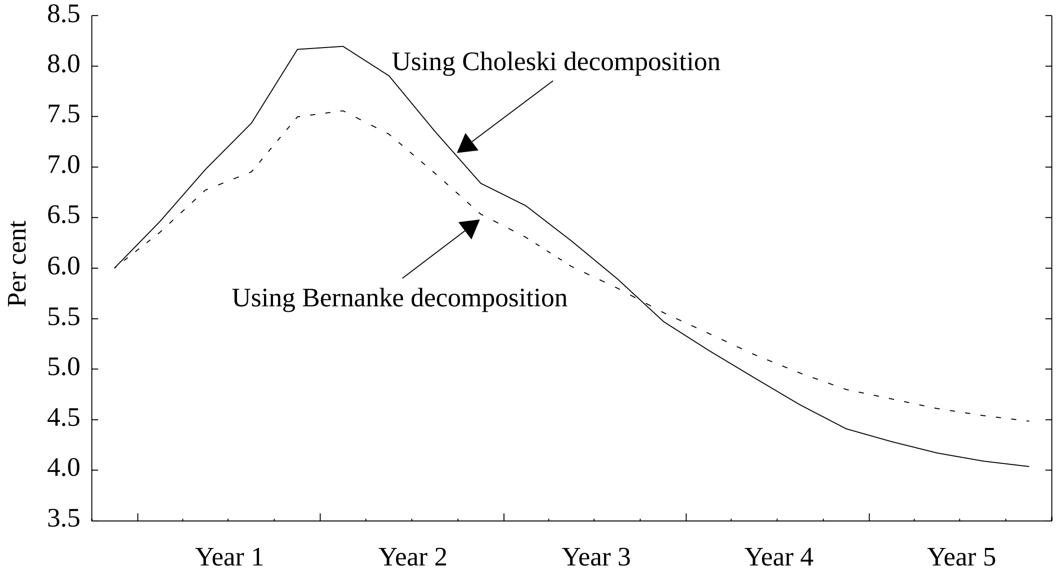


Figure 14
Overnight rate forecasts under alternative decompositions



represent the 68 per cent error bands for the 8-quarters-ahead forecast as shown at the end of year 2 in Figure 9. From distributions such as these we can calculate various probabilities that may interest policy-makers. The probabilities that inflation will be within the 1 to 3 per cent official inflation-control target range or within a tighter range of 1.5 per cent to 2.5 per cent are given in Table 1. Similar distribution functions can be computed for each of the forecast variables. For instance, monitoring ranges for the money-growth rate or the interest rate can be computed that are consistent with achieving the target inflation rate.

In summary, our model can generate the point forecasts and their associated probabilities for any number of starting-point assumptions and/or policy scenarios, providing significant information about possible outcomes and desirable policy scenarios.

6 Future Work

Decompositions other than the Choleski could have been used to identify monetary policy shocks. The estimate of the response of money growth to an interest rate shock has varied over time, and thus it may be appropriate to include an overidentifying restriction in the decomposition of shocks (cf. Bernanke 1986 or Sims 1986). Such a restriction would change the contemporaneous response of money growth to a variation in interest rates from the average response estimated over history with the Choleski decomposition. When one examines recent data, money's response to an interest rate shock appears to have increased. (The greater contemporaneous response of money growth to movements in interest rates might be explained by a change in how rapidly banks respond to policy-induced shocks to interest rates to alter the amount of liquidity they provide to agents in the economy.) The average historical change in money growth for a 100-basis-point change in the overnight rate has been about 0.6 per cent. Using a Bernanke decomposition in another version of the model used below, this response has been increased to 1 per cent.[20]

For the conditional forecast in which policy responds to push inflation to 2 per cent in eight quarters (conditional forecast 2), the inflation and money-growth rates are essentially the same using either the Bernanke or Choleski decomposition (see Figures 12 and 13). However, the size of the interest rate decrease needed is smaller in the Bernanke case than in the Choleski case (see Figure 14). Money growth does relatively more to move inflation towards its target, leaving less work to be done via the interest rate channel.

Our future research will also examine more-sophisticated alternative monetary policy identification techniques, such as those employed for Canada by Fung and Kasumovich (1998) and Fung and Yuan (2000). Varying this aspect of the model will perform a robustness check of its predictions. The Bank is also investigating definitions of transactions money as well as the identification of desired money supply for financial institutions.

