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ABSTRACT

This dissertation examines the validity of the Fisher hypothesis and the Balassa-Samuelson hypothesis by using an approach which is different from those employed in the previous studies. The importance of the hypotheses in the field of international economics is reflected by the ample volume of research work directed to them. Nevertheless, the validity of the hypotheses remains controversial and the findings on the issues are diverse. In light of this, I use a different empirical approach to examine the two hypotheses and hope that the findings here would bring new insight to the literature.

In the first chapter of my dissertation, I investigate whether the Fisher effect holds for the US. The Fisher relationship maintains that nominal interest rates and expected inflation move in a one-to-one manner. As conventional unit root tests find that both nominal interest rates and inflation are unit root processes, most recent papers have used a cointegration approach to verify if the fisher effect holds. Given that US nominal interest rates and inflation fell and rose after reaching certain peaks and troughs over the last few decades, there is doubt in treating the time series as non-stationary. I investigate the issue for the US using two different approaches. In the structural break analysis, I find that the direction and magnitude of breaks in nominal interest rate and inflation follow approximately to what the Fisher effect

predicts. The stability of real interest rates provides further support for the validity of the Fisher link. In the second part of the paper, I use a VAR model to examine the dynamic relationship between nominal rates and inflation. As volatility clustering is present, I include a GARCH effect in the estimation. The results show that nominal rates respond positively to a shock in inflation and the magnitude of cumulated response is only slightly below that predicted by the Fisher hypothesis. The findings are strongly in favor of the presence of the Fisher effect.

The second chapter examines validity of the Balassa-Samuelson hypothesis (BSH) in a sample of nine OECD countries with the US taken as the benchmark. The BSH admits the importance of productivity in explaining the fluctuations of real exchange rates via its impact on the relative non-tradable prices. The results from the structural break analysis indicate that four countries tie with the hypothesis while the other three countries are in partial fit. Similar findings are obtained when government spending is considered in the estimations. Examining the dynamic relationship among the variables by a VAR-GARCH model, the findings support a strong link between productivity shocks and real exchange rates. The results are robust when the time series are either treated as I(0) or I(1). The responses of relative prices to productivity shocks are in the expected directions, however, the sizes are mild in most cases. In this regard, I examine an alternative transmission channel for productivity shocks. The results suggest that the real exchange rate of tradable goods maybe an important channel through which productivity impacts on real exchange rates. As a whole, the findings in this paper are slightly in favor of the hypothesis.

In the third chapter, I extend my study on the Fisher hypothesis to cover the same sample of nine OECD countries. I employ a similar empirical approach as in the first chapter. In the structural break analyses, I investigate if real interest rates are stable over the entire sample period. Since the findings show that the real rates for most of these countries have experienced major shifts over time, I examine the reasons behind these changes by considering some possible factors suggested by the literature. Employing VAR-GARCH models and innovation analyses, I find that nominal interest rates have limited response to inflation shock. The failure of achieving the hypothesized one-to-one relationship is not due to an inappropriate tax adjustment of the nominal rates. After considering the overall results, only two countries in the sample follow closely with the predictions from the Fisher hypothesis. While the evidence of three countries rejects the Fisherian link, the findings for the rest are mixed. I suggest that the evidence for the Fisher hypothesis is weak.

Chapter 1

The Fisher effect from different perspectives

1.1 Introduction

The Fisher effect was put forward by Fisher (1930). It hypothesized that there is a one to one relationship between nominal interest rates and expected inflation provided that the real rate is held constant. Since interest rates are key variables in macroeconomic modeling and policy formulation, the validity of the Fisher effect is crucial to both theoretical researchers and policymakers. If there is evidence in favor of the Fisher hypothesis, it will also lend support to the monetary neutrality proposition which is one of the centerpieces in classical economics. Due to its importance, there is a voluminous literature examining the Fisher effect. However, the findings on whether the Fisherian link holds vary with the countries under investigation and empirical methods being used. Early papers like Fama (1975) and Summers (1983) directly examined the relationship between nominal interest rates and inflation for the US by using least squares method. With the advancement of empirical methods and findings that favors the existence of unit root behavior for nominal interest rates and inflation, most recent empirical studies have focused on examining the cointegration relationship between the variables. However, this technique is appropriate only if both nominal interest rate and inflation are integrated of the same order. Over the last few decades, inflation and nominal interest rates fell and rose after reaching certain peaks and troughs. There is doubt in treating the time series as a unit root process. Furthermore, we expect policymakers of a mature economy to keep both inflation and nominal rates under control. Hence, the appropriateness of employing the cointegration approach may not be appropriate.

In this paper, I will use two different methods to examine the relationship between the nominal interest rates and inflation for the US. The first approach relies on estimating the structural the breaks of each univariate time series. I compare the timing, direction and magnitude of breaks for nominal rate and inflation. If the Fisher effect holds, there will be a close proximity of break time for each series. Furthermore, they will move in the same direction and be approximately the same size. The findings show that the timing of structural breaks does not match strictly. The estimated break time for inflation generally precedes those of nominal rates. On the direction and size of the shifts, the results fit quite well with the predictions from the Fisher equation. The findings are almost the same when tax-adjusted nominal rates or unadjusted nominal rates are used for comparison.

Since the impact of inflation on nominal interest rates may not be contemporaneous, I formulate a VAR model to examine the relationship between the tax-adjusted nominal interest rates and inflation. This second approach takes into consideration the presence of dynamic effects and serves as a countercheck to the previous approach. As opposed to some early studies using VAR models, I will take into account the existence of volatility clustering. A GARCH effect is incorporated into the model and it becomes a VAR-GARCH setup. To avoid unnecessary restrictions in the conditional variance-covariance structure, I will use a full BEKK model (Engle and Kroner 1995). The result indicates that a positive shock to inflation does produce a significant positive effect on nominal interest rates in the impulse response analysis. With respect to the magnitude of responses, a unit shock on inflation will produce an accumulated response of comparable sizes in both nominal rates and inflation. Even though the size of responses does not match perfectly with the Fisher prediction, it is not far apart either. The findings strongly favor the presence of the Fisher effect.

The subsequent sections will be organized as follows. Section 2 is a brief literature review. Section 3 describes the techniques used in estimating the structural breaks and the results will be presented. Section 4 covers the details of VAR-GARCH model and the analysis of results. The final section concludes the paper.

1.2 Literature Review

The relationship between inflation and nominal interest rates is an important topic in international economics. To explain the link between the two variables, different propositions have been suggested. Under the liquidity effect, a positive money shock will push up in inflation and lower nominal interest rates so as to induce economic agents to hold additional real money balance. On the other hand, the Fisher effect suggests that an increase in expected inflation will accompany with an increase in nominal interest rates in a one-to-one manner. As a result, the real interest rate will be neutral to changes in inflation. While the liquidity effect is believed to dominate in the short run, the long run impact of the Fisher effect is more controversial and will be the focus of this paper.

Early studies like Fama (1975) and Summers (1983) examined the empirical relationship by treating nominal interest rates as a predictor of expected inflation using US data. Fama found evidence in support of the Fisherian link for the US during the period from 1953 to 1971. In contrast, Summers admitted the effect was smaller than that predicted by theory and all the power of the relationship comes solely from the period 1965 to 1971. In the 1990s, much of the research effort has been focused on the cointegration relationship between nominal interest rates and inflation. Following the seminal papers of Rose (1988) and Mishkin (1992), Evans and Lewis (1995) investigated the cointegration between nominal interest rates and inflation by applying the dynamic ordinary least square method (DOLS) to estimate the effect of inflation on nominal interest rates. They rejected the one to one adjustment as predicted by the Fisher effect. In response, they modeled a Markov switching model to characterize the shifts in inflation. They showed that if economic agents formed their expectation on inflation with consideration of the structural changes, the results from subsequent cointegration analysis would support the existence of the Fisher effect. Crowder and Hoffman (1996) apply the Johansen (1988) method and vector error correction model (VECM) to investigate the link between tax-adjusted interest rates and inflation for the US from 1951 to 1991 using quarterly data. They support the one to one adjustment as hypothesized by the Fisher effect. Koustas and Serletis (1999) used post-war quarterly data for eleven countries. Though they cannot reject the hypothesis of unit root processes, they find that cointegration does not exist. They in turn adopt a VAR model in first differences and generally reject the Fisher hypothesis for these countries.

There are a growing number of papers which questioned the appropriateness of using conventional cointegration method, for instance, Lanne (2001) and Atkins and Coe (2002). They suggest that the nonstationarity of interest rates and inflation maybe a result of the low power of conventional unit root tests. In response to the ambiguity on the stationarity of interest rates and inflation, these authors use empirical methods which do not require interest rates and inflation to be integrated of the same order. Lanne (2001) estimated an inflation forecasting equation using nominal rate as the independent variable. He uses the Scheffe type confidence intervals of Cavanagh et al. (1995) for subsequent empirical testing. The intuition is that these confidence intervals are asymptotically valid whether the regressor is integrated of order one, zero or is a near unit root process. He finds that the Fisher effect holds in the US for the pre-1979 period but is absent afterwards. Atkins and Coe (2002) test the Fisherian link for Canada and the US by the bounds test developed by Pesaran, Shin and Smith (2001). Their findings are in favor of the Fisherian view. Casting doubt on the integratedness of inflation, Westerlund (2008) propose two new panel cointegration tests which are robust against the presence of stationary regressors. He examines the Fisher effect by using a panel of twenty OECD countries from 1980 to 2004. He admits that the new tests considers cross-sectional data dependency and have higher power than the existing test like Pedroni (2004). The findings suggest that the Fisher hypothesis cannot be rejected based on his panel studies.

1.2.1 My Approach

Most of the empirical studies have regarded nominal rates and inflation as unit root processes and have used the cointegration technique to examine their relationship. The use of the cointegration method is appropriate only if nominal interest rates and inflation are integrated of the same order. Examining nominal interest rates and inflation for the last few decades, the time series fell and rose within a certain range. This evidence indicates that the findings of nonstationarity for these time series are the results of the low power of conventional unit root tests. Thus the cointegration approach is deemed inappropriate and the findings from this method may not reveal the true picture. Furthermore, volatility clustering is a common feature found in most economic time series. Studies based on the dynamic effect of nominal interest rates and inflation without accounting for conditional heteroskedasticity could be deficient. Accordingly, I use the empirical approach as in Grier and Ye (2007) to examine the Fisher effect by estimating and comparing the structural breaks of each time series. The timing and magnitude of breaks will provide evidence for whether the Fisher relationship holds. Afterwards, I will formulate a VAR-GARCH model and will examine the dynamic effect by using impulse response analysis.

1.3 Estimating Structural Breaks

Empirical evidence of the Fisher hypothesis requires the existence of common structural breaks and a one-to-one co-movement for nominal interest rates and expected inflation across regimes. In this section, I estimate and compare the structural breaks of inflation, tax-adjusted nominal interest rates and unadjusted nominal interest rates to see if the Fisher effect holds.

The dataset consists of quarterly observations from 1953 Q1 to 2008 Q1. The three-month US Treasury Bill rate is used to represent nominal interest rates. The data is available from the Federal Reserve Bank of St. Louis. The inflation rate is the annualized, quarterly difference of the logarithm of CPI_U index (all urban) computed from the Bureau of Labor Statistics. To account for the Darby (1975) effect, tax-adjusted nominal interest rate is also computed. My method of calculation follows Rapach and Wohar (2005) and Caporale and Grier (2005). The US marginal tax rate is taken from Padovano and Galli (2001).

Structural breaks in the nominal interest rates and inflation are estimated by using Bai and Perron (1998, 2003) (hereafter BP). The method enables the estimation of multiple structural breaks by using a global optimization approach. Here I use a pure structural break or a simple mean-shifting setup specified as below:

$$y_t = z_t \beta_j + u_t \tag{1}$$

where y_t is the inflation rate or nominal interest rate and z_t is a constant equal to one. β_j is the estimated mean for the jth regime. If there are m breaks in the time series, j equals 1, 2, … m, m+1. Table 1 reports the estimated structural breaks for inflation rate using BP's method[1]. The results indicate that there are three structural breaks in inflation over the period. The break dates are 1967 Q1, 1973 Q1

[1] The maximum number of breaks are set to 7 with the trimming parameter equals 0.1. Serial correlation , heterogeneous variance in residuals over different regimes are allowed.

and 1982 Q2 respectively. These findings are consistent with those found in Rapach and Wohar (2004) and Caporale and Grier (2005).

Table 2 and 3 show the results of break estimation for tax-adjusted nominal interest rate and unadjusted nominal interest rates. The same BP parameter settings for estimating breaks in inflation are used. The findings for adjusted and unadjusted interest rates are very similar. In both cases, there are five breaks for the entire period. The estimated break dates are almost identical.

1.3.1 Comparing the Breaks in Nominal Interest Rate and Inflation

An analysis of the Fisher effect necessitates the matching of the number of structural breaks in each time series and the size of mean-shift. Figure 1 shows graphs for the structural breaks of nominal interest rates, tax-adjusted nominal interest rates and inflation. At first glance, the results reported in Table 1 through 3 do not fit Fisher's predictions very well. There are only three breaks in inflation compared with the five breaks found in both interest rates. In terms of timing of breaks, only the first break of inflation (67 Q1) and tax-adjusted interest rate (67 Q3) or unadjusted interest rate (65 Q3) are perceived to be common breaks. For the others, the break dates found in inflation and interest rates are a distance apart even after considering the confidence intervals of the break dates[2].

[2] The third break in inflation and nominal interest rate is marginally non-overlapping for the 95% confidence interval

Since interest rate movements can be impacted by deliberate monetary policy by the Federal Reserve (Cook 1989, Taylor 1993), the deviations may reflect these policy actions. If we relax the Fisher hypothesis and allow for some time lags for the interest rate responding to changes in inflation, the direction and size of shifts are very close to the Fisherian view.

1.3.2 Matching of Break Date

As mentioned in the previous section, the first break date for both interest rates and inflation happen almost simultaneously, these two breaks are perceived as co-movement in the series. The second break for both the interest rate and inflation occurred in the 1970s and it was also the only break in that period. If we allow for time lags in the break of interest rate, they are the second matched pair. As explained, the third break for interest rates and inflation is very close when considering the confidence interval of break dates, they are treated as another co-movement.

Table 4 indicates the mean-shifts in each regime for both interest rates and inflation. Comparing the size of shifts, both the interest rate and the inflation rate reveal close mean-shifts as predicted by Fisher. If we regard the fourth and fifth breaks in the nominal interest rate as belonging to part of the adjustment process after the third break, the findings well support the Fisher relationship[3].

1.3.3 Analysis of the Real Interest Rate

In the last section, the findings are in favor of the Fisher hypothesis at least in its weak form. This result can be counterchecked by analyzing the real interest rate. Given the real interest rate as:

$$r_t = i_t - \pi_t^e \tag{2}$$

where r_t, i_t and π_t^e are the real rate, nominal rate and expected inflation[4] respectively. From (2), if nominal interest rates and the inflation rate move in a one-to-one manner, the real interest rate should be quite stable. Using this equation, the tax-adjusted real rate is computed. Table 5 reports the estimated structural breaks of real rate using BP. It indicates that there are three breaks found in 1972 Q4, 1980 Q3 and 1986 Q1. Figure 2 depicts the graph of the real rate together with the nominal interest rate and inflation. The real rate remains stable for most of the period covered, though, it shifts during the 70's and 80's.

Since the validity of the Fisher effect requires a stable real rate over the entire period. If major shifts in the real rates are found, it is imperative to check for the

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[3] The findings are robust when I compute the inflation rate by using the personal consumption expenditure price index. Although the BP method identifies one more downward shift for inflation at 90Q4, the same conclusion can be drawn. The results are not reported here but are available upon request.

[4] Here I use the actual inflation at time t to proxy the expected inflation, the same conclusion can be drawn if actual inflation at t+1 is used instead.. Though not attempted here, another possibility is to use survey data on expected inflation, for instance, the University of Michigan Inflation Expectation Survey covers data on expected inflation from 1978 to present.

sources of these "disturbances". If the structural breaks of the real rate is a result of shifts in inflation (Rapach and Wohar 2005), it implies that the nominal interest rate fails to keep a one to one shift with inflation. Consequently, both the Fisher effect and the monetary neutrality propositions will be rejected. As the timing of breaks in the real rate fit very well with the outbreak of oil crises in 1973 and 1979, and the 1986 oil price collapse[5], I examine if changes in relative oil prices can explain these shifts[6]. Further, Caporale and Grier (2005) documented that changes in Fed regime represent different preferred equilibrium real rates. Structural break analysis controlling for different Fed chairs will be implemented as well.

Table 6 reports the structural break estimation after controlling for the relative oil prices. Here I include the relative oil prices as an explanatory variable with a fixed coefficient and apply BP's method in estimating structural breaks. The estimated number of breaks is two which is one less than that if relative oil prices were not included in break estimation. This result shows that changes in oil prices can only explain the real rate shift in 1973 which corresponds to the first oil crisis.

Table 7 shows the results of break estimation if changes in Fed regime[7] are

[5] After the oil price had reached the peak in 1980 at over US$35 per barrel, it fell continuously in subsequent years. In 1986, the oil price even slid down significantly from $27 to $10. The fall of energy prices during the 80's was commonly referred as to the oil glut and was a result of the reduced demand from the slowed global economic activity.

[6] Barro and Sala-i-Martin (1990) maintain that real interest rate is affected by the level of relative oil prices

[7] The Fed chairs include William McChesney Martin, Arthur F. Burns, G. William Miller, Paul A. Volcker, Alan Greenspan and Ben S. Bernanke

considered. I regress the real rate on the Fed regime dummies and used the residuals for break estimation. The results indicate that no break can be found[8]. This result is consistent with Caporale and Grier (2005) and implies that real rates are stable once the Fed regimes are considered. In other words, the finding is supportive of the Fisher hypothesis because nominal interest rates and inflation move in line with each other over the period.

1.4 The VAR-GARCH Model

In the previous section, the results show that over the last half century, the relationship between the nominal interest rate and inflation fits quite well with the predictions of the Fisher hypothesis. Since the structural break analysis reveals that there are lags for the impact of inflation on nominal interest rates, it is meaningful to see if the Fisher effect holds with the inclusion of such a dynamic effect. Most of the previous literature has treated the interest rate and inflation as unit root processes. Nevertheless, many authors now cast doubt on the appropriateness of treating interest rate and inflation as nonstationary. Table 8 shows the results of the augmented Dickey-Fuller unit root tests (ADF) (Dickey and Fuller 1979) and KPSS unit root tests (Kwiatowski et al. 1992). The test results question the validity of treating the underlying time series as nonstationary. Considering the unit root test results and the

[8] The same results are obtained when the real interest rates are derived from the inflation computed by using the personal consumption expenditure price index.

fact that both nominal rates and inflation fluctuate over a certain range for the last few decades, I will use a VAR model in levels to investigate their dynamic relationship. A bivariate unrestricted VAR model:

$$Y_t = \mu + \sum_{j=1}^{p} \Psi_j Y_{t-j} + \varepsilon_t \qquad (3)$$

where Y_t is a column vector of inflation and tax-adjusted nominal interest rate. The number of lags, p, selected is nine and is based on the selection criteria of the sequential modified LR test and Arkaike Information Criterion (AIC)[9]. To test for any remaining serial correlation, the multivariate Ljung-Box portmanteau test is conducted. Table 9 indicates the absence of serial correlation when nine lags are used. Since there may be volatility clustering in interest rates and inflation, I implement the multivariate Ljung-Box test to check for the conditional heteroskedasticity. Table 10 reports the results and suggest that conditional heteroskedasticity does exist which may lower the efficiency of estimation by OLS.

1.4.1 The VAR-GARCH Setup

With regard to the well-documented persistent conditional heteroskedasticity problem in inflation and interest rate, I use a GARCH model to control for the time

[9] The Schwarz Information Criterion (SIC) suggests a more parsimonious lag length than AIC. However, considering the results of subsequent test on serial correlation, I use the lag length as suggested by the latter.

varying conditional variance. In this regard, a GARCH(1,1) formulation is used.[10]

Referring to the conditional variance-covariance structure, I will use the BEKK model (Engle and Kroner 1995). The advantage of this formulation is that it avoids the unnecessary diagonal restrictions which may be a potential source of misspecifications. The appropriateness of using a full BEKK covariance model will be clear if the off-diagonal coefficients are statistically significant. In summary, the model specification will be a VAR(9)-GARCH(1,1) as below:

$$Y_t = \mu + \sum_{j=1}^{p} \Psi_j Y_{t-j} + \varepsilon_t \tag{4}$$

where $Y_t = \begin{bmatrix} \pi_t \\ i_{tax,t} \end{bmatrix}$; $\mu = \begin{bmatrix} \mu_1 \\ \mu_2 \end{bmatrix}$; $\Psi_j = \begin{bmatrix} \Psi_{11}^j & \Psi_{12}^j \\ \Psi_{21}^j & \Psi_{22}^j \end{bmatrix}$; $\varepsilon_t = \begin{bmatrix} \varepsilon_{\pi,t} \\ \varepsilon_{i_{tax},t} \end{bmatrix}$

$$H_t = C_0^{*'} C_0^* + A_{11}^{*'} \varepsilon_{t-1} \varepsilon_{t-1}^{'} A_{11}^* + B_{11}^{*'} H_{t-1} B_{11}^* \tag{5}$$

where $C_0^* = \begin{bmatrix} c_{11}^* & c_{12}^* \\ 0 & c_{22}^* \end{bmatrix}$; $A_{11}^* = \begin{bmatrix} a_{11}^* & a_{12}^* \\ a_{21}^* & a_{22}^* \end{bmatrix}$; $B_{11}^* = \begin{bmatrix} b_{11}^* & b_{12}^* \\ b_{21}^* & b_{22}^* \end{bmatrix}$

Equation (4) represents the mean equations for inflation and the tax-adjusted interest rate in the VAR. Equation (5) is the conditional variance-covariance setup. H_t denotes the conditional covariance which is positive definite for all values of ε_t. Table 11 summarizes the estimation results.

Table 11 shows that most of the estimated coefficients in the conditional

[10] I employ a symmetric GARCH model as the results from the sign bias test of Engle and Ng (1993) do not indicate the presence of asymmetry in the variance-covariance process. Further, I estimate a GARCH-M model for each of the time series but the associated coefficients are not statistically significant.

variance- covariance structure are statistically significant at the 1% level. These findings support the existence of conditional heteroskedasticity in the VAR model. The appropriateness of using a full BEKK model is clear as we check on the estimation results of the off-diagonal coefficients. With the exceptions of a_{12}^* and c_{12}^* in A_{11}^* and C_0^*, all other off-diagonal coefficients, a_{21}^*, b_{12}^* and b_{21}^*, are highly significant. It means that any diagonal restrictions may create specification problems. To check for the sufficiency of the VAR-GARCH model, I implement the multivariate Ljung-Box portmanteau test for the standardized residuals obtained from the model. Table 12 indicates that there is no serial correlation. Table 13 shows that conditional heteroskedasticity has been controlled. Figure 3 depicts graphs of the estimated conditional variance and covariance for the tax-adjusted nominal interest rate and inflation over time. The volatility of nominal interest rate reaches the peak in early 1980s and is relatively mild for the rest of the time. For inflation, the volatility is high during the mid-1970s, early 1980s and recent years. It appears the highest at around 2007. The timings of volatility surges coincide with some of the major economic events like the oil crises and the Federal Reserve Board's new operating procedure in 1979.

1.4.2 Impulse Response Analysis

To examine the effect of an inflation shock on tax-adjusted nominal interest rate, the impulse response analysis is employed. Using the Choleski decomposition, I constructed the impulse responses for a unit shock in inflation on interest rate. Figure 4 depicts the graphs of impulse response together with their bootstrapped 95% confidence intervals. The lower panel of Figure 4 shows that given a positive shock to inflation, interest rate jumps 0.25 percentage point. It continues to rise and reaches 0.35 percentage point at the 10th quarter. After that it falls slowly and the positive effect becomes insignificant after the 17th quarter. This result indicates a positive impact of inflation on nominal rates. In order to compare the entire effect of an inflation shock on both nominal rates and inflation, I construct the cumulated impulse responses in Figure 5. The upper panel of Figure 5 shows that the accumulated inflation increases after an initial inflation shock and reaches 9.58 percentage points at the 24th quarter. It declines and stays at around 7.6 percentage point after the 47th quarter. The lower panel of Figure 5 depicts the accumulated response of interest rates to inflation. It increases from 0.25 to 6.92 percentage point at the 32nd quarter and then falls slowly. Finally, it remains fairly stable at 6.14 percentage point after the 61st quarter.

The findings indicate that inflation impacts positively on nominal rates as predicted by the Fisher effect. The accumulated response of nominal rates to an inflation shock is 6.14% and is close to the accumulated response of 7.6% from that of inflation[11] I would see this result as evidence supporting the Fisher effect.

1.4.3 Results Comparison by Using Alternative Methodologies

In the previous section, the findings generally favor the presence of the Fisher effect. The empirical setup has two distinct features which differ from the other papers. First, I have treated inflation and nominal rates as stationary and have used the raw data directly for estimations. Second, I have considered the time-varying conditional variance in the model formulation. It is insightful to see how the results change if alternative specifications are used in the estimations.

Figure 6 displays the impulse response of interest rate to a shock on inflation for the VAR model without considering the existence of conditional heteroskedasticity. Given a positive shock to inflation, interest rate moves to 0.156 percentage point which is a bit mild comparing to the previous setup. The interest rate then rises and reaches the peak of 0.38 percentage point at the 6th quarter. It continues to fall and become statistically insignificant after the 16th quarter. Again, there exists a positive relationship between inflation and nominal rates. Figure 7 depicts the cumulated

[11] To check the robustness of results, I compute an alternative measure of the cumulative response of inflation by using a compounded inflation derived from the impulse response analysis. The cumulative response of inflation becomes steady at 7.9% which is a bit higher than original result of 7.6%. Though the findings may reflect a higher degree of under-responding for nominal rates, this result does not deviate much from the Fisher hypothesis.
Another check on the Fisher effect is done by using an augmented Fisher relation by including the consumption growth in the empirical model as suggested by the Euler equation. Arnwine and Yigit (2008) found that consumption growth has statistically significant effect on nominal rates in the short run but its effect is only marginal in the long run. Including consumption growth in my empirical model reduces the response ratio of nominal rates to inflation from 0.8 to 0.7. However, the impulse responses of consumption growth are statistically insignificant over the entire horizon. In this regard, I maintain that the results are still supportive of the Fisher hypothesis.

impulse responses for inflation and nominal rates given a shock in inflation. The upper panel shows that inflation rises and peak at 7.90 percentage points in the 28th quarter. It remains steady at 7.30 percentage points after the 60th quarter. The lower panel of Figure 6 traces the changes of accumulated response of interest rates over time. Nominal rates rise continuously and remain steady at the peak of 7.78 percentage points after the 58th quarter. Overall, the findings are similar to those when volatility clustering is considered and it supports the Fisherian link.

In response to some of the previous literature which regarded interest rate and inflation as I(1) processes but found no cointegration relationship, the appropriate approach is to estimate a VAR model in first differences. Figure 8 shows that a unit shock on inflation produces no significant effect on the nominal interest rates. Figure 9 depicts the cumulated impulse response when first differenced data are used. The graphs indicate that inflation and nominal rates stabilize at 1.0 and 0.26 percentage point respectively. The values of these accumulated impulse response are relatively distant apart as there is no overlapping for the 95% confidence intervals. This result rejects the presence of the Fisher effect when first differenced VAR is employed[12].

In summary, we can see that by treating inflation and nominal rates as stationary

[12] Since the Fisher hypothesis focus on the relationship between the level of interest rates and inflation, the evidence from this first-differenced VAR model may not be taken as a strong rejection of the hypothesis.

processes, the empirical findings are supportive of the Fisher effect. Even though the inclusion of GARCH effect may widen the gap between the accumulated responses of nominal rates and inflation, the findings do not deviate far away from the Fisher predictions. Thus, the results are strongly in favor of the Fisher hypothesis.

1.5 Conclusion

This paper investigates the validity of the Fisher effect which is one of the unresolved fundamental issues in macroeconomics. The understanding of the relationship between the nominal interest rate and inflation is crucial to theoretical researchers and policymakers. Even though there is a huge volume of studies attempting to examine the issue, the findings are diverse and equivocal. As conventional unit root tests find the interest rate and inflation as nonstationary, most previous studies use cointegration approach to test for the Fisher effect. Nevertheless, it is well documented that conventional unit root tests have a low power which often fail to reject the null of nonstationarity when it should be. Over the last few decades, interest rate and inflation fell and rose after reaching certain peaks and troughs. It seems inappropriate to use cointegration as the estimation approach. In this paper, the existence of the Fisher effect is examined in two perspectives. In the structural break analysis, nominal interest rate and inflation closely resemble to each other in the break time, direction and magnitude of breaks. Even though they do not follow Fisher's prediction in a perfect sense, the findings are strongly supportive of the proposition. Further evidence is affirmed by studying the breaks in the real interest rate. The result indicates that the real rates are fairly stable in the period covered. The shifts of the real rate can be explained by changes in Fed regime which reflect different preferences of equilibrium real interest rates.

In order to include any dynamic relationship between the nominal rate and inflation, I formulate a VAR-GARCH in subsequent analysis. It also serves as a robustness check to the presence of the Fisher effect. Unlike most previous papers which do not consider volatility clustering or use a restrictive conditional covariance structure, I include the GARCH effect with a full BEKK formulation. The advantage of this framework is that it avoids the unnecessary diagonal restrictions. The impulse response analysis shows a significant effect of inflation shocks on the nominal interest rate. Although the size of accumulated responses for inflation and nominal rates do not match perfectly, they are not far apart either. The findings are strongly in favor of the Fisher effect.

To understand the importance of different modeling, I compare the results with those obtained from two alternative models. They include a VAR model in levels without considering the effect of conditional heteroskedasticity and a first differenced VAR model. The results obtained from the VAR model are similar to my preferred model and support the Fisher hypothesis. On the other hand, the findings from the first differenced VAR model invalidate the presence of Fisherian link.

In conclusion, the findings in this paper are generally in favor of the Fisher effect. Even though the results still deviate from the Fisherian view in its strictest sense, there are strong evidences that the Fisher effect is valid for the United States.

