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IS THE QTM CONTROVERSY SETTLED?

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IS THE QTM CONTROVERSY SETTLED?*

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Abstract

The present study tests the validity of the Quantity Theory of Money with the help of a new test procedure developed by Horvath & Watson (Econometric Theory, 1995) in a multiple cointegration framework. By using a fairly long quarterly data set of USA, Canada, Australia and Italy for the period 1975-I to 1998-II the study found that I(0) velocity is proved in all the sample countries, except Canada. Further, it found that all the sample countries have at least one unknown cointegrating vector between money supply, prices and real income, corroborating the propositions of QTM.

JEL classification: C32, E41

Key Words: Quantity theory of money, Multiple Cointegration

One of the oldest and most controversial theories in economics is the quantity theory of money (QTM). The theory, which was first formulated by Fisher, postulates that there exists a strong positive causal relationship from money supply to the domestic price level given that the velocity of circulation and volume of trade remain unchanged over a period of time. In its original version it has taken the form of an identity or the equation of exchange as MV=PT. This identity explains that the quantity of money (M) times the

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transaction velocity of circulation of money will be equal to the volume of physical transaction (T) multiplied by the average price level in the economy. Over a period of time this QTM has taken different shapes under the Cambridge group (which replaced the volume of transaction (T) with real income (Y)), and Milton Friedman. But the basic propositions of the QTM remain unchanged. They are, given the velocity of circulation of money as a stable function, a) an increase in the growth rate of money, other things remaining same, will have a strong positive impact on the price level, b) changes in money supply will not have any impact on the real income.

To test the QTM empirically it is sufficient if we show that, *ceteris paribus*, there exists a proportional relationship between money supply and prices. But this is the proposition in economic theory, with downward sloping demand curve being an exception, which is extensively tested in different economies under different conditions using various econometric techniques. But researchers have not arrived at a consensus. Since its existence in its recognisable form for more than two hundred years, the theory was criticised by different schools of thought. (For a more detailed discussion on the criticism of the QTM see Laidler (1989)).

In this context, the present study attempts to test the main propositions of QTM with the help of a new multiple cointegration procedure developed by Horvath & Watson (1995), which is statistically a better procedure than the existing Johansen & Juselius (1992). (The size and power of these two procedures were tested in Edison *et. al.* (1997). With the help of Monte Carlo experiments the study concluded that the Horvath & Watson procedure has more predictive power than the Johansen & Juselius). The study considers quarterly data of the United States, Italy, Australia and Canada for the period 1975-I to 1998-II. The data was collected from the various issues of International Monetary Fund's *International Financial Statistics*, and the definitions of the variables are country specific.

The next section synthesises the two multiple cointegration procedures, viz., Johansen & Juselius, and Horvath & Watson for the benefit of future research. The following sections cover the discussion of results, and conclusions are presented in the final section.

Methodology

It is established in the literature that most of the long series macro data will exhibit non-stationary trend. Hence, to establish the relationship between any macro variables one should follow the cointegration technique as traditional regression techniques that are based on classical assumptions will give spurious results when the series is non-stationary. Many studies followed cointegration techniques that are developed by Engle and Granger (1987), Johansen (1991), Johansen & Juselius (1992), and Stock & Watson (1993). With the help of univariate cointegration methods one cannot test the cointegration between more than two variables. To test the cointegration for more than two variables one should follow the structural procedures like multiple cointegration techniques developed by Johansen & Juselius.

The multiple cointegration procedure due to Johansen & Juselius (1992) is a two-step procedure that examines the null hypothesis of no cointegration against the alternative of cointegration in the first stage. If the null hypothesis is rejected then in the second stage the test examines the null hypothesis of the presence of cointegration derived from economic theory against the alternative hypothesis of the presence of an unknown cointegrating vector. But in the Horvath & Watson procedure, which is an improvement over the Johansen & Juselius procedure, null hypothesis of no cointegration is tested against the composite alternative hypothesis of cointegration using a prespecified cointegrating vector. For a better understanding of Horvath & Watson (1995) and its difference from Johansen & Juselius (1992), both these methods are discussed in detail.

Let X_t be an (n x 1) data vector with a sample size 'T'. Under the Johansen & Juselius procedure the hypothesis testing will be

H_0: Number of cointegrating vectors $r = h, \; 0 \leq h < n$

H_A: Number of cointegrating vectors $r = n$

To test this hypothesis, we fit a VAR (p) model, which is represented as

$$\Delta X_t = A_1 \Delta X_{t-1} + A_2 \Delta X_{t-2} + \cdots + A_{p-1} \Delta X_{t-p+1} + A_0 + \Pi X_{t-1} + \varepsilon_t, \qquad \varepsilon_t \sim NIID(0,\Omega) \qquad (1)$$

Since H_0 specifies r=h, we may have some more linear combinations (variables) in the system that are I(1). Hence, we can decompose 'Π' matrix as

$$\Pi = \alpha \beta' \tag{2}$$

where 'α' and 'β' are n x h matrix. Here, we have to estimate (A_0, A_1, . . ., A_{p-1}, Π, Ω) through maximum likelihood procedures, such that 'Π' can be written as in (2).

