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Bank of Canada Banque du Canada

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Abstract

This paper has two main aims. First, to evaluate the robustness of the method used to detrend the data of previous results concerning the lead/lag relationships among money, output and prices in Canada and the information content of monetary aggregates. If the results are insensitive to the detrending procedure, then one can be more confident that the observed correlations reflect underlying relationships among the variables. Second, to examine whether deviations of money from its long-run equilibrium value -- that is, from the relationship that ties together the levels of money, output, prices and other variables in the long run -- contains useful information about future output growth and inflation. If such a long-run relationship exists, then models that do not take it into account may be misspecified. The results confirm the significant role of the monetary aggregates in predicting changes in real GDP and prices found in previous studies. The information content of money, particularly the leading indicator properties of M1 with respect to real GDP and of M2 with respect to prices, is not sensitive to the method used to detrend the data. It is also found that deviations of M2 from its long-run equilibrium value contain information about future inflation in addition to that contained in lagged inflation, lagged M2 growth and an output gap. The results suggest that the inflation process is related to developments in both the money market and the goods market.

Résumé

Le but de la présente étude est double. Premièrement, elle vise à évaluer la robustesse, par rapport à la méthode de filtrage des données utilisée pour éliminer la tendance, des résultats de travaux précédents ayant trait au lien temporel qui existe entre la monnaie, la production et les prix au Canada et à l'information que contiennent les agrégats monétaires. Dans l'hypothèse où les résultats obtenus sont indépendants de la méthode de filtrage employée, il est permis de conclure que les corrélations observées traduisent des relations fondamentales entre les variables. Le second objet de l'étude est de vérifier si les variations de la monnaie par rapport à sa valeur d'équilibre de long terme, c'est-à-dire la relation qui existe, en longue période, entre les niveaux de la monnaie, de la production et des prix ainsi que d'autres variables, peuvent renseigner utilement sur l'inflation future et la croissance future de la production. Si une telle relation existe, il est possible que les modèles qui ne la prennent pas en compte soient entachés d'une erreur de spécification. À l'instar de travaux précédents, les résultats de cette étude confirment le rôle important que jouent les agrégats monétaires en tant qu'indicateurs des variations du PIB réel et des prix. L'information que renferme la monnaie, en particulier les propriétés de M1 et de M2 comme indicateurs avancés du PIB réel et des prix respectivement, est indépendante de la méthode de filtrage utilisée. Il ressort également que les écarts de M2 par rapport à sa valeur d'équilibre de long terme renferment au sujet de l'inflation future de l'information additionnelle à celle que contiennent l'inflation retardée, la croissance retardée de M2 et un déséquilibre de la production. Les résultats donnent à penser que le processus inflationniste est relié à l'évolution tant du marché monétaire que du marché des produits.

The Relationship Between Money, Output and Prices

1. Introduction

The nature of the relationship between money, output and prices has long been one of the most researched issues in monetary economics. It is a central element in explanations of economic fluctuations and of the role of money in the monetary policy process. From the perspective of monetary authorities seeking to influence the pace of total spending, knowledge of the statistical correlations between money, output and prices -- in particular, whether movements in money help to predict movements in output and prices -- is clearly important. Moreover, insofar as movements in the monetary aggregates help to predict movements in output or prices, it is important to know which monetary aggregate is the most informative.

Over the past decade or so, financial innovation and deregulation, advances in time series methods, and the development of alternative explanations of the relationship between money and economic activity -- such as the financial markets imperfections approach and the real business cycle view -- have combined to give impetus to empirical research on the money-output-price relationship.

Central to much of the empirical work in this area has been the specification of trends in macroeconomic time series. Alternative trend specifications of the data have often led to different conclusions about money-output dynamics. For example, Sims' (1980) finding for U.S. data that adding a short-term interest rate to a three-variable (output, money, prices) vector autoregression (VAR) specified in log levels virtually eliminates the marginal predictive content of money (M1) for output is questioned by Litterman and Weiss (1985), who found that adding a quadratic time trend to the four-variable VAR substantially increases the percentage of output variance explained by money. Similarly, Bernanke (1986) found that the inclusion of interest rates in a six-variable system that contains a linear trend does not eliminate the effect of money on output. In contrast, Eichenbaum and Singleton (1986) found that the statistical significance of money is sharply reduced when log differences of variables were used rather than log levels with a time trend.

In an attempt to reconcile these conflicting results, Stock and Watson (1989), focussing on the implications of stochastic and deterministic trends in the data for the distribution of the various test statistics, concluded that the growth of money (M1) does not Granger-cause output growth, but that the deviation of money growth from a linear trend does. Christiano and Ljungqvist (1988) have argued that the discrepancies in results between studies that employ data expressed in log levels and those that employ data expressed in first differences of logs arise because differencing may entail a specification error thus weakening the test statistics.

Krol and Ohanian (1990), following Stock and Watson (1989), investigated for Canada and four other countries whether growth rates of money contain deterministic trends and whether removal of such trends affects statistical inference about money-output causality. They found that over the period 1960M2 to 1985M12, Canadian money supply growth (which they misleadingly refer to as M1) does not Granger-cause output growth (industrial production) or inflation (wholesale prices).[1]

Unlike Krol and Ohanian, Ambler (1989) using a multivariate vector error correction model concluded that "[t]he results of the causality tests indicate that money [M1] matters in Canada. Canadian velocity [in error correction form] has statistically significant predictive content for Canadian industrial output, even though lags of money supply changes and interest rate changes fail to Granger-cause industrial output at conventional significance levels."

Focussing on the information content of monetary aggregates rather than on Granger causality, Hostland, Poloz and Storer (1987) and Muller (1990) found for Canadian data that movements in M1, especially real M1, help explain future movements in real GDP and that movements in M2 help predict movements in the GDP deflator and the CPI. These results were obtained from VARs in which the variables are expressed in first differences of logs. In this paper we extend this line of research in two directions. First, we evaluate whether the information content of monetary aggregates is sensitive to the filter used to detrend the data. Specifically, we employ the Hodrick-Prescott filter to induce stationarity in the variables and then compare the information content of selected monetary aggregates. Second, in the spirit of error correction models, we examine whether deviations of money from its long-run relationship -- that is, the residuals from a cointegrating relationship among money, output, prices and other variables -- are related to

1. These results should be interpreted with caution, not only because as the authors themselves note the power of the Granger-causality tests may be low because of their use of highly parameterized VARs, but also because the money stock they employ is inappropriate. What Krol and Ohanian refer to as M1 is not the Bank of Canada's definition of M1 -- currency and net demand deposits -- but rather the IMF's *International Financial Statistics* definition of "money," which is essentially M1 plus chequable personal savings deposits and chequable non-personal notice deposits, a definition of money that corresponds closely to the no-longer-published aggregate M1A. This aggregate grew at extraordinarily rapid rates in the early 1980s following the introduction of daily interest chequing accounts and is therefore not suitable for the type of analysis carried out by the authors unless the large change in the trend of the series is taken into account.

fluctuations in output and prices. The measures of output, prices and monetary aggregates analyzed are: real GDP, the GDP deflator (PGDP), the consumer price index (CPI), the consumer price index excluding food and energy (CPIFE), the monetary base, M1, M2 and M2-M1.[2]

The paper is organized as follows. In section 2 some "stylized facts" on the cyclical behaviour of output, prices and money are presented. The Hodrick-Prescott (HP) procedure for decomposing (the log of) a time series into its trend and cyclical components is first described. Next, the comovement and phase shift of the monetary aggregates with respect to output and prices, all measured as deviations from their trends, are analyzed. The correlations and lead/lag relations among money, output and prices that emerge when the HP filter is applied to the data are then compared to those that emerge when first differences of logs are used to detrend the data. In section 3 the HP detrended variables are used to construct VARs for output and prices so as to assess and compare the marginal predictive content of the various monetary aggregates. A non-nested specification test is used to select the dominant VAR models and the behaviour over time of these models is then described. In section 4, long-run relationships among M1 and M2 and real GDP, the price level, and other variables are derived, and the deviations of M1 and M2 from these relationships are used to estimate models for output growth and inflation. The main findings and conclusions of the paper are summarized in section 5. Data sources and definitions are provided in an appendix.

2. Cyclical Behaviour of Output, Prices and Money

Following Lucas (1977) and Prescott (1986), we define "business-cycle phenomena" or business cycle regularities as the comovements of deviations from trend of real output (real GDP) and other economic aggregates -- in our case, money and prices. To make the definition operational, it is necessary to select a procedure for computing the trend. We follow Prescott (1986) and Kydland and Prescott (1990) in calculating the trend of a time series by applying the Hodrick-Prescott filter to fit a smooth curve through the data, expressed in logs. Fluctuations in output, prices and money are thus deviations from some gradually changing path.

2. M2-M1 consists of personal savings deposits and non-personal notice deposits. Personal savings deposits comprised 90 per cent of M2-M1 in December 1990.

