

1985

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Citation of this paper:

Gregory, Allan W.. "Testing Interest Rate Parity and Rational Expectations for Canada and the United States." Centre for the Study of International Economic Relations Working Papers, 8503C. London, ON: Department of Economics, University of Western Ontario (1985).

ISSN 0228-4235
ISBN 0-7714-0611-8

THE CENTRE FOR THE STUDY OF INTERNATIONAL ECONOMIC RELATIONS

WORKING PAPER NO. 8503C

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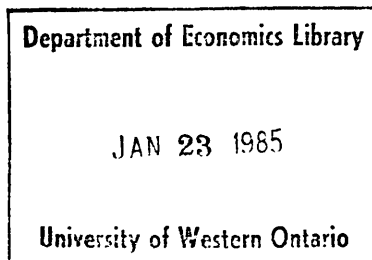
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December 1984

ABSTRACT

The purpose of this paper is to test a 'weak' form of the joint hypothesis of interest rate parity and rational expectations for Canada and the United States. Since the parity equation with rational expectations is itself a partial difference equation, standard solution techniques give rise to a set of testable nonlinear restrictions. The results indicate that the restrictions imposed by rational expectations upon the interest rate parity equation are supported by the data up to the end of the 1970's. However, when the 1980's observations are included in the sample, the hypothesis is rejected. There is evidence to suggest that the process governing the interest rate differential has changed in the 1980's and that this may account for the rejection.

*The author would like to thank David Backus, Zvi Hercowitz, David Longworth, Michael McAleer, Tom McCurdy, Maurice Obstfeld and Michael Veall for helpful comments.



TESTING INTEREST RATE PARITY AND RATIONAL EXPECTATIONS
FOR CANADA AND THE UNITED STATES

1. Introduction

The joint assumption of uncovered interest rate parity and rational expectations has provided a convenient link between international financial assets in many theoretical open economy models. Although this assumption is not without appeal, there has been little research to establish its acceptability on empirical grounds. The tests that have been done are indirect in the sense that they have employed the substitution method (see Cumby and Obstfeld, 1981).¹ For this approach, the expected value of the future spot rate is replaced by its actual future value and, under the null hypothesis of uncovered interest rate parity and rational expectations, the ex post residuals from the parity equation should not be significantly different from white noise. A test of the null hypothesis then involves examining these residuals for serial correlation using various portmanteau tests.

In general, these tests have detected serial correlation and accordingly, the authors have rejected the joint hypothesis of interest rate parity and rational expectations. An advantage of this testing procedure is that it is 'model-free'; that is, no attempt is made to model the movements in exchange rates or the interest rate differential. However, this absence of modelling is not without costs. For instance, these tests provide little information as to why the null hypothesis has been rejected and consequently they cannot indicate where specific weaknesses in the theory may lie. The substitution method of testing interest rate parity and rational expectations is much like a light switch--on/off. Unfortunately when the switch is off, we are often left in the dark. On the other hand, given that under rational expectations the interest rate parity equation is

itself a partial difference equation, a direct and more informative test is afforded by solving the equation using standard techniques and then testing the overidentifying rational expectations restrictions against the data. Of course, the usefulness of these tests must be evaluated in the context of the particular model presented.

One other important consideration in the substitution method of testing is the assumption that the interest parity relation itself holds identically and deterministically. This is a crucial restriction for this procedure. However, Sims (1982) has argued that asset markets are never exactly in equilibrium but, instead asset prices vibrate randomly around equilibrium. Yet, if we relax this deterministic condition and permit serially independent mean zero departures from interest rate parity, then the substitution method does indeed produce ex post residuals that are serially correlated even under interest rate parity and rational expectations.² This is despite the fact the individual disturbances themselves are serially independent. Therefore the substitution method of testing interest rate parity and rational expectations breaks down whenever the deterministic assumption is dropped.³

The purpose of this paper is: (i) to specify and to estimate a simple model of exchange rate determination based upon interest rate parity and rational expectations using Canadian and United States month-end data; and (ii) to test the corresponding cross-equation rational expectations restrictions. We assume that interest rate parity holds up to a stochastic serially independent error term. This, together with the first differencing of the data which is done to achieve stationarity, implies that we are conducting a weaker test of interest rate parity and rational expectations than has traditionally been done. The intention here is to investigate whether there is some empirical support for a weaker hypothesis. In view of its widespread use theoretically, this strategy seems to have some merit.