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Table 1.1 Structural Breaks for Inflation Rate

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	$SupF_T(5)$
20.9535***	18.0849***	19.2424***	13.2274***	13.9487***
$SupF_T(6)$	$SupF_T(7)$			
12.5149***	10.0987***			

$UD\max$	$WD\max$ (10%)	$WD\max$ (5%)	$WD\max$ (1%)
20.9535***	23.4448***	25.6003***	29.7092***

$SupF_T(2\mid 1)$	$SupF_T(3\mid 2)$	$SupF_T(4\mid 3)$	$SupF_T(5\mid 4)$
20.8519***	23.6527***	1.9391	2.5360
$SupF_T(6\mid 5)$	$SupF_T(7\mid 6)$		
1.8264	1.6081		

Number of breaks selected by Global Optimization Procedure $= 3$

Estimated Break Dates	95% Confidence Intervals:
1967 Q1	1965 Q2 – 1969 Q3
1973 Q1	1969 Q3 – 1973 Q3
1982 Q2	1981 Q2 – 1984 Q1

Regime	$\pi\%$	$\Delta\pi\%$
1	1.7118 (0.3982)	
2	4.7798 (0.4737)	3.0680
3	9.1759 (0.7442)	4.3961
4	3.0555 (0.3626)	-6.1205

***, **, * denote 1%, 5% and 10% significance level; the standard errors for all estimates are reported in parentheses

Table 1.2 Structural Breaks for Tax-adjusted Nominal Interest Rate

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	$SupF_T(5)$
8.8660*	10.0490**	40.2658***	48.6364***	40.7042***
$SupF_T(6)$	$SupF_T(7)$			
39.4354***	41.8994***			

$UD\max$	$WD\max$ (10%)	$WD\max$ (5%)	$WD\max$ (1%)
48.6364***	81.1732***	90.1381***	107.8598***

$SupF_T(2\mid1)$	$SupF_T(3\mid2)$	$SupF_T(4\mid3)$	$SupF_T(5\mid4)$
14.2776***	27.1487***	61.6671***	16.2497**
$SupF_T(6\mid5)$	$SupF_T(7\mid6)$		
4.9730	4.4474		

Number of breaks selected by Global Optimization Procedure $= 5$

Estimated Break Dates	95% Confidence Intervals:
1967 Q3	1966 Q4 – 1968 Q1
1978 Q2	1977 Q3 – 1978 Q3
1984 Q3	1984 Q2 – 1986 Q1
1991 Q2	1990 Q4 – 1992 Q1
2001 Q1	1999 Q3 – 2001 Q3

Regime	i_{tax}%	Δi_{tax}%
1	2.2074 (0.0994)	
2	4.5407 (0.1496)	2.3333
3	8.5576 (0.4000)	4.0169
4	5.5572 (0.1595)	-3.0004
5	3.7361 (0.1135)	-1.8212
6	2.1282 (0.2164)	-1.6079

***, **, * denote 1%, 5% and 10% significance level; the standard errors for all estimates are reported in parentheses

Table 1.3 Structural Breaks for Unadjusted Nominal Interest Rate

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	$SupF_T(5)$
10.0171**	9.5105**	40.6625***	49.2059***	41.0014***
$SupF_T(6)$	$SupF_T(7)$			
36.4790***	37.6794***			

$UD\max$	$WD\max$ (10%)	$WD\max$ (5%)	$WD\max$ (1%)
49.2059***	72.9977***	81.0597***	96.9964***

$SupF_T(2\|1)$	$SupF_T(3\|2)$	$SupF_T(4\|3)$	$SupF_T(5\|4)$
13.9403***	25.5380***	61.6671***	16.2497**
$SupF_T(6\|5)$	$SupF_T(7\|6)$		
6.8347	5.8074		

Number of breaks selected by Global Optimization Procedure $= 5$

Estimated Break Dates	95% Confidence Intervals:
1965 Q3	1964 Q4 – 1965 Q4
1978 Q2	1977 Q3 – 1978 Q3
1984 Q3	1984 Q2 – 1986 Q1
1991 Q2	1990 Q4 – 1992 Q1
2001 Q1	1999 Q3 – 2001 Q3

Regime	i %	Δi %
1	2.6327 (0.1264)	
2	5.6047 (0.1745)	2.9720
3	10.6140 (0.4934)	5.0093
4	6.8778 (0.1974)	-3.7362
5	4.6238 (0.1405)	-2.2539
6	2.6339 (0.2678)	-1.9899

***, **, * denote 1%, 5% and 10% significance level; the standard errors for all estimates are reported in parentheses

Table 1.4 Mean Shifts for Nominal Interest Rate and Inflation

regime	mean-shift (π)	mean-shift (i_{tax})	mean-shift (i)
1			
2	3.0680	2.3333	2.9720
3	4.3961	4.0169	5.0093
4	-6.1204	-6.4294*	-7.9801*

* total mean shifts of the 3rd, 4th and 5th breaks

Table 1.5 Structural Breaks for Tax-adjusted Real Interest Rate

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	$SupF_T(5)$
13.2717***	16.6108***	15.4316***	13.7771***	12.8127***

$UD\max$	$WD\max$ (10%)	$WD\max$ (5%)	$WD\max$ (1%)
16.6108***	19.6022***	21.7125***	25.7046***

$SupF_T(2\mid 1)$	$SupF_T(3\mid 2)$	$SupF_T(4\mid 3)$	$SupF_T(5\mid 4)$
20.9507***	14.4176***	6.1263	6.1263

Number of breaks selected by Global Optimization Procedure $=3$

Estimated Break Dates	95% Confidence Intervals:
1972 Q4	1969 Q2 – 1974 Q3
1980 Q3	1979 Q3 – 1981 Q2
1986 Q1	1983 Q4 – 1989 Q4

Regime	r_{tax}%	Δr_{tax}%
1	0.0650 (0.3084)	
2	-3.3584 (0.6739)	-3.4234
3	3.8640 (0.8410)	7.2224
4	0.3944 (0.3354)	-3.4696

***, **, * denote 1%, 5% and 10% significance level; the standard errors for all estimates are reported in parentheses

Table 1.6 Structural Breaks for Tax-adjusted Real Interest Rate Controlling for the Relative Oil Prices

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$
27.2320***	39.1430***	32.6186***	25.9556***

$UD\max$	$WD\max$ (10%)	$WD\max$ (5%)	$WD\max$ (1%)
39.1430***	41.9107***	44.9749***	13.0700***

$SupF_T(2\|1)$	$SupF_T(3\|2)$	$SupF_T(4\|3)$
22.9413***	8.8274	3.1922

Number of breaks selected by Global Optimization Procedure $= 2$

Estimated Break Dates	95% Confidence Intervals:
1980 Q3	1979 Q4 – 1981 Q1
1986 Q1	1985 Q1 – 1987 Q2

Regime	r_{tax}%	Δr_{tax}%
1	1.3364 (0.4634)	
2	8.9150 (1.0165)	7.5786
3	3.2374 (0.4097)	-5.6776

Relative oil price parameter: -0.1629 (0.0271)

***, **, * denote 1%, 5% and 10% significance level; the standard errors for all estimates are reported in parentheses

Table 1.7 Structural Breaks for Tax-adjusted Real Interest Rate Controlling for Fed Regimes

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$
2.7410	6.0604	4.1893	2.9056

$UD\max$	$WD\max$ (10%)	$WD\max$ (5%)	$WD\max$ (1%)
6.0604	6.4890	6.9634	7.7698

$SupF_T(2\|1)$	$SupF_T(3\|2)$	$SupF_T(4\|3)$
6.5402	2.7220	1.6018

No break can be found

***, **, * denote 1%, 5% and 10% significance level

Table 1.8 Unit Root Tests

	ADF	*KPSS*
i	-2.4426	0.4003
i_{tax}	-2.4218	0.4100
π	-3.1160	0.2810
10% CV	-2.5739	0.3470
5% CV	-2.8747	0.4630
1% CV	-3.4605	0.7390

Table 1.9 Testing for Autocorrelations (VAR Model)

Multivariate Ljung-Box Portmanteau Test	
$Q(4)$	2.8735
$Q(8)$	6.5331
$Q(12)$	14.9104

***, **, * denote 1%, 5% and 10% significance level; standardized residuals are used in the tests

Table 1.10 Testing for Conditional Heteroskedasticity (VAR Model)

Multivariate Ljung-Box Portmanteau Test	
$Q^2(4)$	60.8971***
$Q^2(8)$	67.8183***
$Q^2(12)$	70.9907***

***, **, * denote 1%, 5% and 10% significance level; the squares of standardized residuals are used in the tests

Table 1.11. Estimation Results of the VAR-GARCH Model

Conditional Mean Equations

$$Y_t = \mu + \sum_{j=1}^{p} \Psi_j Y_{t-j} + \varepsilon_t$$

$$Y_t = \begin{bmatrix} \pi_t \\ i_{tax,t} \end{bmatrix} \qquad \mu = \begin{bmatrix} \mu_1 \\ \mu_2 \end{bmatrix} \qquad \Psi_j = \begin{bmatrix} \Psi_{11}^j & \Psi_{12}^j \\ \Psi_{21}^j & \Psi_{22}^j \end{bmatrix} \qquad \varepsilon_t = \begin{bmatrix} \varepsilon_{\pi,t} \\ \varepsilon_{i_{tax},t} \end{bmatrix}$$

$$\mu = \begin{bmatrix} \underset{(0.5505)}{1.1554} \\ \underset{(0.1358)}{0.2253} \end{bmatrix}$$

$$\Psi_1 = \begin{bmatrix} \underset{(0.0734)}{0.0501} & \underset{(0.3336)}{0.6032} \\ \underset{(0.0181)}{0.0034} & \underset{(0.0823)}{1.1830} \end{bmatrix} \quad \Psi_2 = \begin{bmatrix} \underset{(0.0703)}{0.1412} & \underset{(0.4265)}{-0.2420} \\ \underset{(0.0173)}{0.0214} & \underset{(0.1053)}{-0.3441} \end{bmatrix} \quad \Psi_3 = \begin{bmatrix} \underset{(0.0706)}{0.1174} & \underset{(0.4236)}{0.6621} \\ \underset{(0.0174)}{0.0017} & \underset{(0.1045)}{0.2719} \end{bmatrix}$$

$$\Psi_4 = \begin{bmatrix} \underset{(0.0707)}{0.3408} & \underset{(0.4443)}{-0.7756} \\ \underset{(0.0175)}{0.0039} & \underset{(0.1096)}{-0.1856} \end{bmatrix} \quad \Psi_5 = \begin{bmatrix} \underset{(0.0745)}{0.0717} & \underset{(0.4511)}{-0.1319} \\ \underset{(0.0184)}{-0.0012} & \underset{(0.1113)}{-0.0193} \end{bmatrix} \quad \Psi_6 = \begin{bmatrix} \underset{(0.0717)}{-0.0098} & \underset{(0.4477)}{0.0991} \\ \underset{(0.0177)}{-0.0056} & \underset{(0.1105)}{-0.0389} \end{bmatrix}$$

$$\Psi_7 = \begin{bmatrix} \underset{(0.0734)}{-0.0488} & \underset{(0.4274)}{0.8612} \\ \underset{(0.0181)}{0.0025} & \underset{(0.1055)}{0.0099} \end{bmatrix} \quad \Psi_8 = \begin{bmatrix} \underset{(0.0728)}{0.2282} & \underset{(0.4321)}{-1.7303} \\ \underset{(0.0180)}{0.0010} & \underset{(0.1066)}{0.1050} \end{bmatrix} \quad \Psi_9 = \begin{bmatrix} \underset{(0.0749)}{-0.2019} & \underset{(0.3395)}{0.6765} \\ \underset{(0.0185)}{0.0123} & \underset{(0.0838)}{-0.0807} \end{bmatrix}$$

Conditional Variance-Covariance Structure

$$H_t = C_0^{*'} C_0^{*} + A_{11}^{*'} \varepsilon_{t-1} \varepsilon_{t-1}^{'} A_{11}^{*} + B_{11}^{*'} H_{t-1} B_{11}^{*}$$

$$C_0^* = \begin{bmatrix} \underset{(0.0509)}{0.8075} & \underset{(0.0140)}{0.0040} \\ 0 & \underset{(0.0476)}{-0.0001} \end{bmatrix} \quad A_{11}^* = \begin{bmatrix} \underset{(0.0056)}{0.2540} & \underset{(0.2375)}{0.1127} \\ \underset{(0.0000)}{0.0326} & \underset{(0.0089)}{0.7564} \end{bmatrix} \quad B_{11}^* = \begin{bmatrix} \underset{(0.0040)}{0.9306} & \underset{(0.0350)}{0.0770} \\ \underset{(0.0001)}{-0.0063} & \underset{(0.0030)}{0.7142} \end{bmatrix}$$

Note: the standard errors for all estimates are reported in parentheses.

Table 1.12 Testing for Autocorrelations (VAR-GARCH Model)

Multivariate Ljung-Box Portmanteau Test	
$Q(4)$	6.9372
$Q(8)$	23.4915
$Q(12)$	31.6641

***, **, * denote 1%, 5% and 10% significance level; standardized residuals are used in the test

Table 1.13 Testing for Conditional Heteroskedasticity (VAR-GARCH Model)

Multivariate Ljung-Box Portmanteau Test	
$Q^2(4)$	12.0142
$Q^2(8)$	35.0386
$Q^2(12)$	46.4624

***, **, * denote 1%, 5% and 10% significance level; the square of standardized residuals are used in the test

Figure 1.1 Structural Breaks of Nominal Interest Rate and Inflation

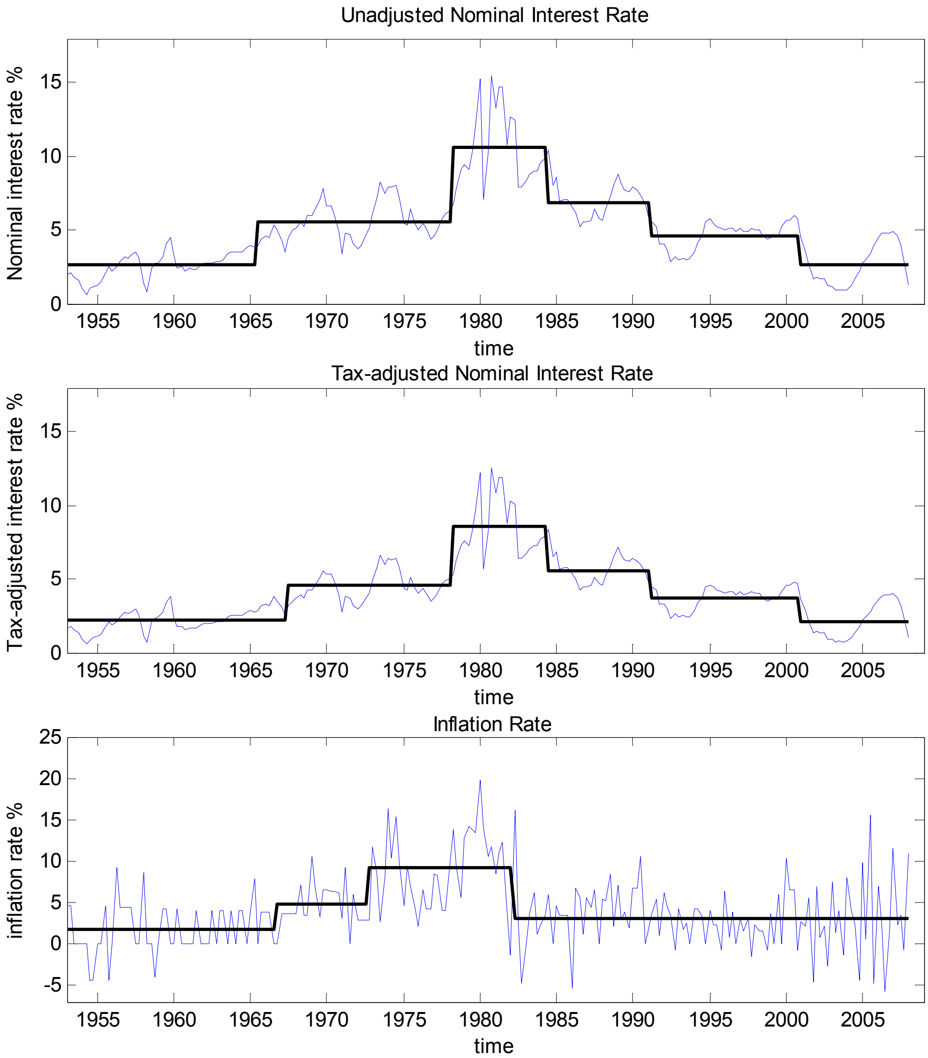


Figure 1.2 Structural Breaks of Nominal Interest Rate, Inflation and Tax-adjusted Real Rate

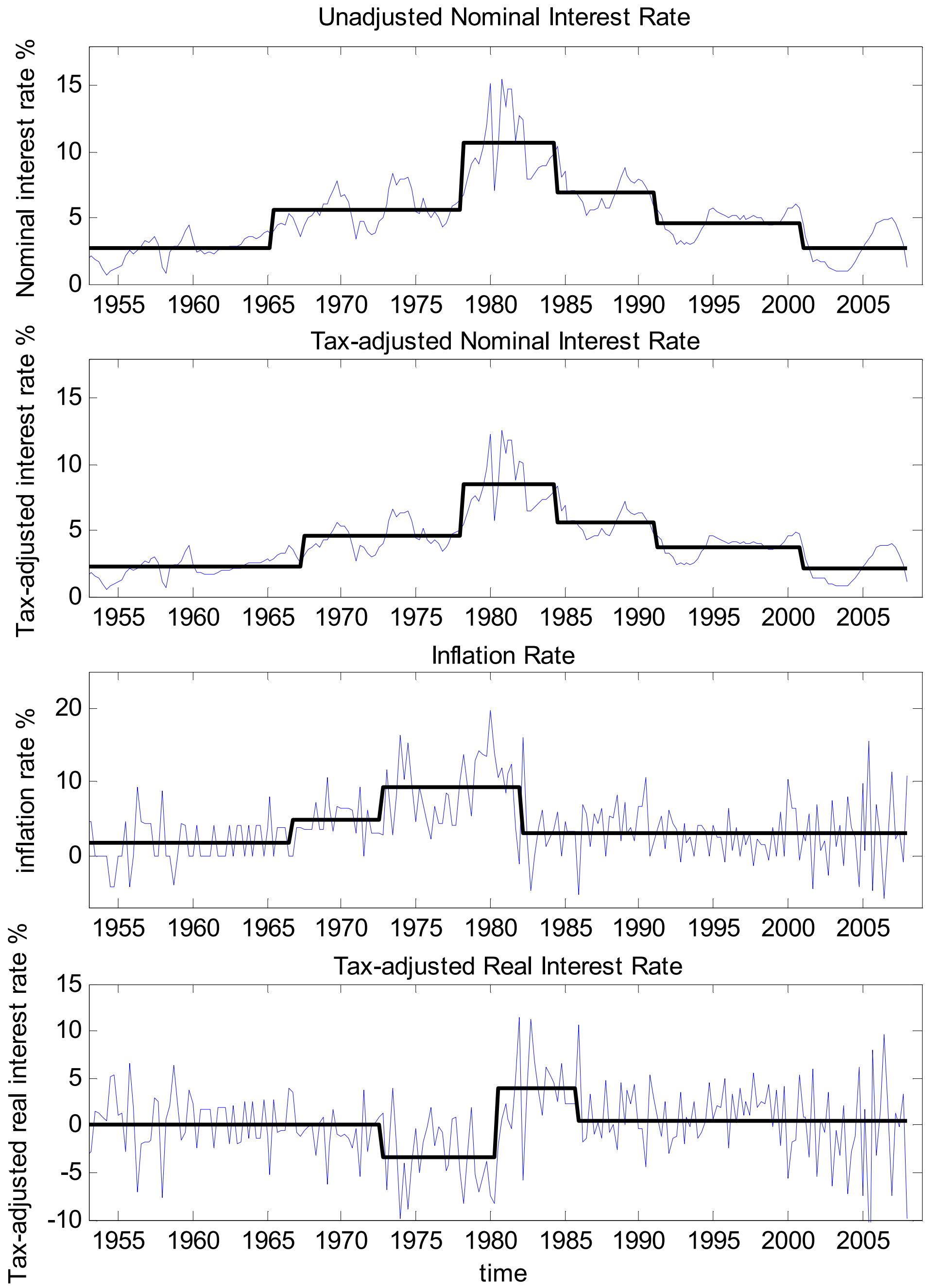


Figure 1.3 Conditional Variance-Covariance (Inflation & Interest Rate)

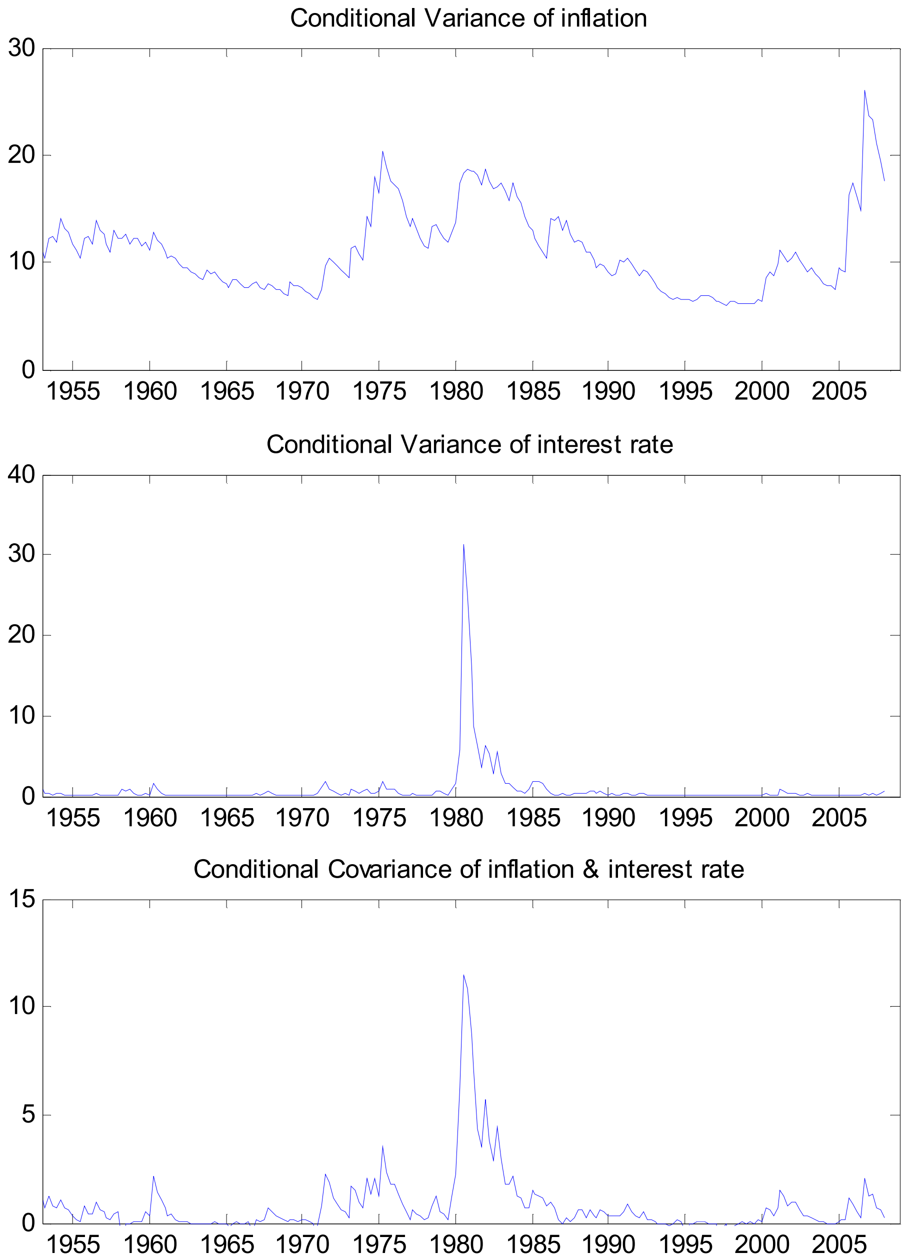
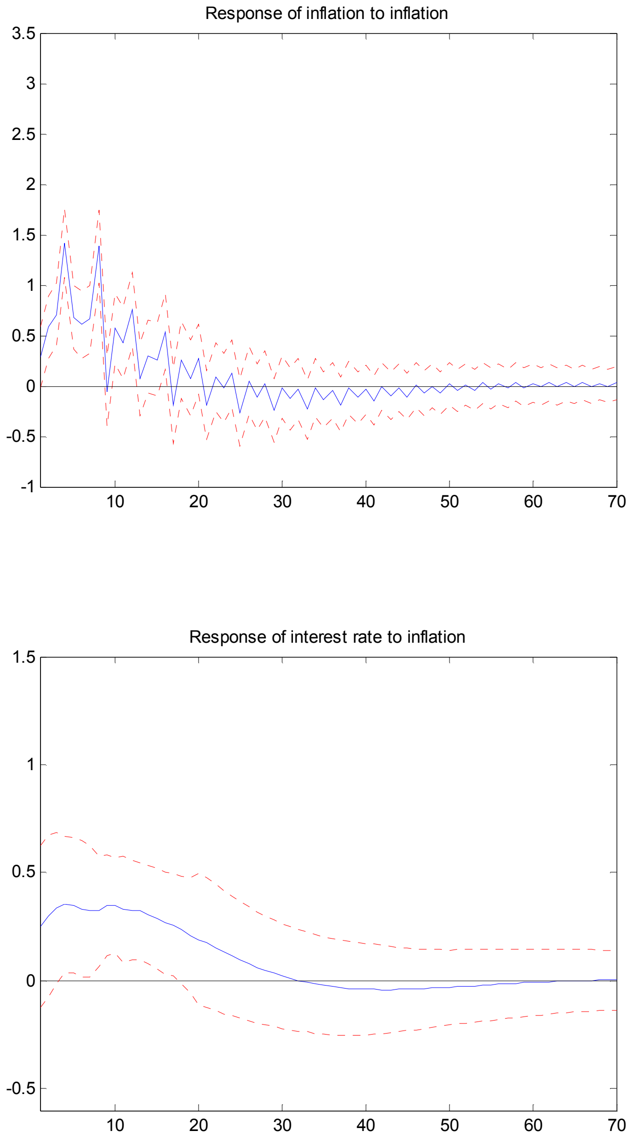


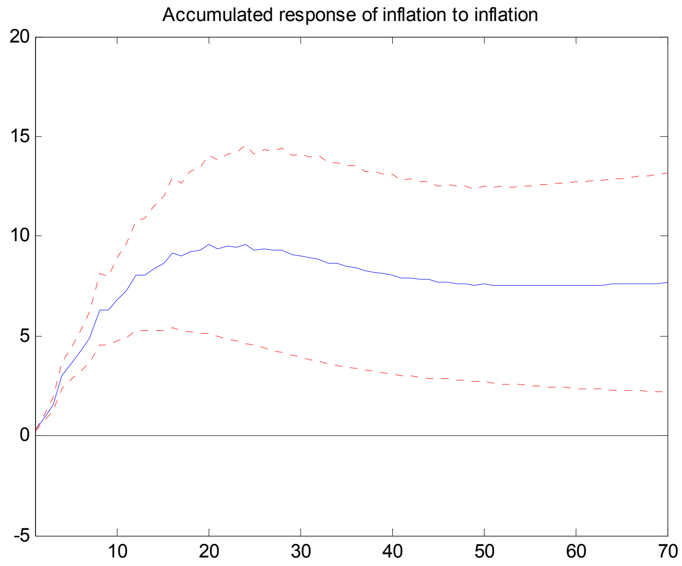
Figure 1.4 Impulse Responses (VAR-GARCH Model)

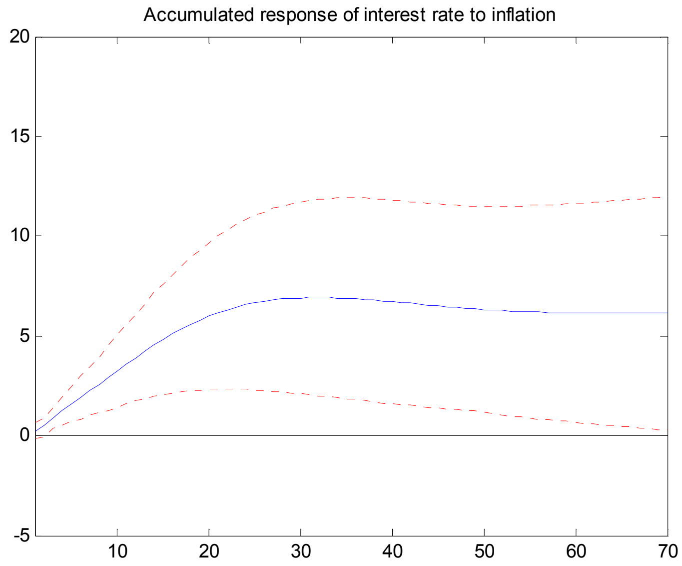


Note: The above shows the impulse response of inflation and tax-adjusted nominal interest rates when a unit inflation shock is applied.

The dotted lines represent the 95% confidence interval based on 1000 replications

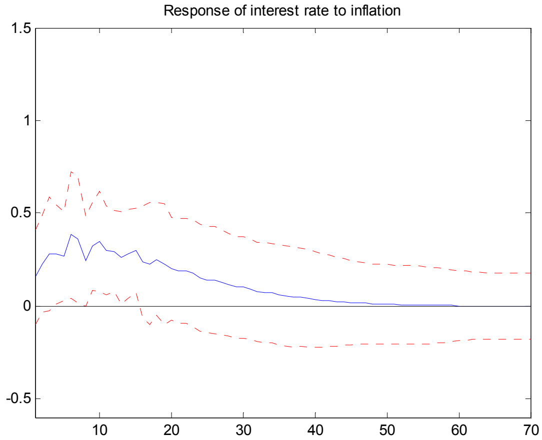
Figure 1.5 Cumulated Impulse Responses (VAR-GARCH Model)





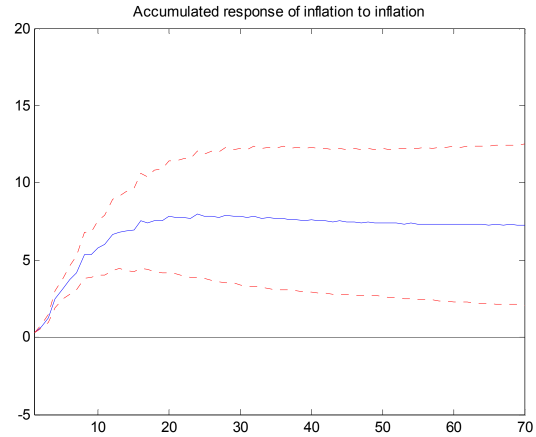
Note: The dotted lines represent the 95% confidence interval based on 1000 replications

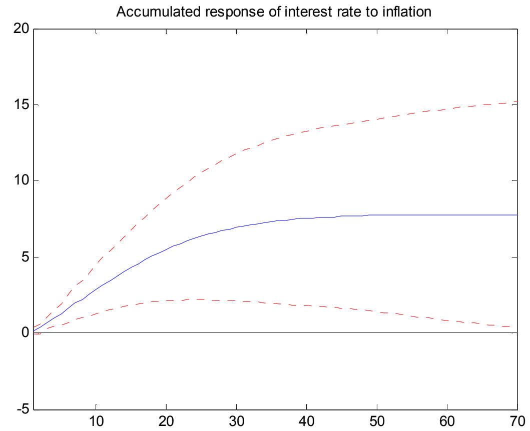
Figure 1.6 Impulse Responses (VAR Model)



Note: The dotted lines represent the 95% confidence interval based on 1000 replications

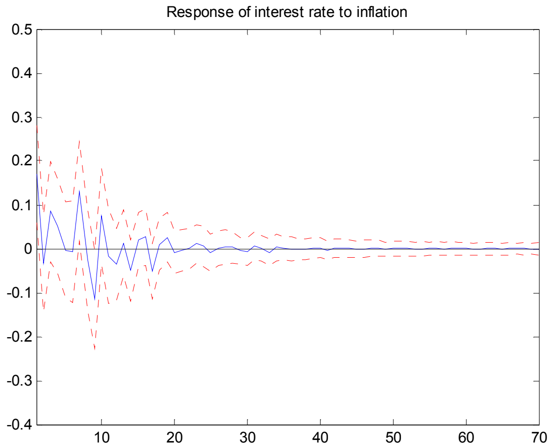
Figure 1.7 Cumulated Impulse Responses (VAR Model)





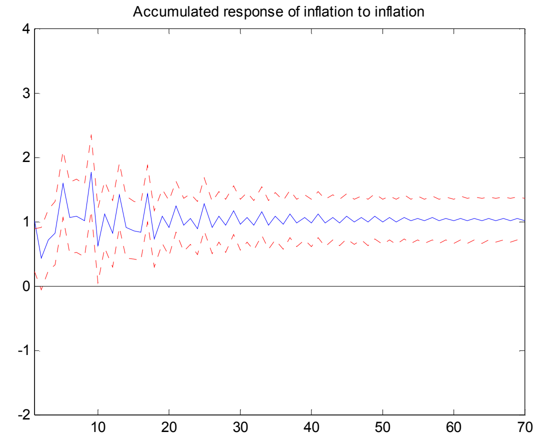
Note: The dotted lines represent the 95% confidence interval based on 1000 replications

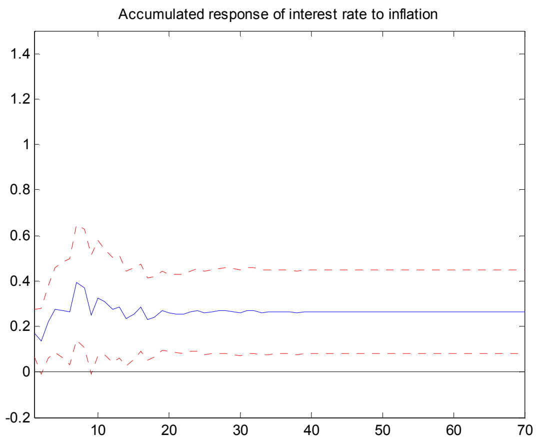
Figure 1.8 Impulse Responses (First-Differenced VAR Model)



Note: The dotted lines represent the 95% confidence interval based on 1000 replications

Figure 1.9 Cumulated Impulse Responses (First-Differenced VAR Model)





Note: The dotted lines represent the 95% confidence interval based on 1000 replications

Chapter 2

How well does the Balassa-Samuelson hypothesis fit in a sample of nine OECD countries?

