Aggregate Money Demand Functions in Five Industrial Countries: Are They Cointegrated?

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ABSTRACT

In this paper we take issue with the claim made in some recent empirical studies that real money balances, real income and interest rates are cointegrated, or, alternatively, that velocity is a stationary variable, which is in contrast with the well known stylised facts about the behaviour of monetary aggregates in the UK and other industrial countries. We show that in fact this surprising result can be explained away in terms of statistical bias. It is only because in these studies inference is based on a mis-specified VAR that the null of no cointegration can be rejected - the standard result that money demand functions exhibit instability and that velocity is a non-stationary variable is confirmed when the analysis is carried out within a correctly specified system.

KEY WORDS

money demand, velocity, cointegration

RESUMO

Neste artigo discute-se o resultado obtido em alguns estudos empíricos recentes de que saldos monetários reais, renda real e taxa de juros são cointegrados ou, alternativamente, que a velocidade é uma variável estacionária, o que está em contraste com os fatos estilizados bem conhecidos sobre os agregados monetários no Reino Unido e outros países industrializados. Mostra-se que de fato este resultado surpreendente se deve a um viés estatístico. Somente porque nestes estudos inferência é baseada num VAR mal especificado é que possível rejeitar a nula de não cointegração. O resultado padrão de que as funções de demanda por moeda exibem instabilidade e que a velocidade é uma variável não estacionária é confirmada quando a análise é feita usando-se um sistema corretamente especificado.

PALAVRAS-CHAVE

demanda por moeda, velocidade, cointegração

JEL Classification

E41

INTRODUCTION

Finding a stable long-run relationship linking real money balances to real income and interest rates is notoriously difficult. Whilst early empirical studies seemed to suggest that a log-linear equation of this kind exhibited stability (see, e.g., GOLDFELD, 1973), subsequently it became apparent that the relationship had broken down. For instance, in the US the case of the "missing money" in 1974:1-1976:2, the great velocity decline in 1982:1-1983:2, and the M1 explosion of 1985:1-1986:4 all resulted in shifts in the demand for money (see BABA, HENDRY AND STARR, 1992). In the UK a breakdown occurred in 1973, when M3 rose sharply as a result of the massive increase in wholesale bank deposits to fund higher bank lending to the private sector. In both countries there was a major policy shift in 1979, the US Federal Reserve Board switching from interest rate targeting to monetary base control, and the UK government adopting monetary control as the centrepiece of its anti-inflationary policy. Reviewing the literature, Goldfeld and Sichel (1990) concluded that the existing empirical models suggested instability in the money demand function.

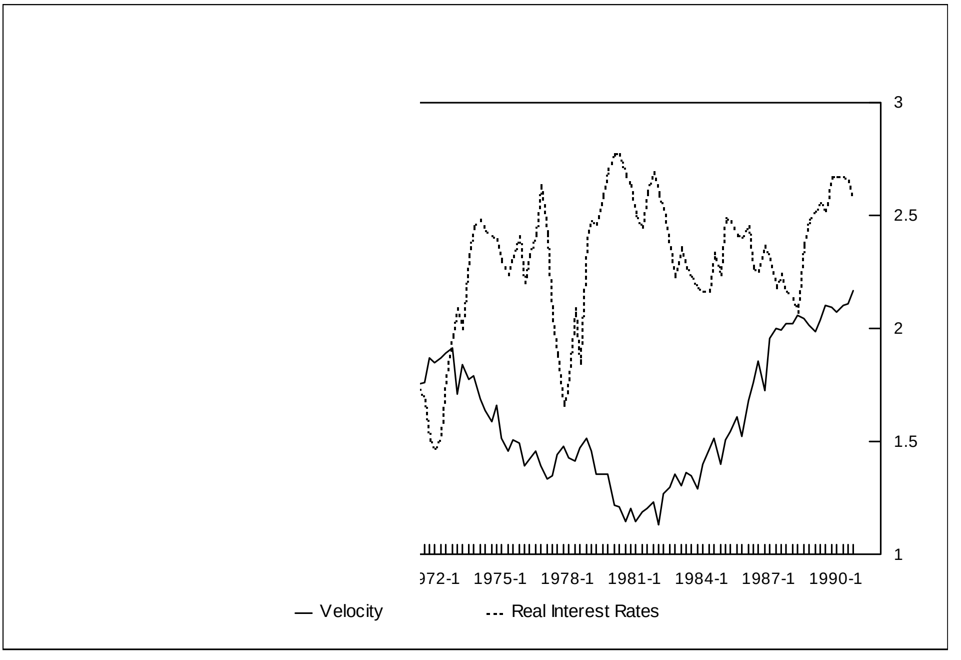
The claim that a stable money demand exists, more specifically that real M1, real income and short-term interest rates are cointegrated, or, alternatively, that velocity is a stationary variable (the two statements being equivalent, as long as interest rates are I(0)), has resurfaced in some recent studies. A typical example is the work of Hoffman, Rasche and Tieslau (1995) and Hoffman and Rasche (1996), who examine the stability of long-run demand functions for narrowly defined real money (M1) in five industrial countries including the UK, and find cointegration in all five countries with a unit elasticity on income (thereby confirming the well known velocity relationship), once a step dummy, which is 1.0 after 1981:4, is included (in the case of the UK, an additional dummy, which is 1.0 beginning in 1986:1, was also found to be necessary). They base their analysis on the Johansen (1988) procedure and argue that the inference is very robust - experimenting with lag lengths 3, 4, and 5 does not affect the general conclusions.

In this paper we argue that this is a striking result which is in contrast to the well known stylised facts about money demand. Consider, for instance, the case of the UK. Existing empirical studies generally reach the conclusion that monetary aggregates are not cointegrated with nominal income with a unit coefficient;[1] however, cointegration can be achieved by adding other variables, such as wealth, financial innovation variables or cumulated interest rates, to a standard money demand function (see, e.g., HALL *et al.*, 1990; HENDRY AND ERICSSON, 1991, 1993). This is because velocity is highly trended, and only by including a similar effect is it possible to build a well balanced equation. Chart 1 shows the inverse of velocity for the UK derived from the Hoffman *et al.* (1995)[2] data set. There is a very clear downward trend until 1981 and then this is followed by a clear reversal and a strong upward trend. This phenomenon is well understood in the UK, until 1981 all M1 was non interest bearing and financial innovation in the form of more flexible checking accounts, credit cards etc. produced the downward trend which we are familiar with throughout the world. After 1981 an increasingly important component of M1 began to earn interest and so M1 began to behave more like broad money. In fact because of this clear break in definition most work on the UK has focused on the non-interest bearing component of M1 and the interest bearing component separately. The non-interest bearing component has an unbroken downward trend over the whole period. The main point, however, to be drawn from chart 1 is that even if we ignore this break in definition velocity simply does not look like a stationary process. This point is further emphasised when we recall that Hoffman *et al.* (1995) actually provide recursive tests over a large number of periods and they find cointegration even over the period 1957:1-1980:4, examining only the pre-break period. This result must be wrong. Similar considerations apply to the other major industrial countries, where the relationship also broke down.