At least the present investigation will provide some evidence of how useful an approximation the joint hypothesis of interest rate parity and rational expectations is for Canada and the United States.

A key question of the testing is to determine whether the time-series representation of the interest rate differential process appears in the exchange rate equation in the form prescribed by interest rate parity and rational expectations. Another aspect considered in this study is to determine whether there have been periods of time for which the joint hypothesis of rational expectations and interest rate parity is a reasonable characterization. Therefore we examine whether conclusions based upon full-sample estimation continue to hold for various subperiods.⁴ In this way we may investigate when the postulated model of exchange rate determination accurately describes the facts and when it does not. This may be especially helpful from the viewpoint of model building.

The results indicate that with the model cast in first differences, the rational expectations restrictions placed upon the interest rate parity equation are supported by the data up to the end of the 1970's. However, when the observations from the 1980's are included in the sample, the restrictions are rejected.

In Section 2 the model is developed and in Section 3 the results are presented. Concluding remarks are given in Section 4.

2. The Model

Uncovered interest rate parity relates the expected change in the spot exchange rate to the interest rate differential on similar assets in the different currencies. This relation may be written as:

$$(1) \quad s_t - E_t s_{t+1} = i_t^* - i_t + u_t, \quad i=1, \dots, N$$

where s_t is the logarithm of the spot exchange rate at time t , E_t is the expectation operator conditional upon the information available at time t , i_t and i_t^* are the domestic and foreign nominal interest rates respectively and u_t is a mean zero serially independent disturbance term.⁵ All variables are measured as deviations from their means. The fact that u_t appears in equation (1) implies that we are assuming that interest rate parity holds up to a stochastic serially independent error term. Thus, we permit non-systematic departures from interest rate parity and assume $E_t u_{t+j} = 0$ for all $j=1, \dots$.

In order to solve the partial difference equation (1), the data generating process for the interest rate differential, $z_t = i_t^* - i_t$, must be modelled. If we assume that the interest rate differential is stationary and ergodic, then by Wold's decomposition theorem, the process has an infinite moving average representation.⁶ Following Baillie, Lippens and McMahon (1983), we approximate the infinite moving average process by a finite autoregressive process of order p :

$$(2) \quad z_t = \sum_{i=1}^p \varphi_i z_{t-i} + \epsilon_t,$$

where the roots of the polynomial in the lag operator, $1 - \varphi_1 L - \dots - \varphi_p L^p$ lie outside the unit circle and ϵ_t is white noise.

Although we have chosen to model the interest rate differential as an autoregressive process, it is not our intention to suggest that Canadian interest rates are determined in a purely 'mechanical' way. To some extent and degree, the policy of the Bank of Canada over the seventies has been directed toward managing the nominal interest rates. While it is true that monetary policy in Canada has consistently focussed upon controlling the nominal interest rates, the justifications and the intended goals and benefits from doing so have changed. For example, in the early 1970's

conventional wisdom suggested that prudent management of interest rates would promote smoothly functioning financial markets and lead to healthy investment. However, in the mid-seventies, attention was directed towards the growth rate of certain monetary aggregates and a new argument for controlling interest rates was advanced. In particular, targets for growth in the narrowly defined money supply (M1) were to be achieved using interest rates as the policy instrument (see Bank of Canada Annual Report 1975). Nevertheless, even for the period of money targeting, there appeared to have been departures from stated policy. For instance, as noted by Courchene (1981), the Bank of Canada in 1978 became especially concerned with the dramatic depreciation of the Canadian dollar and took defensive action.

For our estimation period, it would have been extremely difficult to take into account all the considerations used by the Bank in establishing an interest rate. However, since Canadian interest rates have always tended to drift towards those that have prevailed in the U.S., a close approximation is provided by modelling the interest rate differential as a stationary autoregressive process. Evidence in Gregory and Raynauld (1984) suggests that the lagged interest rate differentials are important determinants of Canadian interest rates. Also, in the empirical application, we added a constant to equation (2). This allows a constant difference to persist between the interest rates in the long run. However, as in Gregory and Raynauld (1984), the constant never proved significant in estimation and was omitted from the analysis.