2.1 Introduction

Balassa (1964) and Samuelson (1964) assert that an improvement of the productivity of one country over the other will lead to a higher relative non-tradable price and an appreciation of the real exchange rate. Given the importance of exchange rate dynamics in the field of open economy, the Balassa-Samuelson hypothesis (BSH) of productivity shocks on real exchange rates has been a much debated topic for the last few decades. Most empirical papers employ cointegration techniques to study the relationship among the economic variables and their findings are diverse. For instance, Strauss (1996), Canzoneri et al. (1999) and Alexius (2005) support BSH. Meanwhile, Rogoff (1992) fails to find evidence in favor of the BSH and the findings of Chinn (2000) are mixed. In these papers, the authors also investigate the impact of demand-side factors on real exchange rates in addition to the productivity effects. Another issue which arouses concern is the appropriateness of applying cointegration techniques. With the development of new empirical methods, a number of recent papers have rejected the unit root hypothesis of real exchange rates or of the related economic time series (Wu (1996), Strauss (1999) and Parikh and Wakerly (2000)).

In this paper, I examine the validity of the BSH for nine OECD countries using the US as the base country. Instead of using the cointegration method, I estimate the structural breaks for real exchange rates, relative non-tradable prices and productivity differentials. Consequently, the timing and direction of breaks for the time series will be monitored to see if they fit the BSH. If the BSH holds, an upward shift of productivity differentials (i.e. improvement of productivity relative to the US) should accompany an upward shift of relative non-tradable prices and an appreciation of real exchange rates. The findings are slightly in favor of the BSH since four of the nine countries fit the hypothesis relatively well and three partially fit the BSH. However, the remaining two countries violate the proposition. Similar results are obtained when government spending is considered in the break estimations.

In the second part of the paper, I use a VAR-GARCH model to investigate the dynamic relationship among the time series. The inclusion of the GARCH formulation is necessary due to the existence of volatility clustering. The findings support a strong link between productivity shocks and real exchange rates when the time series are either treated as I(0) or I(1). The response of relative non-tradable prices generally has the expected sign but is comparatively mild.

In response to the growing literature which suggest an alternative transmission channel for productivity shock (Betts and Kehoe 2006, Lee and Tang 2007), I replace the relative non-tradable price by the real exchange rate of tradable goods and compute the impulse responses when a unit productivity shock is applied. The results indicate that the effect of a productivity shock may also be transmitted via this alternative channel.

The subsequent sections in this paper will be organized as follows. Section 2 is a brief literature review. Section 3 describes the dataset and provides a preliminary check on the relationships of productivity differentials, relative non-tradable prices and real exchange rates. In section 4, I estimate the structural breaks and examine whether the direction and timing of breaks fit the BSH. Section 5 examines the dynamic relationships of the time series by using a VAR-GARCH model. In section 6, I check the robustness of the results by treating the time series as I(1) processes. Furthermore, I investigate the impact of productivity shocks on the real exchange rate of tradable goods and the real exchange rate. In the final section, I conclude the paper.

2.2 Literature Review

The Balassa-Samuelson Hypothesis (BSH) originates from Balassa (1964) and Samuelson (1964). The hypothesis predicts that an improvement in productivities of the home country to that of the foreign country will lead to an increase in relative non-tradable prices (in terms of the tradable prices) and an appreciation of the home country's real exchange rates. The argument is that productivity shocks, which fall mainly on the tradable sectors, will affect the price ratio of non-tradable goods to tradable goods. The changes in relative prices in turn will impact the real exchange rate. In their original framework, the authors regard productivity as the most important factor in explaining the changes in real exchange rates. They assume that factors are perfectly mobile across sectors and hence the demand-side forces will not affect the relative prices. Officer (1976) is one of the early papers which examine the effect of productivity shocks on real exchange rates. He conducts cross-sectional studies on a sample of fifteen countries for each year from 1950 to 1973. His findings indicate that there is no significant relationship between real exchange rates and productivity differentials. In another study, Hsieh (1982) examines the impact of productivity on real exchange rates for each of the eight OECD countries included. His approach allows for studying the validity of BSH individually for each country and the results generally agree with the hypothesis. With the growing use of time series methods, conventional unit root tests always suggest the non-stationarity of the related economic variables. As a result, the majority of later empirical works employ cointegration techniques. Rogoff (1992) uses the Engle and Granger (1987) cointegration method to investigate both government expenditures and productivity shocks as important determinants of real exchange rates. He collects quarterly data on Japan from 1975 to 1990 and taking the US as the base country. He fails to find significant relationships between productivity differentials and real exchange rates for Japan and the US. Furthermore, he finds that increases in government spending will lead to the depreciation of real exchange rates which is opposite to his prediction. Strauss (1996) applies the Johansen and Juselius (1990) method and finds support for the BSH. Using annual data of six OECD countries from 1960 to 1990 and taking Germany as the benchmark, he shows that domestic and foreign productivity differentials do explain the changes in real exchange rates in a way as predicted by the BSH. Canzoneri et al. (1999) examines two important components of the BSH by applying panel cointegration to a sample of 13 OECD countries. First, they test whether the variation of relative non-tradable prices reflect changes in relative labor productivities. Second, they investigate the validity of assuming the purchasing power parity (PPP) to hold for tradable goods. Their results support the effect of relative labor productivities on real exchange rates. However, whether the PPP for tradable goods holds or not depends on the choice of the numeraire currency. Chinn (2000) focuses on nine countries in the Asia-Pacific region and has mixed findings. The author assembles sectoral data for his sample of countries from 1970 to 1992. Using an error correction model, he examines the link between real exchange rates and relative prices, and between real exchange rates and productivity differentials.

The results indicate that relative prices have impact on real exchange rates only for Indonesia, Japan and Korea. Meanwhile, only Japan, Malaysia and Philippines report a significant effect of productivity on real exchange rates. In addition, government spending does not appear to have impact on real exchange rates in his paper. In a more recent paper, Alexius (2005) examines the effect of productivity shocks, monetary shocks, and government expenditures on real exchange rates. The author includes four countries in his dataset and investigates each of the bilateral relationships by the cointegration method. His findings show that productivity shocks are the most important factor determining the real exchange rates. Galstyan and Lane (2009) investigates the effect of productivity differentials, government consumption and government investment on real exchange rates for the European Union, the US and Japan. The authors apply the Dynamic Ordinary Least Square method and find that increases in productivity differentials and government consumption lead to the appreciation of real exchange rates. However, the effect of government investment can be either positive or negative.

The appropriateness of using a cointegration approach depends on whether the underlying time series are integrated of the same order. Considering some of the recent literature, there is doubt about the use of cointegration methods. Wu (1996) admits the low power of conventional unit root tests, he employs a panel unit root test based on Levin and Lin (1992) for his sample of 18 OECD countries. The results support the stationarity of real exchange rates. In another study, Parikh and Wakerly (2000) find similar results in their panel unit root test. In examining the validity of the BSH, Strauss (1999) conducts panel unit root tests on relative non-tradable prices, productivity differentials, share of government spending on GDP, and real exchange rates. The results reveal that all these variables follow a stationary process. The author suggests that the impact of productivity differentials and government spending reflects their persistent effect on relative non-tradable prices and real exchange rates. In response to these recent findings, Bahmani-Oskooee and Nasir (2004) employ the Autoregressive Distributed Lag (ARDL) approach for forty-four countries using annual data from 1960 to 1990. Taking the US as the base country, they studied the relationship between productivity differentials for each of the countries. Their findings support the BSH in thirty-two countries out of the total forty-four.

Some recent papers, for instance, Betts and Kehoe (2006) and Lee and Tang (2007)[13], have identified deviation in tradable prices as an alternative transmission channel for the effect of productivity shocks on real exchange rates. In the former paper, the authors investigate the bilateral exchange rate for the five major trading partners of the US with the US dollar as the numeraire. To assess the relationship

[13] In both papers, the authors show that the real exchange rate (RER) is the sum of the real exchange rate of tradable goods (RER_t)and the relative non-tradable price (RP):

$$RER = RER_t + RP$$

Hence, both RER_t and RP can affect the real exchange rate.

between real exchange rates and relative non-tradable prices, they compute three different statistics. These include the sample correlation between real exchange rates and relative non-tradable prices, ratio of sample standard deviation between real exchange rates and relative non-tradable prices, and the variance decomposition in which the proportion of fluctuations for real exchange rates are due to relative prices. They find that tradable prices, instead of non-tradable prices, explain a large fraction of real exchange rate fluctuations. Lee and Tang (2007) use panel cointegration techniques to examine the effect of productivity differentials on real exchange rates. The results support that productivity shocks have an impact on real exchange rates in line with the BSH. However, the transmission is via the tradable-based exchange rates rather than the non-tradable counterpart.

2.2.1 The Approach of this Paper

In this paper, I use an approach that departs from conventional methods in investigating the validity of the BSH. The methodology here is based on Grier and Ye (2008). In the first part of the paper, I estimate the structural breaks for real exchange rates, productivity differentials and relative non-tradable prices for each of the nine OECD countries taking the US as the base country. The timing and direction of breaks will then be evaluated in detail. In the next section, I examine the dynamic relationship of the time series. Since some of the recent literature doubts the non-stationarity of the related variables, the appropriateness of applying cointegration methods is being questioned. Here I formulate a VAR model by using the raw data. In that, I investigate if productivity shocks have a persistent effect on relative prices and real exchange rates. Since conditional heteroskasticity is found to exist, I include GARCH effects in the model as well. To complete the analysis, I implement alternative approaches and compare the results to see if new insights are obtained.

2.3 The Dataset

The dataset consists of nine OECD countries - Australia, Canada, Germany, Japan, South Korea, Mexico, New Zealand, Switzerland and the United Kingdom. In all relative measures, the United States will be taken as the base country. The data comes from the International Financial Statistics and is quarterly. Due to the availability of data, the time period used varies with the countries. The time span ranges from 1957Q1 to 2007Q4 (Canada and the UK) to 1987Q2 to 2007Q4 (New Zealand)[14].

Productivity is measured by the logarithm of the real GDP per capita. Hence, the productivity differential is the difference between the productivity of the home country to that of the US. The non-tradable prices, as measured by the tradables, are

[14] The time period of data for all countries end at 07Q4 but with different starting points: Australia (59Q3), Canada (57Q1), Germany (60Q1), Japan (60Q1), Korea (70Q1), Mexico (85Q1), New Zealand (87Q2), Switzerland (70Q1) and the UK (57Q1).

the logarithm differences between the consumer price index (CPI) and the producer price index (PPI). Since there are more non-tradables in the CPI than the PPI, an increase in this measure is consistent with a rise in the non-tradable prices. The relative non-tradable prices will then be the difference between the non-tradable prices of the home country and the US's. Finally, the CPI based logarithm real exchange rates are used in this paper[15].

Before turning to my empirical approach, it will be interesting to have some preliminary idea about the relationship among the productivity differentials, relative prices, and real exchange rates for these countries. Table 1 reports the correlation coefficients between each pair of variables. $R(\alpha,\rho)$, $R(\alpha,q)$ and $R(\rho,q)$ denote the correlations between productivity differentials and relative prices, productivity differentials and real exchange rates, and relative prices and real exchange rates. The BSH postulates a positive value for $R(\alpha,\rho)$ while it should be negative for $R(\alpha,q)$ and $R(\rho,q)$. The results show that five of the countries are consistent with the hypothesis - Australia, Canada, Japan, New Zealand, and Switzerland. For the other countries, they deviate from the BSH in at least one of the correlation coefficients. For instance, the productivity differentials of Germany are negatively correlated with the real exchange rate as predicted by the hypothesis. However,

[15] Similar measurements for productivity differentials, relative prices and real exchange rates are used in the literature. See Balassa (1964), Engel (1999), De Loach (2001) and Alexius (2005).

there is a negative relationship between productivity differentials and relative prices and a positive relationship between prices and real exchange rates.

2.4 Empirical Setup of the Structural Break Estimation

In estimating the structural breaks of productivity differentials, relative prices and real exchange rates, I apply the Bai and Perron (1998, 2003) (Hereafter BP) methodology. In this case, the structural break of the time series are estimated by using a pure mean-shifting setup as specified below:

$$y_{i,t} = z_t \gamma_i^j + u_{i,t} \qquad (1)$$

where $y_{i,t}$ is the productivity differentials, relative prices or real exchange rates[16] for country i while z_t is a constant equal to one. γ_i^j is the estimated mean for country i and the value of this mean varies with the regime j. If the BSH is valid, we will expect these data series to exhibit close matching of breaks in the specified directions. For instance, an upward shift in the productivity differentials (representing the productivity improvement of the home country relative to that of the US) should be accompanied with an upward shift in the relative prices and a downward shift in the real exchange rate (appreciation). Table 2 reports the estimated breaks for the productivity differentials, relative prices and real exchange

[16] In the case of Germany, the Deutsche Mark was replaced by the Euro in 1999. In order to account for the change in unit of measurement, I regress the real exchange rate against a time dummy of its adopting the Euro. The residuals are then taken as the real exchange rate of Germany after controlling for the difference in scale of measurement during the two periods. This adjusted real exchange rate will be used in subsequent estimations.

rates for each of the countries. For ease of comparison, Figure 1 shows graphically how well the breaks are being matched.

2.4.1 Matching of Breaks

In comparing the breaks for the time series, I will search for breaks in productivity differentials and then check if there are corresponding shifts, which are close in the timing and with the expected break direction, in both relative prices and real exchange rates. This is consistent with the BSH which regards productivity differentials as the source of variations in relative prices and real exchange rates. The results show that once the breaks of productivity differentials are identified, only four countries do have matching shifts with the predicted directions in both relative non-tradable prices and real exchange rates. For the other countries, there are either missing links between the time series or movements in real exchange rates and relative prices violating the BSH.

Countries with Breaks Consistent with the BSH

Australia, Canada, Japan, and Switzerland are the countries which show evidence of matching breaks in real exchange rates and relative prices for shifts in productivity differentials. For Australia and Canada, their productivities deteriorate relative to that of the US at similar point of time in 83Q1 (Australia) and 82Q1 (Canada). In the case of Australia, there is a downward shift in the relative price and an upward shift in the real exchange rate at 85Q1 and 82Q4. All these shifts are in the predicted directions and have a break time close to that found in the productivity differentials[17]. For Canada, the relative price shifts in 79Q3 and is followed by another one in 93Q4. The direction of movement for these two breaks is in line with the BSH that a fall in productivity differentials will lead to lower relative prices. Though the real exchange rate of Canadian dollar does not shift until 93Q4, this upward movement is still consistent with the BSH.

Turning to the findings for Japan, there are three breaks in each of the time series. The breaks for productivity differentials are in 69Q3, 77Q3 and 86Q2. For relative prices and real exchange rates, the breaks are found in 66Q4, 74Q2, 93Q1 and 72Q4, 85Q4, 00Q4 respectively. Although the break time does not tie closely, all breaks have directions consistent with the BSH. For Switzerland, the findings support the BSH as the shifts in productivity differentials (77Q2) have matching breaks in relative prices (75Q2) and downward movements in real exchange rates (75Q2, 86Q1)[18].

Countries with Mixed Findings

The findings for Germany, Korea and New Zealand are mixed. The productivity differentials of Germany surges in 73Q1 which fit fell with the increase

[17] There is another break in productivity differentials for Australia at 97Q3. Nevertheless, the relative prices and real exchange rate do not have corresponding major shifts around this time.
[18] It is interesting to find that some of these breaks coincided with the time when these countries adopt a floating exchange rate regime, for instance, Australia (83), Canada (70) and Japan (71). As long as shifts in productivity differentials are accompanied with breaks in relative prices and real exchange rates, I take this as evidence supporting the BSH.

in relative prices (72Q4) and the appreciation of real exchange rates (71Q4). However, the relative prices then exhibit two subsequent downward breaks in 84Q3 and (1Q4 despite the fact that productivity continue to surge in 86Q4. The real exchange rate does not show any breaks during this time even though there is a rise in productivity and a fall in prices. In the case of New Zealand, the breaks in productivity differentials (97Q4, 03Q3) match very well with those of real exchange rates (97Q3, 03Q1) and in the predicted directions. Nevertheless, the relative prices do not respond to productivity surge after a matching break in 98Q1. For Korea, there are matching breaks between productivity differentials and relative prices. However, no breaks for the real exchange rate of the KoreanWon can be detected[19].

Countries Violating the BSH

The findings for Mexico and the United Kingdom deviate from the proposition. In both countries, shifts in productivity differentials are associated with movements in real exchange rates or relative prices at odd with the BSH. For instance, the real exchange rate of peso appreciates even though the productivity differentials of Mexico are worsening. Similar peculiar movements are found in the United Kingdom. While the productivity differentials of the United Kingdom plummet in 67Q3 and 75Q2, its real exchange rates shift downward in 77Q3. On the other hand,

[19] By visual inspection, there was a sharp decline of productivity differentials during the Asian financial crisis in 97 and this was accompanied with an abrupt depreciation of Won. This evidence supports the BSH though it is not detected in the break estimation due to its transitory nature.

its relative prices rise in 73Q1 and fall in 84Q2. Hence, the general results found in Mexico[20] and the United Kingdom are not in line with the BSH.

2.4.2 The Government Expenditure

In the original idea of the BSH, factors of production are assumed to be perfectly mobile. As a result, demand-side factors, such as government spending, do not have an impact on the real exchange rate. Papers such as Rogoff (1992), Strauss (1999), Chinn (2000), Alexius (2005) and Galstyan and Lane (2009) generalize the BSH by including the government spending to GDP ratio as a factor affecting the real exchange rate. If government consumption falls mainly on non-tradable goods, the relative non-tradable prices rise and real exchange rates will appreciate in response to an increase in government spending.

Since government activities may affect the relative prices and real exchange rates, the shifts in these time series may be due to changes in government expenditure instead of productivity differentials. I estimate the structural breaks of relative prices and real exchange rates again by including the government expenditure as an explanatory variable. The government expenditure is expressed as the proportion to total GDP. The findings here serve as a robustness check on the previous results when government spending is considered.

[20] The only exception is the undetected spike of peso which matches well with the fall in productivity differentials in 94Q3. This period of time corresponds to the Mexican peso crisis. For the rest of time, the movement of peso and productivity violate the predictions from the BSH. Furthermore, the relative prices remain quite stable over the entire period.

2.4.3 Structural Breaks of the Relative Prices and Real Exchange Rates Controlling for the Government Expenditure

Table 3 summarizes the results of estimated breaks after controlling for changes in government spending. The overall results only change slightly when government spending is considered. This implies that government spending may not have a major impact on the shifts of relative prices and real exchange rates. It is also interesting to find that when a country has a positive coefficient of government spending on relative prices, it will have a negative impact on the real exchange rate. It means that if government spending increases the relative price of non-tradable goods, it will lead to an appreciation of real exchange rates and vice versa. The only exception is Mexico though the effect of government spending on relative prices is statistically insignificant.

Figure 2 depicts the estimated breaks of relative prices and real exchange rates, after controlling for the government spending, along with the shifts of productivity differentials. Countries which follow closely to the BSH include Canada, Japan, New Zealand, and Switzerland. In the case of New Zealand and Switzerland, the inclusion of government spending improves their fit with the hypothesis. For Korea, shifts in productivity differentials match well with the relative non-tradable prices. However, its real exchange rates depreciate when both relative prices and productivity differentials shift upward. Similar to the previous section, the findings for Mexico and the United Kingdom disagree with the BSH. Thus, the same conclusion can be drawn for these countries. Finally, the inclusion of government spending weakens the evidence of BSH for Australia and Germany. Even though the fall in productivity in Australia during 83Q1 matches well with the drop in relative prices in 84Q2, there is no major change in the real exchange rate around this period. For Germany, the real exchange rate depreciates in 98Q4. However, there is no corresponding shift in the productivity differentials at this time. Again, the relative non-tradable prices fall with improving productivities. This violates the proposition of the BSH.

2.5 The Dynamic Effects of Productivity Differentials, Relative Prices and Real Exchange Rates

The structural break analyses provide useful insight on the co-movements of productivity differentials, relative prices, and real exchange rates. In view of the long run relationship among the time series, it is likely that they affect each other over time. Furthermore, there maybe feedback effects among these economic variables. In this section, I consider a VAR model to capture this dynamic relationship. There are advantages of using this model formulation. First, the model examines the inter-relationship of all the variables in a single framework. Second, the impact of shocks in productivity differentials can be determined in the subsequent impulse response analysis. Finally, it serves as a robustness check for the validity of the BSH.

Many of the previous papers have treated real exchange rates, productivity differentials, and relative prices as non-stationary. Consequently, they apply the cointegration technique or the first-differenced VAR model to investigate the relationship of the time series. In light of the low power of the traditional unit root tests, the appropriateness of treating these time series as non-stationary becomes vague. Recent empirical studies have employed the more powerful panel unit root tests to re-examine the stationarity of real exchange rates. Wu (1995), Strauss (1999), and Parikh and Wakerly (2000) all reject the null that real exchange rates are unit root processes. Furthermore, Strauss (1999) also finds evidence supporting the stationarity of productivity differentials, relative non-tradable prices, and government expenditure measured as a percentage of the GDP in his sample of countries. Table 4 shows that different unit root tests may produce different results for the time series due to the low power of these tests. Table 5 reports the results when a Fisher type panel unit root test base on Maddala and Wu (1999) is implemented. It indicates that the null of unit root processes are rejected for the variables considered. Here I construct a VAR model in levels. In this framework, I examine whether changes in productivity differentials to have persistent effects on relative prices and the real exchange rate.

2.5.1 The Empirical Model

In order to examine the relationship for productivity differentials, relative prices and real exchange rates, the VAR model is specified as follows:

$$X_t = c + \sum_{i=1}^{p} \beta_i X_{t-i} + \varepsilon_t \qquad (2)$$

where $X_t = \begin{bmatrix} \alpha_t \\ \rho_t \\ q_t \end{bmatrix}$; $c = \begin{bmatrix} c_1 \\ c_2 \\ c_3 \end{bmatrix}$; $\beta_i = \begin{bmatrix} \beta_{11}^i & \beta_{12}^i & \beta_{13}^i \\ \beta_{21}^i & \beta_{22}^i & \beta_{23}^i \\ \beta_{31}^i & \beta_{32}^i & \beta_{33}^i \end{bmatrix}$; $\varepsilon_t = \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3t} \end{bmatrix}$

X_t is a column vector of the productivity differentials (α), relative non-tradable prices (ρ) and real exchange rates (q). The number of lags, p, chosen for each country is based on the sequential modified LR test and the Schwarz information criterion (SIC) and it ranges from 1 to 8 lags. After estimating the above VAR model for each country, I check for the existence of conditional heteroskedasticity by implementing the multivariate Ljung-Box portmanteau test. The results in Table 6 indicate that conditional heteroskedasticity exists for all the countries in the sample except Mexico. In response, I include GARCH effects and estimate a VAR-GARCH model for these countries besides Mexico.

2.5.2 The VAR-GARCH Setup

To control for the time-varying conditional variance problem, I employ a

VAR-GARCH(1,1) model. In consideration of the computational efficiency and the number of parameters involved, I use the Constant Correlation Coefficient (CCC) model of Bollerslev (1990) for the conditional variance-covariance structure. Hence, the complete empirical setup is as below:

$$\alpha_t = c_1 + \sum_{i=1}^{p} \beta_{11,i}\alpha_{t-i} + \sum_{i=1}^{p} \beta_{12,i}\rho_{t-i} + \sum_{i=1}^{p} \beta_{13,i}q_{t-i} + \varepsilon_{1t} \tag{3.1}$$

$$\rho_t = c_2 + \sum_{i=1}^{p} \beta_{21,i}\alpha_{t-i} + \sum_{i=1}^{p} \beta_{22,i}\rho_{t-i} + \sum_{i=1}^{p} \beta_{23,i}q_{t-i} + \varepsilon_{2t} \tag{3.2}$$

$$q_t = c_3 + \sum_{i=1}^{p} \beta_{31,i}\alpha_{t-i} + \sum_{i=1}^{p} \beta_{32,i}\rho_{t-i} + \sum_{i=1}^{p} \beta_{33,i}q_{t-i} + \varepsilon_{3t} \tag{3.3}$$

$$h_{1t} = \theta_1 + a_1\varepsilon_{1t-1}^2 + b_1 h_{1t-1} \tag{3.4}$$

$$h_{2t} = \theta_2 + a_2\varepsilon_{2t-1}^2 + b_2 h_{2t-1} \tag{3.5}$$

$$h_{3t} = \theta_3 + a_3\varepsilon_{3t-1}^2 + b_3 h_{3t-1} \tag{3.6}$$

$$h_{12t} = \omega_{12}\sqrt{h_{1t}}\sqrt{h_{2t}} \tag{3.7}$$

$$h_{13t} = \omega_{13}\sqrt{h_{1t}}\sqrt{h_{3t}} \tag{3.8}$$

$$h_{23t} = \omega_{23}\sqrt{h_{2t}}\sqrt{h_{3t}} \tag{3.9}$$

Equations (3.1) to (3.3) are the mean equations for productivity differentials, relative prices and real exchange rates. As mentioned before, p is the number of lags used and it varies with the country under examination. h_{it} and h_{ijt}, where $i, j = 1,2,3$ and $i \neq j$, denote the conditional variance and covariance. Equations (3.4) to (3.6) are the conditional variance of productivity differentials, relative prices and real exchange rates. Finally, equations (3.7) to (3.9) are the corresponding conditional covariance with ω_{ij} denotes the respective correlation coefficient.

Table 7 shows the estimation results for the nine OECD countries. The estimated coefficients in the conditional variance-covariance structure are mostly statistically significant. With the exceptions of Australia, the conditional correlation coefficients follow the same pattern. The conditional correlations between productivity differentials and relative prices are all positive. On the other hand, the conditional correlation coefficients between productivity differentials and real exchange rates, and between relative prices and real exchange rates are found to be negative. Table 8 reports the multivariate Ljung-Box test for the standardized residuals obtained from the VAR-GARCH model. It indicates that conditional heteroskedasticity no longer exists.

2.5.3 Impulse Response Analyses

The BSH predicts that a positive shock in productivity differentials will lead to an increase in relative prices and an appreciation of real exchange rates. Employing the Choleski decomposition, I construct the impulse responses in an order that when a unit productivity shock is applied, the relative prices and real exchange rates are affected subsequently. Panel A to I of Figure 3 graphically depict the results. In each panel, the graphs on the left are the computed impulse responses for productivity differentials, relative prices, and real exchange rates to an innovation in productivity differentials. Meanwhile, the corresponding cumulated impulse responses are put on the right hand side. The dotted lines are the bootstrapped 95% confidence intervals.

Generally speaking, the directions of responses for relative prices and real exchange rates are consistent with the predictions from the BSH. In all cases, the relative price rises and the real exchange rate appreciate in response to a positive shock in productivity differentials[21]. Even though some of these responses may be small and statistically insignificant, the findings still indicate different degree of support to the BSH for the countries. I divide the countries into three different groups according to their closeness to the BSH.

Countries which follow closely to the BSH

The countries included in this group are Canada and New Zealand. The impulse responses for these two countries match well with the BSH. When a unit positive productivity shock is applied, their relative prices surge and remain statistically significant for an extended period. Similarly, the real exchange rate appreciates significantly over a long time horizon. For Canada, the cumulated responses of relative prices increase and remain statistically significant in the positive region over the entire period. Meanwhile, the real exchange rate of Canadian dollar appreciates in response to the productivity shock and the effect is significant for the

[21] However, the findings also show that the response of relative non-tradable price for Germany turns negative and is statistically significant in the very long run.

first 56 quarters. In the case of New Zealand, similar results can be found. The positive effect on relative prices last for 42 quarters while the appreciating effect on real exchange rates become statistically insignificant only after the 24th quarter. Even though the impact of productivity shock on both relative prices and real exchange rates are less persistent compared with those of Canada, the results are still in favor of the BSH.

Countries showing significant link between productivity differentials and real exchange rates

Most of the countries in the sample belong to this group. Here productivity shocks lead to increases in relative prices and appreciation of real exchange rates. While the impact of productivity on real exchange rates is statistically significant, the response of relative prices is comparatively small. Countries classified in this group include Australia, Germany, Japan, Switzerland, and the UK.

For all countries in this group, the real exchange rates appreciate in response to positive productivity shocks. The cumulated responses of real exchange rates remain statistically significant for a time horizon ranges from 22 quarters (Australia) to 36 quarters (Japan). These findings support a positive link between productivity differentials and real exchange rates. However, the responses of relative prices to productivity shocks are minimal in all cases. The cumulated responses of relative prices are either insignificant for the entire period (Australia, Japan, Switzerland) or are only statistically significant for a few quarters (Germany, the United Kingdom). The findings here cast doubt on the validity of relative price as the transmission channel of productivity effect and it will be discussed in later section of this paper.

Countries showing significant link between productivity differentials and relative prices

The countries placed in this group are Korea and Mexico. Given a positive shock to productivity differentials, relative prices surge and remain statistically significant for a while. In sharp contrast, the responses of their real exchange rates are minimal and mostly insignificant. The countries classified in this group include Korea and Mexico. Given a positive shock to productivity differentials, the cumulated responses of relative prices for Korea keep on rising and are significant over the 80 quarters. Nevertheless, the responses of real exchange rates are small and transitory. The effect is significant only for the first three quarters. For Mexico, its real exchange rates show restricted response to productivity shocks. In contrast to Korea, the relative prices of Mexico respond over a short time to productivity shock and its cumulated responses are statistically significant only for 9 quarters.

In summary, the results of innovation analyses indicate that both Canada and New Zealand provide strong evidence to the validity of the BSH. While the findings for Australia, Japan, Germany, Switzerland, and the United Kingdom are in favor of the BSH, the results of Korea and Mexico are not as strong as the other countries'.

2.6 Results Comparison by Using Alternative Setups

The results obtained in the previous section are based on treating the real exchange rates, productivity differentials, and relative prices as stationary. In order to check the robustness of the results if the time series are I(1) processes, I implement a panel cointegration test of Westerlund (2007) among the real exchange rates, productivity differentials and relative prices. There are two sets of test statistics, P_τ, P_α and G_τ, G_α. The former two are panel statistics and the latter two are group mean statistics. The panel statistics are used to test the null of no cointegration against the alternative of cointegration for the panel as a whole. On the other hand, the group mean statistics test the same null but the alternative is that at least one country shows evidence of cointegration. The three columns in Table 9 report the test results for the presence of cointegration between real exchange rates and productivity differentials, relative prices and productivity differentials, and real exchange rates and relative prices respectively. With the exception of the panel statistics for real exchange rates and relative prices, the results generally do not support the existence of any cointegration relationships. In this regard, I construct a first-differenced VAR model and see how the results will be affected.