Conclusion

The M1 VECM has predicted inflation reasonably well over history and still appears to be a good forecasting model, especially in light of modifications like using adjusted M1, identifying policy shocks, and deriving probabilities for inflation outcomes.

Forecasts from the VECM can augment the information coming from other models used at the Bank. They can provide alternative views of what could happen in the economy and give some information about the "balance of risks." Multiple models could be especially helpful to policy-makers during times of extreme uncertainty and/or structural shifts, but even in

20. The 1 per cent estimate of the contemporaneous response of money to a 100-basis-point change in the overnight rate is within 2 standard deviations of the estimate of the money-response parameter.

relatively stable times, advice from different models helps to balance risks about the outlook for the future.[21]

Different models that yield similar predictions would tend to lessen policy-makers' uncertainty regarding possible outcomes, *ceteris paribus*, making policy judgments somewhat easier. However, relying on multiple models has the greatest value when a model relying on one set of variables and assumptions forecasts one outcome and another model with a different set of variables and assumptions forecasts another—perhaps quite different—outcome. In any event, advice based on multiple models should give policy-makers more information and hence allow them to achieve their desired goals. As Alan Blinder (1998, 12) advises, "Use a wide variety of models and don't ever trust any one of them too much."

21. See, for example, Engert and Selody (1998) and Berk (1997). Different models are used to entertain a possible shock, such as a change in policy or a real-side shock, and evaluate its impact on the forecasts of relevant variables. Such an approach may also help in assessing the uncertainty associated with particular shocks.

Appendix
Details of the Adjusted-M1 VECM

Step 1: Estimating long-run money demand and the money gap

The Johansen-Juselius methodology is used to test for the existence of a unique long-run cointegrating relationship between money, inflation, output, and interest rates (non-seasonally adjusted data). The model is an error-correction model because deviations of money demanded from money supplied (the money gap) are assumed to be corrected in the long run. The model has the form

$$\Delta X_t = \Gamma(L)\Delta X_t + DZ_t + \alpha\beta'[X_{t-1}, D80a_{t-1}], \tag{A1}$$

where

$X_t = [M1_t, CPI_t, Y_t, RONf_t]$

$RONf_t$ = level of "policy-free" overnight interest rate $= RON_t - \varepsilon_t$

ε_t is the residual from the interest rate equation (A8)

$M1_t$ = log level of adjusted M1

Y_t = log level of real output

CPI_t = log level of the consumer price index

Z_t = [constant, 3 seasonal dummies, output gap$_{t-1}$, Δlog(exchange rate) from t to t–3, $\Delta USCP90_t$ rate, $D80b^*\Delta NPN_t$, $D80a_t$]

output gap$_{t-1}$ = Y_t – Bank of Canada's estimate of potential output from QPM

$USCP90$ = U.S. 90-day commercial paper rate

$D80b$ = 0 for 1979Q4 and before, and 1 thereafter

NPN_t = non-personal notice deposits

$D80a_t$ = 0 for 1979Q4 and before, and 1 for 1983Q1 and after. Increases linearly from 0 to 1 from 1980Q1 to 1982Q4.

$\Gamma(L)$ = matrix of parameters for a fourth-order lag process

Equation (A1) is estimated from 1956Q1 to 1998Q4.

The money gap is calculated as

$$mgap_t = c + M1_t - CPI_t - \hat{\beta}_{yt} Y_t + \hat{\beta}_{rt} RONf_t + \hat{\beta}_{d81t} D80a_t, \qquad \text{(A2)}$$

where

c = long-run constant to ensure the gap converges to 0 in steady state

$\hat{\beta}_{yt}, \hat{\beta}_{rt}, \hat{\beta}_{d81t}$ = Johansen estimates of the long-run parameters

Some additional variables need to be calculated before step 3, the forecasting step.