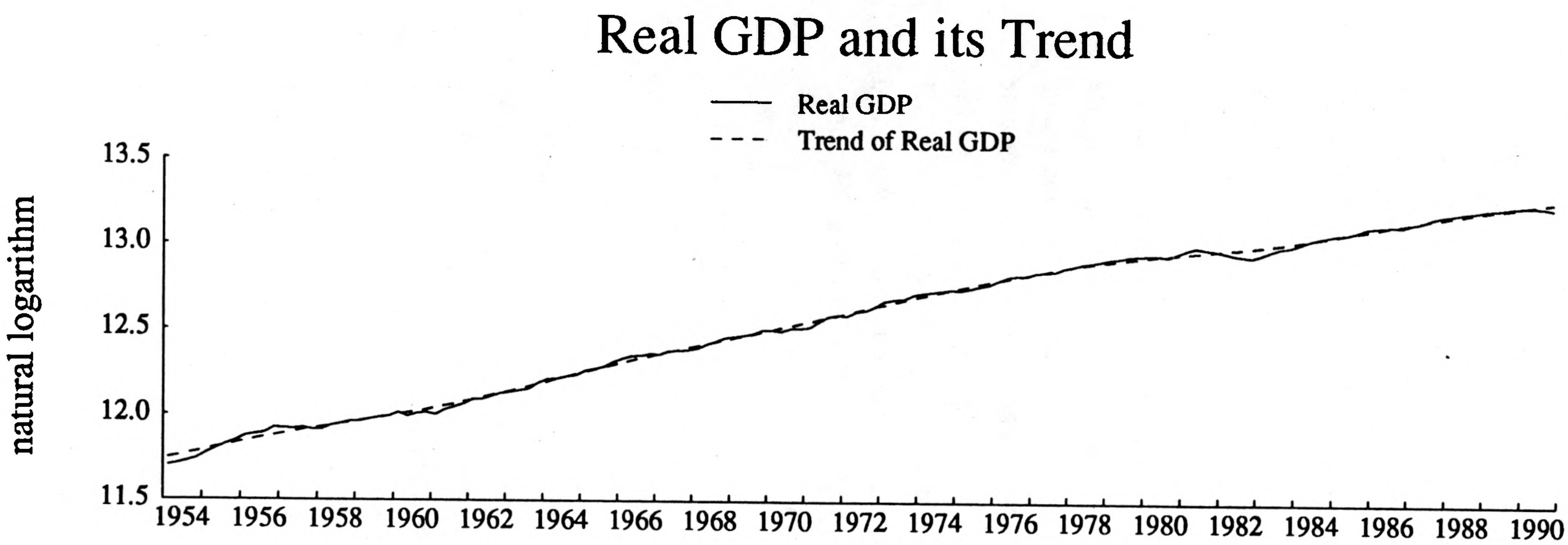

Figure 1A

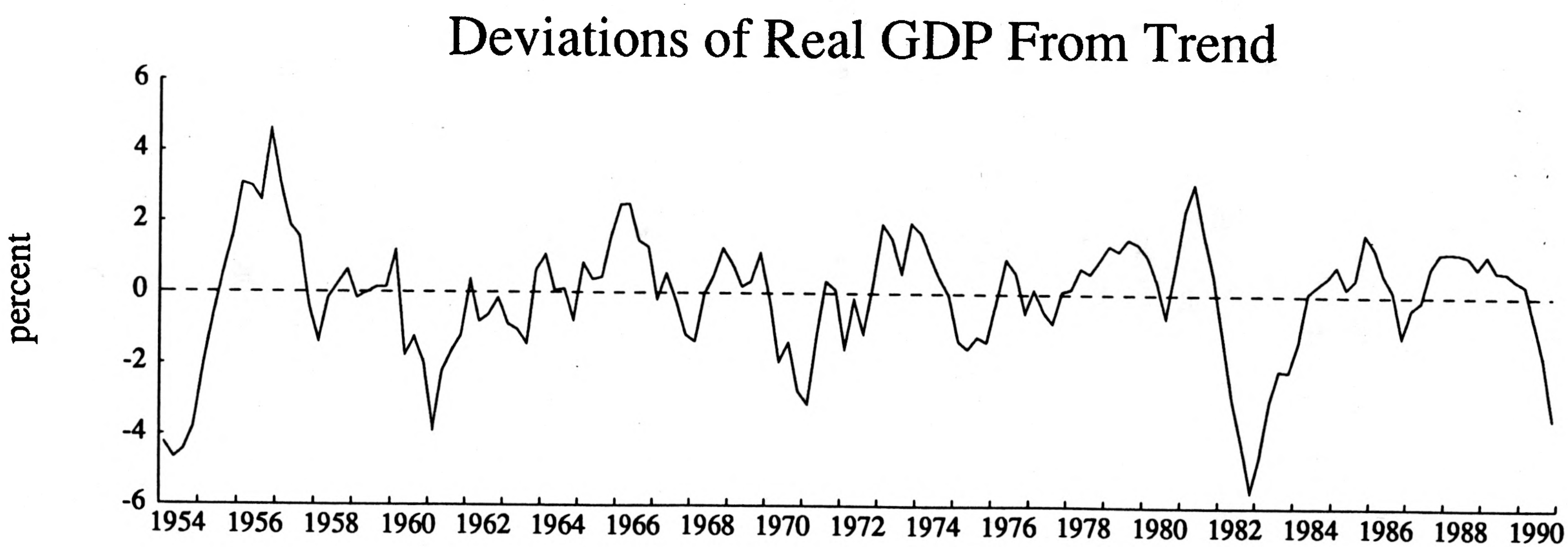

Figure 1B

The Hodrick-Prescott procedure consists of selecting the trend Y_t^P that minimizes the sum of squared deviations of Y_t from Y_t^P subject to the constraint that the sum of second differences of the trend component not be too large:

$$\min \sum_{t=1}^{T} (Y_t - Y_t^P)^2$$

subject to

$$\sum_{t=2}^{T-1} [(Y_{t+1}^P - Y_t^P) - (Y_t^P - Y_{t-1}^P)]^2 \leq \lambda$$

The constraint serves to penalize variations in the growth rate of the trend component, with the penalty weight given by the Lagrange multiplier of the constraint. For quarterly data it has been found that setting λ equal to 1600 produces a smooth trend.[3] All the data series were decomposed into trend and cycle using the same value of λ. Figure 1 shows the decomposition of real GDP.

The business cycle regularities that emerge for the period 1970Q1 to 1990Q4 are summarized in Tables 1 to 5 and in Figures 2 to 5.[4] These show the amplitude of fluctuations of real output, money and prices, and the degree of comovement and phase shift with respect to real output (and prices) of the various aggregates.

The monetary aggregates are more volatile than real GDP (Table 1). M1 is the most variable of the monetary aggregates, followed by M2 and the monetary base.[5] Prices are also more volatile than real GDP from 1970Q1 to 1979Q4, but less variable from 1980Q1 to 1990Q4, reflecting the greater variation in output associated with the 1981-82 and 1990 recessions. Of the price series, the GDP implicit deflator (PGDP) shows the greatest amplitude of fluctuations, followed by the CPI and the CPI excluding food and energy

3. The trend path is smoother the smaller is λ. In the limit, if $\lambda = 0$ the least squares linear time trend is obtained. With λ set at 1600, the HP filter defines Y^P as a centred 32-quarter moving average of Y.

4. All variables are expressed in logs. Thus, M1/M2 refers to lnM1 - lnM2, while M2-M1 refers to ln(M2-M1).

5. The greater variability of M2-M1 reflects the negative correlation between M2 and M1 during the sample period.

Table 1
Amplitude of Fluctuations
Standard Deviation, percent

HP Filter

Variable	1970Q1 - 1990Q4	1970Q1 - 1979Q4	1980Q1 - 1990Q4
Monetary Aggregate			
MB	1.64	1.68	1.60
M1	2.82	2.59	3.04
M2	2.25	2.04	2.46
M2-M1	3.18	3.12	3.05
RMB	2.22	2.10	2.33
RM1	3.63	3.49	3.77
RM2	1.71	1.21	2.04
Price Level			
PGDP	1.91	2.26	1.45
CPI	1.75	2.04	1.38
CPI ex. F&E	1.53	1.69	1.35
Real GDP	1.60	1.27	1.86

First-Difference Filter

Variable	1970Q1 - 1990Q4	1970Q1 - 1979Q4	1980Q1 - 1990Q4
Monetary Aggregate			
MB	1.41	0.96	1.34
M1	1.96	1.74	1.96
M2	1.13	0.99	1.09
M2-M1	1.48	1.49	1.32
RMB	1.45	1.06	1.49
RM1	2.10	1.93	2.17
RM2	0.97	0.84	1.00
Price Level			
PGDP	0.88	0.92	0.74
CPI	0.82	0.86	0.76
CPI ex. F&E	0.68	0.69	0.67
Real GDP	1.01	0.97	1.00

(CPIFE). This ranking contrasts with that for the United States where, as reported by Kydland and Prescott (1990), the CPI is more volatile than the GNP implicit deflator. The contrast reflects the relative influence of terms-of-trade shocks in the two economies.

The cross correlations with real GDP show that the monetary base and M1 are procyclical, whereas M2 is somewhat countercyclical. In terms of cyclical timing, the monetary base moves more or less contemporaneously with the cycle. However, M1, and especially real M1, leads real GDP by a couple of quarters. Strong M1 (that is, growth of M1 above trend) leads strong output, which in turn leads strong M2. But strong M2 leads weak output. Hence, combining M1 with M2 (see the line labelled M1/M2 in Table 2) strengthens the lead to output -- a relationship reported recently by William Robson of the C. D. Howe Institute.[6] As noted below, M2 is highly correlated with prices, which also lag output and are countercyclical, so that the ratio of M1 to M2 approximates real M1. When the monetary aggregates are expressed in real terms (i.e., deflated by CPI), output is most strongly correlated with real M1. The lead/lag relationships between the monetary aggregates and real GDP are clearly evident in Figures 2.

The cross correlations of prices and the monetary aggregates display a different pattern from those of output and the monetary aggregates. M2 is the monetary aggregate most highly correlated with prices, with the peak correlation occurring at the first lag for PGDP, at the second lag for CPI, and at the third lag for CPIFE. The highest correlation is between M2 and CPIFE. Deviations from trend in M2 and the various price measures are illustrated in Figures 3 - 5.

Another feature to note is that the price level is countercyclical, a business cycle "regularity" that has also been reported for postwar U.S. data by, among others, Cooley and Ohanian (1989), Kydland and Prescott (1990) and Plosser (1991). The negative correlation between real output and prices can result from the dominance of supply shocks[7] or from monetary shocks, as in real business cycle models with a cash-in-advance constraint (e.g., Cooley and Hansen, 1989).[8] Another interpretation is that inflationary pressures induce the monetary authorities to tighten monetary conditions, leading to a cyclical correction in aggregate demand.

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6. William Robson, "Money supply figures point to economic upturn in spring," *Financial Post*.

7. This is consistent with the finding of Dea and Ng (1990) that supply shocks account for over 80 per cent of short-run output fluctuations in Canada.

8. In Cooley and Hansen (1989), money affects the cyclical properties of the real economy through the influence on consumption and labour-leisure allocation decisions of anticipated inflation operating via the inflation tax. There is no role for unexpected inflation in the model. Thus, it does not exclude the possible influence of money through its informational implications for economic agents (e.g., the influence on expectations of relative prices).

Table 2

Comovement with Real GDP of Monetary Aggregates and Prices
Deviations from Trend: 1970Q1 - 1990Q4

	Cross Correlation of Real GDP with Variable at time														
Variable	t-7	t-6	t-5	t-4	t-3	t-2	t-1	t	t+1	t+2	t+3	t+4	t+5	t+6	t+7
Monetary Aggregate															
MB	-0.47	-0.41	-0.30	-0.16	0.00	0.20	0.37	0.45	***0.46***	0.41	0.38	0.42	0.45	0.44	0.43
M1	-0.21	-0.09	0.10	0.27	0.47	0.63	***0.65***	0.50	0.27	0.07	-0.06	-0.06	-0.01	0.03	0.09
M2	-0.52	-0.58	***-0.62***	***-0.62***	-0.57	-0.46	-0.31	-0.17	-0.03	0.13	0.30	0.45	0.56	0.59	0.56
M1/M2	0.15	0.29	0.47	0.61	0.73	***0.78***	0.69	0.49	0.23	-0.03	-0.23	-0.32	-0.36	-0.36	-0.29
RMB	-0.18	-0.02	0.17	0.36	0.52	0.65	***0.73***	0.72	0.63	0.49	0.35	0.25	0.16	0.07	0.00
RM1	-0.05	0.12	0.33	0.51	0.68	***0.80***	0.78	0.62	0.38	0.17	0.00	-0.08	-0.10	-0.12	-0.11
RM2	-0.46	-0.39	-0.31	-0.21	-0.09	0.04	0.18	0.27	0.32	0.41	0.49	0.54	***0.55***	0.50	0.39
Price Level															
PGDP	-0.33	-0.44	-0.54	***-0.57***	-0.56	-0.52	-0.45	-0.37	-0.25	-0.13	-0.01	0.09	0.19	0.27	0.33
CPI	-0.22	-0.37	-0.50	-0.59	***-0.63***	-0.62	-0.57	-0.48	-0.35	-0.23	-0.08	0.07	0.19	0.28	0.35
CPI ex F&E	-0.08	-0.23	-0.40	-0.54	-0.64	-0.69	***-0.70***	-0.63	-0.52	-0.39	-0.25	-0.08	0.06	0.19	0.29
Real GDP	-0.17	-0.10	-0.03	0.12	0.33	0.55	***0.80***	1.00							

Table 3

Comovement with GDP Implicit Deflator of Monetary Aggregates, Prices and Real GDP
Deviations from Trend: 1970Q1 - 1990Q4

	Cross Correlation of GDP Implicit Deflator with Variable at time															
Variable	**t-7**	**t-6**	**t-5**	**t-4**	**t-3**	**t-2**	**t-1**	**t**	**t+1**	**t+2**	**t+3**	**t+4**	**t+5**	**t+6**	**t+7**
Monetary Aggregate															
MB	0.54	0.59	***0.62***	0.60	0.57	0.51	0.41	0.29	0.14	0.00	-0.14	-0.26	-0.37	-0.44	-0.51
M1	***0.44***	0.43	0.39	0.32	0.24	0.16	0.04	-0.06	-0.17	-0.27	-0.32	-0.33	-0.32	-0.30	-0.30
M2	0.34	0.45	0.55	0.64	0.70	0.75	***0.76***	0.72	0.64	0.52	0.37	0.20	0.01	-0.17	-0.34
M2-M1	0.16	0.27	0.39	0.50	0.60	0.68	0.72	***0.73***	0.69	0.59	0.45	0.27	0.09	-0.10	-0.26
Price Level															
PGDP	-0.01	0.18	0.36	0.54	0.70	0.85	***0.95***	1.00							
CPI	-0.13	0.06	0.25	0.42	0.59	0.74	0.86	***0.93***	***0.93***	0.88	0.79	0.65	0.51	0.33	0.14
CPI ex F&E	-0.38	-0.21	-0.03	0.15	0.34	0.52	0.69	0.83	0.91	***0.93***	0.90	0.80	0.67	0.52	0.35
Real GDP	0.31	0.27	0.19	-0.10	-0.01	-0.12	-0.25	-0.37	-0.45	-0.52	-0.56	***-0.57***	-0.54	-0.44	-0.32

Table 4

Comovement with CPI of Monetary Aggregates, Prices and Real GDP
Deviations from Trend: 1970Q1 - 1990Q4