Figure 4 Panel A through I show the impulse response and cumulated response of productivity differentials, relative prices and real exchange rates when a positive shock in productivity is applied for the sample of countries. In the first-differenced VAR model, the computed impulse responses are short-lived. Turning to the cumulated impulse responses, the findings reveal that both real exchange rates and relative prices move in the predicted directions. Again, the results for Canada and New Zealand follow closely to the BSH. As in the previous section, the findings support a strong relationship between productivity and real exchange rates for Australia, Germany, Japan, Switzerland and the UK. In the case of Japan, the cumulated response of relative prices is positive and significant for the first 16 quarters upon a unit productive shock. Finally, the evidence of the BSH is less obvious for Korea and Mexico. The overall results imply that the BSH seems to hold even if the time series are considered as I(1) processes.

2.6.1 Productivity Differentials and Real Exchange Rates of Tradable Goods

The BSH postulates that changes in productivity differentials will affect real exchange rates through its impact on the relative non-tradable prices. This is because if the purchasing power parity condition (PPP) for tradable goods always holds, the effect of productivity on real exchange rates will fall mainly on the relative prices of non-tradable goods. In the previous section, the findings support a strong link between productivity shocks and real exchange rates. Nevertheless, the responses of relative non-tradable prices are small in many of the countries covered. Some recent papers suggest an alternative transmission channel through which the changes in productivity impact on the real exchange rate. For instance, Betts and Kehoe (2004) and Lee and Tang (2007)[22] both find evidence for the deviations of the real exchange rate of tradable goods in explaining the changes in real exchange rates. Here I examine the relationship among productivity differentials, real exchange rate of tradable goods, and real exchange rates by using a similar VAR model in levels as in the previous section. In this case, I replaced the relative non-tradable price by the real exchange rate of tradable goods[23]. Figure 5 Panel A through I show the impulse responses graphically for the countries considered.

The findings support the notion that changes in productivity differentials lead to deviations of real exchange rate in tradable goods and the real exchange rate. In all countries in the sample, the real exchange rate of the tradable goods appreciates in response to productivity surges though the effect is relatively mild for Korea and Mexico[24]. Combining the results here with those from the previous sections, the

[22] See footnote 1.

[23] The real exchange rate of tradable goods is represented by $e_t + p_t^{US} - p_t^H$ where all measures are in logarithmic form. e_t is the nominal exchange rate with the US as the base country while p_t^{US} *and* p_t^H are the PPI for the US and the home country respectively

[24] The same conclusion can be drawn when I include both relative non-tradable prices and real exchange rate of tradable goods in the VAR model.

evidence is generally in favor of the BSH, however, the real exchange rate of tradable goods can be an important transmission channel for the effect of productivity change.

2.7 Conclusion

Given the importance of exchange rate dynamics in the field of international macroeconomics, the BSH remains a much debated topic. Most empirical studies use cointegration methods in assessing the validity of the BSH. Meanwhile, some of these papers extend the idea of the BSH and incorporate demand-sided factors in determining the real exchange rate. Nevertheless, the findings of these papers are diverse. Furthermore, there is doubt about the appropriateness of treating the involved time series as non-stationary due to the low power of conventional unit root tests. Some recent empirical papers employ the more powerful panel unit root tests and deny the earlier claim of non-stationarity for the economic variables. In view of these findings, the use of cointegration approach may not be valid.

In this paper, I use a different approach to examine the validity of the BSH. In the first part of the paper, the structural breaks of productivity differentials, relative prices and real exchange rates are estimated for each of nine OECD countries. In all relative measures, the US is taken as the base country. The results show that the breaks for Australia, Canada, Japan, and Switzerland fit well with the hypothesis. On the other hand, Germany and New Zealand exhibit a close matching of breaks in productivity and real exchange rates. Considering the effect of aggregate demand on real exchange rates, I follow the literature and include government expenditures in estimating the breaks. After controlling for government spending, the findings do not deviate much from those when the demand-side factor is not considered.

In another section of the paper, I formulate a VAR-GARCH model to examine the dynamic relationship among the variables. Here I incorporate the GARCH effect in the model due to the presence of conditional heteroskedasticity. Since the recent literature casts doubt on treating the related time series as non-stationary, I conduct panel unit root tests for the time series. The results reject the null of non-stationarity in all cases. Subsequently, I use the raw data in my empirical model. Generally speaking, the results show varying degree of support to the BSH. Given a unit productivity shock, the directions of impulse responses for relative prices and real exchange rates are in line with the BSH for all nine countries. Canada and New Zealand follow closely with the BSH while Australia, Germany, Japan, Switzerland and the UK show a significant link between productivity shocks and real exchange rates. Finally, Korea and Mexico show that relative prices react positively upon a positive productivity shock, however, the responses for real exchange rates are minimal and transitory. As a robustness check to the results, I treat the time series as non-stationary and apply a first-differenced VAR model for these countries. Similar conclusion can be drawn when the time series are taken as non-stationary.

The impulse response analyses indicate that there exists a significant link between productivities and real exchange rates for most of the countries in the sample. However, the response of relative non-tradable prices tends to be small in most cases. Consequently, I replace the relative non-tradable price by the real exchange rate of tradable goods to see if the latter could be an alternative transmission channel of productivity shocks. In all cases, the real exchange rate of tradable goods deem an important transmission channel for productivity shocks.

In conclusion, the findings in this paper are mildly in favor of the BSH. The evidence that changes in productivity differentials will affect real exchange rates between two countries is strong. However, the results also suggest that relative non-tradable prices may not be the only channel through which the productivity effect falls on the real exchange rate.

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Table 2.1 Correlation Coefficients: Productivity Differentials (α), Relative Prices (ρ) and Real Exchange Rates (q)

Country	$R(\alpha,\rho)$	$R(\alpha,q)$	$R(\rho,q)$
Australia	0.7254	-0.1559	-0.4271
Canada	0.8448	-0.6729	-0.7547
Germany	-0.4596	-0.8988	0.2584
Japan	0.9075	-0.9537	-0.9150
Korea	0.6907	-0.4606	-0.1275
Mexico	0.1236	0.5708	-0.3271
New Zealand	0.5024	-0.9698	-0.6562
Switzerland	0.7399	-0.9794	-0.7216
UK	-0.4125	0.3358	-0.4783

Note: $R(x,y)$ is the correlation coefficient between x and y

Table 2.2 Results of Structural Break Estimation

Australia

Productivity Differentials								
$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	UDmax	WDmax(1%)	$SupF_T(2\|1)$	$SupF_T(3\|2)$	$SupF_T(4\|3)$
201.6044**	593.9839**	159.7251**	180.6950**	593.9839**	779.9211**	12.6080**	3.2472	0.1794
Number of breaks selected = 2								
$\hat{T}_1$	$\hat{T}_2$	$\hat{\alpha}_1$	$\hat{\alpha}_2$	$\hat{\alpha}_3$	$\Delta\hat{\alpha}_1$	$\Delta\hat{\alpha}_2$		
83Q1	97Q3	−1.1593	−1.6506	−1.7629	−0.4914	−0.1123		
(82Q4–83Q3)	(90Q3–00Q3)	(0.0060)	(0.0162)	(0.0268)				
Relative Non-tradable Prices								
$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	UDmax	WDmax(1%)	$SupF_T(2\|1)$	$SupF_T(3\|2)$	$SupF_T(4\|3)$
16.0102**	46.3032**	36.7441**	66.3605**	66.3605**	131.7561**	12.0093**	3.6535	4.7141
Number of breaks selected = 2								
$\hat{T}_1$	$\hat{T}_2$	$\hat{\rho}_1$	$\hat{\rho}_2$	$\hat{\rho}_3$	$\Delta\hat{\rho}_1$	$\Delta\hat{\rho}_2$		
73Q1	85Q1	0.0779	0.1773	0.0241	0.0993	−0.1531		
(72Q3–74Q1)	(83Q2–85Q2)	(0.0077)	(0.0053)	(0.0118)				
Real Exchange Rates								
$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	UDmax	WDmax(1%)	$SupF_T(2\|1)$	$SupF_T(3\|2)$	$SupF_T(4\|3)$
29.3975**	215.6929**	161.6710**	121.9841**	215.6929**	203.2122**	93.5281**	6.0936	3.4552
Number of breaks selected = 2								
$\hat{T}_1$	$\hat{T}_2$	$\hat{q}_1$	$\hat{q}_2$	$\hat{q}_3$	$\Delta\hat{q}_1$	$\Delta\hat{q}_2$		
72Q3	82Q4	0.5325	0.1750	0.3452	−0.3575	0.1701		
(72Q2–72Q4)	(80Q4–83Q2)	(0.0130)	(0.0111)	(0.0135)				

***, * denote 1%, and 5% significance level; the standard errors are reported in parentheses*

Table 2.2 Results of Structural Break Estimation (Cont'd)

Canada

Productivity Differentials									
$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	UDmax	WDmax(1%)	$SupF_T(2\|1)$	$SupF_T(3\|2)$	$SupF_T(4\|3)$	
392.2077**	36.7184**	84.0662**	162.7367**	392.2077**	392.2077**	4.3637	5.5807	4.6289	
Number of breaks selected = 1									
$\hat{T}_1$	$\hat{\alpha}_1$	$\hat{\alpha}_2$	$\Delta\hat{\alpha}_1$						
82Q1 (81Q3–82Q2)	0.0175 (0.0066)	–0.1973 (0.0085)	–0.2148						
Relative Non-tradable Prices									
$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	UDmax	WDmax(1%)	$SupF_T(2\|1)$	$SupF_T(3\|2)$	$SupF_T(4\|3)$	
166.9392**	126.5135**	168.0181**	137.7991**	168.0181**	273.5946**	46.0609**	16.2208**	1.9738	
Number of breaks selected = 3									
$\hat{T}_1$	$\hat{T}_2$	$\hat{T}_3$	$\hat{\rho}_1$	$\hat{\rho}_2$	$\hat{\rho}_3$	$\hat{\rho}_4$	$\Delta\hat{\rho}_1$	$\Delta\hat{\rho}_2$	$\Delta\hat{\rho}_3$
72Q1 (69Q2–76Q4)	79Q3 (78Q4–80Q1)	93Q4 (93Q3–94Q1)	0.2062 (0.0038)	0.2291 (0.0042)	0.1661 (0.0039)	0.0522 (0.0039)	0.0229	–0.0630	–0.1139
Real Exchange Rates									
$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	UDmax	WDmax(1%)	$SupF_T(2\|1)$	$SupF_T(3\|2)$	$SupF_T(4\|3)$	
29.1621**	49.9226**	33.2620**	27.3725**	49.9226**	65.5500**	41.0911**	3.7079	6.8932	
Number of breaks selected = 2									
$\hat{T}_1$	$\hat{T}_2$	$\hat{q}_1$	$\hat{q}_2$	$\hat{q}_3$	$\Delta\hat{q}_1$	$\Delta\hat{q}_2$			
70Q2 (67Q1–72Q1)	93Q4 (92Q3–94Q4)	0.2990 (0.0116)	0.1953 (0.0111)	0.3819 (0.0158)	–0.1037	0.1866			

***, * denote 1%, and 5% significance level; the standard errors are reported in parentheses*

Table 2.2 Results of Structural Break Estimation (Cont'd)

Germany

Productivity Differentials

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	UDmax	WDmax(1%)	$SupF_T(2\|1)$	$SupF_T(3\|2)$	$SupF_T(4\|3)$
94.2192**	574.9939**	1920.2970**	1079.0882**	1079.0882**	3105.3224**	51.2966**	6.8240	0.0377

Number of breaks selected = 2

$\hat{T}_1$	$\hat{T}_2$	$\hat{\alpha}_1$	$\hat{\alpha}_2$	$\hat{\alpha}_3$	$\Delta\hat{\alpha}_1$	$\Delta\hat{\alpha}_2$
73Q1	86Q4	−2.4258	−1.8562	−1.5483	0.5696	0.3079
(72Q2–73Q3)	(85Q1–88Q4)	(0.0289)	(0.0344)	(0.0253)		

Relative Non-tradable Prices

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	UDmax	WDmax(1%)	$SupF_T(2\|1)$	$SupF_T(3\|2)$	$SupF_T(4\|3)$
1260.2516**	213.8147**	429.3963**	365.2443**	1260.2516**	1260.2516**	226.7430**	16.2764**	1.6574

Number of breaks selected = 3

$\hat{T}_1$	$\hat{T}_2$	$\hat{T}_3$	$\hat{\rho}_1$	$\hat{\rho}_2$	$\hat{\rho}_3$	$\hat{\rho}_4$	$\Delta\hat{\rho}_1$	$\Delta\hat{\rho}_2$	$\Delta\hat{\rho}_3$
72Q4	84Q3	91Q4	0.1805	0.2732	0.1466	−0.0013	0.0927	−0.1267	−0.1479
(72Q3–73Q3)	(84Q2–84Q4)	(91Q2–92Q1)	(0.0060)	(0.0012)	(0.0052)	(0.0056)			

Real Exchange Rates

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	UDmax	WDmax(1%)	$SupF_T(2\|1)$	$SupF_T(3\|2)$	$SupF_T(4\|3)$
117.4608**	45.8101**	158.8934**	155.2235**	158.8934**	308.1901**	2.9325	4.4697	-

Number of breaks selected = 1

$\hat{T}_1$	$\hat{q}_1$	$\hat{q}_2$	$\Delta\hat{q}_1$
71Q4	0.3634	−0.1211	−0.4845
(68Q2–72Q1)	(0.0127)	(0.0426)	

***, * denote 1%, and 5% significance level; the standard errors are reported in parentheses*

Table 2.2 Results of Structural Break Estimation (Cont'd)

Japan

Productivity Differentials

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	UDmax	WDmax(1%)	$SupF_T(2\|1)$	$SupF_T(3\|2)$	$SupF_T(4\|3)$
27.7486**	147.4411**	197.6319**	169.0990**	197.6319**	335.7393**	187.7934**	51.6124**	1.2305

Number of breaks selected = 3

$\hat{T}_1$	$\hat{T}_2$	$\hat{T}_3$	$\hat{\alpha}_1$	$\hat{\alpha}_2$	$\hat{\alpha}_3$	$\hat{\alpha}_4$	$\Delta\hat{\alpha}_1$	$\Delta\hat{\alpha}_2$	$\Delta\hat{\alpha}_3$
69Q3	77Q3	86Q2	−1.6013	−1.0181	−0.6260	0.0245	0.5831	0.3921	0.6505
(68Q4–70Q3)	(77Q2–79Q3)	(85Q1–86Q3)	(0.0530)	(0.0539)	(0.0166)	(0.0441)			

Relative Non-tradable Prices

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	UDmax	WDmax(1%)	$SupF_T(2\|1)$	$SupF_T(3\|2)$	$SupF_T(4\|3)$
110.3671**	201.7734**	256.9705**	217.4462**	256.9705**	431.7309**	53.4295**	19.0680**	4.3631

Number of breaks selected = 3

$\hat{T}_1$	$\hat{T}_2$	$\hat{T}_3$	$\hat{\rho}_1$	$\hat{\rho}_2$	$\hat{\rho}_3$	$\hat{\rho}_4$	$\Delta\hat{\rho}_1$	$\Delta\hat{\rho}_2$	$\Delta\hat{\rho}_3$
66Q4	74Q2	93Q1	−0.5431	−0.3370	−0.0484	0.0077	0.2060	0.2886	0.0562
(66Q1–67Q4)	(73Q4–74Q4)	(89Q3–01Q1)	(0.0220)	(0.0168)	(0.0107)	(0.0085)			

Real Exchange Rates

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	UDmax	WDmax(1%)	$SupF_T(2\|1)$	$SupF_T(3\|2)$	$SupF_T(4\|3)$
78.8770**	134.3969**	236.5865**	240.8172**	240.8172**	478.1330**	19.4201**	19.4920**	1.3539

Number of breaks selected = 2

$\hat{T}_1$	$\hat{T}_2$	$\hat{T}_3$	$\hat{q}_1$	$\hat{q}_2$	$\hat{q}_3$	$\hat{q}_4$	$\Delta\hat{q}_1$	$\Delta\hat{q}_2$	$\Delta\hat{q}_3$
72Q4	85Q4	00Q4	5.6063	5.0466	4.6630	4.8752	−0.5600	−0.3836	0.2122
(71Q4–73Q1)	(84Q1–87Q3)	(99Q4–05Q1)	(0.0164)	(0.0418)	(0.0383)	(0.0281)			

***, * denote 1%, and 5% significance level; the standard errors are reported in parentheses*

Table 2.2 Results of Structural Break Estimation (Cont'd)

Korea									
Productivity Differentials									
$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	UDmax	WDmax(1%)	$SupF_T(2\|1)$	$SupF_T(3\|2)$	$SupF_T(4\|3)$	
10.8847**	47.0582**	71.1139**	48.8560**	71.1139**	114.9986**	55.7929**	1.9367	-	
Number of breaks selected = 2									
$\hat{T}_1$	$\hat{T}_2$	$\hat{\alpha}_1$	$\hat{\alpha}_2$	$\hat{\alpha}_3$	$\Delta\hat{\alpha}_1$	$\Delta\hat{\alpha}_2$			
79Q4 (79Q1–81Q1)	88Q2 (82Q1–88Q3)	−2.5072 (0.0263)	−2.7685 (0.0224)	−2.3921 (0.0616)	−0.2613	0.3764			
Relative Non-tradable Prices									
$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	UDmax	WDmax(1%)	$SupF_T(2\|1)$	$SupF_T(3\|2)$	$SupF_T(4\|3)$	
47.2267**	54.8435**	130.4074**	104.8978**	130.4074**	210.8825**	50.2326**	34.6196**	1.8442	
Number of breaks selected = 3									
$\hat{T}_1$	$\hat{T}_2$	$\hat{T}_3$	$\hat{\rho}_1$	$\hat{\rho}_2$	$\hat{\rho}_3$	$\hat{\rho}_4$	$\Delta\hat{\rho}_1$	$\Delta\hat{\rho}_2$	$\Delta\hat{\rho}_3$
79Q4 (79Q4–83Q3)	90Q1 (90Q1–90Q2)	02Q2 (01Q2–03Q2)	−0.0486 (0.0089)	−0.1006 (0.0001)	0.0145 (0.0071)	0.1041 (0.0103)	−0.0520	0.1151	0.0896
Real Exchange Rates									
$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	UDmax	WDmax(1%)	$SupF_T(2\|1)$	$SupF_T(3\|2)$	$SupF_T(4\|3)$	
4.8119	8.9280	6.2221	8.6809	8.9280	17.2355	2.3360	0.2489	-	
UDmax	WDmax(1%)	$SupF_T(2\|1)$	$SupF_T(3\|2)$	$SupF_T(4\|3)$					
8.9280	17.2355	2.3360	0.2489	-					
Number of breaks selected = 0									

***, * denote 1%, and 5% significance level; the standard errors are reported in parentheses*

Table 2.2 Results of Structural Break Estimation (Cont'd)

Mexico

Productivity Differentials

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	$SupF_T(5)$	UDmax	WDmax(1%)	$SupF_T(2\|1)$	$SupF_T(3\|2)$	$SupF_T(4\|3)$	$SupF_T(5\|4)$
18.4257**	152.4048**	186.6355**	214.6319**	672.4385**	672.4385**	1683.1505**	54.0971**	31.7547**	82.4758**	7.8160

Number of breaks selected = 4

$\hat{T}_1$	$\hat{T}_2$	$\hat{T}_3$	$\hat{T}_4$	$\hat{\alpha}_1$	$\hat{\alpha}_2$	$\hat{\alpha}_3$	$\hat{\alpha}_4$	$\hat{\alpha}_5$	$\Delta\hat{\alpha}_1$	$\Delta\hat{\alpha}_2$	$\Delta\hat{\alpha}_3$	$\Delta\hat{\alpha}_3$
88*Q*1	94*Q*3	98*Q*1	02*Q*2	0.8990	–0.5359	–1.5405	–1.7943	–1.9324	–1.4350	–1.0045	–0.2538	–0.1381
(87*Q*4–88*Q*4)	(94*Q*2–94*Q*4)	(97*Q*4–00*Q*1)	(01*Q*4–02*Q*3)	(0.1822)	(0.0540)	(0.0548)	(0.0085)	(0.0121)				

Relative Non-tradable Prices

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	$SupF_T(5)$	UDmax	WDmax(1%)	$SupF_T(2\|1)$	$SupF_T(3\|2)$	$SupF_T(4\|3)$	$SupF_T(5\|4)$
0.8973	2.7196	7.0810	18.8978	16.2699	18.8978**	40.7244**	3.9098	0.0949	0.0498	-

Number of breaks selected = 0

Real Exchange Rates

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	$SupF_T(5)$	UDmax	WDmax(1%)	$SupF_T(2\|1)$	$SupF_T(3\|2)$	$SupF_T(4\|3)$	$SupF_T(5\|4)$
20.3527**	21.1719**	15.5274**	63.1642**	14.1088**	114.1088**	285.6205**	10.5087**	3.5858	4.5904	2.8315

Number of breaks selected = 2

$\hat{T}_1$	$\hat{T}_2$	$\hat{q}_1$	$\hat{q}_2$	$\hat{q}_3$	$\Delta\hat{q}_1$	$\Delta\hat{q}_2$
88*Q*1	98*Q*4	2.7599	2.4235	2.2688	–0.3364	–0.1546
(85*Q*4–90*Q*2)	(98*Q*2–07*Q*4)	(0.0810)	(0.0443)	(0.0159)		

***, * denote 1%, and 5% significance level; the standard errors are reported in parentheses*

Table 2.2 Results of Structural Break Estimation (Cont'd)

New Zealand								
Productivity Differentials								
$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	UDmax	WDmax(1%)	$SupF_T(2\|1)$	$SupF_T(3\|2)$	$SupF_T(4\|3)$
16.5819**	44.6553**	44.9628**	112.2686**	112.2686**	222.9048**	92.4463**	5.2587	3.5721
Number of breaks selected = 2								
$\hat{T}_1$	$\hat{T}_2$	$\hat{\alpha}_1$	$\hat{\alpha}_2$	$\hat{\alpha}_3$	$\Delta\hat{\alpha}_1$	$\Delta\hat{\alpha}_2$		
97Q4 (97Q3–98Q4)	03Q3 (03Q2–03Q4)	–1.9801 (0.0200)	–2.2262 (0.0154)	–1.8403 (0.0221)	–0.2461	0.3859		
Relative Non-tradable Prices								
$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	UDmax	WDmax(1%)	$SupF_T(2\|1)$	$SupF_T(3\|2)$	$SupF_T(4\|3)$
58.1111**	298.1813**	260.8356**	251.4908**	298.1813**	499.3251**	15.9249**	2.5062	-
Number of breaks selected = 2								
$\hat{T}_1$	$\hat{T}_2$	$\hat{\rho}_1$	$\hat{\rho}_2$	$\hat{\rho}_3$	$\Delta\hat{\rho}_1$	$\Delta\hat{\rho}_2$		
91Q3 (91Q2–91Q4)	98Q1 (96Q1–98Q2)	0.1463 (0.0027)	0.0789 (0.0037)	0.0097 (0.0091)	–0.0674	–0.0692		
Real Exchange Rates								
$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	UDmax	WDmax(1%)	$SupF_T(2\|1)$	$SupF_T(3\|2)$	$SupF_T(4\|3)$
12.5133**	42.7378**	23.6078**	45.4072**	45.4072**	90.1543**	31.4809**	3.7082	0.8266
Number of breaks selected = 2								
$\hat{T}_1$	$\hat{T}_2$	$\hat{q}_1$	$\hat{q}_2$	$\hat{q}_3$	$\Delta\hat{q}_1$	$\Delta\hat{q}_2$		
97Q3 (95Q2–98Q2)	03Q1 (02Q4–04Q4)	0.4319 (0.0238)	0.7184 (0.0505)	0.3951 (0.0246)	0.2865	–0.3233		

***, * denote 1%, and 5% significance level; the standard errors are reported in parentheses*

Table 2.2 Results of Structural Break Estimation (Cont'd)

Switzerland

Productivity Differentials

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	UDmax	WDmax(1%)	$SupF_T(2\|1)$	$SupF_T(3\|2)$	$SupF_T(4\|3)$
29.6856**	23.9108**	27.3941**	24.2506**	29.6856**	48.1487**	5.1499	9.0851	6.0248

Number of breaks selected = 1

$\hat{T}_1$	$\hat{\alpha}_1$	$\hat{\alpha}_2$	$\Delta\hat{\alpha}_1$
77Q2	−1.7093	−1.1990	0.5103
(74Q3–79Q3)	(0.0819)	(0.0441)	

Relative Non-tradable Prices

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	UDmax	WDmax(1%)	$SupF_T(2\|1)$	$SupF_T(3\|2)$	$SupF_T(4\|3)$
365.7822**	146.1585**	172.5445**	128.6897**	365.7822**	365.7822**	12.6443**	8.2318	7.1569

Number of breaks selected = 2

$\hat{T}_1$	$\hat{T}_2$	$\hat{\rho}_1$	$\hat{\rho}_2$	$\hat{\rho}_3$	$\Delta\hat{\rho}_1$	$\Delta\hat{\rho}_2$
75Q2	02Q2	−0.1981	−0.0360	0.0390	0.1621	0.0750
(74Q3–75Q3)	(97Q4–05Q1)	(0.0075)	(0.0073)	(0.0196)		

Real Exchange Rates

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	UDmax	WDmax(1%)	$SupF_T(2\|1)$	$SupF_T(3\|2)$	$SupF_T(4\|3)$
13.1477**	63.2375**	43.6255**	45.2029**	63.2375**	89.7486**	25.3573**	4.0196	4.0196

Number of breaks selected = 1

$\hat{T}_1$	$\hat{T}_2$	$\hat{q}_1$	$\hat{q}_2$	$\hat{q}_3$	$\Delta\hat{q}_1$	$\Delta\hat{q}_2$
75Q2	86Q1	0.9658	0.6038	0.3275	−0.3620	−0.2764
(72Q1–76Q1)	(81Q4–91Q2)	(0.0426)	(0.0565)	(0.0368)		

***, * denote 1%, and 5% significance level; the standard errors are reported in parentheses*

Table 2.2 Results of Structural Break Estimation (Cont'd)

The United Kingdom

Productivity Differentials

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	UDmax	WDmax(1%)	$SupF_T(2\|1)$	$SupF_T(3\|2)$	$SupF_T(4\|3)$
12.0564**	23.5778**	18.7779**	26.6037**	26.6037**	52.8205**	30.6836**	0.4254	0.4763

Number of breaks selected = 2

$\hat{T}_1$	$\hat{T}_2$	$\hat{\alpha}_1$	$\hat{\alpha}_2$	$\hat{\alpha}_3$	$\Delta\hat{\alpha}_1$	$\Delta\hat{\alpha}_2$
67Q3	75Q2	–1.0403	–1.2315	–1.5841	–0.1912	–0.3526
(67Q2–71Q2)	(75Q2–75Q4)	(0.0324)	(0.0105)	(0.0785)		

Relative Non-tradable Prices

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	UDmax	WDmax(1%)	$SupF_T(2\|1)$	$SupF_T(3\|2)$	$SupF_T(4\|3)$
29.4392**	809.4080**	987.8074**	470.8691**	987.8074**	1597.3886**	74.0333**	6.0009	0.4484

Number of breaks selected = 2

$\hat{T}_1$	$\hat{T}_2$	$\hat{\rho}_1$	$\hat{\rho}_2$	$\hat{\rho}_3$	$\Delta\hat{\rho}_1$	$\Delta\hat{\rho}_2$
73Q1	84Q2	–0.0807	0.1654	0.0350	0.2461	–0.1304
(72Q3–73Q2)	(83Q4–86Q1)	(0.0046)	(0.0141)	(0.0053)		

Real Exchange Rates

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	UDmax	WDmax(1%)	$SupF_T(2\|1)$	$SupF_T(3\|2)$	$SupF_T(4\|3)$
38.7900**	39.7876**	29.0468**	40.1223**	40.1223**	79.6613**	5.6329	2.0926	1.5698

Number of breaks selected = 1

$\hat{T}_1$	$\hat{q}_1$	$\hat{q}_2$	$\Delta\hat{q}_1$
77Q3	–0.2275	–0.4542	–0.2267
(69Q4–78Q2)	(0.0151)	(0.0329)	

***, * denote 1%, and 5% significance level; the standard errors are reported in parentheses*

Table 2.3 Structural Breaks after Controlling for the Government Expenditure

Country		Break Time			Mean				Magnitude Of Shift			Government Expenditure Parameter
Australia	RP	$\hat{T}_1$ 73Q1 (72Q1–73Q3)	$\hat{T}_2$ 84Q2 (83Q1–85Q3)		$\hat{\rho}_1$ 0.0346 (0.0245)	$\hat{\rho}_2$ 0.1895 (0.0126)	$\hat{\rho}_3$ 0.0528 (0.0180)		$\Delta\hat{\rho}_1$ 0.1549	$\Delta\hat{\rho}_2$ −0.1367		-1.0502 (0.6181)
	RER	$\hat{T}_1$ 72Q4 (72Q1–73Q1)			$\hat{q}_1$ 0.7618 (0.0814)	$\hat{q}_2$ 0.1900 (0.0263)			$\Delta\hat{q}_1$ −0.5718			5.6109 (1.6762)
Canada	RP	$\hat{T}_1$ 71Q4 (69Q3–73Q3)	$\hat{T}_2$ 79Q2 (78Q4–80Q2)	$\hat{T}_3$ 94Q1 (93Q1–94Q2)	$\hat{\rho}_1$ 0.2002 (0.0090)	$\hat{\rho}_2$ 0.2342 (0.0079)	$\hat{\rho}_3$ 0.1762 (0.0166)	$\hat{\rho}_4$ 0.0656 (0.0279)	$\Delta\hat{\rho}_1$ 0.0340	$\Delta\hat{\rho}_2$ −0.0580	$\Delta\hat{\rho}_3$ −0.1106	-0.3428 (0.5358)
	RER	$\hat{T}_1$ 70Q2 (69Q2–70Q4)	$\hat{T}_2$ 93Q4 (92Q3–95Q1)		$\hat{q}_1$ 0.3360 (0.0160)	$\hat{q}_2$ 0.1527 (0.0218)	$\hat{q}_3$ 0.3050 (0.0423)		$\Delta\hat{q}_1$ −0.1833	$\Delta\hat{q}_2$ 0.1523		1.8097 (0.8056)
Germany	RP	$\hat{T}_1$ 72Q4 (71Q3–74Q1)	$\hat{T}_2$ 83Q3 (83Q1–84Q1)	$\hat{T}_3$ 91Q4 (91Q3–92Q2)	$\hat{\rho}_1$ 0.1917 (0.0078)	$\hat{\rho}_2$ 0.2612 (0.0151)	$\hat{\rho}_3$ 0.1380 (0.0129)	$\hat{\rho}_4$ −0.0252 (0.0154)	$\Delta\hat{\rho}_1$ 0.0695	$\Delta\hat{\rho}_2$ −0.1232	$\Delta\hat{\rho}_3$ −0.1632	0.6331 (0.4036)
	RER	$\hat{T}_1$ 89Q3 (88Q2–98Q2)	$\hat{T}_2$ 98Q4 (98Q3–00Q2)		$\hat{q}_1$ 0.1753 (0.0090)	$\hat{q}_2$ −0.1322 (0.0208)	$\hat{q}_3$ 0.2409 (0.0283)		$\Delta\hat{q}_1$ −0.3075	$\Delta\hat{q}_2$ 0.3731		-6.9375 (0.6400)

RP and RER denote the relative non-tradable price and the real exchange rate; standard errors are reported in parentheses

Table 2.3 Structural Breaks after Controlling for the Government Expenditure (Cont'd)