1 For a survey of the evidence, see GOODHART (1989) and also TEMPERTON (1991).

2 We are very grateful to Prof. Rasche for kindly supplying the data.

CHART 1 - UK VELOCITY (LHS) VS REAL INTEREST RATES (RHS) - (Inverse of Velocity and log of Real Rates)



The purpose of this paper is to look further into this issue by using the same dataset and investigating why the Johansen trace statistic is giving such implausible results in this case. We shall show that the standard result that long-run money demand exhibits instability holds if the analysis is carried out within a correctly specified system; as long as interest rates are a stationary variable, this also implies that velocity is non-stationary, as one would expect given the actual behaviour of monetary aggregates in the major industrial countries.

The layout of the paper is the following. Section 1 explains under what conditions the Johansen method yield valid statistical inference, and what criteria should be used to select the correct model specification. Section 2 presents the empirical results. Last section offers some concluding remarks.

1. THE JOHANSEN METHODOLOGY

The Johansen (1988, 1991) approach to testing and estimating cointegrated systems is now well known and has become widely used. It is also well known in the literature that valid inference within the Johansen framework requires the VAR to be correctly specified - any evidence of serially correlated or non-Gaussian residuals invalidates the results. Furthermore, in general, although the maximum likelihood (ML) parameter estimates are relatively robust to the choice of lag length p of the VAR, inference about the cointegrating rank is rather sensitive (see HALL, 1991). There are broadly two approaches which may be used to ensure the adequacy of the VAR. The first is to check a broad range of diagnostics on the VAR and to choose the minimum lag length which still ensures that all the equations are free from misspecification (this would certainly include serial correlation, heteroskedasticity and normality). The second option is to use one of the information criteria to pick an adequate lag length. Both approaches are used in the literature, the first is used by Johansen himself and many others and can lead to more parsimonious VARs if suitable inclusion of seasonals, dummies and other special effects is made. The information criteria approach can often lead to very high order VAR specifications which may run into small sample problems.

Hall (1991) pointed out that the asymptotic inference process can go wrong for two basic reasons. If the VAR is too short and hence misspecified in some way then the test statistics of the cointegrating rank will be biased upwards. If the VAR is heavily over parameterised then the asymptotic statistics will be again biased upwards as the test procedure is effectively running out of degrees of freedom. This second problem can be partly dealt with by using a small sample adjustment to the test but then the power of the test can be adversely effected when the VAR is again overparameterised.

Other recent papers present further evidence that the asymptotic critical values cannot be relied upon in the case of small samples. For instance, Gregory (1994) shows that other tests of cointegration perform better than the Johansen test in small samples (and with a high number of explanatory variables), in the sense that the former have a lower (i.e. better) *size* (the rejection frequency when the null hypothesis of no cointegration is true). The necessary upward (downward) adjustment of the critical values (test statistics) has been worked out by Reinsel and Ahn (1988), and shown to yield more appropriate critical values by Cheung and Lai (1993).[3]

2. EMPIRICAL RESULTS

In this section we reconsider the empirical results presented by Hoffman at al (1995), and Hoffman and Rasche (1996) in the light of the above discussion, and show that their inference is invalidated by statistical bias. First we consider the case of the UK in some detail, and then we replicate the analysis for the other industrial countries.

3.1 UK

We begin by focusing on the period 1957:1-1980:4 as this allows us to completely abstract from the statistical problems caused by the break in the data. We then re-estimated the same vector error correction model (VECM) as in Hoffman *et al.* (1995) using Johansen's (1988, 1991) method, but varying the lag length from 1 to 15.[4] The trace statistic with and without a small sample adjustment, the Akaike Information Criterion (AIC) and diagnostic tests for autocorrelation and normality are reported in Table 1a. This clearly shows that the range of the test statistic is quite large, ranging from 69 at lag 4 to 26 at lag 10, so the results are sensitive to the choice of VAR length. Both the unadjusted and the adjusted trace statistics tend to fall as the lag length increases (with the exceptions of $p=4$). The Akaike Information Criterion (AIC) reaches a maximum at lag 10 while the

3 Some more simulation evidence on small sample properties of multivariate cointegration tests can be found in RICHARDS (1995).

4 The estimation was carried out using PcFiml 8.0 (see DOORNIK AND HENDRY, 1994).

residuals only begin to approach normality at a lag length of 12 or more. So proper inference should not be based on a VAR specification of less than 10, which interestingly enough gives the minimum asymptotic test statistic, this is well below the critical values which would allow us to reject non-cointegration.

So on either method of VAR selection no evidence of cointegration can be found. This is the result we expected, given the well known stylised facts about the behaviour of monetary aggregates in the UK and the empirical findings reported in numerous econometric studies.

However even this conclusion is not safe because of the presence of strong non-normality as demonstrated by the final column in Table 1a. We therefore carry out a search exercise to find the minimum set of dummy variables which will allow us to achieve a reasonable approximation to normality as judged by the vector normality test reported. Table 1b then repeats the analysis of Table 1a while including all the necessary dummy variables to give normality. This inclusion of a relatively small set of dummy variables changes the results quite dramatically, the optimal lag length is reduced to 7 and at this lag the VAR is well specified. If we had chosen to minimise the lag length subject to passing the tests we could have actually chosen a lag length of between 4 and 6. At any of these lag lengths we are able to reject the hypothesis of a zero cointegrating rank in favour of the presence of cointegration. However when we consider the actual estimates of the cointegrating vector (shown in the second row of Table 6) it is clear what is happening. The sharp downward trend in velocity is being captured by an elasticity on income of only 0.36. We clearly have a missing trend in terms of financial innovation and this missing trend is affecting the coefficient of the remaining trend variable, income. If we try to impose a unit coefficient on income the Likelihood ratio test of this restriction convincingly rejects this hypothesis (as shown in column 5 of Table 6). So once the VAR has been correctly specified in statistical terms we are able to convincingly reject the notion that the velocity of money is a stable cointegrating vector in contrast to the work of Hoffman Rasche and Tieslau.

For the sake of completeness, the same exercise was also carried out over the whole sample period (1957:1 1990:4) including all the shift dummies used by Hoffman *et al*. The relevant statistics are shown in Table 1c. It is intuitively obvious that shift dummies are not going to be an adequate way of describing the structural break which occurred in the trend in M1 velocity shown in Chart 1. We would expect this procedure to produce heteroskedatic errors and strong non-normality. This is indeed the case, even a 15th order VAR is not sufficiently complex to allow us to accept the assumption of normality at a 90% confidence interval. The information criteria reaches a maximum at 5 lags and serial correlation effectively disappears at this point also, but both of these procedures are based on a normal error process and they can be highly misleading in the presence of strong non-normality. If we ignored this point we would of course conclude that cointegration actually does exist over the full sample.