Step 2: The interest rate gap

The interest rate gap, $RGAP_t$, is estimated from the auxiliary equation

$$R_t = k + aUSR_t, \qquad \text{(A3)}$$

where

$R_t = RON_t$ – expected inflation$_t$

$USR_t = USCP90_t$ – expected U.S. inflation$_t$

Expected, $E[inflation_t]$ = actual inflation from t–1 to t

Expected U.S. inflation$_t$ = actual U.S. inflation from t–1 to t

Therefore the real interest rate gap is $R_t - (k + aUSR_t)$. To obtain a nominal interest rate gap, an expected-inflation gap is added. The resulting nominal interest rate gap is

$$RGAP_t = R_t - (k + aUSR_t) + E[inflation_t] - inflation_{ss}, \qquad \text{(A4)}$$

where expected inflation is defined as above, and steady-state inflation is assumed to be the average inflation rate for the previous 10 years. In 1993Q1 the steady-state inflation rate shifts to 2 per cent and stays at that level.

Step 3: The forecasting model

Equation 1: M1

$$\Delta M1_t = \Gamma_1(L)\begin{bmatrix}\Delta M1_t \\ \Delta CPI_t \\ \Delta Y_t \\ \Delta RON_t\end{bmatrix} + D_1 Z_t + \alpha_1 MGAP_{t-1}, \qquad \text{(A5)}$$

where

Z_t = [constant, output gap_{t-1}, Δ log(exchange rate) from t to $t-3$, $\Delta USCP90_t$ rate, $D80b{*}\Delta NPN_t$, $MONPOL_{t-1}$]

$MONPOL_{t-1}$ = 0 for 1987Q4 and before, the 4-quarter inflation rate less target inflation thereafter. Target inflation is 3 per cent from 1988Q1 to 1992Q4, then declines to 2 per cent in 1995Q4 and stays at that level.

$MGAP_{t-1}$ = the money gap derived above in step 1

Equation 2: Price

$$\Delta CPI_t = \Gamma_2(L)\begin{bmatrix}\Delta M1_t \\ \Delta CPI_t \\ \Delta Y_t \\ \Delta RON_t\end{bmatrix} + D_1 Z_t + \alpha_1 MGAP_{t-1}, \qquad \text{(A6)}$$

where

Z_t = [constant, output gap_{t-1}, Δ log(exchange rate) from t to $t-3$, $\Delta USCP90_t$ rate, $D80b{*}\Delta NPN_t$, $D80a$, $DPOLICY$]

$DPOLICY$ = 0 for 1992Q4 and before, increases to 1 in 1999Q4 and after

$MGAP_{t-1}$ = the money gap derived in step 1

The *DPOLICY* shift dummy is introduced as a permanent shift dummy in this price equation to represent a shift to a new lower steady-state inflation rate. The equation is restricted in such a manner that it yields a steady-state inflation rate of 2 per cent.

Equation 3: Output

$$\Delta Y_t = \Gamma_3(L)\begin{bmatrix}\Delta M1_t - \Delta CPI_t\\ \Delta Y_t\\ spread_t\end{bmatrix} + D_1 Z_t + \alpha_1 MGAP_{t-1}, \qquad \text{(A7)}$$

where

$spread_t$ = overnight rate – 10-year-and-over bond rate from QPM

Z_t = [constant, output gap_{t-1}, $\Delta USCP90_t$ rate, $D80b^*\Delta NPN_t$, $D91$, $D89$]

$D91$ = 0 for 1990Q4 and before and 1 thereafter

$D89$ = 0 prior to 1989Q1, 1 between 1989Q1 and 1996Q2, and 0 thereafter

The equation was restricted so that the steady-state output growth rate is 2.3 per cent and so that the coefficients on prices have the opposite sign but same magnitude as those on money (real money growth, rather than nominal money growth is used in the equation).

Equation 4: The overnight rate

$$\Delta RON_t = \Gamma_4(L)\begin{bmatrix}\Delta M1_t & \Delta CPI_t & \Delta Y_t & \Delta RON_t\end{bmatrix} + D_2 Z_t$$
$$+ \alpha_2 MGAP_{t-1} + \gamma_1 RGAP_{t-1} + \gamma_2 UIP_{t-1}, \qquad \text{(A8)}$$

where

Z_t = [constant, output gap_{t-1}, Δlog(exchange rate) at t, $\Delta USCP90_t$ rate from t to $t-3$, $D80b^*\Delta NPN_t$, $MONPOL_{t-1}$]