Country		Break Time	Mean	Magnitude Of Shift	Government Expenditure Parameter
Japan	RP	$\hat{T}_1$ 70Q4 (70Q2–72Q3); $\hat{T}_2$ 77Q4 (77Q1–80Q3)	$\hat{\rho}_1$ −0.4455 (0.0596); $\hat{\rho}_2$ −0.1423 (0.0464); $\hat{\rho}_3$ −0.0085 (0.0074)	$\Delta\hat{\rho}_1$ 0.3032; $\Delta\hat{\rho}_2$ 0.1338	0.4847 (0.2986)
	RER	$\hat{T}_1$ 72Q4 (72Q1–73Q1); $\hat{T}_2$ 86Q1 (84Q1–87Q2); $\hat{T}_3$ 96Q4 (92Q1–05Q1)	$\hat{q}_1$ 5.5937 (0.1586); $\hat{q}_2$ 5.0359 (0.0712); $\hat{q}_3$ 4.6310 (0.0591); $\hat{q}_4$ 4.8238 (0.0403)	$\Delta\hat{q}_1$ −0.5578; $\Delta\hat{q}_2$ −0.4049; $\Delta\hat{q}_3$ 0.1928	-0.1348 (1.2563)
Korea	RP	$\hat{T}_1$ 79Q4 (79Q3–83Q2); $\hat{T}_2$ 90Q1 (89Q1–90Q2); $\hat{T}_3$ 02Q2 (01Q1–03Q3)	$\hat{\rho}_1$ −0.0304 (0.0076); $\hat{\rho}_2$ −0.0864 (0.0061); $\hat{\rho}_3$ 0.0238 (0.0042); $\hat{\rho}_4$ 0.1087 (0.0098)	$\Delta\hat{\rho}_1$ −0.0560; $\Delta\hat{\rho}_2$ 0.1102; $\Delta\hat{\rho}_3$ 0.0849	0.2717 (0.1197)
	RER	$\hat{T}_1$ 97Q3 (92Q1–00Q2)	$\hat{q}_1$ 6.7026 (0.0392); $\hat{q}_2$ 6.9695 (0.0665)	$\Delta\hat{q}_1$ 0.2669	-2.7404 (0.7463)
Mexico	RP	No break can be found			-0.0624 (0.1560)
	RER	$\hat{T}_1$ 88Q1 (85Q3–90Q1)	$\hat{q}_1$ 2.5991 (0.0679); $\hat{q}_2$ 2.2507 (0.0641)	$\Delta\hat{q}_1$ −0.3484	-1.9337 (0.8553)

RP and RER denote the relative non-tradable price and the real exchange rate; standard errors are reported in parentheses

Table 2.3 Structural Breaks after Controlling for the Government Expenditure (Cont'd)

Country		Break Time	Mean	Magnitude Of Shift	Government Expenditure Parameter
New -	RP	$\hat{T}_1$ 91Q4 (91Q3–92Q1); $\hat{T}_2$ 99Q4 (98Q4–00Q1); $\hat{T}_3$ 02Q4 (01Q3–05Q2)	$\hat{\rho}_1$ 0.1513 (0.0136); $\hat{\rho}_2$ 0.0791 (0.0184); $\hat{\rho}_3$ –0.0267 (0.0245); $\hat{\rho}_4$ 0.0375 (0.0158)	$\Delta\hat{\rho}_1$ –0.0722; $\Delta\hat{\rho}_2$ –0.1058; $\Delta\hat{\rho}_3$ 0.0642	-0.3752 (0.6185)
Zealand	RER	$\hat{T}_1$ 99Q4 (98Q3–01Q2); $\hat{T}_2$ 04Q3 (04Q2–05Q2)	$\hat{q}_1$ 0.2327 (0.0415); $\hat{q}_2$ 0.4788 (0.0776); $\hat{q}_3$ 0.1352 (0.0413)	$\Delta\hat{q}_1$ 0.2461; $\Delta\hat{q}_2$ –0.3436	9.1392 (1.7766)
Switzer-	RP	$\hat{T}_1$ 75Q2 (74Q2–75Q3); $\hat{T}_2$ 02Q2 (97Q1–05Q2)	$\hat{\rho}_1$ –0.1414 (0.0239); $\hat{\rho}_2$ 0.0064 (0.0191); $\hat{\rho}_3$ 0.0769 (0.0221)	$\Delta\hat{\rho}_1$ 0.1478; $\Delta\hat{\rho}_2$ 0.0705	0.8770 (0.4938)
Land	RER	$\hat{T}_1$ 77Q3 (73Q4–80Q1)	$\hat{q}_1$ 0.4614 (0.0828); $\hat{q}_2$ 0.0519 (0.0953)	$\Delta\hat{q}_1$ –0.4095	-7.2625 (1.6697)
UK	RP	$\hat{T}_1$ 73Q1 (72Q1–74Q3); $\hat{T}_2$ 80Q3 (77Q1–81Q2); $\hat{T}_3$ 91Q1 (91Q1–95Q1)	$\hat{\rho}_1$ –0.1167 (0.0009); $\hat{\rho}_2$ –0.0312 (0.0054); $\hat{\rho}_3$ –0.1183 (0.0059); $\hat{\rho}_4$ –0.1984 (0.0056)	$\Delta\hat{\rho}_1$ 0.0855; $\Delta\hat{\rho}_2$ –0.0871; $\Delta\hat{\rho}_3$ –0.0801	4.9652 (0.1360)
	RER	$\hat{T}_1$ 87Q3 (83Q4–90Q2)	$\hat{q}_1$ –0.1883 (0.0124); $\hat{q}_2$ –0.3469 (0.0357)	$\Delta\hat{q}_1$ –0.1586	-3.4739 (0.7459)

RP and RER denote the relative non-tradable price and the real exchange rate; standard errors are reported in parentheses

Table 2.4 Unit Root Tests

	Real Exchange Rates		Productivity Differentials		Relative Prices	
	ADF	KPSS	ADF	KPSS	ADF	KPSS
Australia	-1.7112	0.2110	-1.1335	0.1637	-1.7985	0.2133
Canada	-1.9189	0.1759	0.3329	0.1187	-1.1476	0.1605
Germany	-1.8735	0.1893	-2.0594	0.2372	-1.7152	0.3074
Japan	-1.2222	0.3230	-1.4694	0.2930	-1.9925	0.3886
Korea	-2.9971	0.0804	-2.5509	0.1087	-1.2370	0.2128
Mexico	-2.6136	0.0937	-4.3571	0.2534	-2.6550	0.1108
New Zealand	-0.8536	0.1441	-0.8189	0.1537	-1.4079	0.1464
Switzerland	-2.7164	0.1908	-2.6807	0.2165	-2.1923	0.1460
UK	-3.4027	0.0354	-1.1711	0.3120	-1.1202	0.2255
	ADF	KPSS				
CV (1%)	-4.0063	0.2160				
CV (5%)	-3.4333	0.1460				
CV (10%)	-3.1405	0.1190				

Table 2.5 Panel Unit Root Test

	Real Exchange Rates	Productivity Differentials	Relative Prices
Test statistics	62.7799**	66.5568**	84.8070**

**, * denote 1% and 5% significance levels;
The panel unit root test is based on Maddala and Wu (1999) in which the null hypothesis is the unit root process.

Table 2.6 Multivariate Ljung-Box Test (VAR Model)

	Level of Residuals			Square of Residuals		
	$Q(4)$	$Q(8)$	$Q(12)$	$Q^2(4)$	$Q^2(8)$	$Q^2(12)$
Australia	31.2012	64.8488	99.6720	65.7182**	110.1811**	630.0398**
Canada	4.1288	27.9958	58.9111	94.6687**	134.9174**	177.7384**
Germany	9.0529	56.8527	94.3780	101.0018**	113.0293**	130.1325*
Japan	18.7576	49.9474	87.0466	72.5805**	108.6299**	154.3984**
Korea	24.9927	62.2808	88.4065	66.4909**	119.5076**	129.7232*
Mexico	8.1511	34.2916	50.8276	38.4858	52.3556	65.5265
New Zealand	27.0996	52.5545	74.8837	62.0430**	94.1204**	123.6980*
Switzerland	30.7572	79.6764	106.3314	48.6222**	77.9597	106.8909
UK	3.6044	23.9635	60.3868	65.3604**	92.3227**	117.3757

**, * denote 1% and 5% significance levels; standardized residuals and their squares are used for the test

Table 2.7 Estimation Results: VAR-GARCH Model

	Australia			Canada			Germany		
	PD(α_t)	RP(ρ_t)	RER(q_t)	PD(α_t)	RP(ρ_t)	RER(q_t)	PD(α_t)	RP(ρ_t)	RER(q_t)
c	-0.009	0.028**	0.050	0.006	0.016*	0.009	0.022	-0.029	-0.201**
αt-1	0.863**	-0.087*	-0.133	0.719**	0.005	-0.102	0.813**	0.015	-0.133
αt-2	0.136	0.099**	0.153	0.049	-0.056	0.016	0.192	0.078	0.042
αt-3				0.158	0.052	-0.042	0.034	-0.035	-0.396*
αt-4				0.087	0.04	0.024	-0.03	-0.073*	0.371**
αt-5				0.150	0.079	-0.016			
αt-6				-0.157	-0.092*	0.113			
αt-7									
αt-8									
ρt-1	-0.265	0.996**	-0.009	-0.398*	1.103**	0.361	-0.058	1.240**	0.008
ρt-2	0.222	-0.072	-0.065	0.188	-0.229	-0.616	-0.022	-0.493**	-0.373
ρt-3				0.118	0.15	0.019	0.371	0.684**	-0.318
ρt-4				-0.113	-0.046	0.087	-0.286	-0.456	0.491
ρt-5				0.051	-0.111	0.055			
ρt-6				0.097	0.071	0.086			
ρt-7									
ρt-8									
q t-1	-0.597**	-0.171**	0.855**	-0.664**	-0.117**	1.126**	-0.589**	0.014	0.973*
q t-2	0.613**	0.158**	0.108	0.360**	0.089*	-0.182	0.558**	0.022	-0.145
q t-3				0.098	-0.039	0.081	-0.029	0.009	0.077
q t-4				0.103	0.017	0.039	0.077	-0.056	-0.057
q t-5				0.221*	0.095*	-0.278*			
q t-6				-0.116	-0.055	0.183			
q t-7									
q t-8									
θ	0	0	0	0	0	0	0	0.001**	0
a	0.114**	0.572**	0.250	0.271**	0.171**	0.210**	0	1.000*	0.377**
b	0.820**	0.379**	0.750**	0.512**	0.817**	0.790**	0.142	0	0.623**
ω_{12}	-0.168**			0.218**			0.050		
ω_{13}		-0.585**			-0.458**			-0.517**	
ω_{23}			0.093			-0.251**			-0.131**

**, * denote 1% and 5% significance levels; VAR model is used for Mexico

PD, RP and RER stand for the productivity differentials, relative prices and real exchange rates

θ, a, and b are the coefficients for the conditional variance equations while ω_{ij} represents the conditional correlations

Table 2.7 Estimation Results: VAR-GARCH Model (cont'd)

	Japan			Korea			Mexico		
	PD(α_t)	RP(ρ_t)	RER(q_t)	PD(α_t)	RP(ρ_t)	RER(q_t)	PD(α_t)	RP(ρ_t)	RER(q_t)
c	-0.147	-0.038	0.435*	-0.033	0.019	0.678*	-0.236	-0.017	0.613*
αt-1	1.022**	-0.025	0.238	0.921**	-0.018	0.063	0.969**	0.035	0.233
αt-2	-0.284	0.049	-0.179	-0.122	0.051	0.015	0.109	0.018	-0.104
αt-3	-0.001	-0.023	0.016	-0.054	-0.008	-0.057	-0.625	-0.111	0.106
αt-4	0.905**	0.002	-0.002	0.878**	-0.018	0.048	0.850**	0.088	-0.208
αt-5	-0.963**	0.040	-0.266	-0.891**	0.022	-0.036	-0.133	0.015	-0.459
αt-6	0.293	-0.030	0.167	0.14	-0.021	-0.042	-0.22	-0.041	0.468
αt-7									
αt-8									
ρt-1	-0.568	0.923**	0.599	0.585*	1.256**	0.404	0.105	1.004**	0.338
ρt-2	0.848	0.073	-1.047*	0.538	-0.495**	-1.079*	0.563	-0.069	-0.593
ρt-3	-0.471	-0.201	0.592	-1.080*	0.162	0.357	-0.179	-0.136	0.329
ρt-4	0.635	0.233*	-0.11	0.941*	0.117	0.013	-1.000	0.189	0.757
ρt-5	-1.133*	-0.247*	-0.016	-1.093**	-0.147	0.318	1.611*	-0.273	-1.895*
ρt-6	0.797*	0.173*	-0.092	0.267	0.099	0.065	-0.924	0.064	1.134*
ρt-7									
ρt-8									
q t-1	-0.056	-0.049	1.287**	-0.624**	-0.126**	0.935**	-0.346	-0.004	1.196**
q t-2	0.032	0.053	-0.468*	0.439**	0.091*	0.123	0.547	0.044	-0.449
q t-3	-0.490**	-0.010	0.445**	0.011	0.030	0.019	-0.962**	-0.083	0.600*
q t-4	1.127**	-0.033	-0.129	0.209*	0.002	-0.218	0.950**	0.033	-0.309
q t-5	-0.930**	0.061	-0.323	0.312**	-0.012	0.149	-0.148	0.057	-0.444
q t-6	0.348	-0.014	0.096	-0.389**	0.016	-0.108	0.021	-0.038	0.167
q t-7									
q t-8									
θ	0.001	0	0	0.001**	0	0.004**			
a	0.315	0.184**	0.235**	0.803**	0.839**	0.036**			
b	0.685	0.746**	0.765**	0.197**	0.161**	0			
ω_{12}	0.026			0.095**					
ω_{13}		-0.673**			-0.528**				
ω_{23}			-0.320**			-0.104			

**, * denote 1% and 5% significance levels; VAR model is used for Mexico

PD, RP and RER stand for the productivity differentials, relative prices and real exchange rates

θ, a, and b are the coefficients for the conditional variance equations while ω_{ij} represents the conditional correlations

Table 2.7 Estimation Results: VAR-GARCH Model (cont'd)

	New Zealand			Switzerland			UK		
	PD(α_t)	RP(ρ_t)	RER(q_t)	PD(α_t)	RP(ρ_t)	RER(q_t)	PD(α_t)	RP(ρ_t)	RER(q_t)
c	0.027	0.008	-0.252	-0.100	-0.012	0.060	-0.032	0.004	0.016
αt-1	0.318	-0.014	0.009	0.902*	-0.020	0.054	1.217**	-0.048	-0.044
αt-2	0.660	0.008	-0.163				-0.092	0.118	0.163
αt-3							-0.301	0.056	-0.084
αt-4							0.490**	-0.172	-0.351
αt-5							-0.288	0.107	0.249
αt-6							-0.079	-0.056	0.164
αt-7							0.142	-0.03	-0.271
αt-8							-0.134	0.028	0.207
ρt-1	-0.218	1.103**	0.05	0.022	0.956**	0.031	0.120	1.118**	-0.073
ρt-2	-0.216	-0.164	0.145				-0.033	0.155	0.099
ρt-3							-0.321	-0.069	0.039
ρt-4							0.479	-0.005	-0.421
ρt-5							-0.537*	-0.381**	0.388
ρt-6							0.267	0.241*	0.100
ρt-7							0.232	-0.106	-0.163
ρt-8							-0.208	0.04	-0.016
q t-1	-0.798	-0.141	1.107*	-0.043	-0.029	1.003**	0.129	-0.09	1.058**
q t-2	0.731	0.106	-0.267				0.159	0.162	-0.05
q t-3							-0.454	0.076	0.039
q t-4							0.478	-0.222	-0.316
q t-5							-0.092	0.153	0.006
q t-6							-0.283	-0.091	0.334
q t-7							0.104	-0.057	-0.15
q t-8							0.041	0.071	0.001
θ	0.001**	0.000	0.002**	0.004**	0.001**	0.001*	0.001**	0.000	0.000
a	0.737**	0.110**	0.416**	0.001	0.228**	0.007	0.118**	1.000**	0.208
b	0.036**	0.891**	0.098*	0.179	0.251	0.937**	0.816**	0.000	0.712
ω_{12}	0.204**			0.023			0.098**		
ω_{13}		-0.959**			-0.880**			-0.900**	
ω_{23}			-0.243**			-0.100**			-0.185**

**, * denote 1% and 5% significance levels; VAR model is used for Mexico

PD, RP and RER stand for the productivity differentials, relative prices and real exchange rates

θ, a, and b are the coefficients for the conditional variance equations while ω_{ij} represents the conditional correlations

Table 2.8 Multivariate Ljung-Box Test (VAR-GARCH Model)

	Level of Residuals			Square of Residuals		
	$Q(4)$	$Q(8)$	$Q(12)$	$Q^2(4)$	$Q^2(8)$	$Q^2(12)$
Australia	33.3405	71.4156	97.7705	25.0145	52.4058	84.5848
Canada	13.6323	39.0289	89.9962	29.6400	63.5262	89.9962
Germany	35.6061	67.3306	114.4289	33.7985	62.2081	77.5880
Japan	22.5591	58.6190	84.1907	22.3365	33.2031	64.1968
Korea	33.1162	60.0805	102.3673	34.9866	59.5952	94.1573
New Zealand	22.2477	53.0039	81.8876	22.3642	66.3613	102.9976
Switzerland	32.0167	77.4238	101.0617	32.4757	70.6523	95.6521
UK	25.3154	56.4967	93.0789	30.4976	74.4180	115.3447

**, * denote 1% and 5% significance levels; standardized residuals and their squares are used in the tests

Table 2.9 Panel Cointegration Test

	(q,α)	(rp,α)	(q,rp)
P_τ	-2.482	-4.876	-6.014*
P_α	-1.970	-4.805	-8.065**
G_τ	-1.382	-2.187	-1.996
G_α	-3.535	-7.500	-8.175

**, * denote 1% and 5% significance levels;

The panel cointegration test is based on Westerlund (2007);

P_τ and P_α represent the panel statistics while G_τ and G_α represent the group mean statistics.

Figure 2.1 Structural Breaks: Productivity Differentials, Relative Non-tradable Prices and Real Exchange Rates

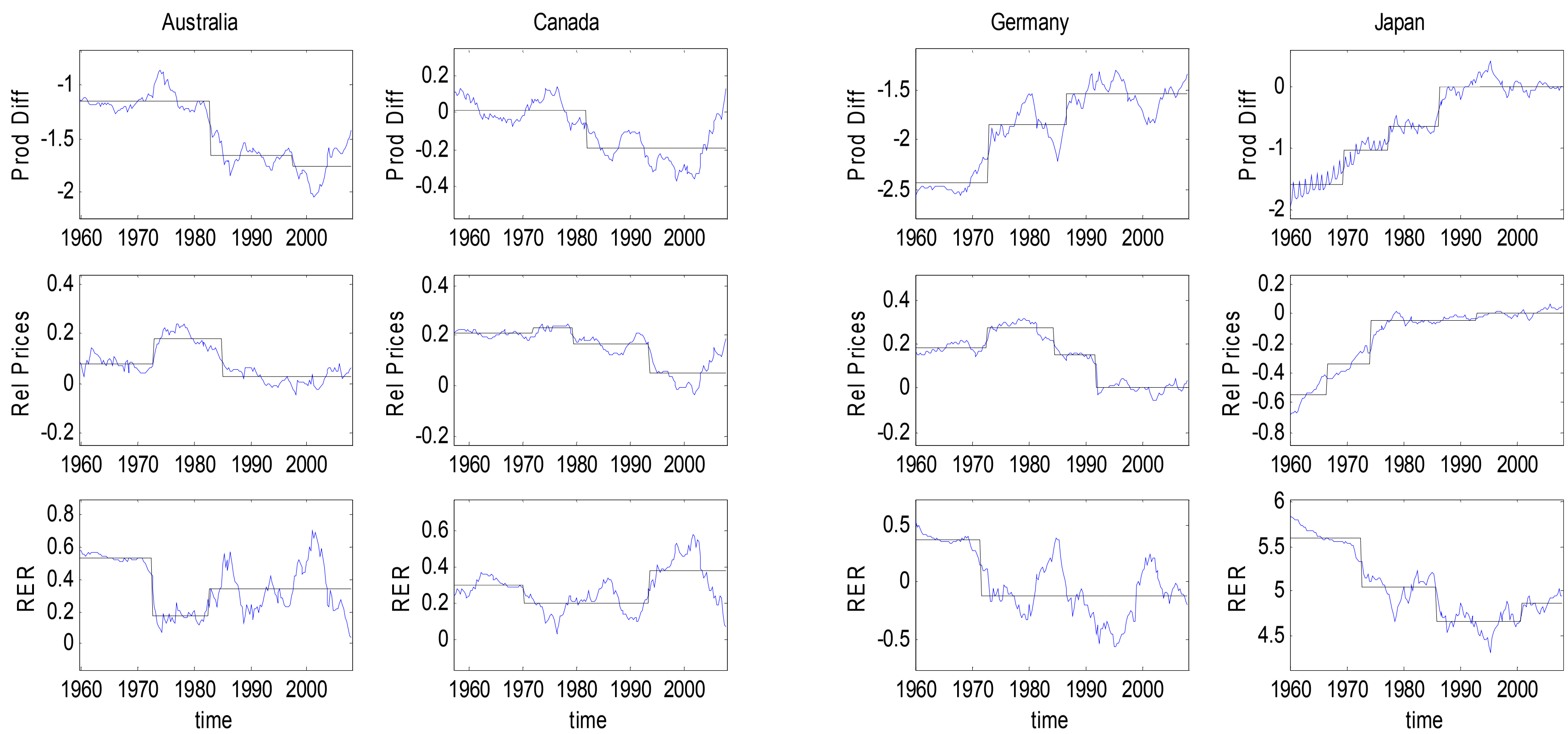


Figure 2.1 Structural Breaks: Productivity Differentials, Relative Non-tradable Prices and Real Exchange Rates (cont'd)

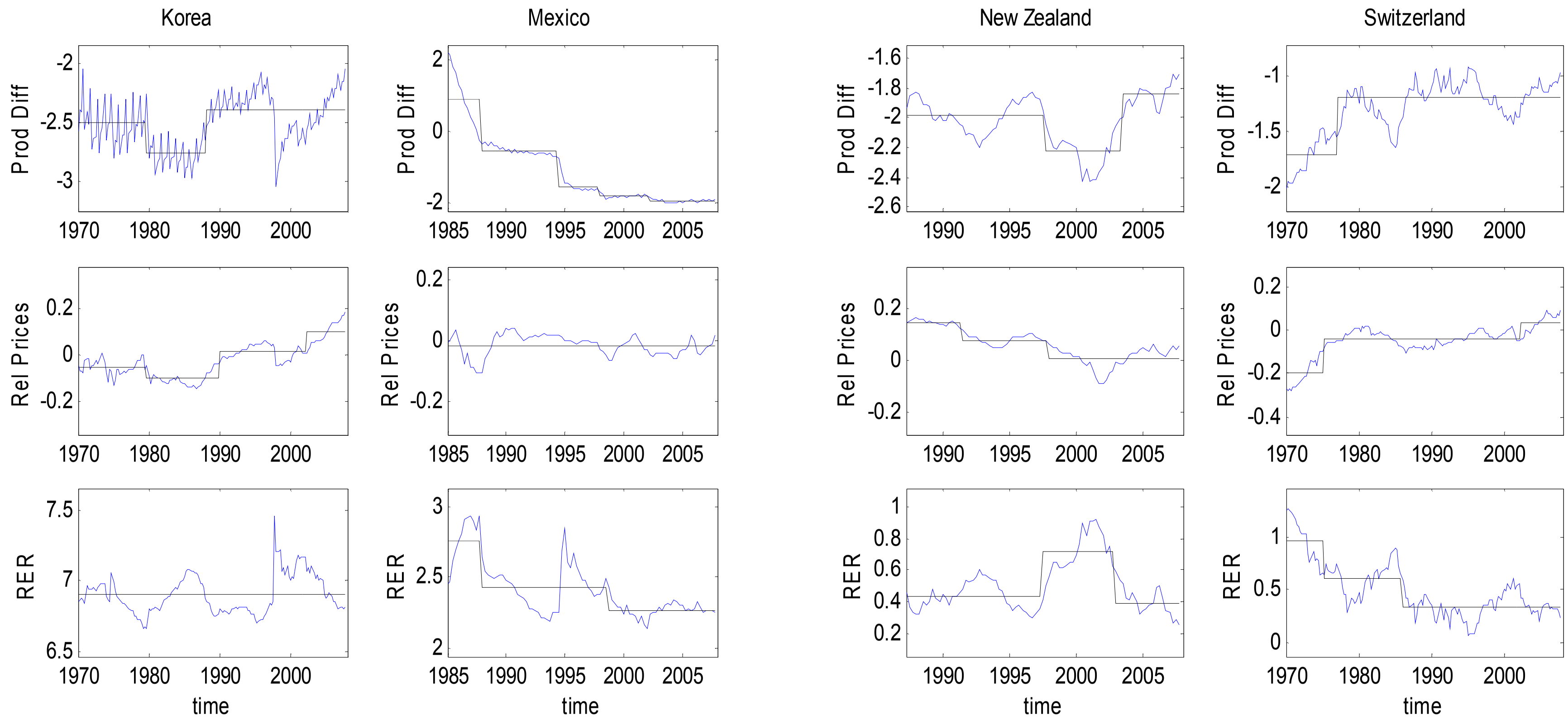


Figure 2.1 Structural Breaks: Productivity Differentials, Relative Non-tradable Prices and Real Exchange Rates (cont'd)

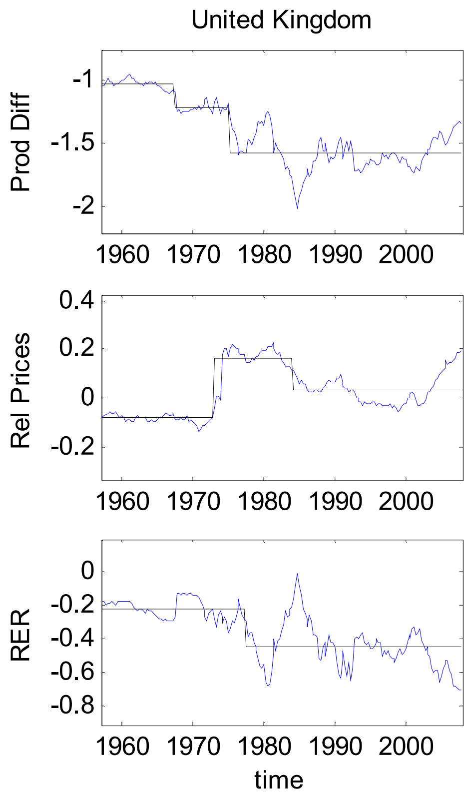


Figure 2.2 Structural Breaks after Controlling for the Government Expenditure

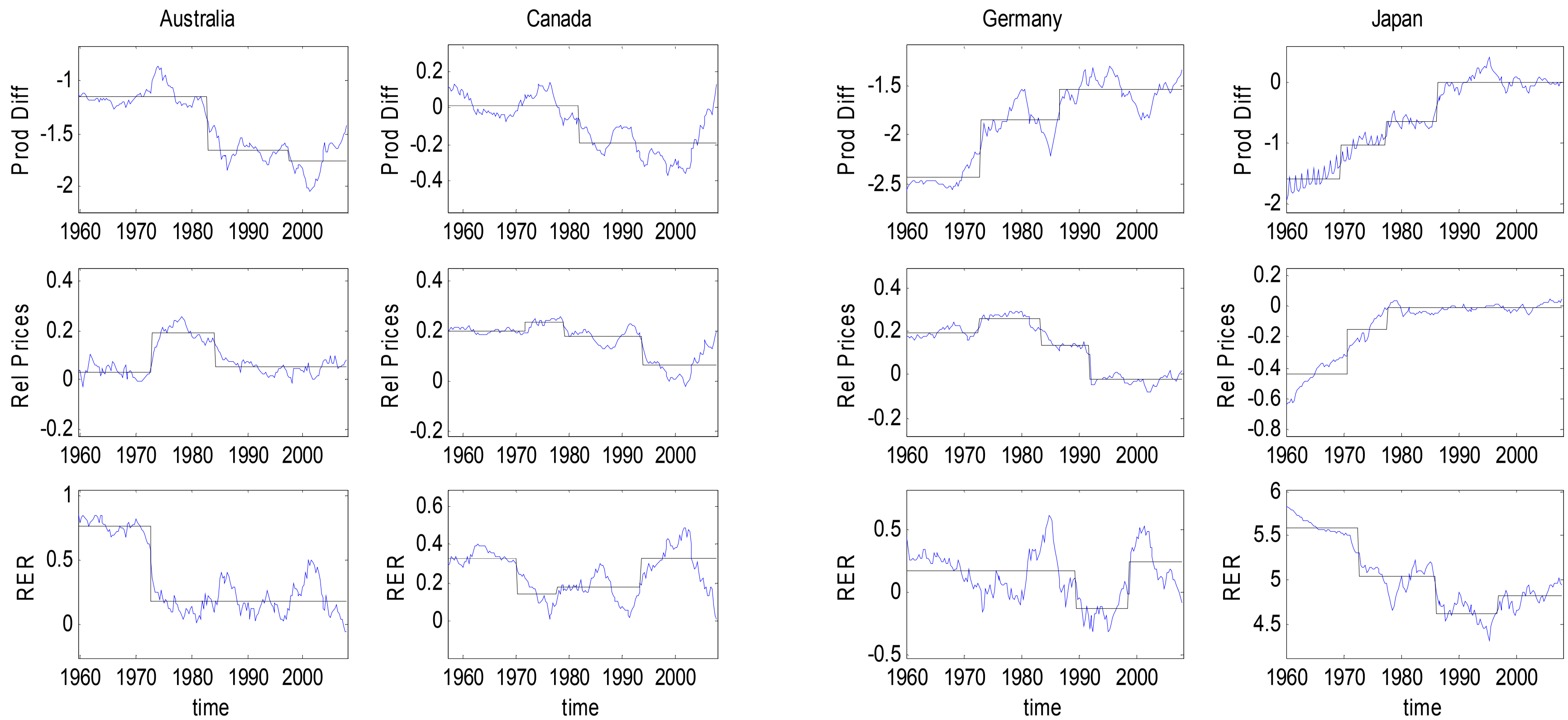


Figure 2.2 Structural Breaks after Controlling for the Government Expenditure (cont'd)

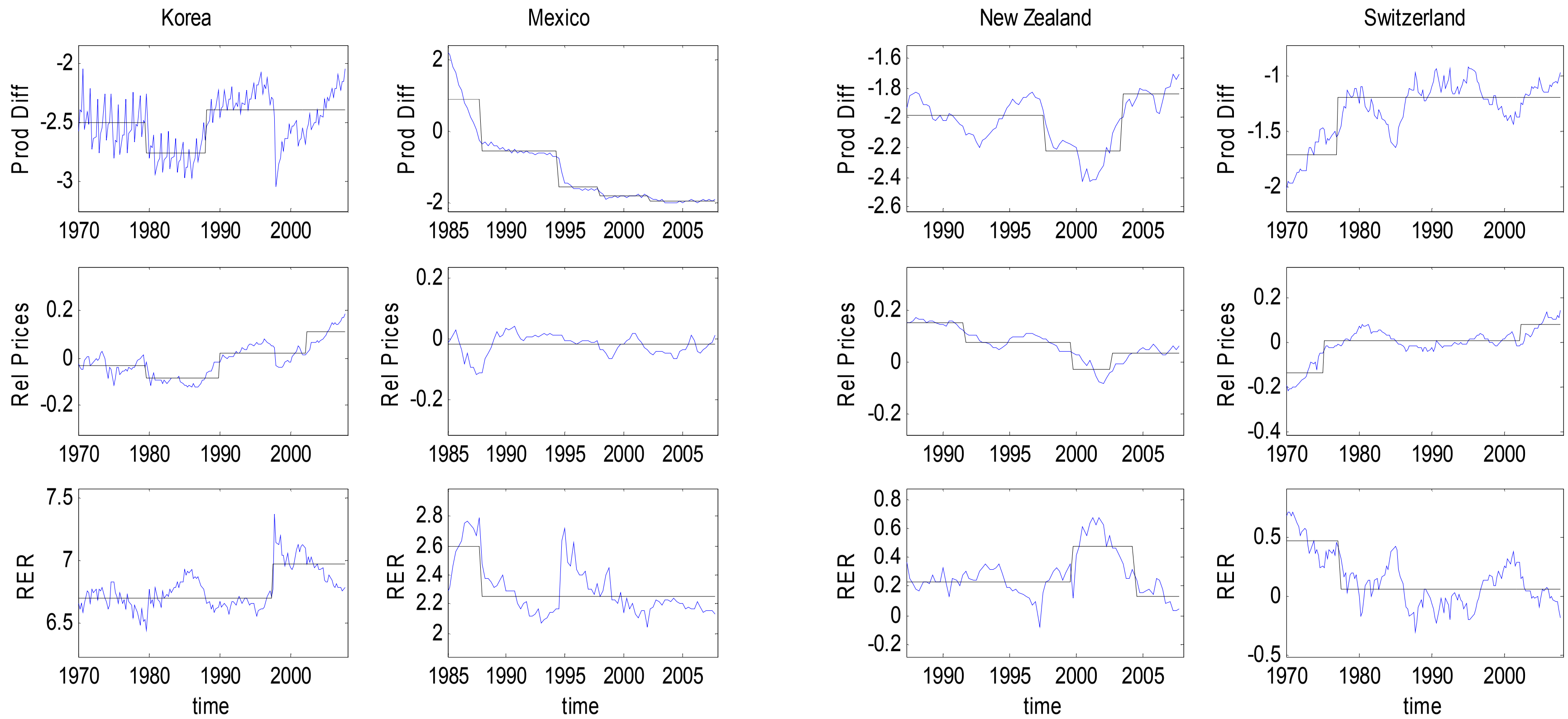


Figure 2.2 Structural Breaks after Controlling for the Government Expenditure (cont'd)