	Cross Correlation of CPI with Variable at time														
Variable	**t-7**	**t-6**	**t-5**	**t-4**	**t-3**	**t-2**	**t-1**	**t**	**t+1**	**t+2**	**t+3**	**t+4**	**t+5**	**t+6**	**t+7**
Monetary Aggregate															
MB	0.57	***0.60***	0.59	0.55	0.49	0.41	0.29	0.15	0.02	-0.13	-0.24	-0.32	-0.41	-0.46	-0.49
M1	***0.42***	0.38	0.29	0.18	0.08	-0.02	-0.13	-0.21	-0.27	-0.32	-0.30	-0.25	-0.21	-0.17	-0.16
M2	0.39	0.54	0.66	0.75	0.80	***0.81***	0.77	0.66	0.51	0.34	0.17	-0.01	-0.18	-0.34	-0.49
M2-M1	0.21	0.37	0.52	0.64	0.73	***0.78***	0.77	0.70	0.58	0.43	0.25	0.07	-0.11	-0.27	-0.41
Price Level															
PGDP	0.13	0.32	0.50	0.65	0.79	0.88	***0.93***	***0.93***	0.86	0.74	0.59	0.42	0.25	0.06	-0.12
CPI	-0.03	0.17	0.36	0.53	0.70	0.84	***0.94***	1.00							
CPI ex F&E	-0.29	-0.11	0.08	0.28	0.47	0.64	0.79	0.90	***0.94***	0.91	0.84	0.72	0.56	0.39	0.20
Real GDP	0.33	0.28	0.20	0.08	-0.08	-0.22	-0.34	-0.48	-0.57	-0.62	***-0.63***	-0.58	-0.47	-0.32	-0.18

Table 5

Comovement with CPI ex Food and Energy of Monetary Aggregates, Prices and Real GDP
Deviations from Trend: 1970Q1 - 1990Q4

	Cross Correlation of CPI ex Food and Energy with Variable at time														
Variable	**t-7**	**t-6**	**t-5**	**t-4**	**t-3**	**t-2**	**t-1**	**t**	**t+1**	**t+2**	**t+3**	**t+4**	**t+5**	**t+6**	**t+7**
Monetary Aggregate															
MB	***0.63***	0.61	0.57	0.51	0.43	0.28	0.12	-0.05	-0.20	-0.33	-0.42	-0.48	-0.56	-0.60	-0.63
M1	0.32	0.25	0.15	0.04	-0.07	-0.19	-0.28	-0.32	***-0.33***	-0.32	-0.26	-0.20	-0.16	-0.15	-0.16
M2	0.59	0.70	0.77	0.82	***0.83***	0.79	0.69	0.54	0.36	0.15	-0.05	-0.25	-0.44	-0.60	-0.71
M2-M1	0.45	0.58	0.69	0.77	***0.81***	***0.81***	0.75	0.63	0.45	0.25	0.02	-0.19	-0.38	-0.53	-0.63
Price Level															
PGDP	0.35	0.52	0.68	0.81	0.89	***0.93***	0.90	0.83	0.69	0.51	0.33	0.14	-0.04	-0.21	-0.37
CPI	0.21	0.40	0.57	0.72	0.84	0.92	***0.94***	0.90	0.78	0.63	0.46	0.27	0.09	-0.10	-0.28
CPI ex F&E	-0.09	0.10	0.30	0.50	0.68	0.83	***0.94***	1.00							
Real GDP	0.29	0.20	0.08	-0.07	-0.23	-0.38	-0.51	-0.63	***-0.70***	-0.69	-0.63	-0.52	-0.36	-0.18	-0.03

Deviations From Trend: Real GDP and the Monetary Aggregates

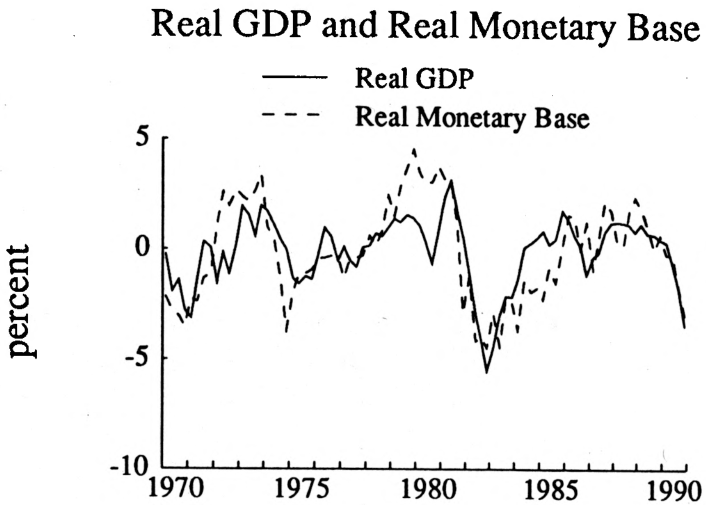
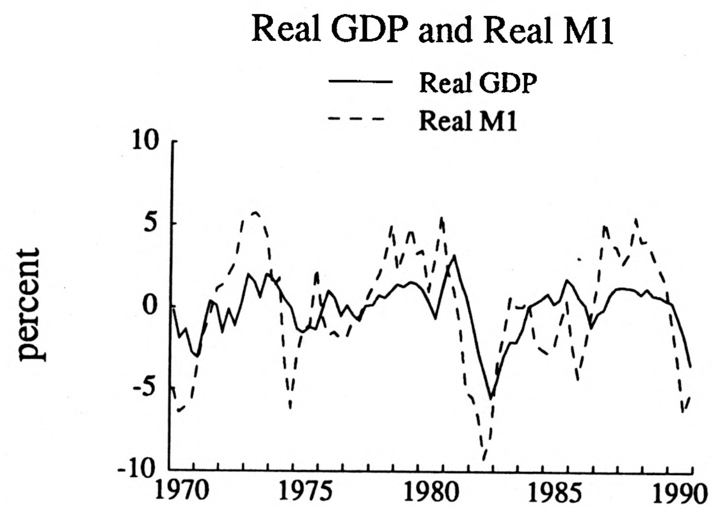


Figure 2A



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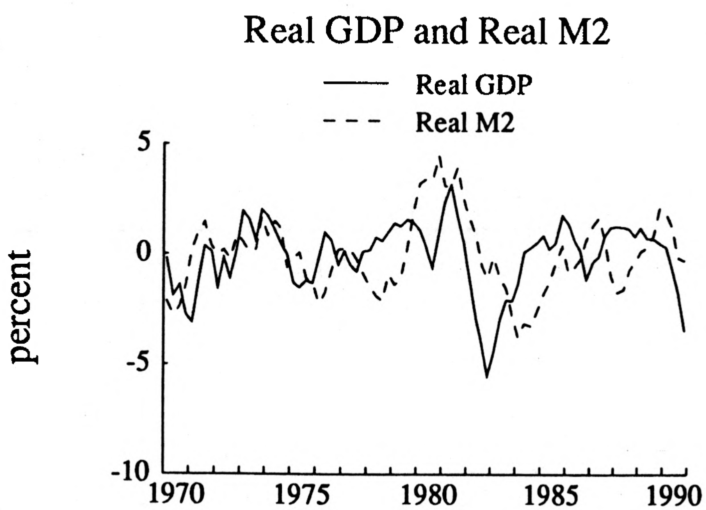

Figure 2C

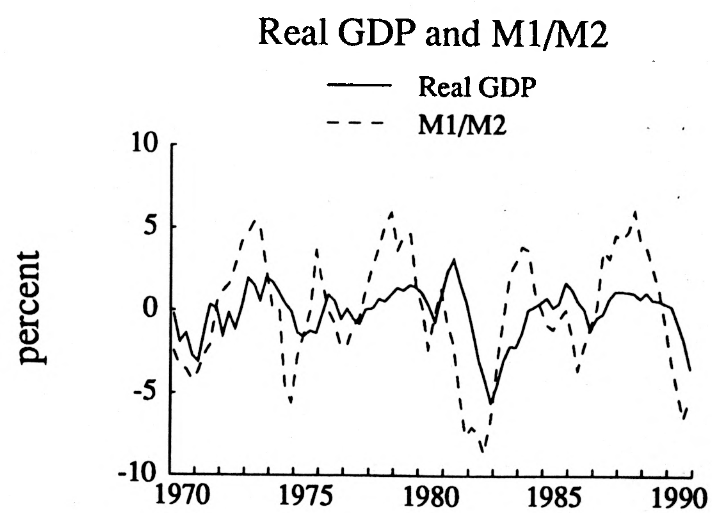

Figure 2D

Deviations From Trend: GDP Deflator and the Monetary Aggregates

GDP Deflator and Monetary Base

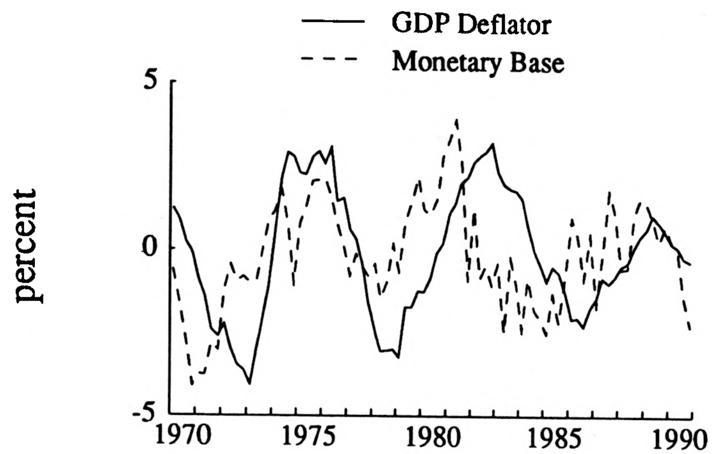

Figure 3A

GDP Deflator and M1

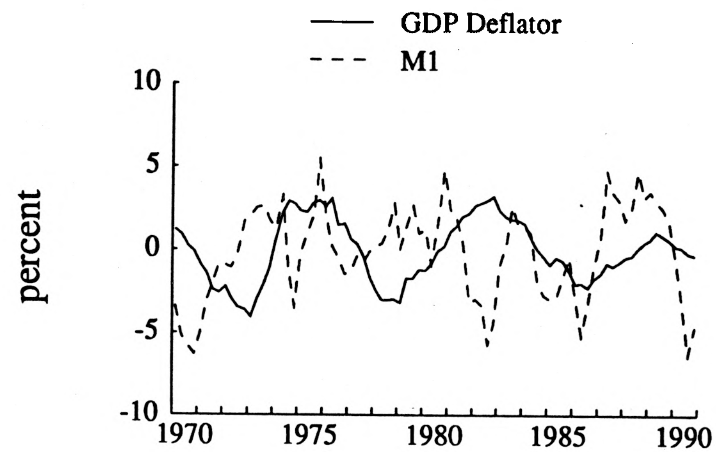

Figure 3B

GDP Deflator and M2

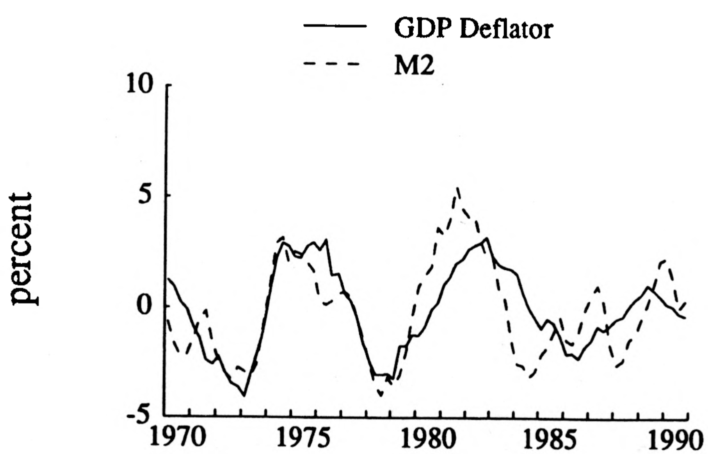

Figure 3C

GDP Deflator and (M2-M1)