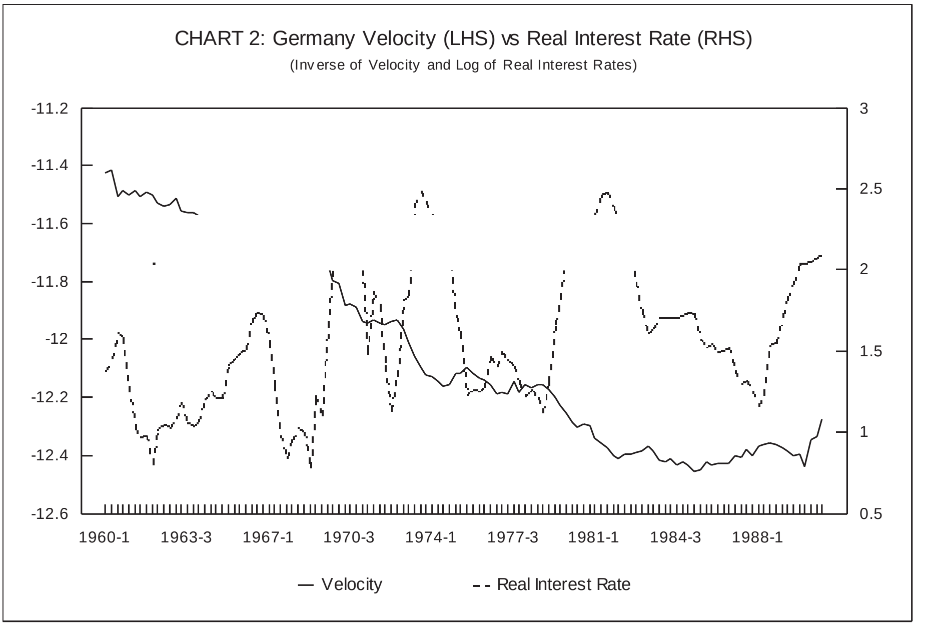
We then go on, in Table 1d, to add a set of dummy variables to achieve normality and to repeat the exercise. The optimal lag length is then given at lag 8 while satisfactory diagnostics are achieved for a lag length greater than 6. At this lag length once again we can reject the hypothesis of non-cointegration. The first row of Table 6 gives the resulting cointegrating vector. The income elasticity has now risen to 1.7 to capture the rising trend in velocity over the second part of the sample. Clearly just the instability of this coefficient throws considerable doubt on the validity of this cointegrating relationship. But again when we test the unit elasticity of income hypothesis we find that it is convincingly rejected. So although the results are different over the full sample the qualitative conclusion that there is no velocity like cointegrating relationship is made even more powerfully over the full sample than over the shorter one.

This example emphasises the need to check the diagnostics of the VAR even when using one of the information criteria as a selection procedure for the lag length, correct inference can only be drawn within this maximum likelihood procedure when the model meets the full set of gaussian assumptions upon which the estimator rests.

3.2 Germany

Chart 2 shows the time path for velocity and interest rates for Germany from 1960 to 1990. The VECM was estimated over the shorter sample period 1963:4-1980:4 and the full sample 1963:4-1990:4. In the former case, the AIC suggests selecting lag length 12 as the appropriate specification, and the corresponding trace statistic, once the necessary small sample correction has been made, indicates that the cointegrating rank of the system is zero. In the case of the full sample estimates, Table 2b, there is strong evidence of non-normality but little evidence of cointegration. In Table 2c we correct for the non-normality which makes it more likely that cointegration exists but again when we examine the cointegrating vector the income elasticity is 1.3 and we can reject the hypothesis of a unit income elasticity at the 10% level.

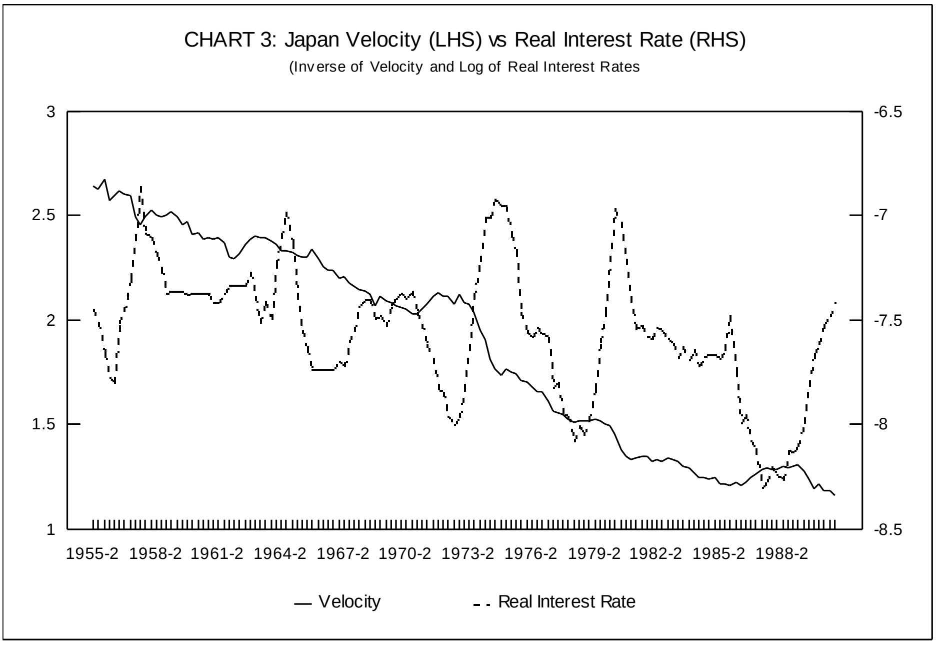
CHART 2 - GERMANY VELOCITY (LHS) VS REAL INTEREST RATE (RHS) - (Inverse of Velocity and Log of Real Interest Rates)



3.3 Japan

Chart 3 shows velocity and interest rates for Japan over the period 1955 to 1990. The sub-sample is here 1959:1-1980:1, whilst the full sample is 1959:1-1990:4. Here once again over the full and sub samples the residuals are highly non normal, for brevity we omit these table and Tables 3a and 3b report the results for the VARs with added dummy variables to ensure normality. The conclusions of both tables is that there is cointegration but when we examine the cointegrating vectors in Table 6 we again see elasticities of 1.2 to 1.3 and the test of the unit elasticity restriction is convincingly rejected. So again once inference is made within a proper setting we find that the velocity relationship is not a valid one.