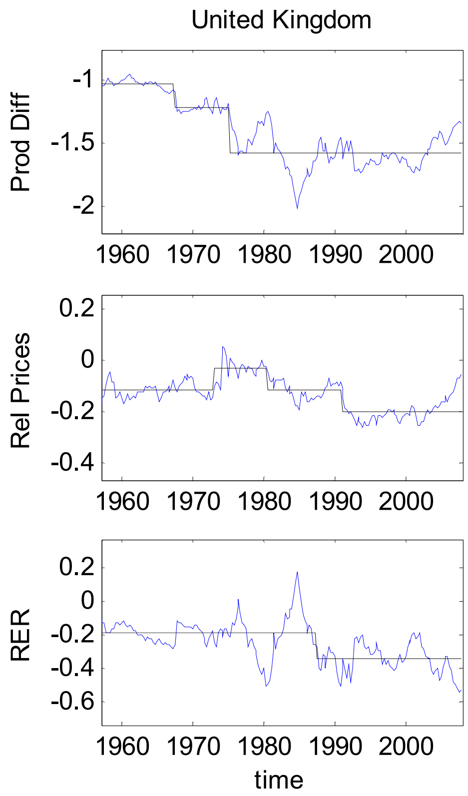
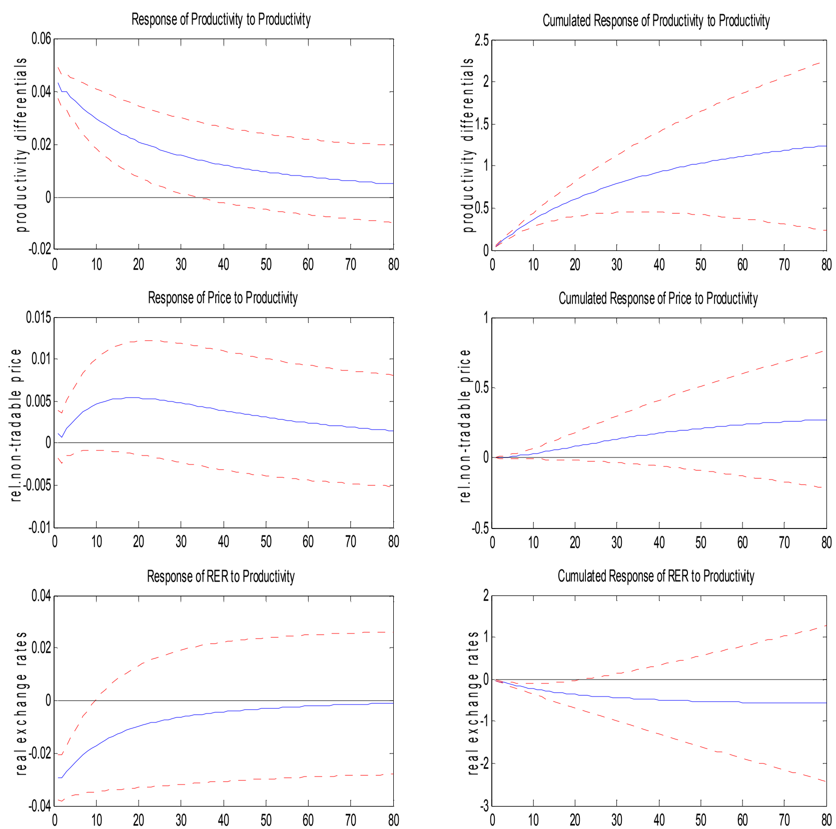
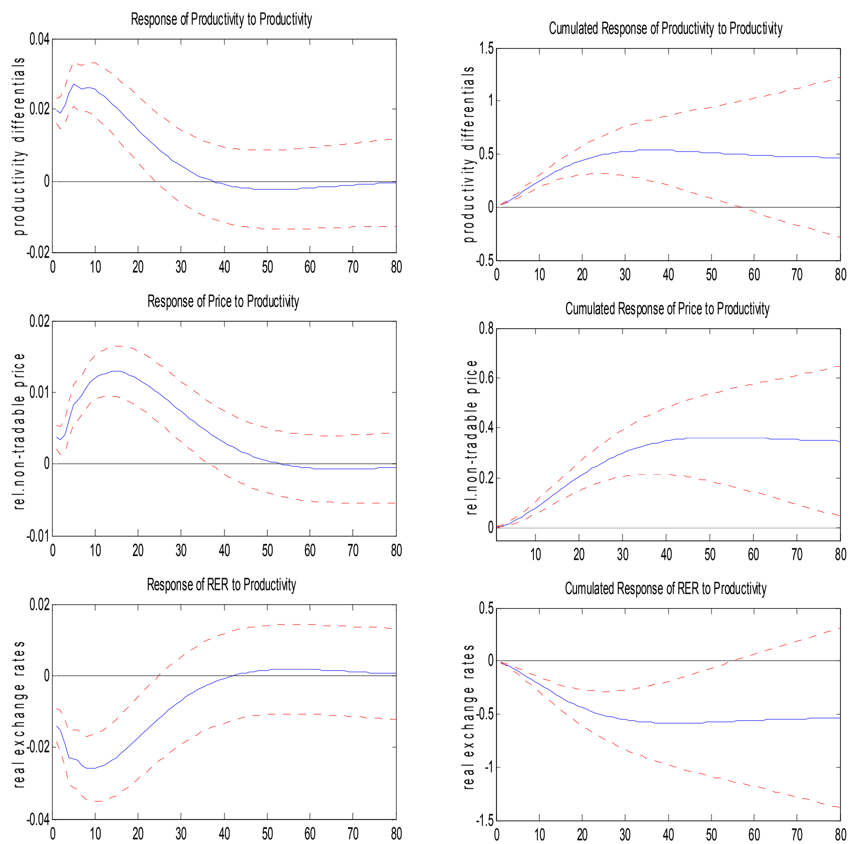


Figure 2.3 Impulse Responses and Cumulated Impulse Responses – VAR-GARCH Model

Panel A: Australia



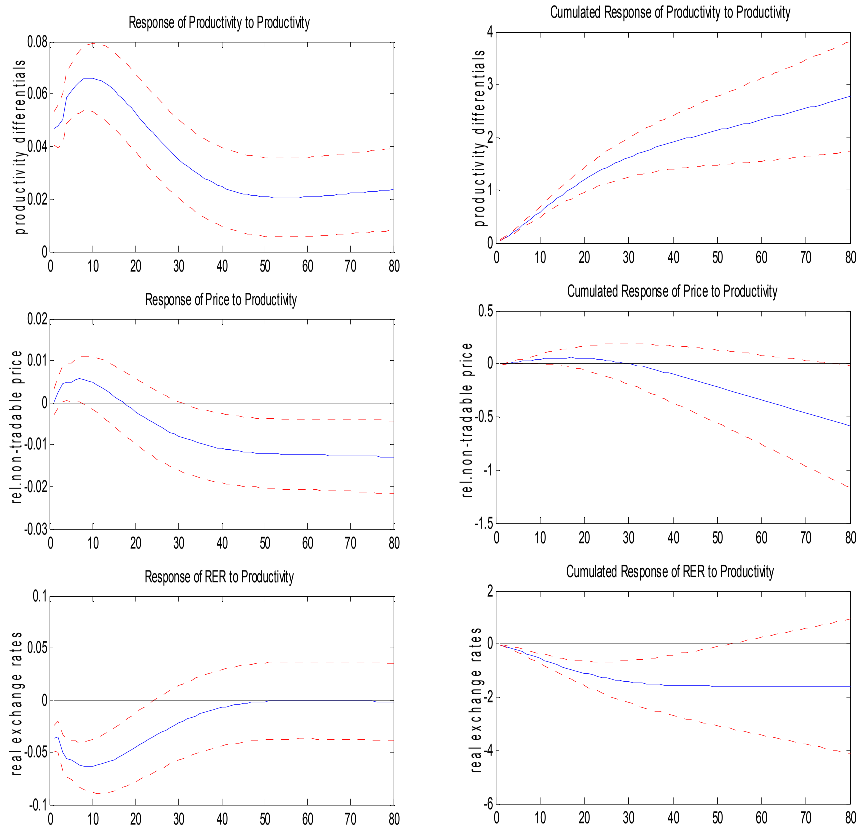
Panel B: Canada



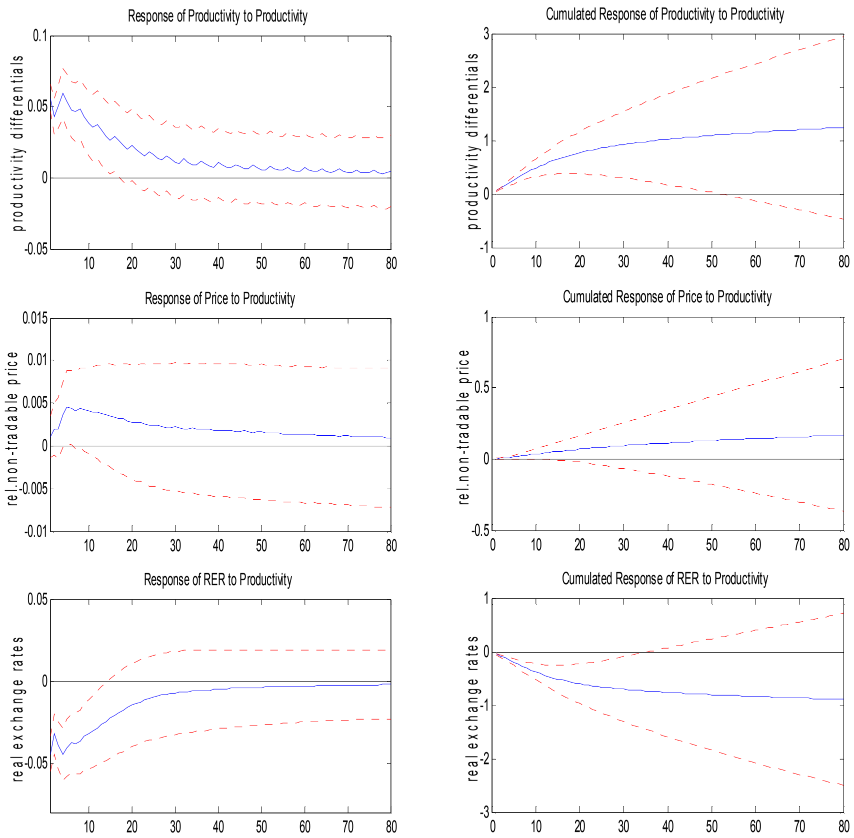
The dotted lines represent 95% confidence interval base on 1000 replications

Figure 2.3 Impulse Responses and Cumulated Impulse Responses – VAR-GARCH Model

Panel C: Germany



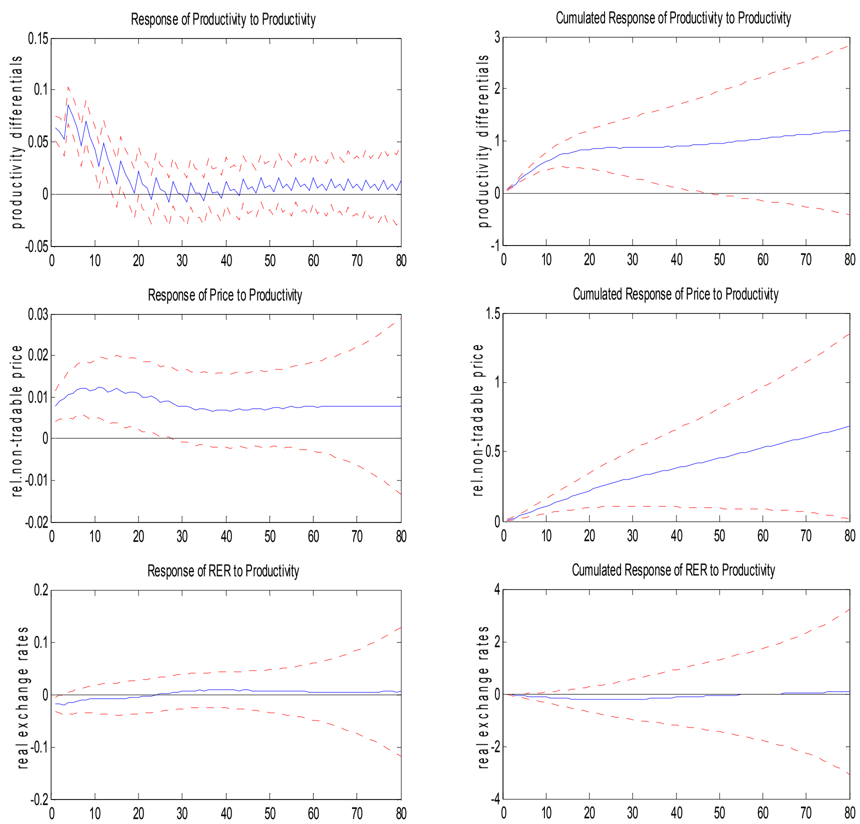
Panel D: Japan



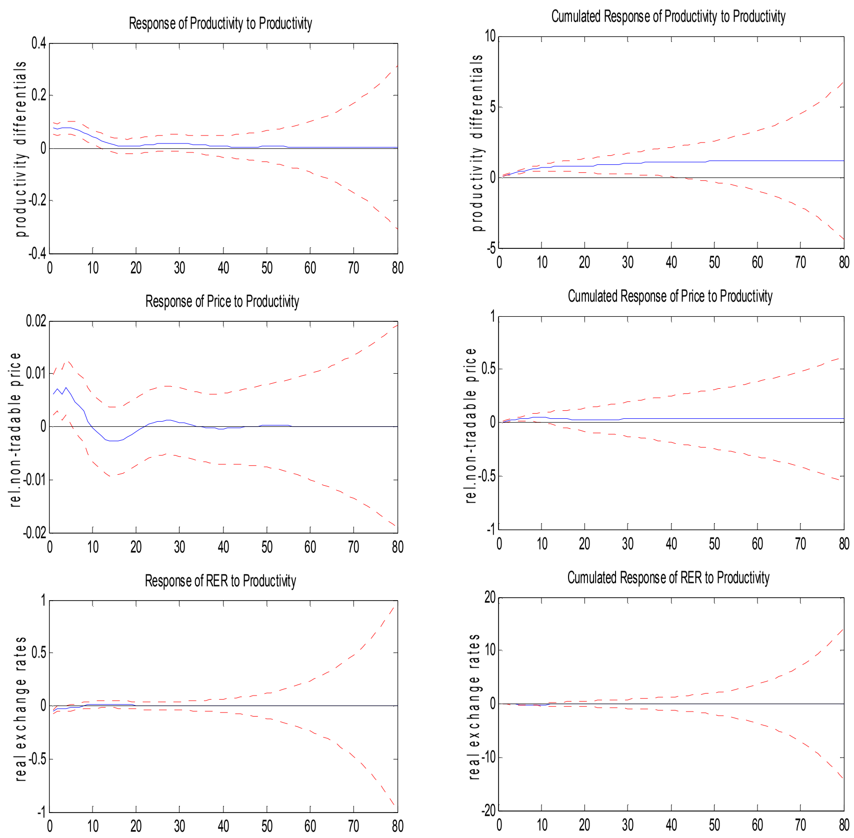
The dotted lines represent 95% confidence interval base on 1000 replications

Figure 2.3 Impulse Responses and Cumulated Impulse Responses – VAR-GARCH Model

Panel E: Korea



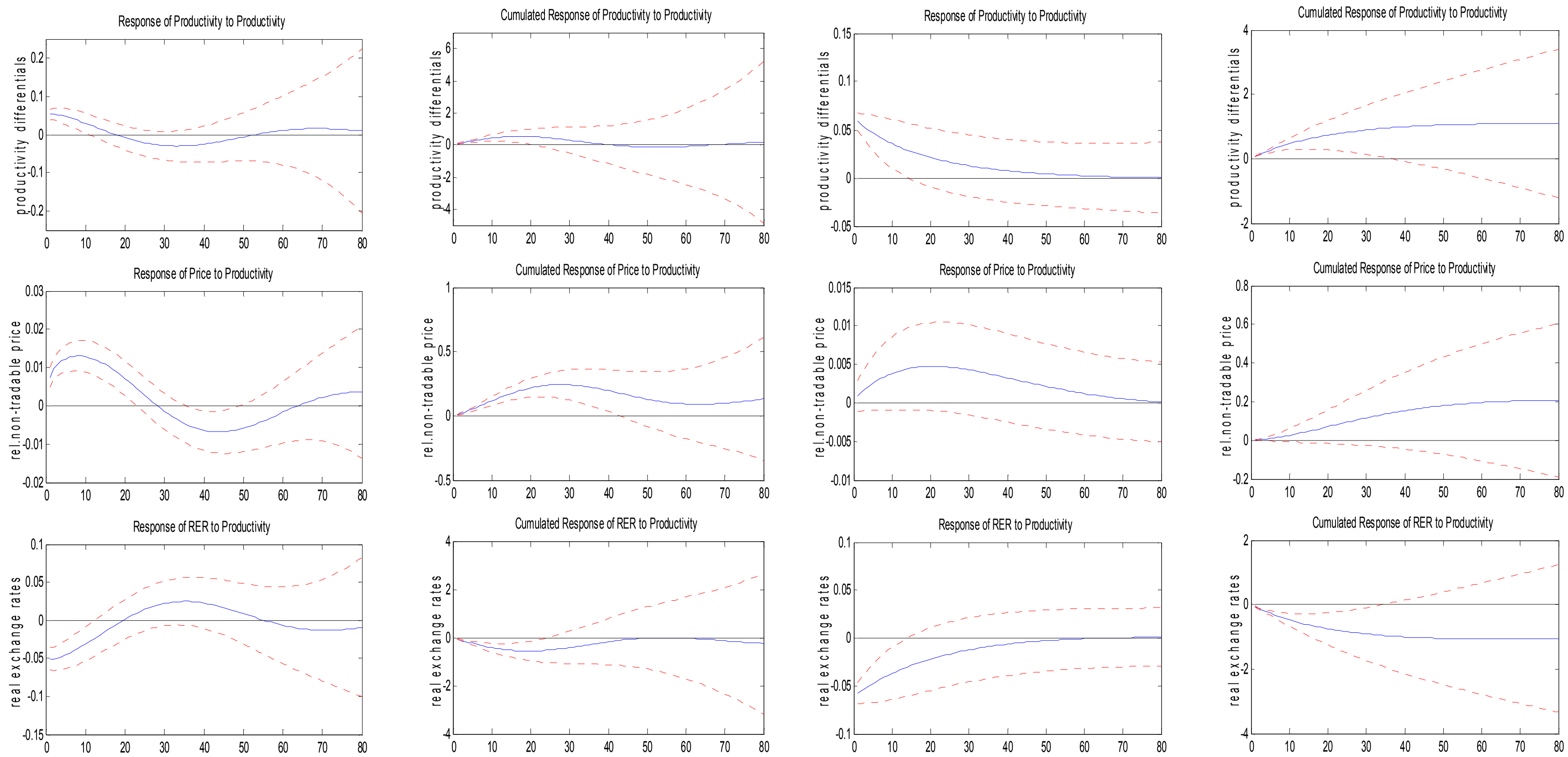
Panel F: Mexico (VAR)



The dotted lines represent 95% confidence interval base on 1000 replications

Figure 2.3 Impulse Responses and Cumulated Impulse Responses – VAR-GARCH Model

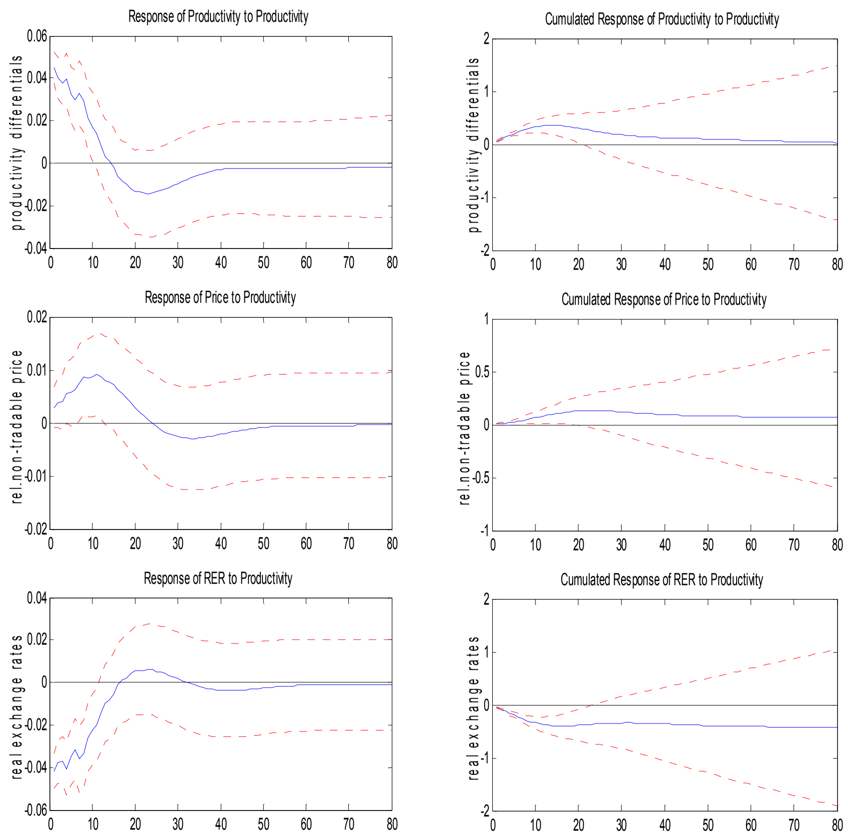
Panel G: New Zealand **Panel H: Switzerland**



The dotted lines represent 95% confidence interval base on 1000 replications

Figure 2.3 Impulse Responses and Cumulated Impulse Responses – VAR-GARCH Model

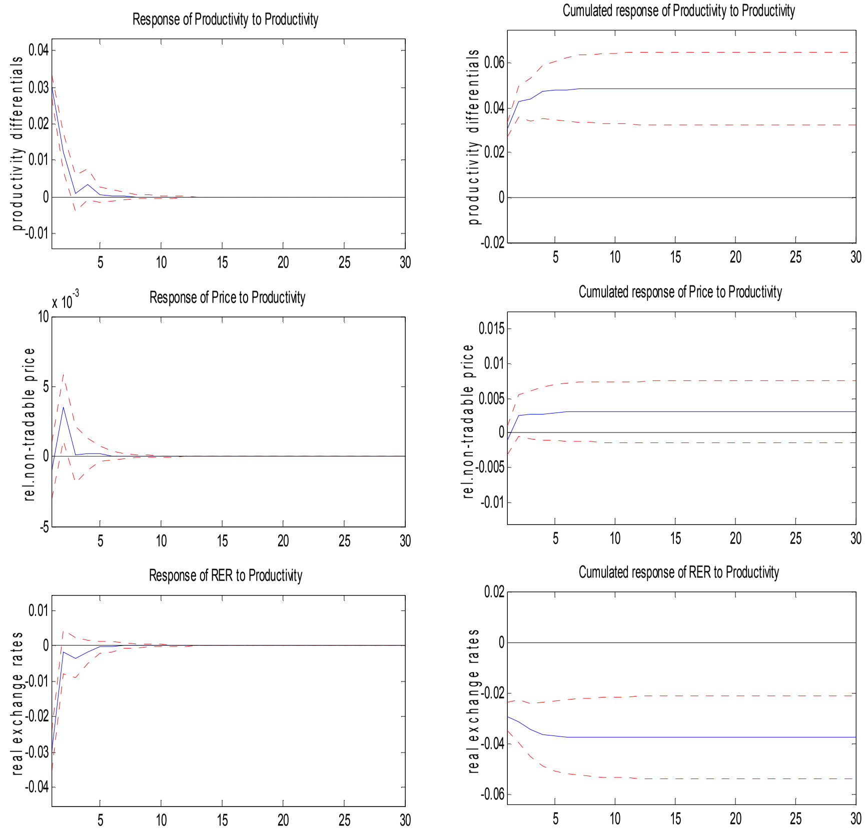
<u>Panel G: UK</u>



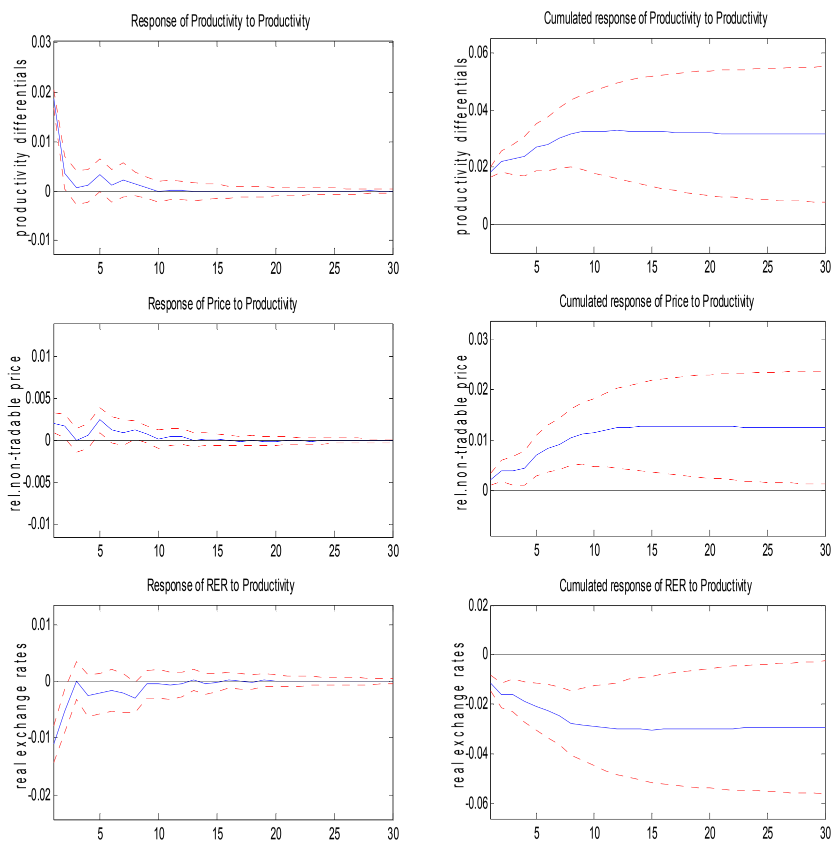
The dotted lines represent 95% confidence interval base on 1000 replications

Figure 2.4 Impulse Responses and Cumulated Impulse Responses – First-Differenced VAR Model

Panel A: Australia



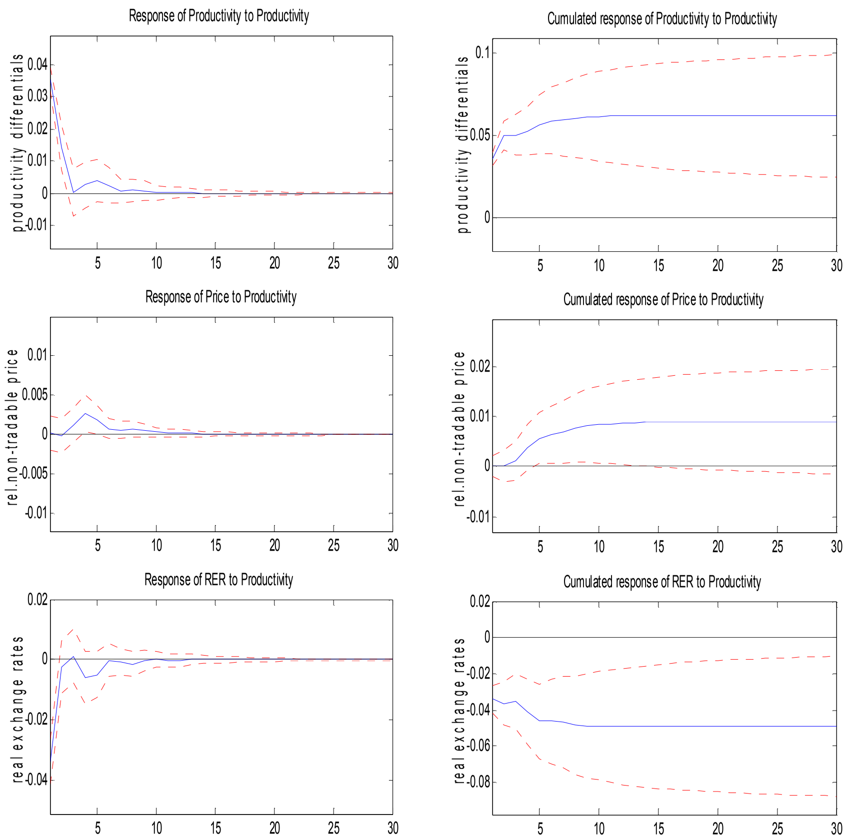
Panel B: Canada



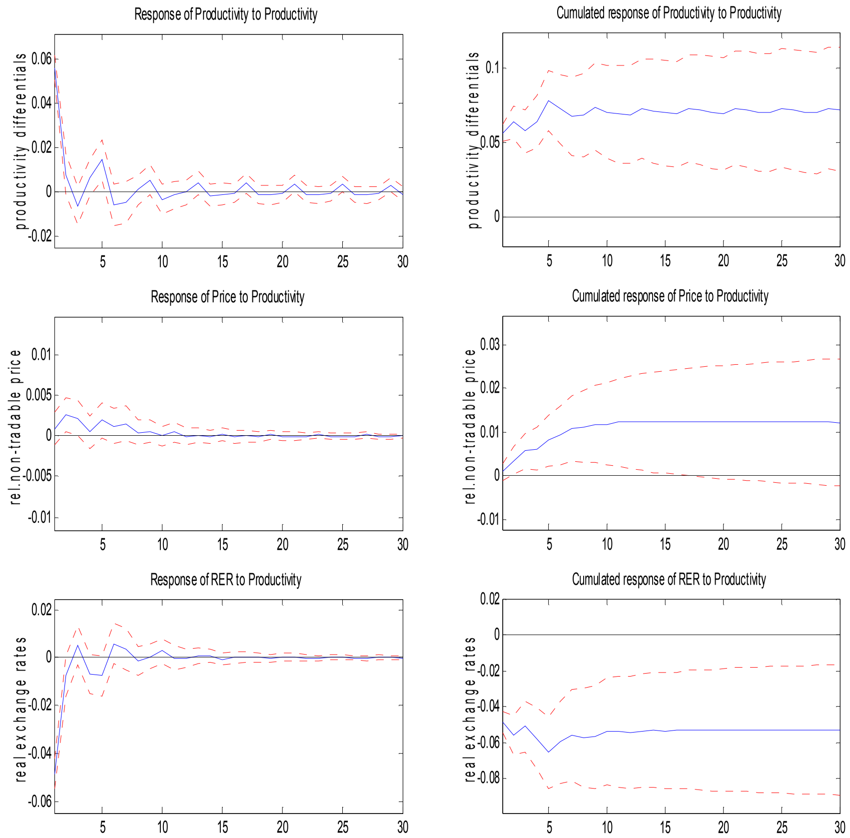
The dotted lines represent 95% confidence interval base on 1000 replications