Assuming that z_t is part of agents' information sets so that $E_t z_t = z_t$, the solution to the partial difference equation (1) is (see Gourieroux, Laffont and Monfort, 1982):

$$(3) \quad s_t = \frac{(1 + \varphi_2 L + \dots + \varphi_p L^{p-1})}{(1 - \varphi_1 - \dots - \varphi_p)} z_t + u_t ,$$

with $1 - \phi_1 - \dots - \phi_p \neq 0$.⁷ Rational agents take into account the process governing the interest rate differential when forecasting future spot exchange rates. This places testable restrictions upon the manner in which current and lagged interest rate differentials influence exchange rate movements. The unrestricted model corresponding to equation (3) is:

$$(4) \quad s_t = \sum_{i=0}^{p-1} \alpha_i z_{t-i} + u_t .$$

Notice that there are p non-linear restrictions placed upon the parameters of equations (2) and (4). Also we did add a constant to both the restricted and unrestricted equations but found it was never significant at conventional levels.

As we argued earlier, allowing an independent and identically distributed error term into the interest rate parity equation (1) negates the substitution method as a valid test procedure. To see this, consider the decomposition of the future spot rate into two orthogonal components:

$$(5) \quad s_{t+1} = E_t s_{t+1} + \eta_{t+1} ,$$

where $\eta_{t+1} = (s_{t+1} - E_t s_{t+1})$ and is serially independent. For the present model under rational expectations this is:

$$(6) \quad \eta_{t+1} = u_{t+1} + \frac{\epsilon_{t+1}}{1 - \phi_1 - \dots - \phi_p} .$$

The substitution method involves calculating an ex post residual w_t as:

$$(7) \quad w_t = s_t - s_{t+1} - z_t ,$$

and testing whether this is serially independent using portmanteau tests. However, for our model we may obtain an explicit form for w_t which is:

$$(8) \quad w_t = u_t - \eta_{t+1} \\ = u_t - u_{t+1} - \frac{\epsilon_{t+1}}{1 - \phi_1 - \dots - \phi_p} .$$

Clearly, w_t is serially correlated even under the assumption that $E(u_t \epsilon_t) = 0$ for all t . The ex post residual in such a test is composed of a linear combination of two error terms, one of which is a first-order moving average process with a unit root. Thus, the portmanteau tests should detect serial correlation even when the interest parity and rational expectations assumptions are true.

3. Testing and Results

Since the stationarity of the processes is essential, both the spot and interest differential were first differenced. Also, these first differenced variables were regressed against a constant and eleven seasonal dummies. The residuals from these two regressions were then taken as the relevant variables. Casting the variables in first differences implies that we are testing a weaker version of interest rate parity and rational expectations. In the past these kinds of transformation were often applied to test weaker forms of purchasing power parity.

Since innovations or shocks to the interest rate differential process are likely to be correlated with shocks to the foreign exchange market, we have allowed for a contemporaneous correlation between ϵ_t and u_t in estimation.⁸ Letting $v_t^T = [u_t \epsilon_t]$, we assume that $v_t^T \stackrel{NID}{\sim} (0, \Omega)$. The restricted model (equations (2) and (3)) is estimated by full information maximum likelihood (FIML). The nonlinear restrictions may be easily tested using a likelihood ratio test. To do this we estimate the unrestricted system (equation (2) and equation (4)) also by FIML and take twice the difference of the log likelihood obtained from unrestricted and restricted systems estimation. Under the null hypothesis of interest rate parity and rational expectations this is asymptotically distributed

as χ^2 with p degrees of freedom. With regard to the properties of this testing procedure, Monte Carlo evidence in Hoffman and Schmidt (1981) and Gregory and Veall (1984) suggest that the likelihood ratio tests of the nonlinear rational expectations restrictions compared against the chi-square distribution have quite good small sample properties. Reasonable test results can often be obtained for data sets with as few as twenty observations.

The model was estimated using month-end data from 1972 (1) to 1982 (12) giving one hundred and thirty-two observations. The data were kindly supplied by the Bank of Canada and are available on request from the author. The spot exchange rate is a closing rate and two different sets of interest rates were tried. These were Canadian and American thirty-day Financial and Commercial Paper Rates (adjusted to monthly rates of return). Since the two sets of results are almost identical, we present only those using the Financial Paper rates.⁹

In Table 1 both the unrestricted (equations (2) and (4)) and the restricted (equations (2) and (4)) estimates from full-sample FIML estimation are presented. The appropriate order of the autoregressive process for the forcing variable z_t was determined on the basis of a likelihood ratio test of an order p process versus one of $(p+1)$ and $(p-1)$ on the unrestricted model. The error structure was subsequently checked using the modified Box-Pierce portmaneau test (see Ljung and Box, 1978). According to this method, the appropriate order for the change in the interest rate differential process was six.