CHART 3 - JAPAN VELOCITY (LHS) VS REAL INTEREST RATE (RHS) - (Inverse Velocity and Log of Real Interest Rate)

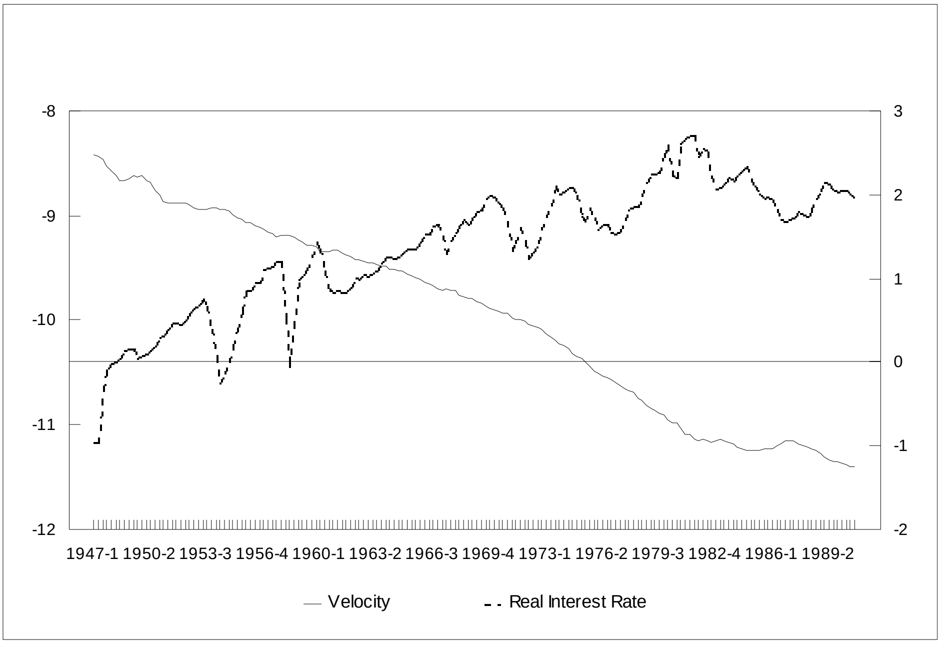


3.4 USA

Chart 4 shows velocity and interest rates for the USA from 1947 to 1990. For the US the estimation was carried out over the sample periods 1950:4-

1980:4 and 1950:4-1990:4 respectively. Again the basic VAR was found to have highly non- normal errors and so in Tables 4a and 4b we present the result for the model with extra dummies to achieve normality. Both the full and sub samples finds an optimal lag length of 8 quarters which yields the result that there is no cointegration, there is some signs of serial correlation at this lag length but extending the lag further does not change the conclusion as to the presence of cointegration. So once again when the inference is conducted properly there is no evidence that the velocity relationship is a stable one.

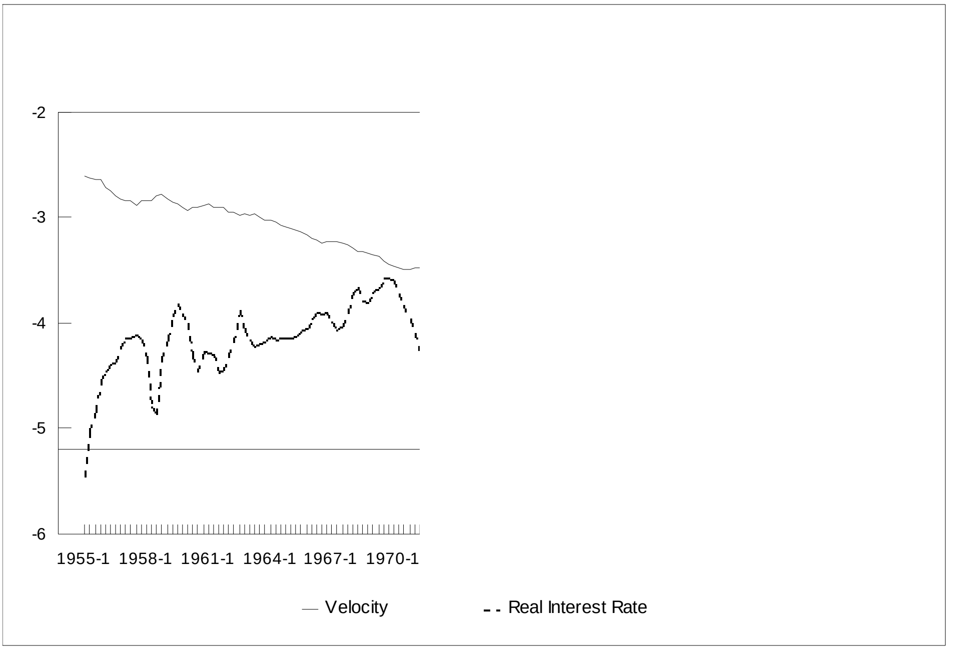
CHART 4 - US VELOCITY (LHS) VS REAL INTEREST RATE (RHS) - (Inverse Velocity and Log of Real Interest Rate)



3.5 Canada

Chart 5 shows velocity and interest rates for Canada from 1955 to 1990. The VAR was estimated in this case over the periods 1958:4-1980:4 and 1958:4 1990:4. Both sets of estimates proved to exhibit strong non-normality. The results reported in Tables 5a and 5 b therefore report the model with added dummies to overcome this problem. The choice of lag length is a little difficult here, over the full sample the AIC is maximised with just one lag but there is still signs of serial correlation until lag 6 is used. the sub sample sees a local maximum to the AIC at 1 but higher Figures at 11 and 15. At almost all possible choices cointegration is accepted. However as table 6 demonstrates this is with a coefficient on income of around 0.8 and the hypothesis that this can be restricted to unity is again convincingly rejected. So the conclusion is again that the velocity relationship is not an acceptable representation of the data.

CHART 5 - CANADA VELOCITY (LHS) VS REAL INTEREST RATE (RHS) - (Inverse Velocity and Log of Real Interest Rate)



CONCLUSIONS

Chart 1 through to 5 show the inverse of velocity for the five industrial countries we have considered - in all cases it is clear that this is a non-stationary series either over the whole period or over the sub-period up to 1981 and that it is highly trended. We set out in this paper to see why the application of the Johansen test procedure in some recent studies such as

Hoffman *et al* (1995) and Hoffman and Rasche (1996) gave such counterintuitive results as to suggest that over either period cointegration between real money, interest rates and income with a unit coefficient and hence stationarity was a reasonable assumption. We have argued that the test procedure is crucially affected by the correct specification of the VAR and we have shown that where an adequate VAR can be achieved the assumption of cointegration is no longer supported. We have also shown that where there are important structural breaks which are not adequately dealt with it may be impossible to achieve correct inference from this procedure.

This emphasises the importance of comprehensive pre-testing of the VAR model, it also indicates that the simple graphical analysis of data can play a very important role in building adequate models.