Figure 2.4 Impulse Responses and Cumulated Impulse Responses – First-Differenced VAR Model

Panel C: Germany



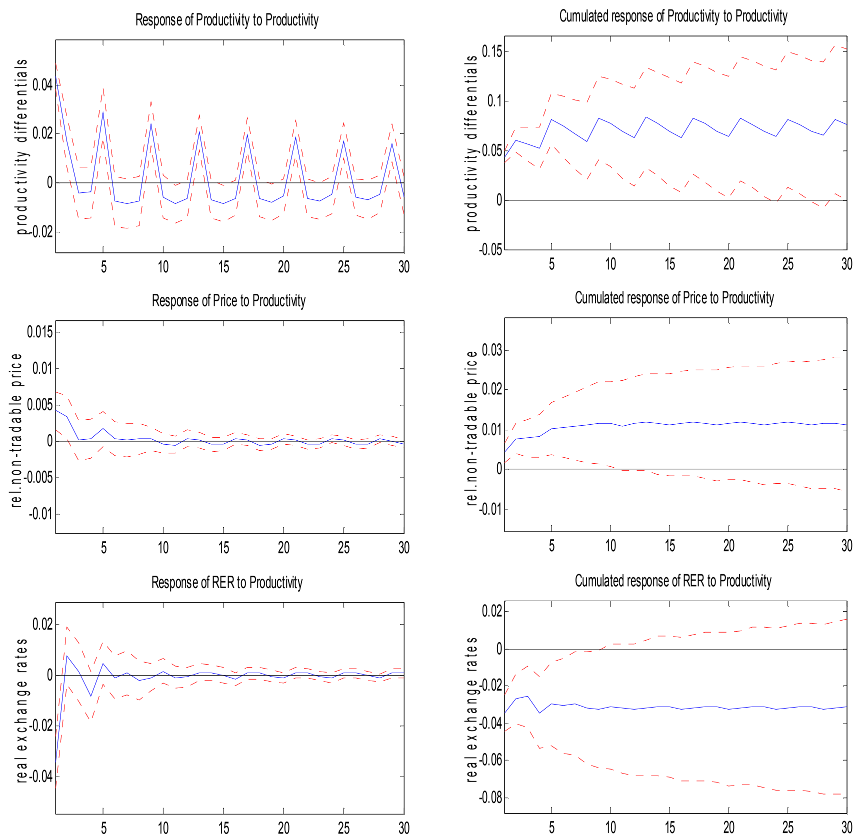
Panel D: Japan



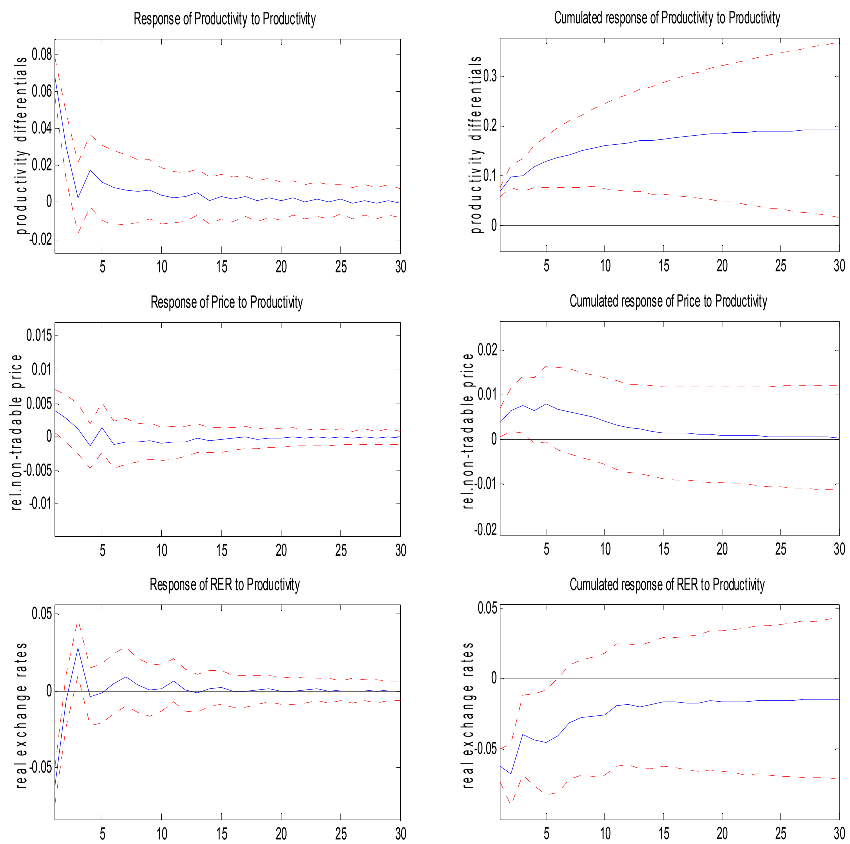
The dotted lines represent 95% confidence interval base on 1000 replications

Figure 2.4 Impulse Responses and Cumulated Impulse Responses – First-Differenced VAR Model

Panel E: Korea



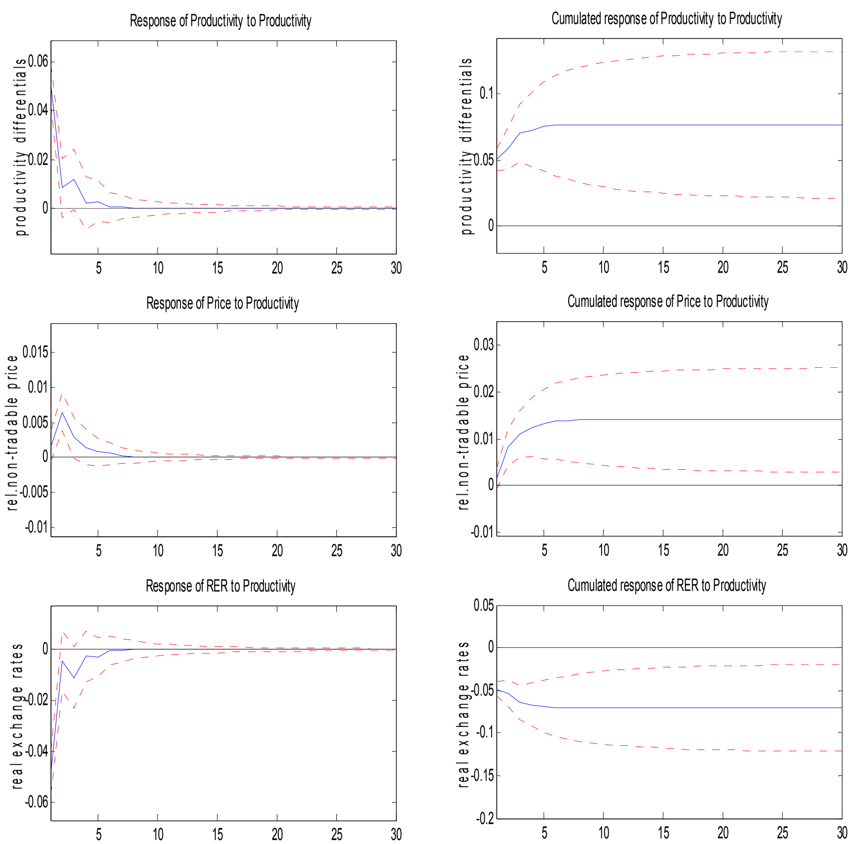
Panel F: Mexico



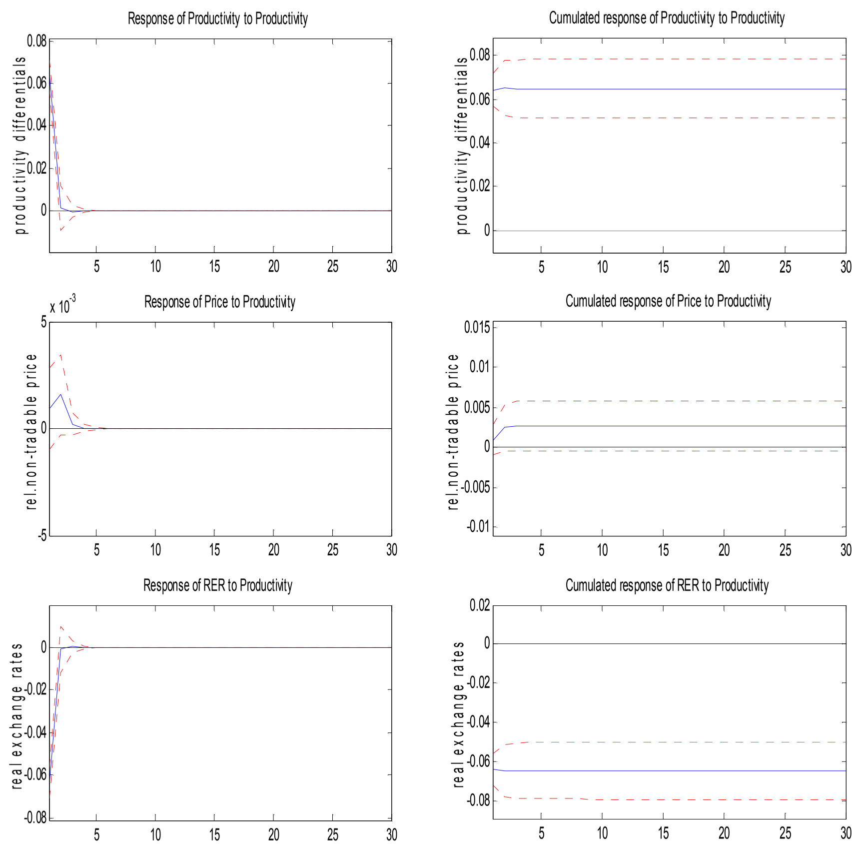
The dotted lines represent 95% confidence interval base on 1000 replications

Figure 2.4 Impulse Responses and Cumulated Impulse Responses – First-Differenced VAR Model

Panel G: New Zealand



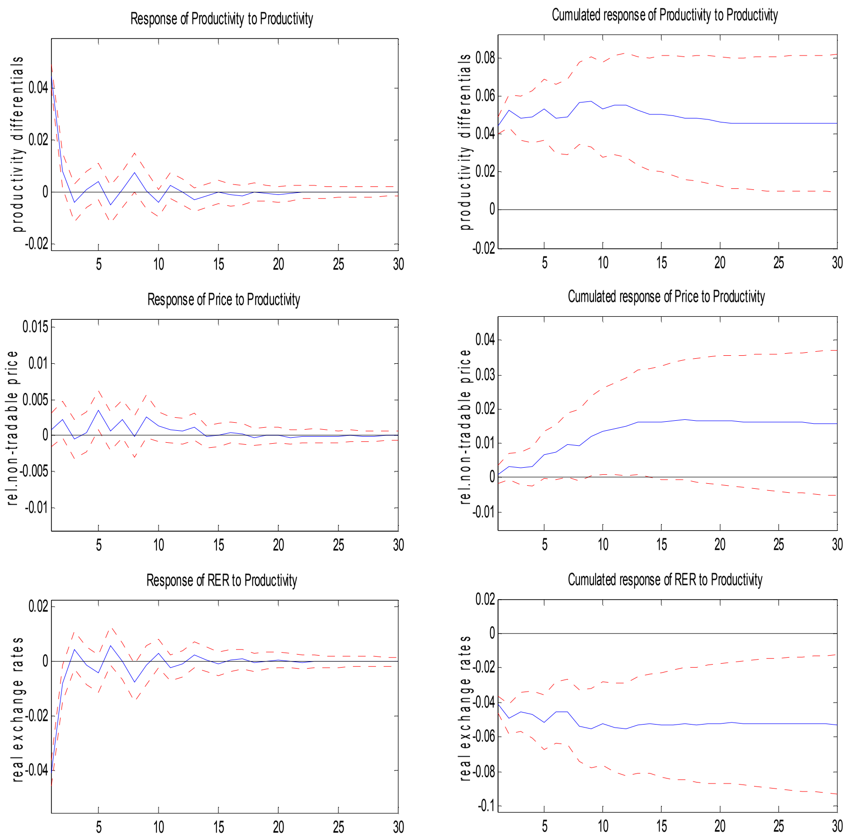
Panel H: Switzerland



The dotted lines represent 95% confidence interval base on 1000 replications

Figure 2.4 Impulse Responses and Cumulated Impulse Responses – First-Differenced VAR Model

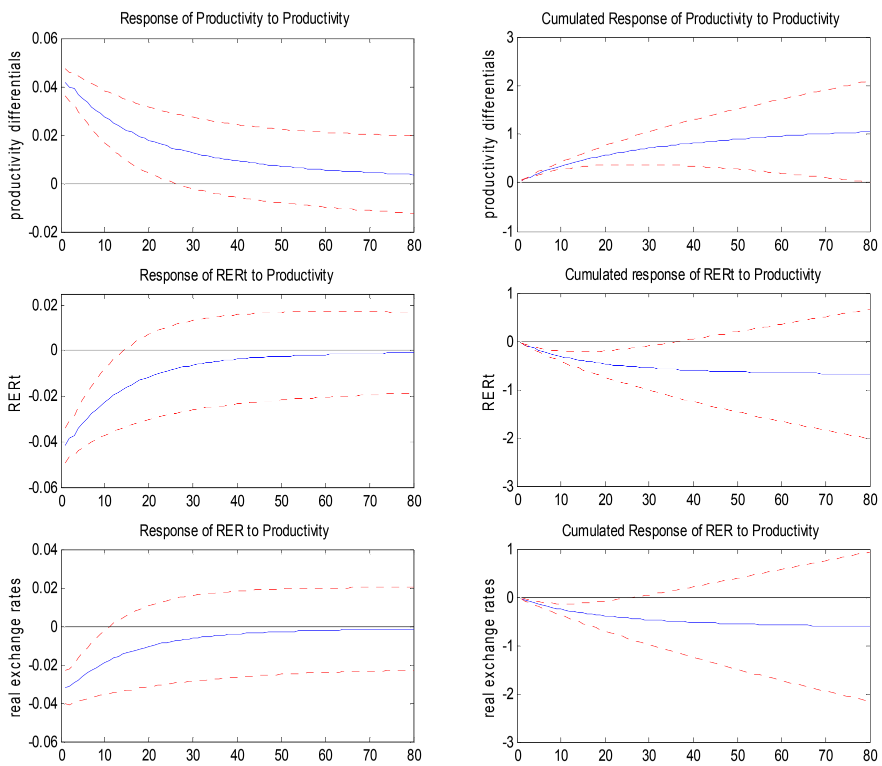
Panel I: UK



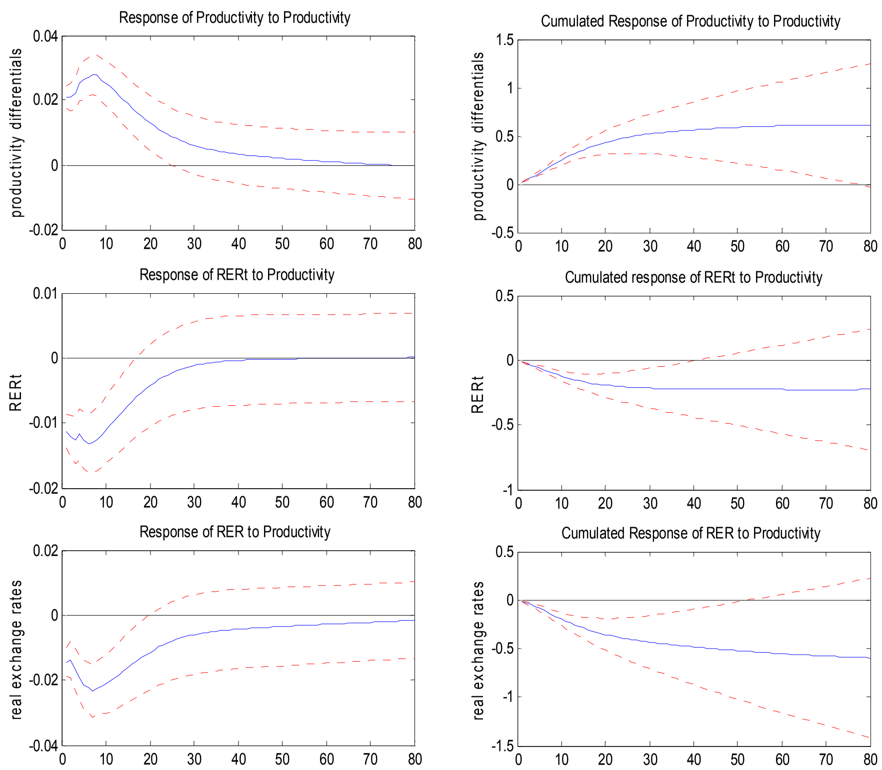
The dotted lines represent 95% confidence interval base on 1000 replications

Figure 2.5 Impulse Responses and Cumulated Impulse Responses – Real Exchange Rate of Tradable Goods as a Channel of Transmission

Panel A: Australia



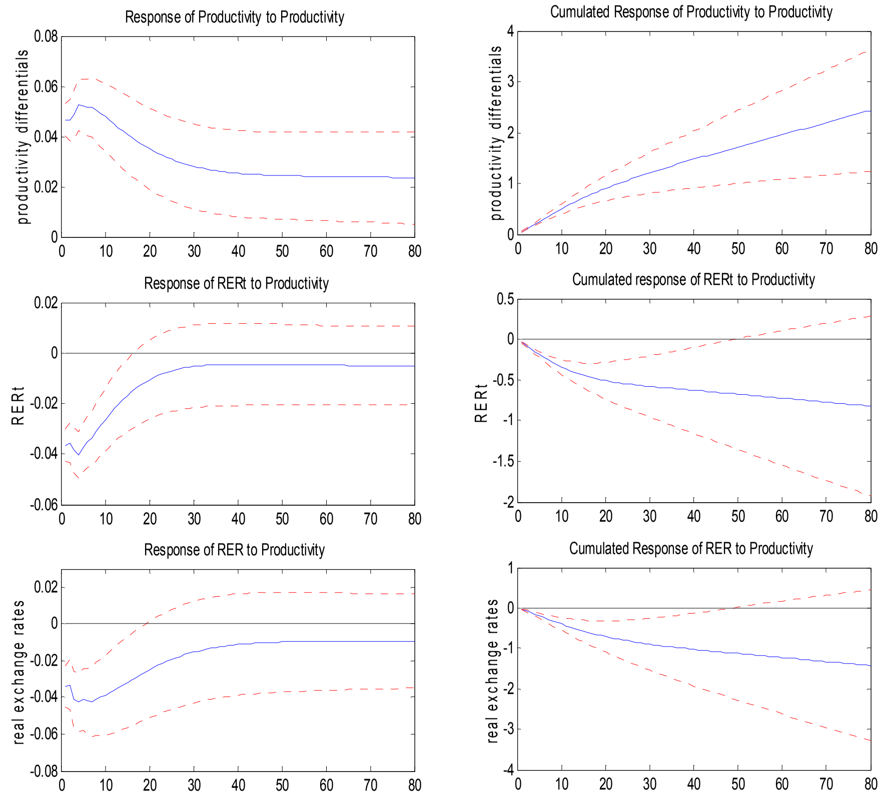
Panel B: Canada



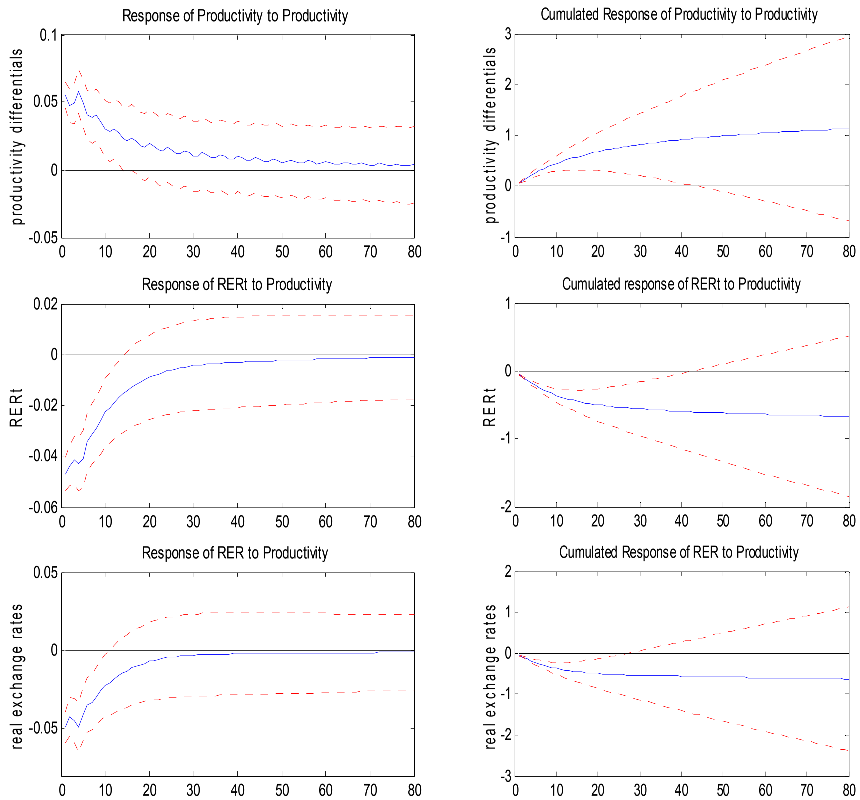
The dotted lines represent 95% confidence interval base on 1000 replications

Figure 2.5 Impulse Responses and Cumulated Impulse Responses –Real Exchange Rate of Tradable Goods as a Channel of Transmission

Panel C: Germany



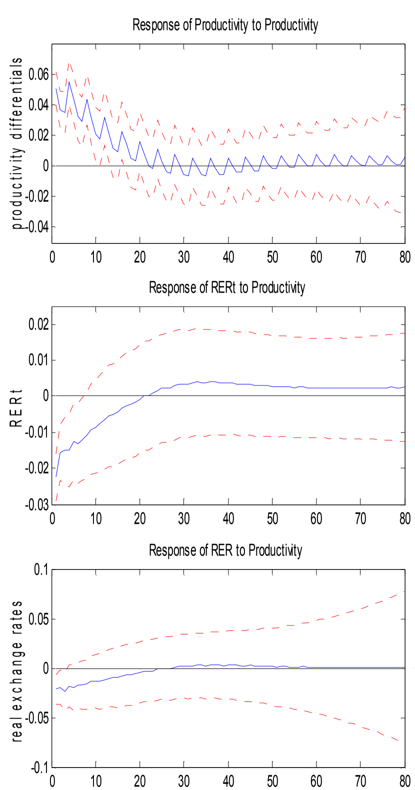
Panel D: Japan



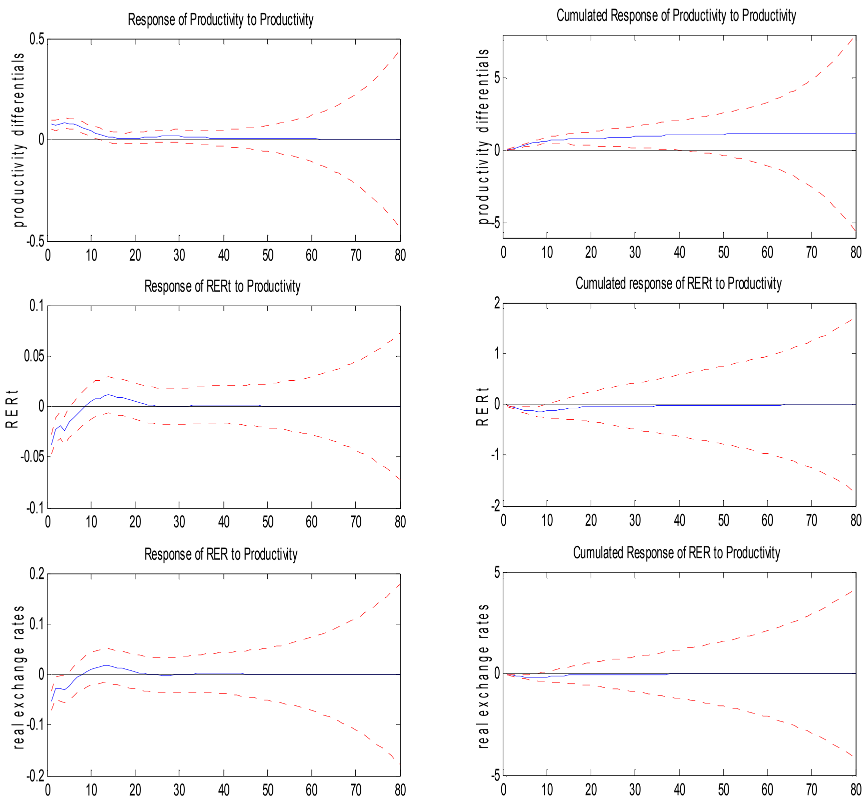
The dotted lines represent 95% confidence interval base on 1000 replications

Figure 2.5 Impulse Responses and Cumulated Impulse Responses –Real Exchange Rate of Tradable Goods as a Channel of Transmission

Panel E: Korea



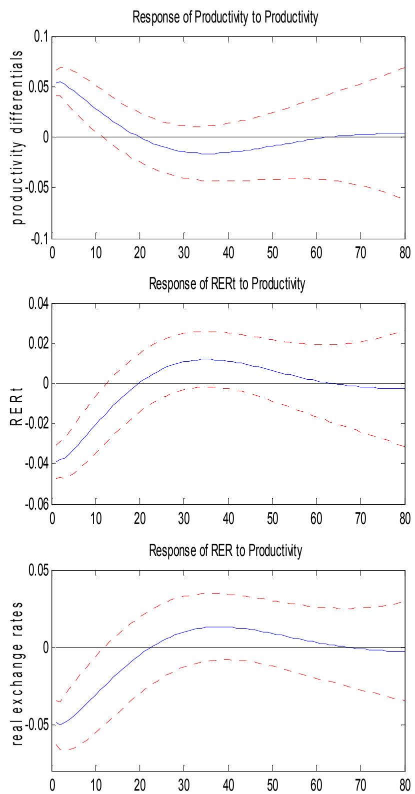
Panel F: Mexico



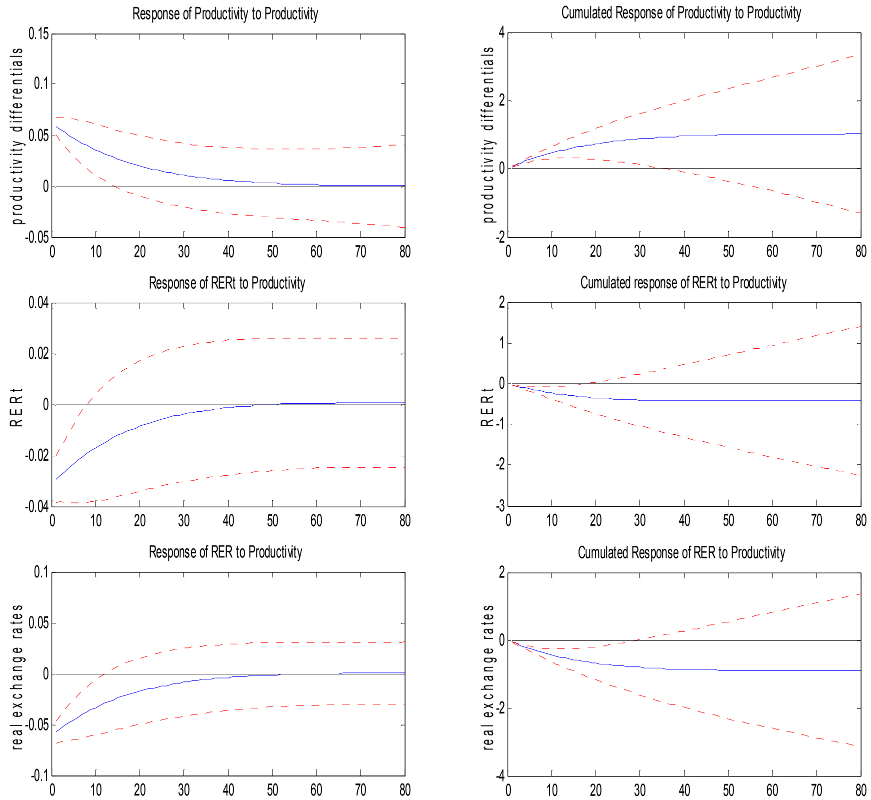
The dotted lines represent 95% confidence interval base on 1000 replications

Figure 2.5 Impulse Responses and Cumulated Impulse Responses –Real Exchange Rate of Tradable Goods as a Channel of Transmission

Panel G: New Zealand



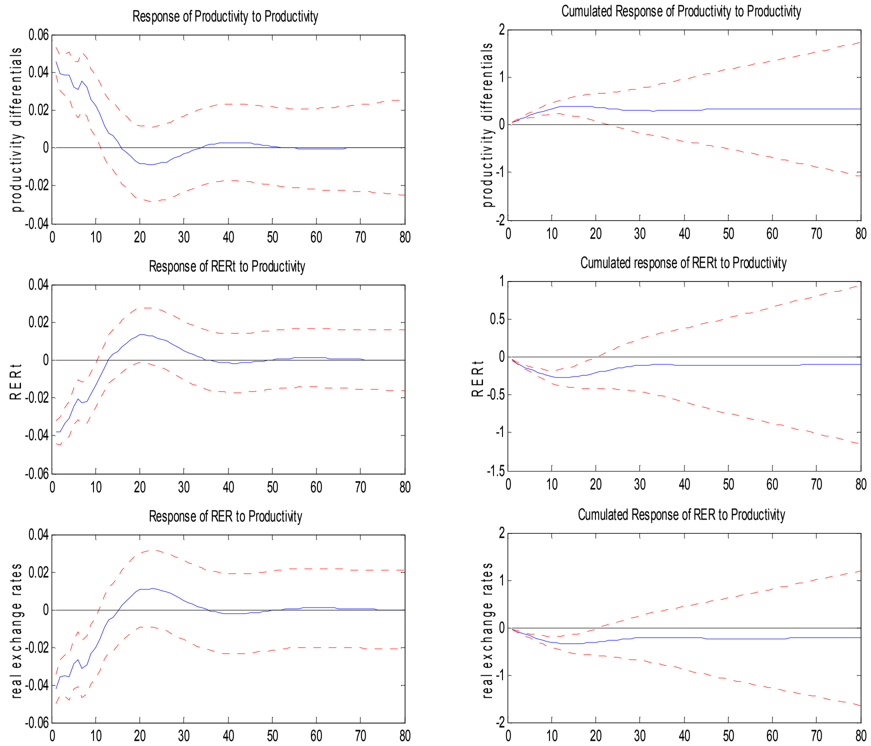
Panel H: Switzerland



The dotted lines represent 95% confidence interval base on 1000 replications

Figure 2.5 Impulse Responses and Cumulated Impulse Responses –Real Exchange Rate of Tradable Goods as a Channel of Transmission

Panel I: UK



The dotted lines represent 95% confidence interval base on 1000 replications

Chapter 3

The Fisher effect: Evidence from nine OECD countries

3.1 Introduction

Fisher (1930) suggested that the relationship between nominal interest rates and expected inflation can be represented by an identity in which the two variables move in a one-to-one manner. Regarded as one of the building blocks in the field of international economics, the Fisher hypothesis has been widely used in both theoretical economic modeling and policy decision making. For decades, the interest of studying the relationship between inflation and nominal interest rates has remained intense and new research works on the subject matter are bringing new insight to the literature. In the mean time, the empirical techniques employed by scholars have also been evolving with the development of new econometric methodologies. Early empirical work such as Fama (1975) and Summers (1983) applied least square method to investigate the Fisherian link. After Nelson and Plosser (1982), there was more and more concern about the unit root behavior of many macroeconomic time series. Based on the evidence from unit root tests, most later empirical works such as Evans and Lewis (1995), Crowder and Hoffman (1996) and Koustas and Serletis (1999) treated inflation and nominal rates as non-stationary. Consequently, they applied cointegration techniques in their studies. Even though the cointegration approach has been the mainstream methodology used, there are other scholars suspicious of considering the time series as a unit root process. The reason is that conventional unit root tests have low power, so the findings from these tests may not reveal the true underlying behavior of these variables. For instance, Lanne (2001) and Atkins and Coe (2002) used empirical techniques which consider the possibility that inflation and nominal rates are indeed stationary.