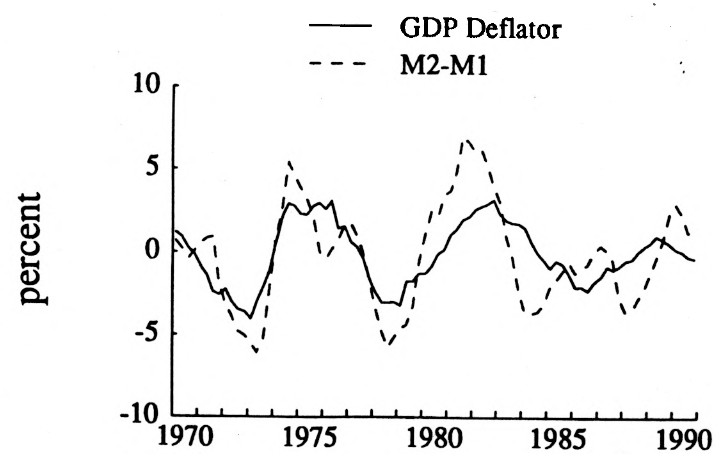

Figure 3D

Deviations From Trend: CPI and the Monetary Aggregates

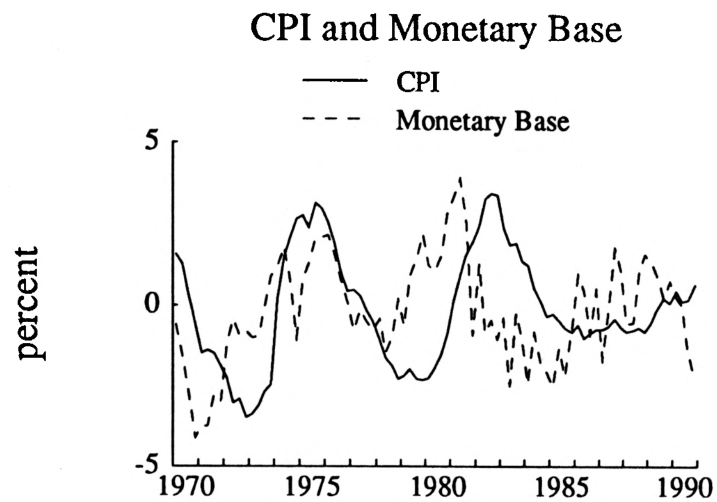

Figure 4A

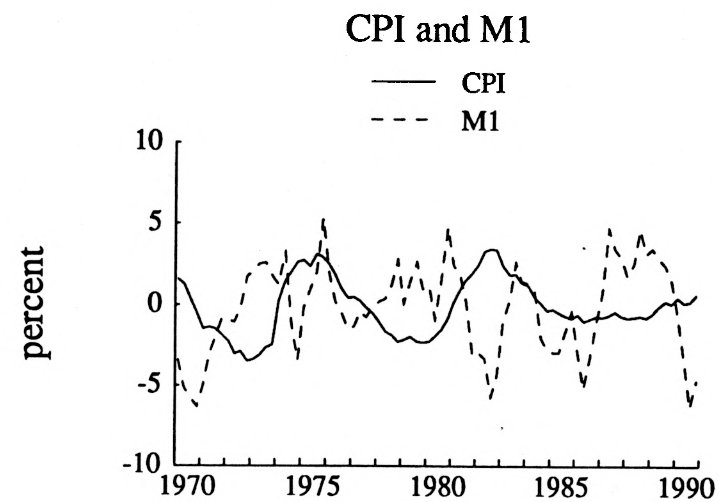

Figure 4B

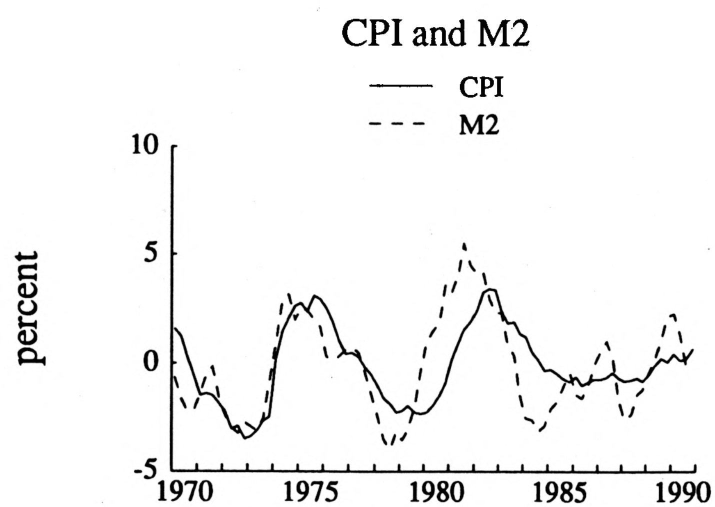

Figure 4C

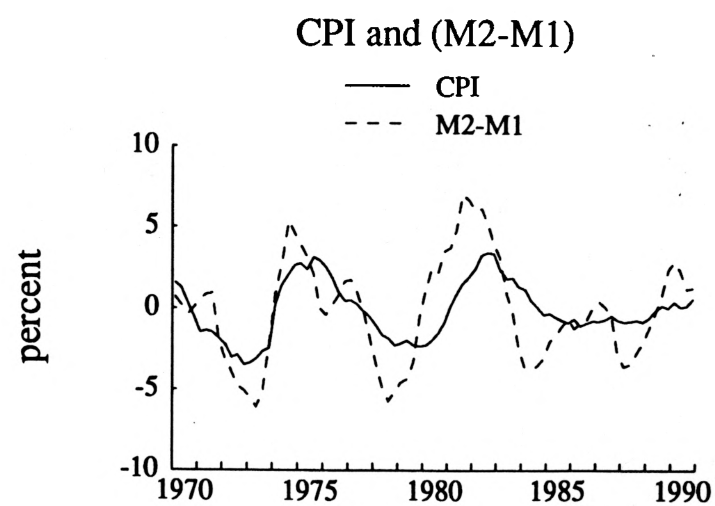

Figure 4D

Deviations From Trend: CPIFE and the Monetary Aggregates

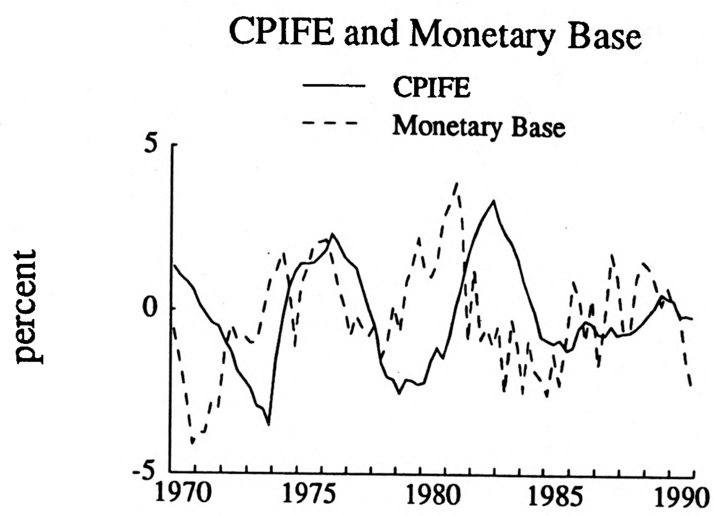

Figure 5A

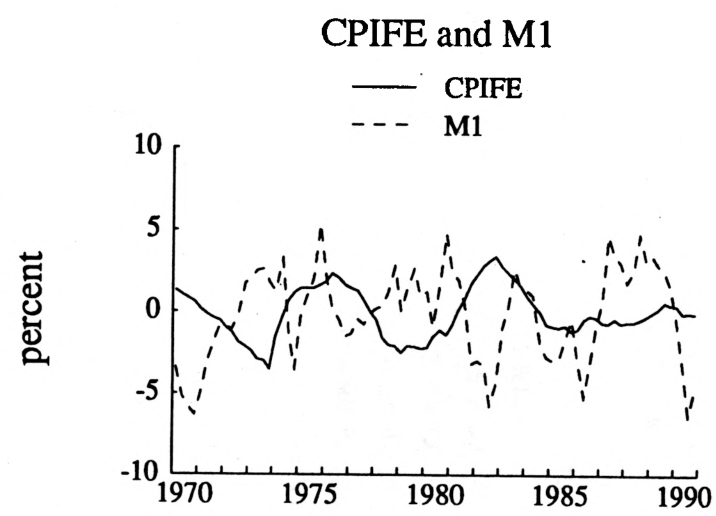

Figure 5B

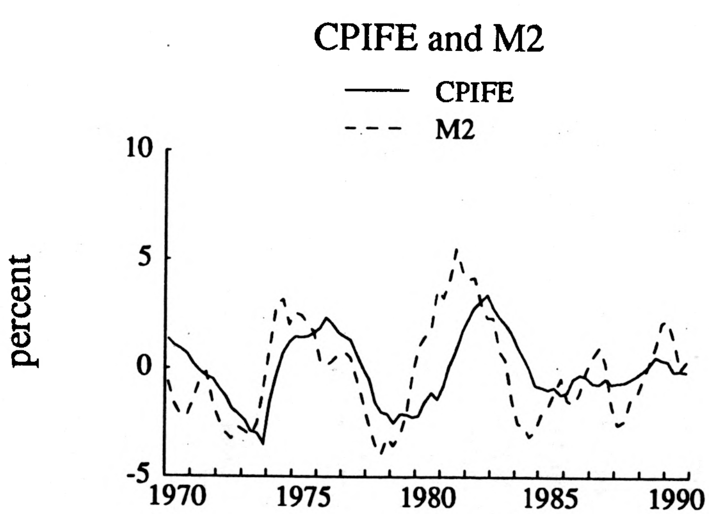

Figure 5C

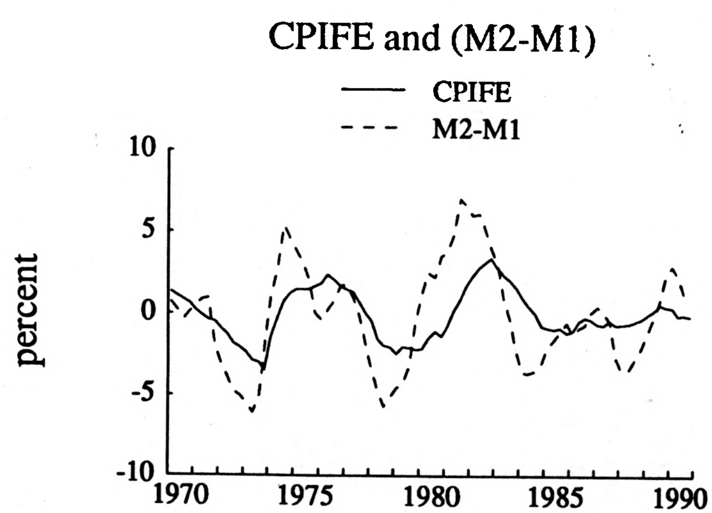

Figure 5D

Finally, as noted in the introduction, time series that are dominated by trends are usually filtered to remove the trend component. In this section we have used the HP filter to detrend the data. An alternative transformation frequently applied to time series to induce stationarity is to take first differences of the logged data. The first-difference filter allows only a very small proportion of the low-frequency components of the data to be passed through to the transformed series, while the HP filter allows a greater proportion of the low-frequency components to be passed through. This raises the question as to whether the observed cyclical regularities are sensitive to the choice of detrending procedure. For our data series this is generally not the case. The results on the relative amplitude of fluctuations of real output, prices and money, the lead-lag relationships of the monetary aggregates with respect to real output and prices, and the countercyclical behaviour of prices that emerge when the HP filter is applied to the data are also apparent when the first difference filter is used (Tables 1 and 6-8).[9]

3. Multivariate Time-Series Representations of Output and Prices

The correlations between money, output and prices described above, although informative, give only a partial picture. The reason is that the correlations are not conditioned on any other information. In other words, correlations between money and output and money and prices which are conditional on other variables may differ from the simple correlations. In this section we focus on the marginal predictive content of the monetary aggregates. That is, we examine whether movements in money help predict movements in output when past movements in output are taken into account, and whether money continues to have predictive content when other variables are considered. A similar analysis is carried out for the predictive content of money with respect to prices. It should be noted that our objective is not to draw inferences about structural relationships, but rather to describe the time series characteristics of the data.

Univariate autoregressive models of real GDP and of prices[10] were first estimated for the 1970Q1 to 1990Q4 period using Akaike's Final Prediction Error (FPE) criterion to select

9. It should also be remarked that King and Rebelo (1989) have shown that the cyclical components generated by the HP filter are stationary when the underlying time series are difference stationary. Indeed, Augmented Dickey-Fuller tests indicate that the null hypothesis of a unit root in the HP detrended series can be rejected at the 5 per cent level for real GDP, the three price series, M1, and M2-M1 and at the 10 per cent level for real M1, M2 and real M2.

10. For ease of exposition, in this section the expressions real GDP (or output), prices and money continue to be used as shorthand for the deviations of real GDP, the various price measures and the monetary aggregates from their trends.