TABLE 1A - UNITED KINGDOM (SAMPLE PERIOD: 1957:1 1980:4) TRACE STATISTIC, AIC AND DIAGNOSTICS

n	-TΣ log(1-μ)	using T-nm	AIC	F-test	Normality
1	49.54**	47.81**	820.04	3.2449[0.000]**	19.184[0.0034]**
2	46.66**	43.40**	829.70	2.9502[0.000]**	28.391[0.0001]**
3	46.79**	41.90**	841.28	2.2328[0.0001]*	32.179[0.000]**
4	69.12**	59.48**	857.08	1.6706[0.0098]*	31.554[0.000]**
5	46.51**	38.40*	868.06	1.4393[0.0511]	29.904[0.000]**
6	39.33**	31.10*	872.66	1.0261[0.43921]	24.67[0.0004]**
7	34.10*	25.78	877.43	0.86267[0.7126	24.153[0.0005]**
8	34.41*	24.81	881.17	0.76748[0.8461]	18.034[0.0061]**
9	28.88	19.81	887.73	0.80106[0.8008]	22.264[0.0011]**
10	26.08	16.98	<u>889.41</u>	0.79095[0.8120]	18.913[0.0043]**
11	33.48*	20.48	883.46	0.87086[0.6936]	17.917[0.0064]**
12	28.65	16.37	875.37	0.91499[0.6225]	12.692[0.0482]*
13	35.56**	18.85	871.70	0.67372[0.9239]	12.661[0.0487]*
14	34.82*	16.98	864.34	0.68067[0.9135]	7.9018[0.2454]
15	39.98**	17.77	858.33	0.85833[0.6993]	4.5377[0.6043]

Note: 1) n is the lag length of the VAR;

2) ** and * indicate rejection of the null at the 5% and 10% respectively;

3) AIC is the Akaike Information Criterion;

4) the normality test is a vector normality test (see DOORNIK AND HENDRY, 1994 for more details);

5) the F-test is a Lagrange-Multiplier test for serial correlation.

TABLE 1B - UNITED KINGDOM (SAMPLE PERIOD: 1957:4 1980:4) - TRACE STATISTIC, AIC AND DIAGNOSTICS

n	-TΣlog(1-μ)	using T-nm	AIC	F-test	Normality
1	47.98**	46.20**	1622	2.9328[0.0000]**	18.048[0.0061]**
2	43.94**	40.69**	1630	2.7024[0.0000]**	22.862[0.0008]**
3	43.74**	38.88**	1636	2.3343[0.0001]**	15.368[0.0176]*
4	62.28**	53.05**	1626	1.5503[0.0277]*	10.976[0.0891]
5	51.14**	41.67**	1634	1.2783[0.1435]	16.629[0.0107]*
6	50.48**	39.27**	1640	1.0960[0.3399]	10.951[0.0899]
7	42.92**	31.80*	<u>1643</u>	0.9341[0.5931]	8.0429[0.2350]
8	51.03**	35.91**	1642	0.6654[0.9874]	7.0946[0.3122]
9	40.10**	26.73	1643	0.6478[0.9471]	8.1670[0.2261]
10	45.01**	28.34	1642	0.7616[0.8755]	6.2202[0.3390]
11	43.50**	25.78	1638	0.6024[0.9670]	4.6220[0.5931]
12	31.03**	17.24	1616	0.5761[0.9755]	5.9176[0.4325]
13	46.26**	23.99	1592	0.6279[0.9489]	6.6650[0.3529]
14	45.19**	21.76	1571	0.8233[0.7475]	7.6435[0.2654]
15	43.76**	19.45	1556	0.9375[0.5853]	8.1942[0.2242]

Note: 1) n is the lag length of the VAR;

2) ** and * indicate rejection of the null at the 5% and 10% respectively;

3) AIC is the Akaike Information Criterion;

4) the normality test is a vector normality test (see DOORNIK AND HENDRY, 1994 for more details);

5) the F-test is a Lagrange-Multiplier test for serial correlation.

6) Dummies: 78:3, 78:4, 79:1

TABLE 1C - UNITED KINGDOM (SAMPLE PERIOD: 1957:1 1990:4) - TRACE STATISTIC, AIC AND DIAGNOSTICS

n	-TΣlog(1-μ)	using T-nm	AIC	F-test	Normality
1	62.44**	61.05**	1301.43	3.2761[0.000]**	28.782[0.0001]**
2	63.14**	60.31**	1306.65	2.6718[0.000]**	34.703[0.000]**
3	66.06**	61.59**	1309.47	2.4192[0.000]**	27.229[0.0001]**
4	82.97**	75.42**	1323.06	1.5551[0.0174]*	30.398[0.000]**
5	62.55**	55.38**	<u>1324.53</u>	1.2905[0.1128]	26.215[0.0002]**
6	60.92**	52.49**	1323.76	0.87332[0.7019]	20.055[0.0027]**
7	55.89**	46.79**	1319.74	0.79476[0.8221]	23.174[0.0007]**
8	60.96**	49.53**	1315.49	0.63049[0.9679]	19.973[0.0028]**
9	60.01**	47.25**	1306.86	0.61602[0.9736]	22.417[0.0010]**
10	47.18**	35.95**	1294.63	0.72143[0.9046]	20.943[0.0019]**
11	47.32**	34.83**	1284.64	0.89178[0.6687]	18.118[0.0059]**
12	46.41**	32.90**	1276.99	0.92678[0.6077]	17.72[0.0070]**
13	44.31**	30.26*	1266.41	0.89266[0.6661]	17.456[0.0077]**
14	48.44**	31.76*	1258.76	0.76581[0.8534]	18.444[0.0052]**
15	55.75**	35.01*	1254.80	0.84749[0.7382]	16.796[0.0101]*

Note: 1) n is the lag length of the VAR;

2) ** and * indicate rejection of the null at the 5% and 10% respectively;

3) AIC is the Akaike Information Criterion;

4) the normality test is a vector normality test (see DOORNIK AND HENDRY, 1994 for more details);

5) the F-test is a Lagrange-Multiplier test for serial correlation.

TABLE 1D - UNITED KINGDOM (SAMPLE PERIOD: 1957:4 1990:4) - TRACE STATISTIC, AIC AND DIAGNOSTICS

n	-TΣlog(1-μ)	using T-nm	AIC	F-test	Normality
1	58.06**	56.18**	2358	2.8948[0.0000]**	27.331[0.0001]**
2	60.16**	57.18**	2381	2.1777[0.0001]**	29.787[0.0000]**
3	58.32**	53.98**	2391	2.6571[0.0000]**	14.392[0.0255]*
4	63.10**	56.84**	2414	1.9109[0.0010]**	20.686[0.0021]**
5	53.89**	47.21**	2432	1.3978[0.0586]*	12.017[0.0616]*
6	58.17**	49.52**	2440	1.0417[0.4089]	7.2183[0.3011]
7	60.42**	49.94**	2444	1.0309[0.4270]	7.3799[0.2871]
8	66.08**	53.98**	<u>2445</u>	0.7637[0.8592]	8.6820[0.1913]
9	68.01**	52.83**	2445	0.9407[0.5834]	9.3626[0.1542]
10	57.51**	43.35**	2431	1.2086[0.1904]	7.0999[0.3117]
11	54.33**	39.51**	2424	1.0418[0.4115]	5.4300[0.4900]
12	55.65**	39.09**	2421	1.0247[0.4399]	5.5161[0.4795]
13	56.34**	38.18**	2414	0.9524[0.5628]	5.5614[0.4741]
14	63.91**	41.73**	2414	0.8341[0.7588]	6.9776[0.3229]
15	72.22**	45.36**	2412	0.7742[0.8408]	6.0952[0.4126]

Note: 1) n is the lag length of the VAR;

2) ** and * indicate rejection of the null at the 5% and 10% respectively;

3) AIC is the Akaike Information Criterion;

4) the normality test is a vector normality test (see DOORNIK AND HENDRY, 1994 for more details);

5) the F-test is a Lagrange-Multiplier test for serial correlation.