$RGAP_{t-1}$ = the interest rate gap derived above in step 2

UIP_{t-1} = deviation from uncovered interest rate parity when UIP is defined as

$$UIP_t = RON_t - (uscp90_t + 400(lforex_{t+1} - lforex_t) + k + (a-1)USR_t), \qquad \text{(A9)}$$

where a and k are from equation (A4) above and

$lforex$ = log level of Can\$/US\$ exchange rate

Equation 5: Relative purchasing power parity

$$RPPP_t = \Gamma_3(L)\left[\Delta M1_t \ \Delta Y_t \ \Delta RON_t \ RPPP_t\right] + D_2 Z_t + \gamma_2 RGAP_{t-1}, \qquad \text{(A10)}$$

where

$RPPP_t = \Delta SPOT - \Delta CPI + \Delta USCPI$

Z_t = [constant, output gap_{t-1}, $\Delta USCP90_t$ rate from t to $t-2$, D60Q1, $D73{*}RPPP_{t-1}$, Δlpcom from t to $t-2$]

D60(Q1) = one-period dummy with a value of 1 in 1960Q1

D73 = a permanent shift dummy with a value of 1 from 1973Q1 and 0 before

lpcom = log level of commodity prices

SPOT = log level of spot Can$/US$ exchange rate

Equation 6: The change in non-personal notice deposits

An AR(4) with constant shift dummies *D*80*a*, *D*87Q3, where

D87Q3 = 1 from 1987Q3 and 0 before.

Equation 7: The U.S. inflation rate

An unrestricted AR(4) on the quarter-over-quarter U.S. inflation rate.

Equation 8: The U.S. 90-day real rate

An AR(2) on the U.S. 90-day real rate with constant shift dummies for 1973Q1 to 1979Q4 and 1981Q1 to 1986Q1.

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Discussion

Stefan Gerlach

Overview

The Adam and Hendry paper estimates a simple but attractive VECM on Canadian data, incorporating M1 and the consumer price index as the key variables. Their paper is motivated by the fact that while in the past a tight and stable relationship existed between these variables, it broke down in the early 1990s. Adam and Hendry argue that there are three possible causes for this: the "restructuring" of the Canadian economy, the introduction of inflation targeting, and financial innovation that drove a wedge between the economically relevant measure of narrow money and M1. They focus on the third explanation and propose a strategy to adjust M1 to overcome the "distortions" in this aggregate. Moreover, they demonstrate that when the new data are used, the estimated model is well-behaved over the entire sample period. Finally, they show how the model can be used to forecast inflation and for policy analysis and simulation.

My first reaction to their paper was very positive. Inflation is a monetary phenomenon, and episodes of even moderate inflation are not possible without sustained growth of the monetary aggregates. Moreover, while movements in money are largely endogenous reactions to the state of the economy, it is difficult to believe that money does not also play an active role in the transmission mechanism. Thus, in my view, money is important, and we should have the good sense to use this fact when conducting policy.

Of course, the fact that money growth causes inflation and the likelihood that money at least partially plays an active role in the transmission mechanism do not necessarily imply that money should be targeted or be *primus inter pares* among indicator variables. The weight that should be attached to money is squarely an empirical question, and it is precisely the type of elegant econometric research Adam and Hendry conduct that may be useful in settling it.

However, in reading their paper I must admit that I was less persuaded of the usefulness of looking hard at money when conducting policy in Canada than they appear to be. Rather than focusing my discussion on narrow, econometric issues—such as whether it makes sense to treat the output gap and the exchange rate as exogenous variables in the cointegration analysis, given that the levels of output and interest rates are taken to be endogenous—I will raise some more-general issues that the paper suggests.

Issue 1: Data Adjustments and Dummies

As Adam and Hendry note, the earlier stable linkage between M1 and inflation seemed to disappear in the 1990s. In order to get the data to speak, they construct an adjusted measure of M1 and show that the model also behaves well in the 1990s if the adjusted data are used. This research strategy warrants several comments.

First, the way in which the adjusted data are computed necessarily implies that the model will fit them well. To adjust the data, Adam and Hendry estimate the VECM on data before the break. They then construct out-of-sample predictions of M1 under the assumption that no break occurred and view the predicted level of the money stock as measuring adjusted M1.[1] To quote them (page 162), "adjusted M1 can be thought of as the money growth that should have been observed . . . if the relationship between money . . . and prices had remained unchanged." In a sense the model fits the adjusted data because it has been used to construct those very data. The circularity of this approach not only suggests that the new data do not add much, if any, information, but also that the full-sample estimates of the VECM are subject to generated regressors bias of unknown importance.