Table 6

Comovement with Real GDP of Monetary Aggregates and Prices
First Difference: 1970Q1 - 1990Q4

	Cross Correlation of Real GDP with Variable at time														
Variable	**t-7**	**t-6**	**t-5**	**t-4**	**t-3**	**t-2**	**t-1**	**t**	**t+1**	**t+2**	**t+3**	**t+4**	**t+5**	**t+6**	**t+7**
Monetary Aggregate															
MB	-0.06	0.00	0.00	0.04	0.08	0.21	***0.31***	0.26	0.28	0.15	0.07	0.18	0.22	0.14	0.21
M1	-0.10	-0.08	0.14	0.08	0.22	***0.49***	***0.49***	0.27	0.08	-0.04	-0.15	0.02	0.12	0.03	0.05
M2	-0.16	-0.17	-0.21	-0.22	-0.15	-0.09	0.07	0.08	-0.01	0.07	0.13	0.26	***0.35***	0.33	0.23
M1/M2	0.00	0.03	0.27	0.23	0.32	***0.57***	0.47	0.24	0.09	-0.09	-0.24	-0.14	-0.09	-0.17	-0.10
RMB	-0.01	0.06	0.12	0.19	0.22	0.32	***0.42***	0.34	0.26	0.20	0.07	0.10	0.13	0.06	0.09
RM1	-0.06	-0.03	0.21	0.18	0.30	***0.54***	0.53	0.31	0.07	0.00	-0.13	-0.04	0.05	-0.03	-0.04
RM2	-0.12	-0.11	-0.08	-0.04	0.03	0.06	0.25	0.21	-0.03	0.16	0.16	0.19	***0.29***	***0.29***	0.10
Price Level															
PGDP	-0.08	-0.08	***-0.23***	-0.19	-0.16	-0.07	-0.03	-0.16	0.04	0.08	0.08	0.12	0.13	0.20	0.11
CPI	-0.08	-0.11	-0.20	-0.26	-0.25	-0.20	-0.19	-0.14	0.03	-0.10	-0.02	0.15	0.16	0.14	***0.23***
CPI ex F&E	-0.04	-0.05	-0.17	-0.27	-0.25	-0.29	***-0.32***	-0.26	-0.09	-0.10	-0.10	0.04	0.09	0.09	0.18
Real GDP	0.04	0.02	-0.13	-0.03	0.10	0.09	***0.34***	1.00							

Table 7

Comovement with GDP Implicit Deflator of Monetary Aggregates, Prices and Real GDP
First Difference: 1970Q1 - 1990Q4

	Cross Correlation of GDP Implicit Deflator with Variable at time														
Variable	**t-7**	**t-6**	**t-5**	**t-4**	**t-3**	**t-2**	**t-1**	**t**	**t+1**	**t+2**	**t+3**	**t+4**	**t+5**	**t+6**	**t+7**
Monetary Aggregate															
MB	***0.49***	0.38	***0.49***	0.40	0.41	0.44	0.36	0.38	0.27	0.24	0.12	0.15	0.05	0.12	0.08
M1	0.26	***0.28***	0.26	0.22	0.17	0.27	0.13	0.12	0.07	-0.08	-0.07	-0.01	0.00	0.11	0.02
M2	0.45	0.42	0.48	0.48	0.49	***0.63***	0.58	0.58	0.57	0.47	0.38	0.32	0.20	0.16	0.04
M2-M1	0.36	0.31	0.39	0.40	0.46	0.56	0.58	0.60	***0.62***	0.58	0.45	0.35	0.22	0.12	0.05
Price Level															
PGDP	0.29	0.33	0.45	0.48	0.57	0.70	***0.73***	1.00							
CPI	0.24	0.32	0.42	0.40	0.54	0.62	0.75	***0.81***	0.76	0.71	0.69	0.56	0.57	0.48	0.38
CPI ex F&E	0.05	0.13	0.21	0.25	0.33	0.46	0.57	0.73	0.73	0.73	***0.75***	0.65	0.58	0.47	0.45
Real GDP	0.08	0.18	0.12	0.11	0.06	0.07	0.05	-0.16	-0.04	-0.10	-0.17	-0.20	***-0.26***	-0.10	-0.06

Table 8

Comovement with CPI and CPI Ex Food and Energy of Monetary Aggregates, Prices and Real GDP
First Difference: 1970Q1 - 1990Q4

Variable	t-7	t-6	t-5	t-4	t-3	t-2	t-1	t	t+1	t+2	t+3	t+4	t+5	t+6	t+7
Cross Correlation of CPI with Variable at time															
Monetary Aggregate															
MB	0.39	0.42	0.38	0.33	0.34	0.35	0.29	0.25	0.25	0.04	0.08	0.05	-0.03	-0.02	***0.43***
M1	***0.23***	***0.23***	0.19	0.08	0.10	0.14	0.06	0.03	0.01	-0.22	-0.06	-0.02	-0.04	0.04	0.05
M2	0.43	0.49	0.55	0.57	0.58	***0.66***	0.63	0.55	0.45	0.26	0.22	0.16	0.07	0.01	-0.07
M2-M1	0.35	0.40	0.48	0.57	0.56	0.64	0.67	0.59	0.49	0.41	0.28	0.19	0.12	0.02	-0.07
Price Level															
PGDP	0.40	0.49	0.57	0.57	0.69	0.72	0.76	***0.81***	0.76	0.62	0.54	0.39	0.41	0.30	0.22
CPI	0.25	0.41	0.42	0.51	0.61	0.71	***0.79***	1.00							
CPI ex F&E	0.12	0.23	0.31	0.40	0.49	0.59	0.65	***0.85***	0.81	0.77	0.69	0.63	0.52	0.51	0.38
Real GDP	0.16	0.11	0.12	0.12	-0.04	-0.12	0.02	-0.14	-0.20	-0.23	-0.26	***-0.29***	-0.25	-0.11	-0.08
Cross Correlation of CPIFE with Variable at time															
Monetary Aggregate															
MB	0.32	0.30	0.30	0.30	***0.37***	0.24	0.19	0.11	0.05	-0.08	-0.03	0.00	-0.15	-0.13	-0.16
M1	0.15	0.14	0.10	0.07	0.08	0.04	-0.11	-0.13	0.07	***-0.19***	-0.04	0.00	-0.03	-0.03	-0.03
M2	0.46	0.49	0.53	0.53	0.58	***0.62***	0.55	0.45	0.37	0.18	0.07	0.01	-0.13	-0.23	-0.28
M2-M1	0.40	0.45	0.50	0.52	0.58	***0.65***	***0.65***	0.54	0.44	0.30	0.09	0.01	-0.11	-0.21	-0.23
Price Level															
PGDP	0.48	0.49	0.58	0.65	***0.76***	0.73	0.73	0.73	0.57	0.46	0.31	0.25	0.20	0.10	0.01
CPI	0.42	0.53	0.54	0.64	0.69	0.77	0.81	***0.85***	0.65	0.58	0.48	0.38	0.29	0.20	0.08
CPI ex F&E	0.20	0.26	0.37	0.47	0.56	0.67	***0.77***	1.00							
Real GDP	0.12	0.05	0.06	0.03	-0.11	-0.11	-0.10	-0.26	***-0.34***	-0.32	-0.25	-0.29	-0.22	-0.04	-0.02

the optimal lag lengths. Bivariate VARs were subsequently estimated by including money (that is, one of the monetary aggregates) in the autoregressive models. So as not to exaggerate the importance of money, other variables were added to the models. These included lags of real GDP for the price models, lags of prices for the real GDP model, short-term interest rates, and various measures of the yield curve.[11] In all cases, up to 10 lags of the variables were allowed to enter the model and Akaike's FPE was used to determine the lag lengths for each of the variables. To test the sensitivity of the chosen specification to the sequence in which the variables were entered, the sequence was changed and the models re-estimated. Generally the same dynamic specification emerged. In cases where it did not, the specification with the lowest FPE was chosen. This procedure was repeated for each of the monetary aggregates. The resulting models are reported in Tables 9 - 11.

Real GDP is found to be best characterized by a fourth-order autoregressive process. When money is added to the autoregressive model, all of the monetary aggregates considered (namely, real monetary base, real M1, real M2 and M1/M2) are statistically significant, but the economic significance of real M2 is rather small. Real M1 and M1/M2 are found to contain the greatest leading information about movements in real GDP. Moreover, their marginal predictive content is concentrated in the first lag. Prices are significant in the VAR which uses M2 as the monetary variable, while the interest rate enters weakly only in the VAR that uses the real monetary base.

Univariate models for prices are best characterized by second- or third-order autoregressive processes: second-order for CPI and third-order for PGDP and CPIFE. M2 and M2-M1 have significant leading information for prices, with the information concentrated in the first four or five lags. The narrower aggregate M1 and the monetary base generally have little or no predictive content for prices at the margin, that is, once lagged prices are taken into account -- see Tables 10 and 11. In addition to the broader monetary aggregates, movements in real GDP and, in some specifications, changes in short-term interest rates, also help explain movements in prices.

For the VARs reported in Tables 9 - 11, the FPEs and SEEs indicate that of the four monetary aggregates examined, real M1 has the greatest predictive content for real GDP, M2 for the GDP deflator and the CPI, and M2-M1 for the CPI ex. food and energy.[12] A formal, simple encompassing test, the Davidson-MacKinnon J test, confirms these results.

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11. Inclusion of the latter seemed particularly relevant in view of the finding by Stock and Watson (1989, 1990) and Friedman and Kuttner (1989) that these variables vitiate the predictive content of money in VARs for U. S. output. However, the yield differentials did not help predict Canadian output or prices.

Table 9

Multivariate VARs for Real GDP (Deviations From Trend) 1970Q1 - 1990Q4

General specification: $Yt = \alpha + \sum_{i=1}^{m1} \beta_i y_{t-1} + \sum_{i=1}^{m2} \delta_i RM_{t-i} + \sum_{i=1}^{m3} \Upsilon_i PGDP_{t-i} + \sum_{i=1}^{m4} \rho_i \Delta R_{t-i}$

Monetary Aggregate

Coefficient	(1) RMB	(2) RM1	(3) RM2	(4) M1/M2
α	-0.001 (-0.86)	-0.001 (-0.86)	-0.001 (-0.89)	-0.001 (-0.93)
β_1	0.88 (7.87)	0.76 (7.03)	1.03 (9.24)	0.82 (7.70)
β_2	-0.37 (-2.48)	-0.26 (-1.88)	-0.37 (-2.23)	-0.27 (-1.98)
β_3	0.14 (0.96)	0.18 (1.33)	0.13 (0.81)	0.11 (1.13)
β_4	-0.26 (2.55)	-0.15 (1.58)	-0.21 (-1.99)	
δ_1	0.25 (4.70)	0.18 (6.31)	0.25 (2.20)	0.17 (6.08)
δ_2			-0.28 (-2.50)	
Υ_1			0.35 (2.14)	
Υ_2			-0.47 (-2.79)	
ρ_4	0.09 (1.19)			
$\bar{R}^2$	0.776	0.811	0.760	0.798
SEE(X100)	0.758	0.697	0.784	0.721
Durbin-h	1.89*	1.79	1.98*	1.60
LM(4)	1.84	3.84	1.92	1.92
FPE	0.622	0.521	0.681	0.550
Elasticity				
η_β	0.34	0.34	0.42	0.63
η_δ	0.11	0.11	-0.03	-0.002
η_Υ	--	--	-0.04	--
η_ρ	-0.05	--	--	--

Note: t-statistics in parentheses. The elasticity $\eta_\delta = \sum_i \delta_i \frac{RM_{t-1}}{\bar{y}}$ and similarly for the other variables.

* Implies that Durbin-h statistic was incalculable, DW is reported instead.