6) Dummies: 78:3, 78:4, 79:1 81:4, 86:1,

TABLE 2A - WEST GERMANY (SAMPLE PERIOD: 1963:4 1980:4) - TRACE STATISTIC, AIC AND DIAGNOSTICS

n	-TΣlog(1-μ)	using T-nm	AIC	F-test	Normality
1	45.02**	43.06**	1426	2.0672[0.0007]**	10.548[0.1034]
2	30.79*	28.11	1419	1.5647[0.0264]*	12.944[0.0439]*
3	36.43**	31.67**	1420	1.2396[0.1779]	7.112[0.3106]
4	26.01	21.48	<u>1493</u>	1.2243[0.1948]	5.4546[0.4870]
5	16.74	13.1	1427	1.0057[0.4774]	5.8472[0.4405]
6	20.26	14.97	1440	0.7361[0.8735]	4.6305[0.5920]
7	23.04	16.03	1430	1.1616[0.2710]	2.7834[0.8355]
8	26.13	17.04	1418	0.94918[0.5683]	3.2395[0.7782]
9	39.98**	24.33	1417	0.82076[0.7596]	9.3959[0.1525]
10	50.95**	28.78	1422	0.77159[0.8191]	10.355[0.1105]
11	29.6	15.44	1424	0.93787[0.5850]	11.856[0.0653]
12	34.09*	16.31	1429	0.69195[0.8897]	11.452[0.0754]
13	26.1	11.35	1418	1.1935[0.2939]	9.1593[0.1648]
14	29.63	11.60	1417	1.0562[0.4489]	9.2561[0.1597]
15	20.49	7.126	1413	1.360[0.2424]	6.8274[0.3371]

Note: 1) n is the lag length of the VAR;

2) ** and * indicate rejection of the null at the 5% and 10% respectively;

3) AIC is the Akaike Information Criterion;

4) the normality test is a vector normality test (see DOORNIK AND HENDRY, 1994 for more details);

5) the F-test is a Lagrange-Multiplier test for serial correlation.

TABLE 2B - WEST GERMANY (SAMPLE PERIOD: 1963:4 1990:4) - TRACE STATISTIC, AIC AND DIAGNOSTICS

n	-TΣlog(1-μ)	using T-nm	AIC	F-test	Normality
1	40.44**	39.32**	2225	2.7516[0.0000]**	141.745[0.0000]**
2	39.91**	37.71**	2221	1.9895[0.0005]**	42.208[0.0000]**
3	42.51**	39.0**	2225	1.4809[0.0333]*	44.838[0.0000]**
4	31.88**	28.37	2238	1.3436[0.0848]	44.418[0.0000]**
5	22.29	19.23	2247	1.1597[0.2416]	45.565[0.0000]**
6	24.74	20.66	2248	0.96134[0.5471]	44.739[0.0000]**
7	32.03*	25.86	2239	0.92682[0.6076]	38.068[0.0000]**
8	25.35	19.77	2240	0.80399[0.8053]	36.074[0.0000]**
9	28.6	21.51	2251	0.96089[0.5481]	40.465[0.0000]**
10	27.42	19.87	2248	1.0148[0.4565]	28.095[0.0001]**
11	25.51	17.79	2244	0.64371[0.9579]	40.731[0.0000]**
12	29.23	19.57	2244	0.74092[0.8796]	39.681[0.0000]**
13	27.2	17.47	2239	0.71838[0.9012]	36.624[0.0000]**
14	32.3*	19.86	2236	1.0232[0.4455]	30.049[0.0000]**
15	26.93	15.81	2214	0.65572[0.9478]	31.442[0.0000]**

Note: 1) n is the lag length of the VAR;

2) ** and * indicate rejection of the null at the 5% and 10% respectively;

3) AIC is the Akaike Information Criterion;

4) the normality test is a vector normality test (see DOORNIK AND HENDRY, 1994 for more details);

5) the F-test is a Lagrange-Multiplier test for serial correlation.

TABLE 2C - WEST GERMANY (SAMPLE PERIOD: 1963:4 1990:4)- TRACE STATISTIC, AIC AND DIAGNOSTICS

n	-TΣlog(1-μ)	using T-nm	AIC	F-test	Normality
1	66.88**	65.04**	2279	2.5825[0.0000]**	13.939[0.0303]*
2	53.42**	50.47**	2299	2.1334[0.0001]**	15.571[0.0163]*
3	61.84**	56.73**	2307	1.4401[0.0445]*	11.218[0.0819]
4	48.27**	42.96**	2314	1.1250[0.2851]	10.778[0.0955]
5	34.11*	30.27*	2314	0.9663[0.5383]	9.4525[0.1497]
6	37.37**	31.20*	2319	0.8504[0.7369]	4.3617[0.6279]
7	40.38*	32.60*	2318	0.7479[0.8759]	3.2179[0.7810]
8	34.49*	29.70	2308	0.7162[0.9073]	1.5338[0.9572]
9	44.91**	33.79*	2316	0.8587[0.7218]	3.1345[0.7918]
10	45.10**	32.69**	2320	0.8784[0.6891]	2.7455[0.8400]
11	40.71**	28.39	2322	0.8527[0.7301]	2.8969[0.8217]
12	41.33**	27.68	2315	0.8438[0.7869]	4.2705[0.6401]
13	41.09**	26.38	2304	0.7976[0.8093]	3.0427[0.8035]
14	43.15**	26.52	2296	1.1814[0.2306]	3.1094[0.7950]
15	37.86**	22.23	2304	0.7718[0.8399]	1.7577[0.9406]

Note: 1) n is the lag length of the VAR;

2) ** and * indicate rejection of the null at the 5% and 10% respectively;

3) AIC is the Akaike Information Criterion;

4) the normality test is a vector normality test (see DOORNIK AND HENDRY, 1994 for more details);

5) the F-test is a Lagrange-Multiplier test for serial correlation.