Second, whether the adjustment of the data and the use of structural-break dummies are sensible depends on what the model is to be used for. If the purpose is to interpret historical data, then this approach is eminently reasonable. For instance, Adam and Hendry show that when the adjusted data are used, the estimated income elasticity of money demand is stable over time and almost exactly 0.5, as suggested by Baumol and Tobin's justly famous square-root formula of money demand.

However, if the model is to be used for policy analysis, accepting the data adjustments and the inclusion of structural-break dummies is more difficult. In fact, central banks hesitate to rely on money when conducting

1. Strictly speaking, they regress the forecast values on some other variables and use the fitted regression to construct the adjusted-M1 data.

policy precisely because such adjustments and dummy variables are typically necessary to interpret monetary data. To put this differently, although Adam and Hendry's model does a good job in predicting inflation, in order to use it for policy purposes, one must also forecast the need for future data adjustments and additional break dummies, both of which are hidden but integral parts of the model. A particular concern is that structural breaks are not always immediately obvious. In their paper, for instance, Adam and Hendry take care to adjust M1 for shifts that occurred some seven years before writing.

Issue 2: Is This Model Better than Alternative Models?

Adam and Hendry demonstrate that the VECM can be used to forecast inflation and to determine the appropriate path for short-term interest rates given a desired path for inflation. Of course, while this model may be useful for these purposes, that does not imply that it is the best model. There might be better non-monetary models that can be used for the same purposes. In reading their paper one therefore naturally wonders how well the model compares with alternative forecasting models, of which there ought to be a fair number available for Canada. In my view, Adam and Hendry would be more persuasive if they had demonstrated that their model indeed provides more accurate inflation forecasts than the competition does. Since we care about money because we care about inflation, a natural starting point would be to look at single-equation models of the inflation process. Encompassing tests could then be used to explore the different models' performance.

Issue 3: What Is the Role of Inflation Targeting?

Adam and Hendry recognize that the source of the structural break in the relationship between money and prices need not be financial innovations' influence on M1, but could be developments elsewhere in the economy. They explicitly mention that the shift of the relationship could be due to the adoption of inflation targeting in the early 1990s coincident with the structural break they emphasize. Given that the introduction of inflation targeting was arguably one of the most important developments in modern Canadian monetary history, one that is eminently likely to have affected the price-setting process, it is somewhat puzzling that the authors choose instead to focus the analysis solely on the possibility of a distortion of the M1 data.

To see why inflation targeting might have caused the observed shift in the econometric relationship, consider an economy with a history of low to moderate inflation and with a not fully credible central bank. In such an economy it seems plausible that agents will interpret an increase of money growth as a signal that inflation is about to increase. With rising inflationary expectations influencing wage- and price-setting decisions, it is likely that money growth and actual inflation will be closely associated. Next, introduce an inflation target and suppose that it is perfectly credible, so that the expected rate of inflation is equal to the inflation target. Under these conditions an increase in money growth will have no impact on inflationary expectations and therefore little impact on actual inflation. Thus, inflation targeting may well break the link between money and inflation.

Investigating this issue would necessitate looking more closely at the stability of the individual equations in the VECM, in particular the equation for inflation. Indeed, it would be desirable to introduce a more structural inflation equation that allows for the impact of inflation targeting on inflationary expectations and price setting. Given the high-quality econometric work Adam and Hendry have already done, this extension would seem small.

Discussion

Shamik Dhar

Introduction

Let me start by saying that I like Adam and Hendry's paper and, indeed, the theme of the whole conference. I have a few quibbles about technicalities that I'll detail in a second, but the overall theme is one I concur with—that applied models of this type, in which money plays an active and central role in the transmission mechanism, should be part of every central bank's tool kit. The commitment to a tool kit—a range of models with which to analyze the economy and specific policy questions—is itself very important and is referred to many times in their paper. We at the Bank of England have recently published a book describing the suite of models available to us (Bank of England 1999).

Why Monetary Models?