To estimate all these parameters, we have to follow two-step procedures.

In the first step, regress ΔX_t on $\Delta X_{t-1}, \ldots, \Delta X_{t-p+1}$ and obtain the residuals u_t.

In the second step, regress X_{t-1} on $\Delta X_{t-1}, \Delta X_{t-2}, \ldots \Delta X_{t-p+1}$ and obtain the residuals $\hat{e}_t$.

From the obtained residuals '$\hat{u}_t$' and '$\hat{e}_t$', find the variance-covariance matrices.

$$\hat{\Sigma}_{uu} = (1/T) \sum_{t=1}^{T} \hat{u}_t \hat{u}_t' \tag{3}$$

$$\hat{\Sigma}_{ee} = (1/T) \sum_{t=1}^{T} \hat{e}_t \hat{e}_t' \tag{4}$$

$$\hat{\Sigma}_{ue} = (1/T) \sum_{t=1}^{T} \hat{u}_t \hat{e}_t' \tag{5}$$

With the help of (3) - (5), we can find the maximum likelihood estimator of 'β' by solving the matrix.

$$|\lambda \hat{\Sigma}_{ee} - \hat{\Sigma}_{eu} \, \text{INV}(\hat{\Sigma}_{uu}) \, \hat{\Sigma}_{ue}| = 0 \tag{6a}$$

With the eigen values $\hat{\lambda}_1 > \hat{\lambda}_2 > \text{- - -} > \hat{\lambda}_n$ and the normalized cointegrating vectors

$$\hat{\beta} = (\hat{\beta}_1, \hat{\beta}_2, \text{- - -}, \hat{\beta}_n) \text{ , such that } \hat{\beta}' \hat{\Sigma}_{ee} \hat{\beta} = I$$

Hence, the maximum likelihood estimator of '$\hat{\beta}$ will be

$$L_{max} = |\hat{\Sigma}_{uu}| \prod_{i=1}^{h} \log(1-\hat{\lambda}_i)$$

To test the H_0, we use the likelihood ratio test as $(L_A - L_0)$ where

$$L_0 = -(Tn/2)\log(2\Pi) - (Tn/2) - (T/2)\log|\hat{\Sigma}_{uu}|$$

$$-(T/2)\sum_{i=1}^{h}\log(1-\hat{\lambda}_i) \tag{6b}$$

and

$$L_A = -(Tn/2)\log(2\Pi) - (Tn/2) - (T/2)\log|\hat{\Sigma}_{uu}|$$

$$-(T/2)\sum_{i=1}^{n}\log(1-\hat{\lambda}_i) \tag{7}$$

Hence, $L_A - L_0 = -(T/2)\sum_{i=h+1}^{n}\log(1-\hat{\lambda}_i)$

$$2(L_A - L_0) = -T\sum_{i=h+1}^{n}\log(1-\hat{\lambda}_i) \tag{8}$$

(8) follows 'χ^2' distribution

Further, if the number of cointegrating vectors is found to be 'h', then with the estimated 'β' we can estimate the 'α' and 'Π' as

$$\hat{\alpha} = \hat{\Sigma}_{ue}\hat{\beta}(\hat{\beta}'\hat{\Sigma}_{ee}\hat{\beta})^{-1} \tag{9}$$

and $\hat{\Pi} = \hat{\Sigma}_{ue}\hat{\Sigma}_{ee}^{-1}$ (10)

Horvath & Watson Test

This test is different from Johansen. In this model the test is carried out when some of the cointegrating vectors that are derived from economic theory are prespecified. The hypothesis in this method that is different from the Johansen method, is

H_0: Number of cointegrating vectors will be h_0, which consists of $h_{0k}+h_{0u}$, and

H_a: Number of cointegrating vectors will be h_0+h_1 ($h_1>0$) where h_1 consists of $h_{1k}+h_{1u}$.

Here 'k' and 'u' denote the known and unknown respectively.

- Accordingly, we can also separate the long-run multiplier matrix $\Pi = \alpha \beta'$ as

$\Pi = (\alpha_0, \alpha_1)(\beta_0, \beta_1)'$

where 'β_0' is an n x h_0 to be tested under null and 'β_1' is an n x h_1 to be tested under alternative. Similarly, for 'α_0' and 'α_1'.