LM(4) is the Lagrange Multiplier test statistic for serially uncorrelated errors up to lag four; the critical value is 9.49

Table 10

Multivariate VARs for GDP Deflator and CPI (Deviations From Trend) 1970Q1 - 1990Q4

General specification: $$P_t = \alpha + \sum_{i=1}^{m1} \beta_i P_{t-i} + \sum_{i=1}^{m2} \delta_i M_{t-i} + \sum_{i=1}^{m3} \Upsilon_i y_{t-i}$$

	PGDP			CPI	
Coefficient	(1) -	(2) MB	(3) M2	(1) M2	(2) M2-M1
α	-0.00 (-0.07)	-0.00 (-0.03)	0.00 (0.19)	0.00 (0.19)	-0.00 (-0.04)
β_1	1.21 (11.86)	1.14 (10.49)	1.20 (11.64)	1.26 (11.32)	1.33 (12.51)
β_2	0.05 (0.31)	0.04 (0.26)	-0.06 (-0.34)	-0.39 (-3.64)	-0.44 (-4.18)
β_3	-0.33 (-3.20)	-0.31 (-2.95)	-0.31 (-3.01)		
δ_1		0.02 (0.44)	-0.01 (-0.11)	0.11 (1.76)	0.12 (2.18)
δ_2		0.08 (1.40)	0.26 (2.09)	0.05 (0.48)	-0.06 (-0.65)
δ_3			-0.38 (-3.03)	-0.15 (-1.53)	-0.10 (-1.04)
δ_4			0.24 (3.06)	0.11 (1.66)	0.15 (1.51)
δ_5					-0.06 (-1.04)
Υ_1	0.08 (1.84)		0.09 (2.18)	0.15 (2.85)	0.14 (2.29)
Υ_2				-0.22 (-2.91)	-0.20 (-2.41)
Υ_3				0.16 (3.02)	0.13 (2.13)
$\bar{R}^2$	0.934	0.935	0.942	0.954	0.951
SEE(X100)	0.493	0.490	0.461	0.376	0.387
Durbin-h	0.22	0.81	-0.30	2.04*	-2.31
LM (4)	5.28	6.64	8.80	3.04	3.44
FPE	0.257	0.257	0.236	0.159	0.170
Elasticity					
η_β	1.10	0.85	0.83	0.84	0.87
η_δ	--	0.13	0.21	0.18	0.07
η_Υ	0.05	--	0.06	0.05	0.04

See Note to Table 9.

Table 11

Multivariate VARs for CPI Excluding Food and Energy (Deviations From Trend) 1970Q1 - 1990Q4

General specification: $P_t = \alpha + \sum_{i=1}^{m1} \beta_i P_{t-i} + \sum_{i=1}^{m2} \delta i M_{t-i} + \sum_{i=1}^{m3} \Upsilon_i y_{t-i} + \sum_{i=1}^{m4} \rho_i \Delta R_{t-i}$

Monetary Aggregate

Coefficient	(1) MB	(2) M1	(3) M2	(4) M2-M1
α	-0.00 (-0.19)	-0.00 (-0.35)	0.001 (0.32)	0.00 (0.22)
β_1	1.37 (11.96)	1.37 (12.34)	1.11 (9.91)	1.09 (9.62)
β_2	-0.32 (-1.75)	-0.20 (-1.06)	-0.17 (-0.98)	-0.11 (-0.64)
β_3	-0.16 (-1.47)	-0.26 (-2.42)	-0.14 (-1.28)	-0.18 (-1.60)
δ_1	0.01 (0.20)	-0.03 (-1.28)	0.12 (2.21)	0.18 (3.88)
δ_2	0.01 (0.29)	0.04 (1.40)	0.02 (0.23)	-0.10 (-1.26)
δ_3	0.07 (1.52)		-0.04 (-0.43)	-0.03 (-0.43)
δ_4	-0.10 (-2.32)		-0.07 (-0.79)	-0.01 (-0.09)
δ_5	0.09 (2.24)		0.13 (2.28)	0.08 (1.64)
Υ_1			0.05 (1.55)	0.06 (1.78)
ρ_1	0.06 (1.45)	0.06 (1.54)		
ρ_4				-0.04 (-1.40)
$\bar{R}^2$	0.948	0.944	0.953	0.955
SEE(X100)	0.349	0.362	0.331	0.323
Durbin-h	2.11*	2.08*	2.02*	2.02*
LM(4)	8.88	6.80	2.80	2.32
FPE	0.136	0.143	0.123	0.118
Elasticity				
η_β	0.82	0.86	0.70	0.71
η_δ	0.11	-0.03	0.43	0.31
η_Υ	--	--	0.05	0.06
η_ρ	-0.05	-0.05	--	0.05

See Note to Table 9.

The test consists of selecting one of the models as the "true" model and testing whether the predictions from the alternative models when added to the regression of the "true" model significantly improve the fit. The null hypothesis is that the information in the alternative models is contained in the "true" model. The procedure is then reversed by selecting another model as the true model and repeating the test procedure. If the predictions from one model, model A, add significantly to the fit of another model, model B, but the predictions from model B do not add significantly to the fit of model A, then model A is said to encompass model B. The J test statistics reported in Table 12 indicate that the VAR model for real GDP that includes real M1 (model 2 in the top panel of Table 12)[13] dominates the models with alternative monetary aggregates.

As expected, the VAR models for the GDP deflator and the CPI that use M2 encompass the alternative price models based on other monetary aggregates. The VAR model for the CPI excluding food and energy that uses M2 again encompasses the alternative models which include the monetary base or M1, but it, in turn, is encompassed by the M2-M1 model.[14]

In view of the possibility that financial innovations or developments may have weakened or altered the relationship between money and output or prices, we examined the behaviour over time of the variance-dominant VAR models for real GDP and prices. Chow tests for a general structural change in the estimated relationships at the end of 1980 rejected, at the 5 per cent level, the null hypothesis of no change in the output and CPI equations, but could not reject it for the other two price equations. Further tests for the specific null of no change in the marginal effect of money could only reject the null for the CPI equation. However, for both the real GDP equation and the CPI equation we could not reject the hypothesis of no significant shift in the accuracy of the equation after 1980.[15]

Figure 6 plots the sum of the coefficients on money and the other variables obtained by recursive regressions from 1970Q1-1977Q4 to 1970Q1-1990Q4. For the real GDP equation, the sum of the coefficients on real M1 is quite stable throughout the 1980s. However, the sum of the coefficients on the lagged values of real GDP shifted upward in the early 1980s, suggesting a structural change in the estimated relationship. For the price

---

12. The slightly better performance of M2-M1 than of M2 in the VAR for CPIFE is not because of the inclusion of the lagged interest rate in the equation which uses M2-M1. Even when the interest rate is omitted, the specification which uses M2-M1 does slightly better than M2.

13. The models labelled 1, 2 etc. in Table 12 correspond to the models in columns 1, 2 etc. in Tables 9 -11.

14. Again, this result does not depend on the inclusion of the interest rate in the M2-M1 model.

15. The test consisted of testing for $\beta = 0$ in the regression: $\hat{\varepsilon}_t^2 = \alpha + \beta D_t + v_t$ where $\hat{\varepsilon}$ is the residual of the real GDP (or price) equation and D_t is equal to zero from 1970Q1 to 1980Q4 and one from 1981Q1 to 1990Q4.

Table 12

Encompassing Tests for VAR Models
J-test Statistics

Null

Real GDP Model
(Table 9)

Alternative	1	2	3	4
1	-	0.82	3.31**	2.81**
2	3.77**	-	4.58**	2.74**
3	2.26*	1.50	-	2.41*
4	3.81**	1.02	4.64**	-

	PGDP Model (Table 10)			CPI Model (Table 10)	
	1	2	3	1	2
1	-	0.65	0.25	-	2.32*
2	1.55	-	0.14	0.66	-
3	3.96**	3.64**	-	-	-

CPI ex. Food & Energy Model
(Table 11)

	1	2	3	4
1	-	0.75	1.53	1.22
2	3.24**	-	1.80	1.95
3	0.75	3.77**	-	1.11
4	5.26**	4.28**	2.55*	-

* Null rejected at 5 per cent level
** Null rejected at 1 per cent level

Recursive Regressions: VARs for Real GDP and Prices

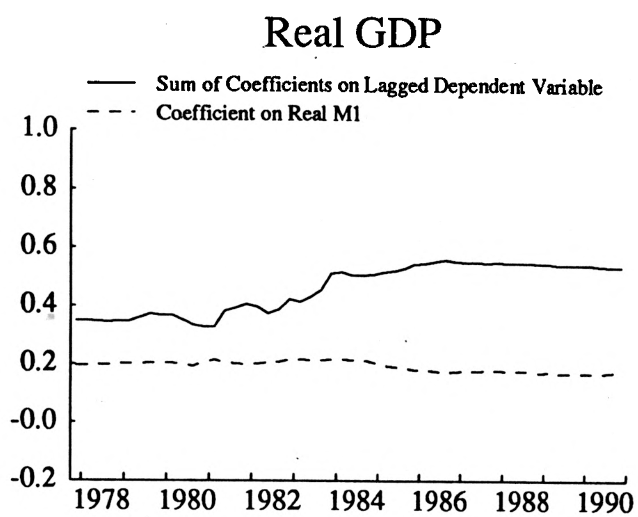

Figure 6A

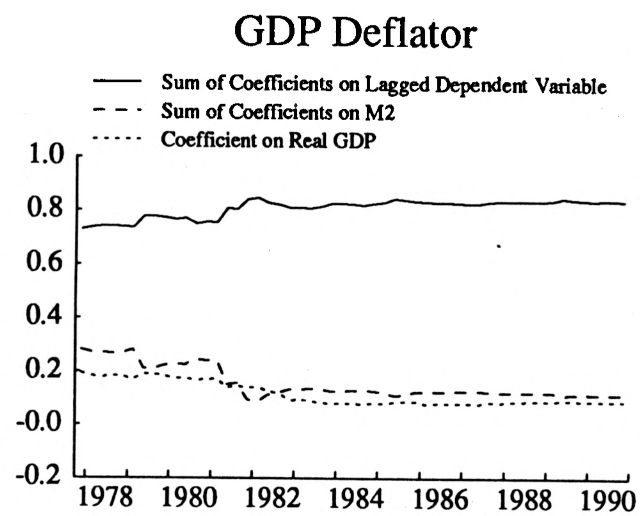

Figure 6B

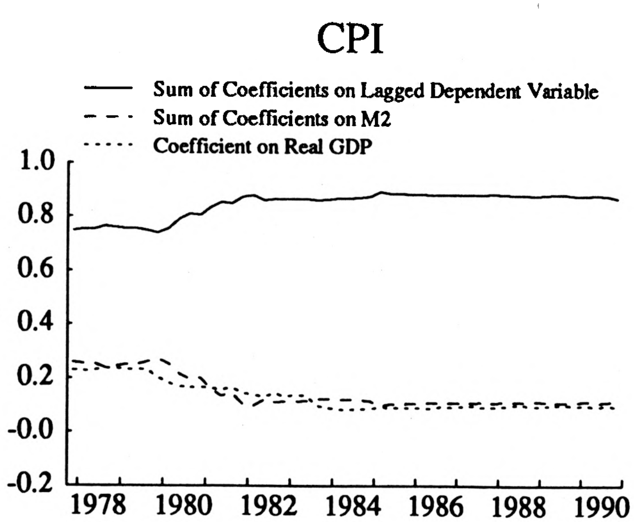

Figure 6C

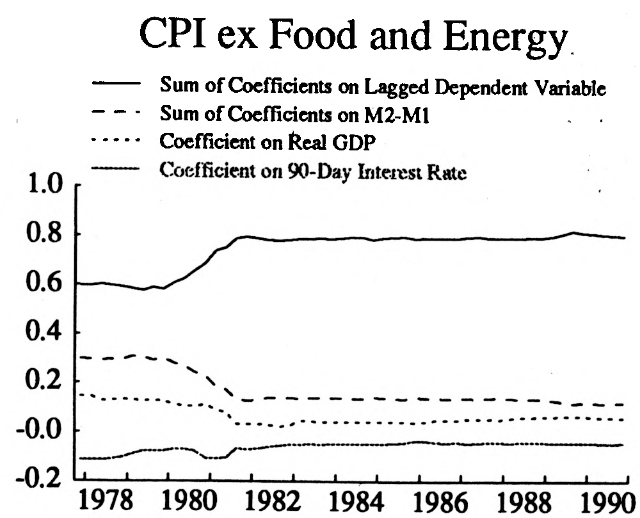

Figure 6D

equations, the sum of the coefficients on M2 (and real GDP) shifted downward in the 1980-81 period, which was matched by a corresponding upward shift in the sum of coefficients on lagged prices and subsequently remained rather constant. Taken together, these results indicate a shift in the relationship between money, output and prices at a time of rapid financial innovation in the early 1980s, but there appear to have been no other significant shifts.

4. Output Growth, Inflation and Error Correction

Hostland, Poloz and Storer (1987) and Muller (1990) used first differences of logs to assess the predictive content of monetary aggregates. This avoids the spurious regression problem in series that contain stochastic trends but are first-difference stationary. However, if there exist (cointegrating) relationships that tie together the levels of money, output, prices and possibly other variables in the long run, then a model that excludes this information may be misspecified (Christiano and Ljungqvist, 1988).[16] In this section we examine whether deviations of M1 and M2 from their long-run equilibrium values contain information about future output growth and/or future inflation.