The unrestricted results suggest that an increase in the rate of change of the U.S. interest rate relative to the Canadian rate implies a depreciation in the Canadian currency. The effect occurs immediately and lasts for about a half a year. Additional lagged values of the change of

the interest rate differentials were never helpful in explaining movements in the change of the exchange rate. When the rational expectations restrictions are imposed (equation (2) and equation (3)), only ϕ_4 is significantly different from zero at conventional levels. Moreover, the calculated statistic for the likelihood ratio test is 26.20 versus a critical value of 12.59 at the five percent level of confidence, thus indicating a resounding rejection of the rational expectations restrictions.¹⁰ However, the situation changes when we undertake sub-sample estimation.

We commenced by re-estimating the models (unrestricted and restricted) from 1972 (1) - 1974 (12) and testing the null hypothesis. The terminal date of 1974 was chosen because of the adoption by the Bank of Canada of a money-targeting policy in 1975. For this estimation period we found: (i) an autoregressive process of order one was satisfactory in explaining movements in the rate of change of interest rate differentials; and (ii) the restrictions imposed by rational expectations upon the interest rate parity equation were supported by the data. We then continued to re-estimate the models adding 12 months to the sample each time until we were able to reject the null hypothesis.

The largest sample period for which the hypothesis is not rejected is 1972 (1) - 1979 (12). These results are reported in the top half of Table 2. All the estimated coefficients are significant and the calculated statistic for the likelihood ratio test is 1.28 as compared to the critical value of 3.84 at the five percent level. When the 1980 observations are added (the bottom half of Table 2), the calculated statistic of 4.30 was obtained. Notice that the estimated coefficient for α_1 is substantially larger than the one corresponding to the 1972 (1) - 1979 (12) period¹¹

and that the estimated coefficient ϕ_1 from restricted estimation is not significant. Severe convergence problems were also encountered for unrestricted full-information maximum likelihood estimation when the 1980 observations were included. Adding the 1982 and 1982 observations produced similar conclusions. For these larger sample periods, not only were the rational expectation restrictions rejected but now higher orders for the autoregressive process for interest rate differential equations were required. A weak argument can be made that this change in the interest rate differential process indicates that Canadian nominal assets have become poorer substitutes for those in the United States. However, at present there are not enough observations available to estimate the model using only the 1980's data.

4. Concluding Remarks

The aim of this paper has been to specify, estimate and test a simple model of exchange rate determination based upon uncovered interest rate parity and rational expectations using Canadian/United States month-end data. With the variables expressed in first differences we tested a weaker version of interest rate parity. The evidence indicates that the restrictions imposed by rational expectations upon the interest rate parity equation are supported by the data up to the end of the 1970's. However, once the 1980's are included in the sample, the joint hypothesis of interest rate parity and rational expectations is rejected.

A possible explanation for the rejection using the most recent data is the change in the process governing the change in the nominal interest rate differentials. Although there is no 'hard' evidence, we might reasonably expect the existence of such instabilities. The 1980's have witnessed unprecedentedly high nominal interest rates with much larger

differentials between Canadian/U.S. rates. We would expect that rational agents would not employ an unstable time-series representation to forecast the expected change of the future spot exchange rate. This shift in structure may in fact be due to a change in the risk premium associated with Canadian/U.S. nominal assets. With this in mind, it may be worthwhile modelling a risk premium in the interest rate parity equation along the lines of Domowitz and Hakkio (1983). It is evident that the 1980's are quite different from historical experience and hopefully, as more observations become available, we may be able to provide some concrete explanations.

Finally, the existing evidence against interest rate parity and rational expectations based upon the substitution method may not be that compelling since the procedure does not yield a consistent test if the parity relation is stochastic. Certainly our results for the 1970's suggest that the joint hypothesis is a closer approximation for Canada and the United States than what conventional wisdom might lead us to believe.