Further, 'β_1' can be partitioned as (β_{1k}, β_{1u}) and α_1 as $(\alpha_{1k}, \alpha_{1u})$

Therefore, $\Pi X_{t-1} = \alpha_0 (\beta_0' X_{t-1}) + \alpha_1 (\beta_1' X_{t-1})$

Therefore, the competing hypothesis will be

H_0: $\alpha_1 = 0$

H_1: $\alpha_1 \neq 0$

i.e., rank of $(\alpha_1 \beta_1') = h_1$

To test the hypothesis, we have to construct the likelihood ratio statistic that depends on the value of β_{0k} and β_{1k} and also on h_{ok}, h_{1k}, h_{ouk} and h_{1uk}.

The likelihood ratio statistic will be

$L_{rh0,h1}(\beta_{0k}, \beta_{1k})$

when $h_{0k} = 0$, the statistic will be $LR(0, \beta_{1k})$ and when $h_{1k} = 0$, the statistic will be $LR(\beta_{0k}, 0)$

$$L_{rh0,h1}(\beta_{0k}, \beta_{1k}) \equiv LR_{0,r0+h1}(0, [\beta_{0k}, \beta_{1k}]) - LR_{0,r0}(0, \beta_{0k}) \quad (11)$$

With the help of H_0 in this test (assume that $h_0 = 0$) the model (1) can be written as

$$\Delta X_t = \alpha_{1k}(\beta'_{1k}X_{t-1}) + \alpha_{1uk}(\beta'_{1uk}X_{t-1}) + \delta Z_t + \varepsilon_t \quad (12)$$

where $\delta = (A_1, A_2, \ldots, A_{p-1})$

$Z_t = [X_{t-1}, X_{t-2}, \ldots, X_{t-p+1}]'$

Here to test the null of $h_0=0$, we take the composite null such that

H_0: $\alpha_{1k} = 0$ and $\alpha_{1uk} = 0$.

This null has to be first tested separately and then the joint hypothesis can be tested.

First test will be on H_0: $h_0=0$ against H_1: $h_1 = h_{1k}$.

Hence, the equation (12) can be written as

$$\Delta X_t = \alpha_{1k}(\beta'_{1k}X_{t-1}) + \delta Z_t + \varepsilon_t \quad (13)$$

(13) can be estimated with simple OLS and the OLS estimator of

α_{1k} will be

$$\hat{\alpha}_{1k} = (\Delta X' M_z X_{-1} \beta_{1k})(\beta'_{1k} X'_{-1} M_z X_{-1} \beta_{1k})^{-1} \quad (14)$$

where $M_z = [I - Z(Z'Z)^{-1} Z']$

To test the H_0, the procedure uses Wald statistic that is equal to

$$W = [\alpha'_{1k}[(\beta'_{1k} X'_{-1} M_z X_{-1} \beta_{1k})^{-1} \otimes \Sigma_\varepsilon]^{-1} [\alpha_{1k}] \quad (15)$$

with the degrees of freedom $(N-h_{0uk}, h_{0k}, h_{1k}, h_{1uk})$

Where $\Sigma_\varepsilon = T^{-1} \Sigma' \Sigma$

Second test:

H_0: h_0=0 against the alternative of

H_1: $h_1 = h_{1uk}$

Hence, (12) will be written as

$$\Delta X_t = \alpha_{1uk}(\beta'_{1uk}X_{t-1}) + \delta Z_t + \varepsilon_t \tag{16}$$

Same (15) cannot be used here as $\beta'_{1uk}X_{t-1}$ depends on unknown parameters. We cannot use the OLS estimators to estimate the 'α_{1uk}'. But we can estimate the Wald statistic as follows:

$$\text{Sup W} = \sum_{i=1}^{h_{1uk}} \lambda i(CC') \tag{17}$$

with the degrees of freedom (N-h_{0uk},h_{0k},h_{1k},h_{1uk})

Where $CC' = [\Sigma_\varepsilon^{-1/2}(\Delta X' M_z X_{-1})(X'_{-1} M_z X_{-1})^{-1}(X'_{-1} M_z \Delta X)\Sigma_\varepsilon^{-1/2}]$ (18)

And λi's are the eigen values of CC'

Third test:

This test is a composite one of the previous two tests which is the main hypothesis of the HW test. Here the null hypothesis of no cointegrating vectors is tested against the alternative of both unknown and unknown cointegrating vectors. That is

H_0 : h_0=0 against

H_1: $h_1 = h_{1k} + h_{1uk}$

Therefore, the model will be same as (12)

$$\Delta X_t = \alpha_{1k}(\beta'_{1k}X_{t-1}) + \alpha_{1uk}(\beta'_{1uk}X_{t-1}) + \delta Z_t + \varepsilon_t$$