The following long-run relationship among M1, real GDP (UGDP), the price level (PGDP), a short-term interest rate (R, the 90-day commercial paper rate), a linear time trend, and a shift variable was estimated for the period 1956Q1 to 1990Q4:[17]

$$\ln M1 = \underset{(-1.95)}{-2.026} \; \underset{(33.31)}{+\,0.934} \ln PGDP \; \underset{(11.38)}{+\,1.002} \ln UGDP \; \underset{(-8.34)}{-\,0.010} R \; \underset{(-3.79)}{-\,0.004} T \; \underset{(-8.37)}{-\,0.138} TD$$

$$\overline{R^2} = 0.999 \qquad DW = 0.476$$

$$ADF = 4.55^{*} \qquad PP = 4.49^{*} \qquad LM(3) = 1.58$$

where TD is equal to zero from 1956Q1 to 1981Q3 and one thereafter. The ADF and PP statistics indicate that it is possible to reject the null hypothesis of no cointegration.[18]

16. This is usually referred to as overdifferencing, e.g., Stock and Watson (1989).

17. Preliminary tests of the individual order of integration of the time series included in the cointegrating regression revealed that each of the series contains a unit root.

Deviation of M1 from Long-Run Equilibrium

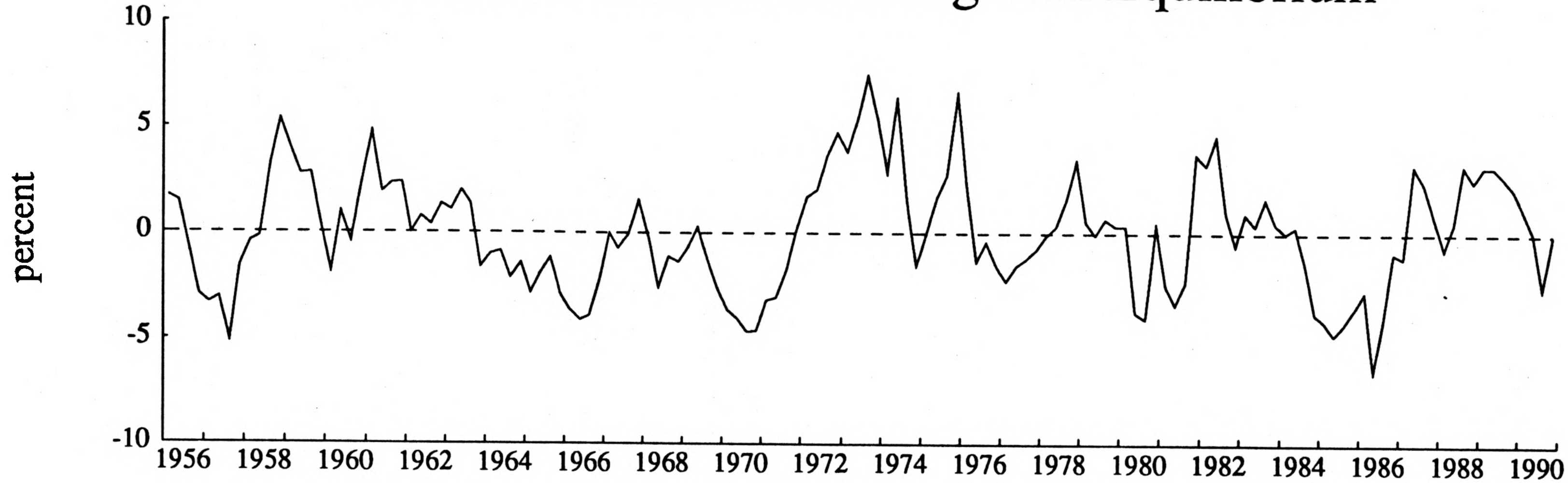

Figure 7A

Deviation of M2 from Long-Run Equilibrium

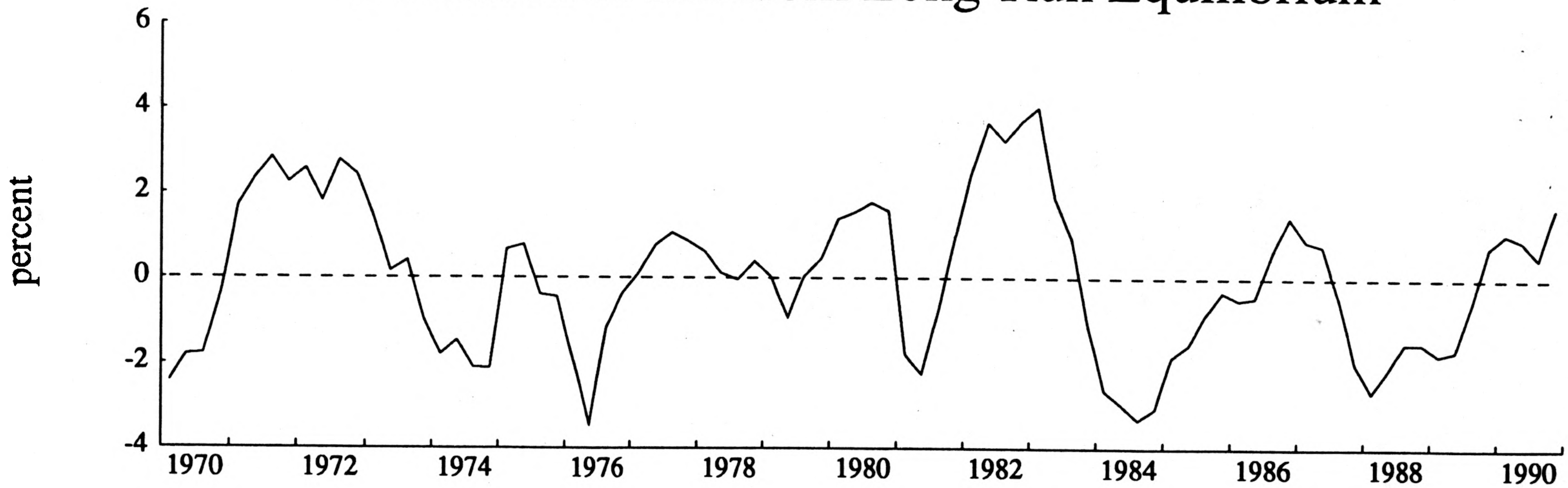

Figure 7B

The residuals of this static regression are plotted in Figure 7A. There appears to be no systematic over-prediction or under-prediction of M1 balances.

Restricting the coefficient on price level to unity does not alter this result:

$$\ln M1 - \ln PGDP = \underset{(-2.05)}{-2.164} + \underset{(11.49)}{1.023} \ln UGDP \underset{(-10.90)}{- 0.011} R \underset{(-4.87)}{- 0.005} T \underset{(-9.69)}{- 0.138} TD$$

$$\overline{R^2} = 0.974 \qquad DW = 0.488$$

$$ADF = 4.61* \qquad PP = 4.51* \qquad LM(3) = 1.19$$

For M2 we adopt a long-run relationship estimated by Caramazza, Hostland and McPhail (1990) in the context of an error-correction model for M2 for the sample period 1969Q1 to 1989Q3[19]:

$$\ln M2 = \ln PGDP + 0.752 \ln UGDP - 0.104 \ln CSB + 0.00532\, T$$

$$ADF = 4.25* \qquad PP = 3.85$$

The null hypothesis of no cointegration can be rejected on the basis of the ADF statistic at the 5 per cent level and on the basis of the PP statistic at the 10 per cent level. Moreover, the residuals of the cointegrating regression, plotted in Figure 7B, reveal a tendency for M2 to revert to its computed long-run equilibrium, judging by the frequent cross-overs of the zero line.

On the basis of the results of the preceding section and of previous information content studies, the residuals from the cointegrating regression for real M1 were included in an equation for real GDP growth, while the residuals from the cointegrating regression for M2 were included in the inflation equations. We refer to these residuals as error-correction (ECM) terms.

The general specification of the real GDP growth equation included lagged values of real GDP growth, the output gap, and lagged values of real M1 growth. Similarly, the general

---

18. ADF and PP are the Augmented Dickey-Fuller and Phillips-Perron cointegration test statistics with truncation lags of 3 and 6, respectively. An * indicates significance at the 5 per cent level based on the critical values reported in Engle and Yoo (1987). The truncation lag for the ADF statistic was chosen on the basis of diagnostic tests for serial correlation. LM(3) is the Lagrange Multiplier test statistic for serially uncorrelated errors up to lag 3.

19. The complete equation is given in the Appendix.

specification of the inflation equations included lagged values of inflation, the ECM term, the output gap, and lagged values of M2 growth.[20] The output gap (GDPGAP) was included to allow developments in the goods market to directly influence output growth and inflation. The measure of the output gap used is the cyclical component of real GDP derived in section 2. Regression results are presented in Table 13.

As regards the real GDP growth equation, the ECM term does not enter the final specification, although it is significant in specifications which exclude lags of real M1 growth.[21,22] Indeed, when lagged values of real M1 growth are included, all other variables (except the output gap) become insignificant, and the significance of the output gap is reduced. These results point to the importance of changes in M1 as a leading indicator of changes in output. The negative, small coefficient on the output gap reflects the tendency of the output gap to be closed slowly over time.

In the inflation equations, about 70 per cent of the variation of inflation is explained by lagged inflation, the ECM term, the output gap, and lagged M2 growth. For the PGDP and the CPIFE equations, but not for the CPI equation, there is no evidence of serial correlation up to lag four. An important feature to note is that the estimated coefficients on the ECM term and the output gap have the expected signs and are statistically significant in all equations. This suggests that in the short run, both money and the price level adjust to restore the long-run relationship among money, prices and output.[23]

In addition to the output gap and the ECM term, all three inflation equations include two lags of inflation and one lag of M2 growth. The statistical significance of the latter variable is consistent with the results of the VAR models in section 3 and with previous information content studies that conclude that M2 contains information about future inflation.

As noted above, the inclusion of both the deviations of M2 from its long-run relationship and the deviations of output from its long-run trend represents the notion that the inflation process may be influenced by developments in both the money market and the goods market -- rather than by those in the money market alone (as in "monetarist" models) or by those in the goods market alone (as in standard Phillips curve models based on an output

20. For ease of exposition we refer to first differences of logs of variables as growth rates.

21. The residuals from the cointegrating regression for M2 also proved insignificant.

22. Using monthly data for the period 1970:7 - 1987:3, Ambler (1989) found an error-correction term for M1 velocity to be significant in a VAR for industrial production.

23. If the coefficient of 0.18 on the ECM term in the demand for M2 equation estimated by Caramazza, Hostland and McPhail is interpreted as the speed at which M2 demand adjusts to shocks, then the results of the present paper suggest that money demand adjusts somewhat faster than prices.

Table 13

Error-Correction Representation of Output Growth and Inflation 1970Q1 - 1990Q4

$$\Delta \ln UGDP = \underset{(5.74)}{0.007} + \underset{(0.84)}{0.09}\,\Delta \ln UGDP_{-1} + \underset{(3.26)}{0.16}\,\Delta \ln RM1_{-1} + \underset{(3.54)}{0.17}\,\Delta \ln RM1_{-2} + \underset{(0.68)}{0.02}\,ECM1_{-2} - \underset{(-1.84)}{0.12}\,GDPGAP_{-1}$$

$\bar{R}^2 = 0.415$ SEE= 0.769 E-2 DW= 2.04 LM(4)=3.20

$$\Delta \ln UGDP = \underset{(9.98)}{0.008} + \underset{(3.72)}{0.17}\,\Delta \ln RM1_{-1} + \underset{(4.55)}{0.20}\,\Delta \ln RM1_{-2} - \underset{(-1.69)}{0.09}\,GDPGAP_{-1}$$

$\bar{R}^2 = 0.420$ SEE= 0.765 E-2 DW= 1.92 LM(4)= 2.96

$$\Delta \ln PGDP = \underset{(1.69)}{0.002} + \underset{(3.11)}{0.30}\,\Delta \ln PGDP_{-1} + \underset{(3.79)}{0.37}\,\Delta \ln PGDP_{-2} + \underset{(3.37)}{0.12}\,ECM2_{-2} + \underset{(3.61)}{0.16}\,GDPGAP_{-1} + \underset{(1.39)}{0.09}\,\Delta \ln M2_{-2}$$

$\bar{R}^2 = 0.676$ SEE= 0.502 E-2 Durbin-h= 1.09 LM(4)= 8.16

$$\Delta \ln CPI = \underset{(0.73)}{0.001} + \underset{(3.39)}{0.35}\,\Delta \ln CPI_{-1} + \underset{(2.95)}{0.28}\,\Delta \ln CPI_{-2} + \underset{(3.34)}{0.10}\,ECM2_{-2} + \underset{(2.76)}{0.10}\,GDPGAP_{-1} + \underset{(3.62)}{0.19}\,\Delta \ln M2_{-1}$$

$\bar{R}^2 = 0.733$ SEE= 0.422 E-2 Durbin-h= -0.43 LM(4)= 12.40

$$\Delta \ln CPIFE = \underset{(1.26)}{0.001} + \underset{(4.33)}{0.45}\,\Delta \ln CPIFE_{-1} + \underset{(2.72)}{0.27}\,\Delta \ln CPIFE_{-2} + \underset{(2.04)}{0.05}\,ECM2_{-2} + \underset{(3.16)}{0.10}\,GDPGAP_{-1} + \underset{(2.21)}{0.10}\,\Delta \ln M2_{-1}$$

$\bar{R}^2 = 0.688$ SEE= 0.377 E-2 Durbin-h= -1.14 LM(4)= 4.96

gap). The combined ECM and output gap terms correspond to the "price gap," i.e., the difference between the actual price level (P) and the long-run equilibrium price level (P*), in the model of Hallman, Porter and Small (1989).