TABLE 1

INTEREST RATE PARITY AND RATIONAL EXPECTATIONS:

1972(1) - 1982(12)

<u>UNRESTRICTED ESTIMATES</u>		<u>RESTRICTED ESTIMATES</u>	
Equation 2	Equation 4	Equation 2	Equation 3
z_t	s_t	z_t	s_t
$\varphi_1 = -0.1160$ (1.24)	$\alpha_0 = 3.299$ (10.03)	$\varphi_1 = -0.1241$ (1.45)	
$\varphi_2 = 0.02000$ (0.22)	$\alpha_1 = 1.007$ (2.43)	$\varphi_2 = 0.04322$ (0.56)	
$\varphi_3 = -0.1663$ (2.33)	$\alpha_2 = 0.9465$ (2.73)	$\varphi_3 = -0.1155$ (1.70)	
$\varphi_4 = -0.2383$ (3.17)	$\alpha_3 = 0.8513$ (2.253)	$\varphi_4 = -0.2144$ (3.05)	
$\varphi_5 = -0.08723$ (0.99)	$\alpha_4 = 0.6884$ (1.88)	$\varphi_5 = -0.9766$ (1.14)	
$\varphi_6 = 0.1536$ (2.02)	$\alpha_5 = 0.9062$ (2.46)	$\varphi_6 = 0.1494$ (1.42)	
DW = 1.93	DW = 1.95	DW = 1.91	DW = 2.08
	L = 951.62		L = 938.52

Note: Absolute t-statistics are given in parentheses. DW is the Durbin-Watson statistic intended solely for descriptive purposes, and L is the log of the likelihood excluding the constant.

TABLE 2

INTEREST RATE PARITY AND RATIONAL EXPECTATIONS

<u>UNRESTRICTED ESTIMATES</u>		<u>RESTRICTED ESTIMATES</u>	
<u>1972(1) - 1979(12)</u>			
Equation 2	Equation 4	Equation 2	Equation 3
z_t	s_t	z_t	s_t
$\varphi_1 = -0.2590$ (2.73)	$\alpha_0 = -0.9411$ (2.40)	$\varphi_1 = -0.2661$ (2.56)	
DW = 1.89	DW = 2.10	DW = 1.88	DW = 2.10
L = 714.19		L = 713.50	
<u>1972(1) - 1980(12)</u>			
z_t	s_t	z_t	s_t
$\varphi_1 = -0.08725$ (2.28)	$\alpha_0 = -6.0007$ (17.85)	$\varphi_1 = -0.0008477$ (0.011)	
DW = 1.89	DW = 2.11	DW = 2.06	DW = 2.09
L = 774.24		L = 722.11	

Note: Absolute t-statistics are given in parentheses, DW is the Durbin-Watson statistic intended solely for descriptive purposes, and L is the log of the likelihood excluding the constant.

Footnotes

¹This method is discussed in Nelson (1975), McCallum (1976) and more recently in Pagan (1983). In contrast Hakkio (1981) has estimated the restricted structure in testing the term structure of the forward premium.

²For that matter whenever a structural equation is stochastic and the substitution involves a future variable (as in the interest parity relation) the subsequent residual in the equation is serially correlated (see Nelson, 1975 and McCallum, 1976). Recently Hayashi and Sims (1984) have proposed a potentially more efficient procedure for estimating these kinds of rational expectations models.

³These remarks should not be interpreted as a general condemnation of the substitution method. Indeed quite the contrary is intended. The substitution method often provides the simplest way possible in which to estimate many rational expectations models. The principal advantage lies in the fact that no particular model need be specified to generate the required expectations. Hence potential misspecification from using an 'incorrect' model can be avoided and the estimation problem becomes one of errors in variables.

⁴In a related study investigating the unbiasedness hypothesis in the forward foreign exchange market, Gregory and McCurdy (1984) have found that conclusions based upon full sample estimation could be very misleading. The estimates of the test equation could be very unstable and subsampling can give some indication of the robustness of the results.

⁵In accordance with rational expectations, we have assumed that it is the conditional mathematical expectation of the future spot rate that appears in equation (1). Also, we have assumed that there is no risk premium. We did

add a constant to each equation considered, but it never proved significant in estimation. However, since the risk premium may be variable, it is not clear that this constant adequately captures this. See Gregory and McCurdy (1984).

⁶We note that tests used in the substitution method also require ergodicity and stationarity.

⁷Gourieroux, Laffont and Monfort (1982) have demonstrated that restricting $\{s_t\}$ to be a stationary series implies that the martingale part of the general solution is a constant sequence. This constant would be eliminated when the mean is removed.

⁸Equation (4) is exactly identified as there is one predetermined variable, z_{t-p} , which does not appear in this equation.

⁹Results using the 30-day Commercial Paper rates are available upon request.

¹⁰Of course, the usual caveat associated with rejecting any joint hypothesis applies: the rejection may be due to interest rate parity or it may be due to rational expectations or both.

¹¹We note that given the negative sign and magnitude of ϕ_1 from unrestricted estimation for both periods, the estimated coefficient of α_0 should be positive and greater than one according to equation (4).

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