6) Dummy: 90:2

7) for West Germany, the short sample 1963:4-1980:4 has normal residuals and no cointegration (see Table 2a)

TABLE 3A - JAPAN (SAMPLE PERIOD: 1959:1 1990:4) - TRACE STATISTIC, AIC AND DIAGNOSTICS

n	-TΣlog(1-μ)	using T-nm	AIC	F-test	Normality
1	46.05**	44.97**	2882	2.5399[0.0000]**	43.860[0.0000]**
2	51.74**	49.31**	2921	1.6297[0.0093]**	24.358[0.0004]**
3	63.72**	59.24**	2936	1.0496[0.3947]	19.964[0.0028]**
4	51.71**	46.87**	2929	1.2227[0.1707]	21.388[0.0016]**
5	55.60**	49.08**	2926	1.3437[0.0834]	21.583[0.0014]**
6	57.78**	49.65**	2924	1.2144[0.1804]	12.158[0.0585]
7	62.66**	52.38**	2926	0.8351[0.7619]	7.6105[0.2681]
8	62.11**	50.46**	<u>3044</u>	1.1439[0.2614]	10.115[0.1199]
9	87.42**	68.98**	2952	1.1440[0.2622]	5.5580[0.4745]
10	78.93**	60.43**	2951	1.1416[0.2663]	7.0838[0.3132]
11	92.58**	68.71**	2956	1.2020[0.1985]	5.0946[0.5317]
12	83.40**	59.95**	2951	1.3493[0.0876]	3.3075[0.7694]
13	86.62**	60.23**	2969	1.0939[0.3339]	3.8439[0.6978]
14	78.84**	52.97**	2967	1.3068[0.1156]	4.1647[0.6544]
15	91.79**	59.52**	2991	1.4310[0.0562]	10.231[0.1153]

Note: 1) n is the lag length of the VAR;

2) ** and * indicate rejection of the null at the 5% and 10% respectively;

3) AIC is the Akaike Information Criterion;

4) the normality test is a vector normality test (see DOORNIK AND HENDRY, 1994 for more details);

5) the F-test is a Lagrange-Multiplier test for serial correlation.

6) Dummies: 68:3, 69:3, 72:4, 73:3, 80:2, 80:3, 85:2, 86:1, 88:3, 89:2, 90:1, 90:2

TABLE 3B - JAPAN (SAMPLE PERIOD: 1959:1 1980:4) - TRACE STATISTIC, AIC AND DIAGNOSTICS

n	-TΣlog(1-μ)	using T-nm	AIC	F-test	Normality
1	23.62	22.82	1921	2.7166[0.0000]**	23.606[0.0006]**
2	32.22*	30.03**	1959	1.6805[0.0096]**	17.030[0.0092]**
3	45.20**	40.58**	1978	1.3721[0.0793]	9.3417[0.1553]
4	35.29*	30.48*	1970	1.4551[0.0487]*	10.615[0.1010]
5	39.94**	33.13**	1966	1.3556[0.0912]	13.268[0.0390]*
6	41.02**	32.63*	1967	1.5083[0.0373]*	6.9697[0.3237]
7	57.01**	43.41**	1982	1.4421[0.0583]	7.2692[0.2967]
8	55.06**	40.04**	1974	1.4435[0.0601]	9.2077[0.1622]
9	61.88**	42.89**	1987	1.2681[0.1597]	11.567[0.0724]
10	68.60**	45.21**	1998	1.2907[0.1466]	16.363[0.0119]*
11	95.45**	59.65**	2017	1.6645[0.0201]	9.3328[0.1557]
12	95.16**	56.23**	2035	1.1564[0.2801]	6.2971[0.3907]
13	77.97**	43.41**	2035	1.2101[0.2298]	6.1437[0.4073]
14	79.51**	41.56**	2034	1.4841[0.0710]	7.5753[0.2709]
15	92.54**	45.22**	<u>2081</u>	1.7939[0.0187]*	10.298[0.1127]

Note: 1) n is the lag length of the VAR;

2) ** and * indicate rejection of the null at the 5% and 10% respectively;

3) AIC is the Akaike Information Criterion;

4) the normality test is a vector normality test (see DOORNIK AND HENDRY, 1994 for more details);

5) the F-test is a Lagrange-Multiplier test for serial correlation.

6) Dummies: 68:3, 69:3, 72:4, 73:3, 80:2, 80:3

TABLE 4A - UNITED STATES (SAMPLE PERIOD: 1950:4 1990:4)- TRACE STATISTIC, AIC AND DIAGNOSTICS

n	-TΣlog(1-μ)	using T-nm	AIC	F-test	Normality
1	70.46**	69.15**	3718	3.2254[0.0000]**	56.235[0.0000]**
2	48.07**	46.28**	3797	2.2546[0.0000]**	45.641[0.0000]**
3	35.99**	33.98**	3819	2.5790[0.0000]**	21.294[0.0016]
4	38.74**	35.82**	3821	2.2744[0.0000]**	14.531[0.0242]
5	34.74*	31.50*	3822	1.6975[0.0049]**	13.854[0.0313]
6	37.80**	33.57*	3837	1.5758[0.0137]*	8.6543[0.1940]
7	36.62**	31.84*	3828	1.6888[0.0054]**	9.1304[0.2287]
8	27.60	23.48	<u>3841</u>	1.5726[0.0144]*	9.9568[0.1265]
9	27.30	22.72	3830	1.8089[0.0019]**	10.471[0.1062]
10	31.19*	25.38	3824	1.6428[0.0084]**	10.105[0.1203]
11	24.39	19.39	3822	1.4726[0.0322]*	9.5419[0.1453]
12	25.44	19.75	3822	1.3142[0.0965]	9.6571[0.1399]
13	27.67	20.97	3819	1.4577[0.0367]*	12.144[0.0588]
14	32.07*	23.71	3816	1.4144[0.0503]	5.8057[0.4453]
15	35.50**	25.58	3814	1.0017[0.4753]	5.8528[0.4399]

Note: 1) n is the lag length of the VAR;

2) ** and * indicate rejection of the null at the 5% and 10% respectively;

3) AIC is the Akaike Information Criterion;

4) the normality test is a vector normality test (see DOORNIK AND HENDRY, 1994 for more details);

5) the F-test is a Lagrange-Multiplier test for serial correlation.