Hallman, Porter and Small define the price gap as:

$$p - p^* = (v - v^*) + (q^* - q)$$

where

$$p^* = m2 + v^* - q^*$$

v is the velocity of M2, v* is the long-run equilibrium value of velocity, q is real GNP, q* is the current value of potential GNP, and where lower case letters represent logs of variables. More generally, if the income elasticity of M2 is not assumed to be unity, the above equations can be re-written as:

$$p - p^* = (\bar{v} - \bar{v}^*) + \alpha(q^* - q)$$

where

$$p^* = m2 + \bar{v}^* - \alpha q^*$$

and where $\bar{v}^*$ is the long-run equilibrium value of velocity adjusted for the fact that the income elasticity of M2, α, is not unity. The deviation of velocity from its long-run equilibrium value in the price gap model corresponds to the ECM term in our model, in which we use an estimated long-run income elasticity of M2 of 0.75.

In the price gap model, inflation is assumed to be a function of (p - p*) and lagged values of inflation. The coefficients on the deviation of velocity from its long-run equilibrium value and on the output gap are constrained to be equal, that is, the two components of the price gap are assumed to explain inflation in conjunction as components of (p - p*) rather than independently. In our model this assumption would correspond to the restriction that the coefficient on the ECM term should be 1/0.75 times that on the output gap.

The estimated coefficients on the ECM term and the output gap range from 0.05 to 0.12 for the ECM term and from 0.10 to 0.16 for the output gap. For the PGDP and CPIFE equations, F tests reject, at the 5 per cent level, the constraint implied by the price gap model that the coefficient on the ECM term is 1/0.75 times that on the output gap.[24]

24. For the PGDP equation the constraint cannot be rejected at the 10 per cent level.

However, the constraint cannot be rejected for the CPI equation. Thus, the price-gap model's underlying assumption that developments in both the money market and the goods market affect the inflation process is supported by our results. But the more restrictive assumption that they do so jointly as part of (p - p*) is not supported.[25]

As was done for the VARs in section 3, we examined the behaviour over time of the real GDP and inflation equations reported in Table 13. Figure 8 plots the estimated values of the various coefficients obtained by recursive least squares. The results are very similar to those reported in section 3. There was a shift in the sum of the estimated coefficients on the lagged dependent variable and in the coefficients on money in the 1981-82 period. Nevertheless, Chow tests for a structural change in the estimated relationships rejected the null hypothesis of no change only for the output equation, while the hypothesis of no significant shift in the accuracy of the equations after 1980 could be rejected only for the PGDP equation.

5. Conclusions

The results of this study confirm the significant role of the monetary aggregates in predicting changes in real GDP and prices found in previous studies. The information content of money, particularly the leading indicator properties of M1 with respect to real GDP and of M2 with respect to prices, is not sensitive to the procedure used to detrend the data. This gives us greater confidence that the observed correlations reflect the underlying relationship among the variables.

Multivariate VAR models for Canadian output and prices used to evaluate the marginal predictive content of monetary aggregates have generally disregarded the potential information in the relationship linking money, output, prices and other variables in the long run. The results of this paper indicate that it is inappropriate to do so, at least for prices.[26] Deviations of M2 from its long-run relationship contain information about future inflation which is additional to that contained in lagged inflation, lagged M2 growth and an output gap. This finding supports the basic conjecture underlying the "price gap model" that the inflation process is influenced by developments in both the money market and the

25. A similar analysis to the one in this section has been carried out for U.S. data by Ebrill and Fries (1990). They found that deviations of U.S. M2 from its long-run relationship are statistically significant in an error-correction representation of the U.S. inflation process only if the output gap is excluded.

26. Ambler's results, see footnote 22, indicate that it may also be inappropriate to do so for industrial production.

Recursive Regressions: Error Correction Models

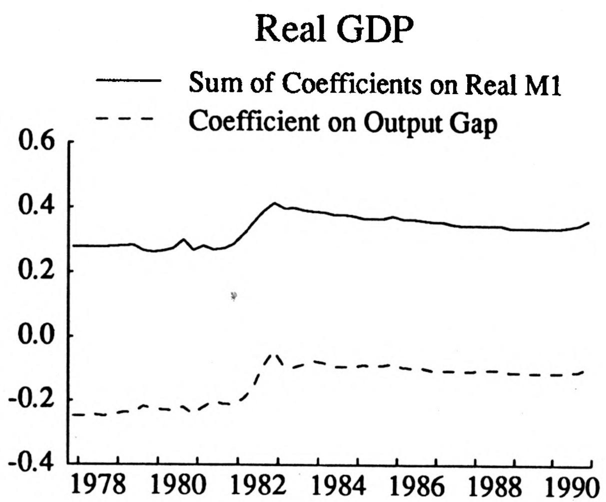

Figure 8A

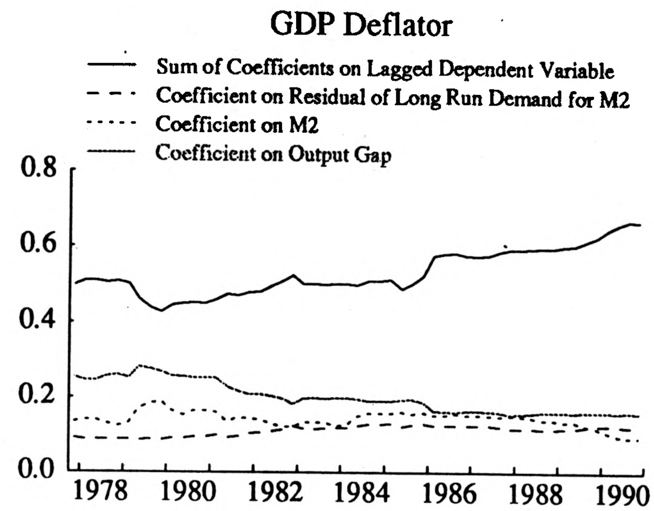

Figure 8B

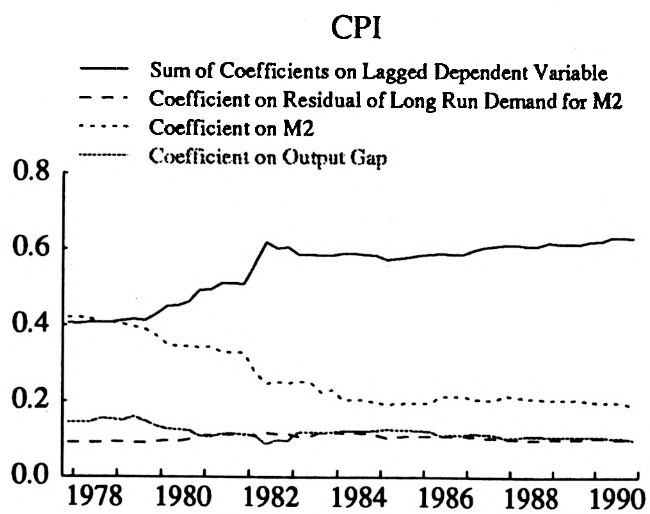

Figure 8C

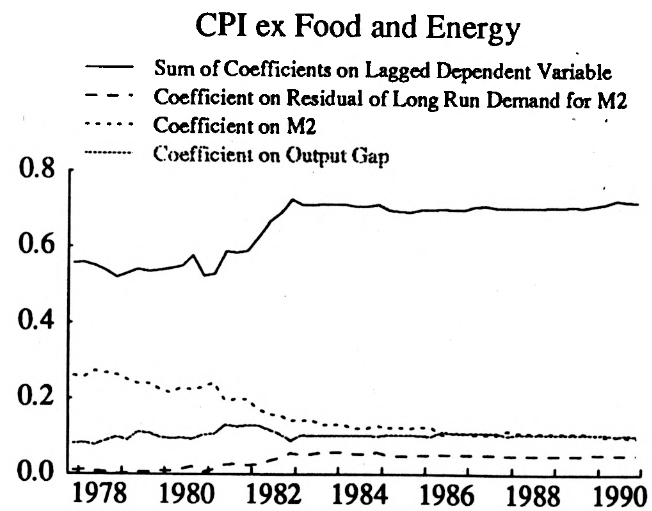

Figure 8D

goods market. However, the model's assumption that deviations of M2 from its long-run equilibrium value and the output gap explain inflation as components of the price gap, rather than independently, is not supported.

Changes in real GDP are explained mainly by lagged values of changes in real M1. Lagged changes in real GDP, short-term interest rates, measures of the yield curve, and an error correction term for M1 are all insignificant in specifications that include changes in real M1. This result contrasts with that of Ambler (1989) who found that an error-correction term for M1 velocity is significant in a multivariate VAR for industrial production, but that lags of changes in M1 are not. Investigation of the sources of this difference is a subject for future research.

Finally, it should be noted that the results presented in this paper may be compatible with more than one type of economic structure and cannot, therefore, be used to draw inferences about such issues as the role of money in business cycles. To discriminate among competing theories of the cycle would require the imposition of more identifying restrictions on the data in the context of a fully articulated model.

Appendix

Notation and Data Sources

UGDP	GDP in constant dollars; CANSIM D20463.
PGDP	GDP deflator; CANSIM D20556.
CPI	Consumer price index, total; CANSIM B820000.
CPIFE	CPI excluding food and energy; CANSIM B820155.
MB	Monetary base, exclusive of required reserves against Government of Canada deposits and adjusted for changes in required reserves; Bank of Canada.
M1	Monetary aggregate M1; CANSIM B1627.
M2	Monetary aggregate M2; CANSIM B1630.
R	90-day prime corporate paper rate; CANSIM B14017.
RFTD	Interest rate on 90-day fixed-term deposits at chartered banks; CANSIM B14043.
CSB	Stock of Canada Savings Bonds, CANSIM B2406, divided by GDP deflator.

All data, except interest rates, are seasonally adjusted. Quarterly observations for the CPI and CPIFE were obtained by taking the average of monthly data.

Hodrick-Prescott Filter

The HP filter was fitted to UGDP, PGDP, CPI, CPIFE, and M1 over the period 1954Q1 - 1990Q4, to MB over the period 1961Q1 - 1990Q4, and to M2 over the period 1968Q1 - 1990Q4.

Long-Run Relationship for M2

The error-correction equation for M2 in Caramazza, Hostland and McPhail (1990) referred to in section 4 of the paper is:

$$\Delta \ln M2 = \underset{(0.564)}{0.516} + \underset{(0.109)}{0.148}\,\Delta \ln M2_{-1} + \underset{(0.129)}{0.221}\,\Delta \ln PGDP + \underset{(0.131)}{0.476}\,\Delta \ln PGDP_{-1}$$

$$+ \underset{(0.067)}{0.170}\,\Delta \ln UGDP + \underset{(0.071)}{0.114}\,\Delta \ln UGDP_{-1} - \underset{(0.160)}{0.200}\,(R - RFTD) - \underset{(0.178)}{0.675}\,(R_{-1} - RFTD_{-1})$$

$$+ \underset{(0.168)}{0.464}\,(R_{-2} - RFTD_{-2}) - \underset{(0.063)}{0.179}\,(\ln M2_{-2} - \ln PGDP_{-2} - 0.752 \ln UGDP_{-2} + \ln CSB_{-2} - 0.00532T)$$

$R^2 = 0.775$ DW = 2.01 SEE(%) = 0.572 ADF = 4.25* PP = 3.85

standard errors in parentheses.

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