In recent years a "consensus" model appears to be arising in the monetary policy literature—call it IS-LM with microfoundations (of a sort). The seminal works are those of Rotemberg and Woodford (1997) and McCallum and Nelson (1998), and these consensus models have proved very useful in many circumstances, for instance in the policy-rules literature. However, central bankers might be surprised to hear that money plays no role in these models; instead, inflation is anchored through a perfectly credible inflation target. Nor is there a role for money in the transmission mechanism of these models, whereas Professor Meltzer of Carnegie Mellon University has recently documented a strong relationship between real activity and lagged real money balances, and Edward Nelson, in internal work at the Bank of England, has found a similar relationship for the U.K. I like to think this conference is addressing the concerns some of us have about this state of affairs. Money may have a role as an indicator in the short run, it might play a role in the transmission mechanism (as the Adam-Hendry paper also seems to suggest), and in some cases it might even help anchor long-run inflation expectations. All these possibilities are explored in different papers at this conference and will remain of interest to monetary economists, even in inflation-targeting central banks.

The Adam and Hendry Model

The authors estimate a VECM using techniques popularized by Johansen and Hendry amongst others. Adam and Hendry identify a standard money-demand function—a relatively narrow real money aggregate (M1) is modelled as a function of income and an interest rate. I would have liked to see some more of the equations as well as key test statistics. I generally struggle with papers that contain reams of equation printout, but their paper goes a little too far in the opposite direction. A few questions immediately spring to mind from the description contained in their section 2.

- First: Adam and Hendry have chosen to model the upward trend in M1 velocity in the output coefficient rather than, say, impose a unit coefficient and run a velocity equation on a deterministic or stochastic trend of some sort. I have no firm views about which of these techniques is preferable, but the sample period is one in which rapid technological progress in payments systems is very important. Certainly in the U.K. and the United States there are signs that narrow money velocity has flattened off and may even be starting to fall now. At the very least it would be nice to see some recursive estimates of this output coefficient and, in the conditional-forecasting context, some means by which any changes in trend velocity could be easily accommodated.
- Second: Why is the interest rate term a level rather than a spread over some market rate? I understand that adjusted M1 includes interest-bearing deposits and that much of this work is motivated with reference to buffer-stock theories of money. I'd have thought both these factors would have argued for a spread term (which they already have in the underlying vector autoregression [VAR]) and would introduce an extra channel (the "spread channel") through which monetary policy operates. I guess Adam and Hendry would argue that the constructed aggregate they use ought to be a measure of transactions money, not savings money, but I need a bit more convincing.
- Third: A number of (I presume) weakly exogenous variables are included to induce VECM stability. These variables include a lag of the output gap and the change in non-personal notice deposits. I am concerned about the number and variety of variables required to induce stability ex post and

also about their role in ex ante forecasting. My question about the output gap is: How is the gap projected when we come to conditional forecasting? Is its projection consistent with the output projections coming from the output equations? If not, is this a problem? Concern with the change in non-personal notice deposits is linked to the velocity question: How do you project non-personal notice deposits in a period of rapid velocity change and make it consistent with the underlying trend velocity assumption?

Having estimated a long-run money-demand function, Adam and Hendry then construct an aggregate money gap, shown in their Figure 1. We have produced similar charts in the U.K. using similar techniques, and they look very like this one. I'm encouraged by this—and concerned at the same time. Your eye is immediately drawn to the great inflation (as Larry Christiano calls it) of the 1970s, which appears to be at least in part a global shock. The correlation and leading-indicator properties were great then, but our practical problem in selling money-based forecasts in the 1990s (certainly to the Monetary Policy Committee at the Bank of England) is that correlation and leading-indicator properties are not so great now. Something happened to inflation expectations in the 1990s, and monetary growth or gaps struggle to explain what that was. Monetarists can take some comfort from the fact that "output gap" models seem to do just as badly—but this is pretty cold comfort.