6) Dummies: 57:1, 57:2, 57:3, 57:4, 58:1, 58:2, 81:4

TABLE 4B - UNITED STATES (SAMPLE PERIOD: 1950:4 1980:4)- TRACE STATISTIC, AIC AND DIAGNOSTICS

n	-TΣlog(1-μ)	using T-nm	AIC	F-test	Normality
1	46.44**	45.28**	2810	2.4350[0.0000]**	36.914[0.0000]**
2	35.33**	33.58*	2868	2.2324[0.0000]**	31.121[0.0000]**
3	23.73	21.97	2859	2.6355[0.0000]**	18.711[0.0047]**
4	27.63	24.89	2862	1.9681[0.0006]**	12.716[0.0478]*
5	25.52	22.36	2855	2.1042[0.0002]**	14.772[0.0221]*
6	26.20	22.31	2871	1.6476[0.0097]**	11.023[0.0877]
7	24.10	19.92	2862	2.0680[0.0003]**	8.6679[0.1931]
8	21.14	19.95	<u>2872</u>	1.4544[0.0419]*	7.8129[0.2521]
9	23.22	18.04	2860	1.3688[0.0747]	7.3953[0.2850]
10	30.18*	22.07	2857	1.6466[0.0110]*	8.8923[0.1797]
11	26.22	19.07	2856	1.2283[0.1732]	10.150[0.1185]
12	28.82	20.24	2869	0.9642[0.5423]	7.2138[0.3015]
13	28.89	19.58	2861	1.2049[0.1988]	9.6351[0.1409]
14	32.80*	21.41	2860	1.0212[0.4470]	4.4592[0.6148]
15	39.21**	24.63	2855	1.3722[0.0810]	3.3707[0.7611]

Note: 1) n is the lag length of the VAR;

2) ** and * indicate rejection of the null at the 5% and 10% respectively;

3) AIC is the Akaike Information Criterion;

4) the normality test is a vector normality test (see DOORNIK AND HENDRY, 1994 for more details);

5) the F-test is a Lagrange-Multiplier test for serial correlation.

6) Dummies: 57:1, 57:2, 57:3, 57:4, 58:1, 58:2

TABLE 5A - CANADA (SAMPLE PERIOD: 1958:4 1990:4) - TRACE STATISTIC, AIC AND DIAGNOSTICS

n	-TΣlog(1-μ)	using T-nm	AIC	F-test	Normality
1	122.3**	119.40**	2918	1.5129[0.0245]*	4.5147[0.6074]
2	72.48**	69.11**	2911	1.5564[0.1780]*	8.8036[0.1849]
3	62.32**	57.98**	2913	1.4147[0.0509]*	7.8078[0.2525]
4	47.99**	52.91**	2911	1.3616[0.0734]*	9.3962[0.1525]
5	57.93**	51.19**	2911	1.5553[0.0190]*	9.2602[0.1595]
6	42.45**	36.53**	2914	0.97605[0.5209]	7.4948[0.2775]
7	36.41**	30.49*	2899	1.2560[0.1436]	7.8156[0.2519]
8	36.33**	29.57	2893	1.2725[0.1316]	6.0755[0.4148]
9	37.05**	29.29	2887	1.6501[0.0102]*	5.9107[0.4333]
10	40.43**	31.02*	2893	1.1489[0.2568]	6.5731[0.3621]
11	43.60**	32.45*	2884	1.1889[0.2106]	8.1303[0.2287]
12	41.69**	30.06*	2886	1.0235[0.4416]	8.2329[0.2215]
13	38.26**	26.69	2878	1.1992[0.2036]	12.501[0.0517]
14	38.48**	25.95	2881	1.2529[0.1552]	12.290[0.0558]
15	36.09**	23.50	2870	1.6051[0.0750]*	10.811[0.0944]

Note: 1) n is the lag length of the VAR;

2) ** and * indicate rejection of the null at the 5% and 10% respectively;

3) AIC is the Akaike Information Criterion;

4) the normality test is a vector normality test (see DOORNIK AND HENDRY, 1994 for more details);

5) the F-test is a Lagrange-Multiplier test for serial correlation.

6) Dummies: 59:4, 62:2, 62:3, 62:4, 74:2, 74:3, 74:4, 75:1, 75:2 76:1, 80:1, 81:4

TABLE 5B - CANADA (SAMPLE PERIOD: 1958:4 1980:4) - TRACE STATISTIC, AIC AND DIAGNOSTICS

n	-TΣlog(1-μ)	using T-nm	AIC	F-test	Normality
1	78.76**	76.02**	<u>2026</u>	1.8921[0.0020]**	6.4746[0.3722]
2	60.18**	56.12**	2015	1.8723[0.0025]**	5.4549[0.4829]
3	43.12**	38.76**	2012	1.5560[0.0256]*	5.5283[0.4780]
4	46.46**	40.20**	2018	1.4651[0.0747]*	9.1362[0.1661]
5	47.12**	39.18**	2019	1.6394[0.0162]*	10.734[0.0970]*
6	32.50**	25.93	2016	1.3570[0.0960]	8.2880[0.2178]
7	36.99**	28.26	2019	1.4196[0.0699]	11.672[0.0697]*
8	36.87**	26.93	2014	1.1151[0.3194]	9.0157[0.1727]
9	39.86**	27.77	2024	1.1311[0.3026]	3.7516[0.7102]
10	45.31**	30.03*	2021	1.0740[0.3804]	5.9361[0.4304]
11	55.51**	34.93*	2029	1.9366[0.0050]	7.7674[0.2556]
12	45.28**	26.96	2022	1.5201[0.0557]	10.825[0.0939]*
13	42.95**	24.13	2028	0.0971[0.5354]	5.9237[0.4318]
14	48.83**	25.79	2044	1.630[0.0430]*	6.5088[0.3687]
15	56.45**	27.91	<u>2049</u>	1.8921[0.0020]*	12.834[0.0457]*

Note: 1) n is the lag length of the VAR;

2) ** and * indicate rejection of the null at the 5% and 10% respectively;

3) AIC is the Akaike Information Criterion;

4) the normality test is a vector normality test (see DOORNIK AND HENDRY, 1994 for more details);

5) the F-test is a Lagrange-Multiplier test for serial correlation.

6) Dummies: 59:4, 62:2, 62:3, 62:4, 74:2, 74:3, 74:4, 75:1, 75:2 76:1, 80:1,

TABLE 6 - HOMOGENEITY TESTS ON THE COINTEGRATING VECTORS

	Cointegrating Vector					
	LM1	LRGDP	LRINT	LR-test	n	Sample
United Kingdom	1.000	-1.722	1.057	20.605 [0.000]**	8	1957:1-1990:4
	1.000	-0.360	0.3157	17.107 [0.000]**	7	1957:1-1980:4
West Germany	1.000	-1.275	0.2793	8.174 [0.016]**	11	1963:4-1990:4
	NC					1963:4-1980:4
Japan	1.000	-1.236	0.0371	27.22 [0.000]**	8	1959:1-1990:4
	1.000	-1.268	-0.0949	64.024 [0.000]**	15	1959:1-1980:4
United States	NC					1950:4-1990:4
	NC					1950:1-1980:4
Canada	1.000	-0.7539	0.3878	11.04 [0.004]**	1	1950:1-1990:4
	1.000	-0.8422	0.3445	19.54 [.0001]**	15	1958:4-1980:4

Note: 1) n is the optimal lag length of the VAR chosen using the AIC

2) the LR-test is a c^2 test of the restriction (1 -1 x) on the cointegrating vector

3) ** and * indicate rejection of the null at the 5% and 10% level respectively

4) cointegration is rejected for West Germany over the sample 1963:4-1980

5) NC, no cointegration for that period and country

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