The Wald statistic[1] for testing this hypothesis will be

$$Sup\ W = [\Delta X'M_Z\beta_{1k}]'[(\beta_{1k}X'_{-1}M_ZX_{-1}\beta_{1k}])^{-1}$$

$$\otimes\hat{\Sigma}_{\varepsilon}^{-1}][\Delta X'M_ZX_{-1}\beta_{1k}] + \sum_{i=1}^{h_{hk}}\lambda i(H'H) \tag{19}$$

with the degrees of freedom $(N\text{-}h_{0uk}, h_{0k}, h_{1k}, h_{1uk})$

where $H'H = \hat{\Sigma}_{\varepsilon}^{-1/2}(\Delta X'M_{ZK}X_{-1}G)(G'X'_{-1}M_{ZK}X_{-1}G)^{-1}$
$(G'X'_{-1}M_{ZK}\Delta X)\ \hat{\Sigma}_{\varepsilon}^{-1/2\,'}$

and $M_{ZK} = [I\text{-}(M_ZX_{-1}\beta_{1k})(\beta'_{1k}X'_{-1}M_ZX_{-1}\beta_{1k})^{-1}(\beta'_{1k}X'_{-1}M_Z)]\ M_Z$

and 'G' is a matrix whose columns are formed by using the Gram-Schmidt orthogonalisation procedure.

Empirical results. In the present study we tried to examine the monetarist propositions by using Horvath and Watson test in the case of the United States (USA), Canada, Italy and Australia. The data used for the study are the quarterly data for the period 1975-I to 1998-II (total 94 observations) and are collected from the various issues of International Monetary Fund's *International Financial Statistics.* All the variables are taken in logarithmic form and dummy variable has been used to deseasonalise the series. Unit root tests were carried out on all the variables to test the stationarity of the series and it is found that all the variables are of I(1) process. These results allow us to apply the cointegration framework. The optimal lag length chosen is four for all the countries. All the estimates were done by using *Shazam software (version 8.0).* The results are given in the table below. We will discuss the three hypotheses separately below.

The known cointegrating vector used in the model to satisfy the condition of stable velocity of circulation of money is (-1 1 1) for the order money supply, output and prices. In the case of the third hypothesis, which tests the presence of both known and unknown cointegrating vectors in the system, we used two competing vectors derived through Gram-Schmidt orthogonalisation process, i.e., (2 1 1) and (0 1 -1).

It was found from the estimated results that all the countries except Canada have supported the stable velocity of circulation of money. The results also show that for all the four countries there exists an unknown cointegrating vector between money supply, output and prices (Test 2) which is highly significant at one per cent level in the case of USA and Italy and at five per cent level in the case of Canada and Australia. We can conclude from this result that for all the four countries there exists at least one unknown cointegrating vector, other than the one known cointegrating vector, if it all exist, between money, output and prices.

When we tested the joint null hypothesis of no cointegrating vector against the alternative of the presence of both known and unknown cointegrating vectors, the results reject the null only in the case of USA and Italy at five per cent and one per cent level of significance. It could not reject the null in the case of Canada and Australia. From these results one can infer that QTM has empirical support from USA and Italy but not full support from Canada and Australia. In Canada and Australia, though it does not support the stable velocity of money condition, our results shows the presence of at least one unknown cointegrating vector in the system. This means that there is another internal mechanism that will take the variables in the system to a stationary path in the long run.

Conclusion

The study tried to test the QTM propositions with the help of a fairly new multiple cointegration test developed by Horvath & Watson (1995). Using quarterly data for USA, Canada, Italy and Australia, the study finds that there is at least one long-run cointegrating relation between the three macro variables, viz., money supply, output and prices, in all the countries. This finding corroborates the view of QTM, and may be interesting to the policy makers in the respective countries concerned. But one cannot generalize this conclusion to all the economies. The relationship between money supply, output and prices may not be the same for all the countries. One must study these relationships in each country separately.

Notes

1. There exists an error on p.991 of Horvath & Watson (1995). In line 4, M_{zk} should be read as

$$M_{ZK} = [I-(M_z X_{-1} \beta_{1k})(\beta'_{1k} X'_{-1} M_z X_{-1} \beta_{1k})^{-1} (\beta'_{1k} X'_{-1} M_Z)]\, M_z.$$

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Results from the Horvath and Watson Procedure

Test	USA	Canada	Italy	Australia
HW1	11.4079**	6.0539	64.6312*	6.8559***
HW2	31.6276*	14.9843**	87.8732*	14.8444**
HW3	13.2903**	6.5637	106.6716*	5.6799

Note: * Significant at 1% level.

** Significant at 5% level.

*** Significant at 10 % level.

See Critical values in Horvath & Watson (1995), p.996-98

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