Adam and Hendry spend some time discussing the construction of their dependent variable money aggregate—adjusted M1, which they describe as "distortion-free" money but which I prefer to think of as "transactions money." This is essentially a weighted average of various asset categories within demand and notice deposits. My only comment here is that we know in theory what the best measure of transactions money is—divisia (or household divisia). And at some future point it might be interesting to redo this work using a divisia aggregate, though I realize that's a major construction task in itself. Also, I thought I'd draw the authors' attention to some work recently done in the U.K. by Terry Mills and Leigh Drake of Loughborough University. These guys construct what they call "an empirical divisia" by looking for cointegrating relationships among the various asset categories that make up U.K. broad money. They find one and, what's more, the cointegrating coefficients (the empirical divisia weights) appear to be pretty stable over time. I prefer to call this approach a "constant-velocity M"—since that is what it is by construction—and it seems to bear some resemblance to Adam and Hendry's intentions. However, there remains a velocity trend in adjusted M1, and I'd be interested in knowing the authors' explanation for what is driving it.

Adam and Hendry identify monetary policy shocks and ingeniously rid themselves of a price puzzle doing so. But this generates another question: Rather than strip monetary surprises out of money demand, would not a better system be one in which the money supply reacted "correctly" to a monetary shock (of different types)? To plug some work of ours for a minute, in a recent paper with Ryland Thomas and Darren Pain (Dhar, Pain, and Thomas 2000), our approach has been to estimate a structural VAR in which a whole range of shocks are identified—including three types of monetary shock. These include a money-demand (or velocity) shock, an inflation-target shock, and a standard monetary policy shock. We do not find a price puzzle precisely because the shocks are identified with avoidance of that in mind. Multiple shocks are also important because, in general, the leading-indicator properties of a money gap will depend on what has caused the gap to arise in the first place. A temporary money-demand shock can have very different consequences for inflation than a temporary money-supply one, even though the money gaps might look the same in the short run. We had a concrete example of this in the U.K. when in the late 1990s we saw a large positive money gap emerge and then dissipate very quickly with no consequences for inflation. Ex post we know that this was a shock to the money demand of financial institutions in particular, but it was difficult to tell that at the time. And indeed our inflation fan chart contained an upward skew for much of 1998 due to this money gap.

Our experience raises the question of whether error-correction systems of this type really get to the heart of buffer-stock theory as its progenitors would recognize it.

How Does Buffer-Stock Money Fit In?

Slightly awkwardly, I think. Buffer-stock theories have an old and honourable tradition in monetary macros, but they sit slightly at odds with current modelling vogues and their links with the econometric methodology outlined here are not always clear. I guess I would argue for Adam and Hendry's work to be complemented by a more structural approach in which shocks and propagation mechanisms are clearly identified and not averaged out in the estimation process. You have the basis for that structural approach in Scott's other work on limited-participation models, and we are currently working on an ECM representation of the limited-participation model we have constructed at the Bank of England (Dhar and Millard 2000).

In summary, though, Charleen and Scott have, in a nice paper, identified that money plays a role in transmitting monetary policy in Canada, and that, I hope, could convince monetary economists here and in other central banks to occasionally put money back into the models they commonly play with.

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General Discussion

Adam and Hendry responded to a number of points the discussants raised. Regarding Stefan Gerlach's comments, first they noted that the forecasts from the M1 VECM need to be taken with a grain of salt, which is why they provide confidence bands around all the forecasts. They also acknowledged that their forecasts may be open to the Lucas critique.

Second, the M1 VECM forecasts have been compared to alternative models in an earlier paper (Engert and Hendry 1998). That paper found that the M1 VECM outperforms a simple autoregressive process and an inflation-forecasting model based on the Phillips curve. Finally, they emphasized that their adjusted M1 classifies all potential shifts of the aggregate as financial innovations. This aggregate would not be used indefinitely. For the future a divisia aggregate might eventually prove useful.

In response to Shamik Dhar's comments, Adam and Hendry noted that the own rate of return on M1 does not explain much of the shift in the aggregate. They also emphasized that the model does not depend heavily on the exogenous variables, such as the output gap, that were added to stabilize the parameters. In future work they intend to reconsider the variables that enter the money-demand relationship. For example, a short-term interest rate is currently used, but they will examine whether a longer-term rate should be used instead.

Charles Freedman observed that central bankers often rely more upon the judgment of economists monitoring current economic developments than on any single forecasting model to predict future paths of inflation and output. This limits the concrete value of ex post forecasting exercises to policy-makers.

* Prepared by Greg Tkacz.

Frank Smets questioned the focus on the money gap when McPhail's paper found that money growth is more suitable to forecasting inflation. An advantage to focusing on the growth rate, he argued, is that it is robust to level shocks.

Reference

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