In this paper, I examine the Fisherian link for a sample of nine OECD countries which include Australia, Canada, Germany, Japan, Korea, Mexico, New Zealand, Switzerland and the United Kingdom. This sample includes countries from different regions of the world and also data is available. Instead of using the conventional approach, I study the relationship between inflation and nominal rates by two empirical methods. First, I consider the Darby (1975) effect and construct tax-adjusted real interest rates for each country. Subsequently, I employ the Bai and Perron (1998, 2003) method to see whether there are major shifts in real rates. If the Fisher hypothesis holds, the real rates should be stable for the whole time period. The results indicate that shifts in real rates are found for all countries in the sample except Switzerland. In order to determine the validity of the Fisher hypothesis, I investigate the factors which may have caused these major shifts. In this regard, I follow the literature and consider determinants such as government spending and real oil prices. In addition, I also examine if changes in US Fed regime have a worldwide impact on real rates of the other countries. The results indicate limited explanatory power for government expenditure and energy prices. However, the Fed regimes do account for many of the real rate shifts. Since some previous studies suggest that major shifts in real rates could be attributed to unmatched variations in inflation, it is imperative to check if the shifts in real rates are due to the failure of one-to-one relationship between the variables. I investigate whether changes in inflation impact the real rates. My findings reveal this possibility for four of the countries in the sample.

In the second part of my paper, I examine the dynamic relationship between inflation and tax-adjusted nominal rates by a VAR model. From the mixed results of different unit root tests, it is doubtful to treat the time series as non-stationary. Since the Fisher hypothesis is a relationship between the level of inflation and nominal rates, I use a VAR model in levels. Due to the presence of conditional heteroskedasticity, I include a GARCH effect in the model. To avoid unnecessary off-diagonal restrictions, I employ a BEKK formulation (Engle and Kroner 1995) for the variance-covariance process. The computed impulse responses indicate that tax-adjusted nominal rates have very limited response to positive inflation shock. To check if these restricted responses are due to inappropriate tax adjustment, I repeat the estimations by replacing the tax-adjusted nominal rates with unadjusted nominal rates. Considering the results from both empirical approaches, only Canada and Switzerland follow closely with the Fisher hypothesis.

The subsequent sections will be organized as follows. Section 2 is a brief literature review. Section 3 describes the structural break analyses and interprets the results. Section 4 examines the dynamic relationship between inflation and nominal rates. In the final section, I conclude the paper.

3.2 Literature Review

The Fisher hypothesis is a well known foundation in international economics and has been widely used in both economic modeling and policy decision making. Despite its ubiquitous applications, the hypothesis remains a controversy in view of the tremendous research effort which has been put on it. Among these empirical studies, two things are characterizing the literature. First, the findings on whether the Fisher hypothesis is valid are mixed. Second, the empirical approach employed has been changing with the development of new econometric methods.

Fama (1975) and Summers (1983) are early papers that examined the relationship between nominal interest rates and inflation. While both papers had applied the least square method and treated nominal rates as a predictor of expected inflation using US data, they drew different conclusions on the validity of the hypothesis. Fama found that the Fisherian link seemed to hold for the US from 1953 to 1971. However, Summers suggested that the link between nominal rates and inflation was small and all the power of relationship comes from the period 1965 to 1971.

With the challenge of Nelson and Plosser (1982) that many macroeconomics time series are non-stationary, alternative empirical methods were used in examining the Fisher hypothesis. Rose (1988) used different measures of nominal interest rates and inflation for two sample periods: 1892 to 1970 and 1901 to 1950. The author found that US real interest rates were not stationary and the findings are robust to the data used. In another study, Mishkin (1992) used monthly US data from 1953 to 1990 and employed the Engle and Granger (1987) technique. His results supported the presence of a long term Fisher effect. Taking the nominal rates and inflation as unit root processes, Evans and Lewis (1995) investigated the effect of inflation on nominal interest rates by using the dynamic ordinary least square method (DOLS). Their findings rejected the one-to-one relationship between the variables. In subsequent section of the paper, the authors showed, however, that if economic agents formed their expectation on inflation with consideration of structural breaks, the Fisher effect would hold. Using quarterly data of the US, Crowder and Hoffman (1996) studied the link between tax-adjusted nominal rates and inflation by applying the Johansen (1988) method. They found that there existed a one-to-one relationship between the variables during the period from 1951 to 1991.

Though most of the previous works have been focused on the US, there are papers which cover other countries as well. Koustas and Serletis (1999) collected post-war quarterly data and examined the Fisher hypothesis for the US, Japan and eight other European countries. They found that inflation and nominal rates were unit root processes, however, their evidence did not support any cointegration relationship between the time series. Alternatively, they employed a first-differenced VAR model, though the results again denied the hypothesis. Madsen (2005) investigated the Fisherian link by using a panel of 14 OECD countries. The author suggested that the failure of previous works in finding the one-to-one relationship between nominal rates and inflation was due to their omission of accommodating supply variables in the model. As a result, the coefficient of the expected inflation would bias downward. Although the paper did show that the coefficient associated with inflation increased when supply variables were included, the size of the coefficient was still far below the hypothesized value.

With the development of new empirical methods, some recent papers questioned the appropriateness of using cointegration technique. The findings of unit root behavior for the inflation and nominal rates may be a result of the low power of conventional unit root tests. In response to this ambiguity, some authors rely on empirical methods which do not require non-stationarity of the related variables. Lanne (2001) estimated an inflation forecasting equation by taking the nominal interest rate as the independent variable. In particular, he conducted empirical tests on the estimated coefficient by using confidence intervals which are asymptotically valid no matter whether the regressor is stationary or not. His findings support the Fisher hypothesis for the US during the pre-1979 period but not afterwards. In another work, Atkin and Coe (2002) test the validity of the Fisher hypothesis for Canada and the US by using the bounds test developed by Pesaran, Shin and Smith (2001). Their findings are in favor of the hypothesis. Using a panel of 20 OECD countries, Westerlund (2008) developed and implemented two panel cointegration tests which are robust even in the presence of stationary regressors. The author claimed that these tests consider cross-sectional data dependency and have high power compared with the conventional techniques. His findings are supportive of the hypothesis.

In this paper, I do not rely on cointegration techniques but employ two alternative empirical approaches to examine the Fisher hypothesis. While the first approach investigates the presence of structural breaks of real interest rates for the nine OECD countries, the second approach focus on the dynamic relationship between inflation and nominal interest rates. As for the latter, I consider in my empirical model a GARCH effect which has been omitted in most previous studies.

3.3 Structural Breaks of Real Interest Rates

The Fisher hypothesis maintains that there is a one-to-one relationship between nominal interest rates and expected inflation. If this is the case, real interest rates, which are the difference between nominal interest rates and expected inflation, will remain stable over time. In this paper, I consider a sample of nine OECD countries[25] and use quarterly data for subsequent examination. The nominal interest rates are measured by the short-term Treasury bill rates. Due to data availability, the government bond yields are used for Australia and Korea while the financing bill rate is taken in the case of Japan. The inflation rate is computed from the quarterly CPI and is annualized. The time frame of data varies with the countries and ranges from 1985Q1 to 2008Q2 (Mexico) to 1957Q2 to 2008Q2 (Australia, Canada, Japan and UK). The source of data is from the International Financial Statistics. To account for the Darby (1975) effect, I computed tax-adjusted real interest rates for each country. I follow Rapach and Wohar (2005) and Caporale and Grier (2005) and use the marginal tax rates reported in Padovano and Galli (2001) for the calculations. Since Korea and Mexico are not included in Padovano and Galli (2001), I follow

[25] The countries include Australia, Canada, Germany, Japan, Korea, Mexico, New Zealand, Switzerland and the United Kingdom.

Mankiw (1987) and Koustas and Serletis (1999) and use the tax revenue as a percentage of GDP as a measure of the average tax rate. Subsequently, the tax-adjusted real interest rates[26] for these countries are constructed.

In order to check how well the Fisher hypothesis fits the real world, I apply Bai and Perron (1998, 2003) (hereafter, BP) methodology to estimate the structural breaks of tax-adjusted real interest rates[27] for the nine OECD countries. If the proposition holds, the real rate should be steady over the entire time horizon.

Table 1 reports the results of estimated structural breaks after applying the BP method for the nine countries. In most cases, there are shifts in the mean of real interest rates during the period and the only exception is Switzerland. Before going into details, only the findings for Switzerland support the Fisher hypothesis. For the rest of countries, there exist one to four breaks in real rates. Figure 1 graphically depicts the shifts in real rates for each country. Australia and the United Kingdom recorded the highest numbers of structural breaks among the sample of countries. While the four breaks of Australia are found in 71Q1, 76Q4, 82Q4 and 99Q2, the estimated break time for the United Kingdom are in 68Q1, 73Q3, 81Q2 and 02Q1 respectively. Countries with three shifts in the real rates include Canada and Korea,

[26] The ex post tax-adjusted real interest rates are used in this study.

[27] I use a pure mean shift setup: $r_{tax,t} = z_t \mu_j + u_t$ where $r_{tax,t}$ is the tax-adjusted real interest rate, z_t is a constant of one and μ_j is the mean real rate for the j[th] regime. u_t denotes the error term.

their breaks occurred in 71Q1, 81Q1 and 99Q1 and 81Q3, 87Q1 and 00Q2. There are two breaks in real rates for Germany (81Q2, 02Q4), Japan (72Q4, 80Q2) and New Zealand (86Q4, 99Q4). Finally, only one major shift is identified in the case of Mexico in 88Q1.

Interestingly, if one takes a close scrutiny on the timings of breaks, the real rates often shift at similar points of time. For instance, there is a "common" break identified during the early 70s for Australia (71Q1), Canada (71Q1), Japan (72Q4) and the United Kingdom (73Q3). Similarly, the early 80s represent another time when the breaks are prevalent in the sample of countries – Australia (82Q4), Canada (81Q1), Germany (81Q2), Japan (80Q2), Korea (81Q3) and the United Kingdom (81Q2). While the size of real rate shifts found in the early seventies and eighties are huge, there is another common break found during the end of 1990s or early 2000s. These breaks include Australia (99Q2), Canada (99Q1), Germany (02Q4), Korea (00Q2), New Zealand (99Q4) and the United Kingdom (02Q1) respectively. Not only are there similar break times for the real rates, Figure 1 reveals that the directions of shifts are always in line with each other. Generally speaking, the real rates drop in the early 70s, rise in the early 80s and drop again around the time of the new century.

Considering the above findings, it is worth investigating what may have caused the structural breaks of real interest rates for these countries. It is interesting to know if the clustering of breaks around similar time among these countries is due to some common external factors. In the coming sub-sections, I examine some of the possible factors which may impact the shifts in real rates. First, I check if each country's government expenditures explain the shifts in real rates. Subsequently, I examine the impact of two worldwide factors, the real oil prices and the changes in US Fed regimes, on real interest rates. In the final part of the structural break analysis, I investigate whether the shifts in real rates are due to changes in inflation as suggested by Driffill and Snell (2003) and Rapach and Wohar (2005). If this is the case, it implies that the Fisher hypothesis is rejected for these countries.

3.3.1 Real Interest Rates and Government Expenditure

The relationship between government spending and real interest rates has been widely discussed in some previous literature. Blanchard and Summers (1984) examine the impact of fiscal policy on real interest rates. In another study, Barro (1997) suggests that while a temporary increase in government spending will raise the real interest rates[28], a permanent change in government spending does not generate a similar impact. To examine whether changes in government expenditure explain the major shifts of real interest rates, I apply the BP method again for these countries

[28] Barro (1997) examines the real interest rate during the five major wars for the US (Civil War, World War I, World War II, Korea and Vietnam). During these wartimes, government consumption is expected to be temporarily high compared with the other periods. However, the empirical evidence does not support the prediction that increases in temporary government spending lead to high real interest rates.

except Switzerland. This time, I re-estimate the breaks in real rates by controlling for the government expenditure measured as a proportion of GDP. Table 2 shows that the inclusion of government consumption does not explain the breaks for most countries in the sample. Australia, Germany, Japan, Korea and New Zealand are found to have the same number of breaks with or without considering government expenditure. On the contrary, government purchase does explain some of the shifts in Canada, Mexico and the United Kingdom. For Canada, the downward shift of real rates during the early 70s disappears after considering the changes in government spending. Nevertheless, the breaks in the early 80s and the end of the 90s are still left unexplained. There is more explanatory power for government expenditure for the United Kingdom and Mexico, while there is one break left unexplained in the early 80s for the United Kingdom and no break is found for Mexico. The results also show that the government expenditure coefficient can be positive or negative. However, it is mostly statistically insignificant except in Mexico, New Zealand and the United Kingdom. While increased government expenditures raise the real rates for Mexico and New Zealand, it lowers the real interest rates for the United Kingdom. As a whole, the findings indicate that even though government expenditure may account for breaks in Mexico and the United Kingdom, it does not explain the real rate shifts for most of the countries included in the sample. Furthermore, it cannot explain why there exist common breaks in real rates for many of these countries.

3.3.2 Real Interest Rates and Real Oil Prices

It has been shown that the real interest rates for the nine OECD countries shift at similar times over the time horizon. The findings lead to the conjecture that some worldwide factors are responsible for causing these shifts. To explain this phenomenon, Wilcox (1983) found evidence of supply shocks to the determination of real interest rates. In particular, he showed that high energy prices would lower the demand for capital and dragged down the real rate. Barro and Sala-i-Martin (1990) studied the determinants of real interest rates in major industrialized countries based on the interaction between investment demand and desired saving. They estimated a system of equations for the real interest rates for each OECD country with both worldwide and own-country variable regressors. Their results showed that real interest rates depend primarily on world factors rather than own-country factors. To check if the worldwide supply shocks have been the forces behind the common breaks among the countries, I apply the BP method with the inclusion of real oil prices as the explanatory variable.

Table 3 reports the estimated structural breaks of real interest rates when real oil prices are considered. Similar to that of government expenditure, real oil prices have limited explanatory power in accounting for the real rate shifts. Surprisingly, the oil price spikes in 1973 and 1979 do not help in explaining the shifts in real rates during the early 70s and 80s for these countries. In contrast, crude oil prices may be related to the downward shifts of real rates around the new century. Once energy prices are considered, the breaks of Australia (99Q2), Korea (00Q2), New Zealand (99Q4) and the United Kingdom (02Q1) no longer exist. The timings of these breaks match with the surging oil prices since the beginning of the new century. Finally, oil prices seem to explain the break of real rates for Mexico in 88Q1 as well.

In general, the results indicate that real oil prices fail to explain the major shifts in real interest rates during the early 70s and 80s. However, it does explain the breaks in real rates around the beginning of the new century.

3.3.3 Real Interest Rates and US Fed Regimes

Given the size of the US economy, changes in policy regimes of the US have also been suggested as the cause of major shifts in real interest rates for the other countries (Bodie, Kane and McDonald 1983, Tzavalis 1999, Divino 2009). In particular, the changes in the Federal Reserve's operating procedure in October 1979[29] coincide with the huge real rate surges both in the US and the rest of countries at that time Considering the findings that US monetary regimes are related to major

[29] After Paul Volcker was nominated as the chair of the Federal Reserve Board, the Fed adopted a non-borrowed reserves operating procedure and increased the emphasis on M1 targets to combat the high inflation rate at that time. For the United Kingdom, the election of Margaret Thatcher as the Prime Minister in 1979 may also help in explaining the shift of real interest rates at that time.

changes in real interest rates[30], Bonser-Neal (1990) examined if shifts in a country's own monetary regimes had similar impact on its real rates. Nevertheless, the author did not find any systematic relationship between real rates and its own monetary regimes for Canada, Germany and the United Kingdom. Consequently, I investigate whether the similar patterns of breaks in real rates for this sample of countries are due to switches in the US Fed regimes.

Table 4 shows the results of real interest rate shifts after controlling for the US Fed regimes[31]. Consistent with the findings of previous studies, changes in US Fed regime account for the breaks during the early 80s for Canada, Germany and Japan. In addition, it also explains the major shifts of real rates for the same group of countries in the early 70s. While the US Fed regime has limited explanatory power to real rate breaks for Australia, Korea and the United Kingdom, it does explain the breaks in Canada, Germany, Japan, Mexico and New Zealand.

3.3.4 Real Interest Rates and Inflation

The validity of the Fisher hypothesis lies in a one-to-one matching in inflation and nominal rates. It means that an increase in inflation will be accompanied with an increase in nominal rates of the same size and leaving the real rates unchanged.

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30 Caporale and Grier (2005) also find that shifts in the US real rates are due to changes in Fed regime.

31 The US Fed chairs for these regimes were William McChesney Martin, Arthur F. Burns, G. William Miller, Paul A. Volcker, Alan Greenspan and Ben S. Bernanke. For each country, I regress respective tax-adjusted real interest rates on the US Fed regime dummies and use the residuals collected for subsequent structural break estimations by the BP method.

In this sense, real interest rates should be neutral to changes in inflation. If shifts in real rates are due to changes in inflation, it means that the one-to-one relationship between nominal interest rates and inflation does not hold. Driffill and Snell (2003) examined the relationship between real interest rates to permanent and temporary real and nominal shocks for the US, Japan, Germany, France and the United Kingdom. They found that the rise in real interest rates in the early 80s was mainly due to nominal shocks of inflation. In another study, Rapach and Wohar (2005) estimated the structural breaks of real interest rates and inflation rates for thirteen industrialized countries. Their results indicate that the breaks of real rates always coincided with the corresponding shifts in inflation. Since both of these empirical works regarded inflation as the source of changes in real rates, their findings rejected the Fisher hypothesis.

As a preliminary check if variations in inflation lead to shifts in real interest rates, I estimate the structural breaks of inflation for each country. Table 5 reports the findings of shifts in inflation and Figure 2 depicts the breaks graphically. Comparing the breaks of inflation with those found in real interest rates, some of the breaks seem to coincide with each other. For instance, the real interest rates of Australia that shift at 71Q1 and 76Q4 are close to those found in inflation at 72Q4 and 77Q4. Similarly, the breaks of real rates for Canada at 71Q1 and 81Q1 match well with the breaks of inflation at 72Q2 and 82Q3[32]. Even though the real interest rate shifts around the new century do not find corresponding inflation breaks in most cases, the findings are in line with Rapach and Wohar (2005).

As a further check, I apply the BP method to estimate the structural breaks of real interest rates, this time controlling for inflation. The results in Table 6 show that the inclusion of contemporary inflation does not explain the major shifts in real rates. In some cases, it even introduces additional breaks in real interest rates. Since inflation may impact on real interest rates by its persistent changes instead of contemporary effect, I estimate the structural breaks of real rates by considering the inflation regimes[33] as an alternative setup. Table 7 reports these findings. As a whole, inflation regimes account for most of the breaks in real interest rates. In particular, there are no unexplained breaks left in Korea, Mexico, New Zealand and the United Kingdom when inflation regimes are considered. While only one break is left for Germany and Japan, two breaks remain for Australia and Canada.

Comparing the real rate breaks after controlling for inflation regimes and US Fed regimes, the former better explains the breaks of Australia, Korea, New Zealand and the United Kingdom. In contrast, US Fed regimes account for more breaks for

[32] Other inflation (π)and real rate (r)shift pairs include: Germany (π: 82Q4, r: 81Q2), Japan (π: 81Q2, r: 81Q2), Korea (π: 81Q3 87Q1 98Q1 , r: 81Q3 87Q1 00Q2), Mexico (π: 88Q1, r: 88Q1), New Zealand (π: 87Q2, r: 86Q4) and UK (π: 69Q4 81Q2, r: 68Q1 81Q2).

[33] The inflation regimes for each country are based on the estimated breaks in inflation previously found in this paper. For the US, Caporale and Grier (2005) found that inflation regimes do not explain the shifts of real interest rates.

Canada and Japan. For Germany and Mexico, the results of break estimations are similar after controlling for respective regimes. As mentioned, if shifts in inflation regime are the reason behind breaks of real rates, it deems the Fisher hypothesis invalid. In view of this, I implement the J-test of Davidson and MacKinnon (1981) to compare which regimes better explain the real interest rates for this sample of countries. Table 8 reports the test results comparing the Fed regime model with the inflation regime model when government spending and real oil prices are also considered. The J-test chooses Fed regimes over inflation regimes for Germany, Japan and New Zealand. In contrast, it picks inflation regimes for Korea and Mexico[34]. However, it does not show preference to either regime model for Australia, Canada and the United Kingdom[35]. Considering the number of breaks that remain after accounting for each regime model and the results from the J-test, inflation may better explain the shifts in real rates for Australia, Korea, Mexico and the United Kingdom. On the other hand, the breaks in real rates for Canada, Germany and Japan are more likely due to the changes in Fed regimes. Finally, the finding for New Zealand is mixed.

Table 9 summarizes how the breaks in real interest rates are explained by the

[34] For Mexico, I consider inflation regime model as the preference as the null of inflation regime is rejected only at a 10% level.

[35] After repeating the J-test without considering government spending and real oil prices, the test select inflation regime model for the United Kingdom. However, the test does not have preference to either model for Canada and Australia in a similar manner.

different factors. The times shown in the table are the estimated break time in real interest rates from the BP method. Below these break times, I have listed the factors which explain these shifts.

3.4 Dynamic Relationship between Nominal Interest Rate and Inflation

In the previous section, Switzerland is the only country which has a stable real interest rate over the last few decades. This finding supports the validity of the Fisher hypothesis in Switzerland. For the rest of the countries, the presence of shifts in mean real interest rates makes the evidence less certain whether the Fisherian link holds or not. To examine the relationship between tax-adjusted nominal interest rates and inflation, I formulate a VAR model and use innovation analyses to provide further check on the validity of the hypothesis for the countries. Table 10 shows the results from different unit root tests. While the augmented Dickey-Fuller (ADF) (Dickey and Fuller 1979) test almost unanimously found that tax-adjusted nominal interest rates are non-stationary for all countries, the results for inflation are less clear. The null of unit root process is rejected at 1% level for Korea, 5% level for Mexico and New Zealand and 10% level for Japan, Switzerland and the United Kingdom. Turning to KPSS test (Kwiatowski et al. 1992), the results suggest that nominal rates and inflation are stationary for Australia, Canada, Germany, Switzerland and the United Kingdom at conventional levels. Finally, I also implement Lumsdaine and

Papell (1997) test which allows for the presence of structural breaks in the time series. The computed statistics are even more in favor of treating nominal rates and inflation as stationary.

Taking into consideration the above test results, I use a VAR model in levels for the tax-adjusted nominal interest rate and inflation. This formulation is also appropriate as the Fisher hypothesis focuses on the relationship between the level of nominal rates and inflation. Hence the empirical model is:

$$Y_t = \mu + \sum_{j=1}^{p} \psi_j Y_{t-j} + \varepsilon_t \qquad with \;\; Y_t = \begin{bmatrix} \pi_t \\ i_{tax,t} \end{bmatrix} \tag{1a}$$

Y is a column vector of inflation (π) and tax-adjusted nominal interest rate (i_{tax}). The number of lags, p, is based on both the Schwarz Information Criterion (SIC) and the Arkaike Information Criterion (AIC). Since the lag length suggested by AIC generally have better control of autocorrelations in subsequent residual tests, the AIC will be the primary benchmark for lag selection. After obtaining the standardized residuals from the VAR model, I implement the multivariate Ljung-Box portmanteau test on serial correlation as well as conditional heteroskedasticity. Table 11 reports the results. The test results indicate that autocorrelations have been well controlled, however, the problem of conditional heteroskedasticity exists for the countries considered. In this regard, I amended the empirical model by incorporating a GARCH component in it.

3.4.1 The VAR-GARCH Model

In order to deal with the time varying conditional variance, I follow Grier et al. (2004) and consider a BEKK model (Engel and Kroner 1995) for the conditional variance-covariance structure. This formulation has an advantage that it does not require any diagonal restrictions which may cause a misspecification problem. Since preliminary tests[36] do not indicate asymmetric effects in the variance-covariance process, I use a BEKK setup as shown below:.

$$Y_t = \mu + \sum_{j=1}^{p} \psi_j Y_{t-j} + \varepsilon_t \tag{1b}$$

$$\text{where } Y_t = \begin{bmatrix} \pi_t \\ i_{tax,t} \end{bmatrix}; \ \mu = \begin{bmatrix} \mu_1 \\ \mu_2 \end{bmatrix}; \ \psi = \begin{bmatrix} \psi_{11}^j & \psi_{12}^j \\ \psi_{21}^j & \psi_{22}^j \end{bmatrix}; \ \varepsilon_t = \begin{bmatrix} \varepsilon_{\pi,t} \\ \varepsilon_{i_{tax},t} \end{bmatrix}$$

$$H_t = C_0^{*'} C_0^* + A_0^{*'} \varepsilon_{t-1} \varepsilon_{t-1}^{'} A_{11}^* + B_{11}^{*'} H_{t-1} B_{11}^* \tag{2}$$

$$\text{where } H_t = \begin{bmatrix} h_{\pi,t} & h_{\pi i_{tax},t} \\ h_{\pi i_{tax},t} & h_{i_{tax},t} \end{bmatrix}; \ C_0^* = \begin{bmatrix} c_{11}^* & c_{12}^* \\ 0 & c_{22}^* \end{bmatrix}; \ A_{11}^* = \begin{bmatrix} a_{11}^* & a_{12}^* \\ a_{21}^* & a_{22}^* \end{bmatrix}; \ B_{11}^* = \begin{bmatrix} b_{11}^* & b_{12}^* \\ b_{21}^* & b_{22}^* \end{bmatrix};$$

The mean equation is represented by (1b) and has the same setup as in the VAR model before. Equation (2) is the variance-covariance structure, where H_t denotes the conditional covariance which is positive definite for all values of ε_t.

Table 12 reports the estimation results for each of the countries. Since many of the off-diagonal coefficients are statistically significant, these findings indicate that

[36] I implement the sign bias tests of Engle and Ng (1993) for asymmetry in the variance-covariance process for each country. The results do not suggest the presence of asymmetry in either the positive or negative bias test. Also, I estimate a GARCH-M model for each series, but the associated coefficient is highly insignificant in all cases.

empirical models with strict diagonal restrictions are misspecified. To see if there remains any serial correlation and conditional heteroskedasticity, I conduct the multivariate Ljung-Box tests again. Table 13 shows that these problems no longer exist.

3.4.2 Impulse Response Analyses

In this section, I employ the Choleski decomposition and construct both the impulse responses and cumulated impulse responses when a unit shock of inflation is applied. The order of variables comes from inflation to tax-adjusted nominal interest rates. In Figure 3, the impulse responses for the nine countries are depicted. In all cases, both inflation and tax-adjusted nominal interest rates react positively to inflation shock and this is consistent to the Fisher hypothesis. Besides a positive link between inflation and nominal interest rates, the Fisher hypothesis also requires the time series to have a one-to-one relationship. Hence, I compare the size of cumulated response of inflation and nominal rates for each country in the sample. Figure 4 shows the cumulated impulse responses for each country in the sample. Overall, both inflation and tax-adjusted nominal interest rates go up given a positive shock on inflation. With the exception of Australia, Canada and the United Kingdom, the cumulated impulse responses of inflation and nominal rates for the other countries are statistically significant for less than 20 quarters. It indicates that we ascertain the positive cumulated responses only within these periods. Since the bootstrapped confidence intervals tend to be large, I do not consider the existence of overlapping bands of impulse response for inflation and nominal rates as evidence of the Fisher hypothesis. Instead, I compare the mean of the cumulated responses for both series as a check for this one-to-one relationship.

In general, the sizes of cumulated response of tax-adjusted nominal interest rates are small compared with those of corresponding inflation. Amongst this sample, three countries, Canada, Korea and Switzerland, are exceptions. For Canada, the cumulated response of inflation and tax-adjusted nominal rates stay close to each other at 18.10% and 18.39% respectively. On the other hand, the cumulated response of inflation and nominal rates become steady at 3.69% and 3.24% in the case of Switzerland. For Korea, the cumulated responses of nominal interest rates ultimately even exceed inflation by 0.66%. While the responses of nominal rates are less than one-to-one for the rest of countries, they show varying degrees of "under-responses". For Germany, the inflation and nominal interest rates become steady at 3.27% and 2.22% which implies that nominal rates only reach approximately 68% of the hypothesized one-to-one ratio. Similarly, the response of nominal rates for Mexico attains 69.67% of the hypothesized size of movement. Turning to the findings of Australia, Japan, New Zealand and the United Kingdom, the gaps between the cumulated response of inflation and nominal rates are huge. The cumulated response of inflation and nominal rates for Australia are 12.32% and 5.78% respectively. This corresponds to a 1 to 0.47 ratio. For the United Kingdom, inflation and nominal rates stay at 14.13% and 7.66% which is a 1 to 0.54 ratio. Tremendous differences between responses of inflation and nominal rates are found in Japan and New Zealand. The former country reported cumulated responses for inflation and nominal rates at 7.92% and 2.30% which represent a 1 to 0.29 ratio. The finding for the latter country is a minimal of 1 to 0.15 ratio with its inflation and nominal rates staying at 20.39% and 3.14% respectively.

The findings here show that tax-adjusted nominal interest rate tends to respond to inflation shock in less than a one-to-one manner except for Canada, Korea and Switzerland[37].

3.4.3 Inflation and Nominal Interest Rates

Considering the results obtained in the previous section, only Canada, Korea and Switzerland seem to fit well with the Fisher hypothesis. Countries with inflation and

[37] I also computed an alternative measure of the cumulative responses by compounding the inflation derived from the impulse responses. The cumulative impulse responses obtained by this alternative measure are only slightly higher than the original measures for most countries in this sample. In the followings, the figure reported on the left inside the bracket are the cumulative responses of inflation from the new measure while those on the right are the original measure --- Aus (13.06%, 12.32%), Canada (19.79%, 18.10%), Germany (3.31%, 3.27%), Japan (8.19% 7.92%), Korea (12.31%, 11.65%), Mexico (52.94%, 43.79%), New Zealand (22.46%, 20.39%), Switzerland (3.73%, 3.69%) and the United Kingdom (15.04%, 14.13%). Though there is a larger difference found in Mexico, the result indicates a more severe under-response for nominal rates. The same conclusion can still be drawn. Another check on the robustness of results is done by using an augmented Fisher relation with the inclusion of consumption growth in the model. In this case, the response of nominal rates to inflation is slightly lowered. Again, similar conclusion can be drawn.

tax-adjusted nominal interest rates deviate fairly from the hypothesized one-to-one ratio include Germany and Mexico. Amongst this sample, the findings for Australia, Japan, New Zealand and the United Kingdom cast strong doubt to the validity of the Fisherian link. The overall results indicate a strong tendency for limited responses of tax-adjusted nominal interest rates to inflation shock. Obviously, it will be meaningful to see if this lack of responses is a result of an inappropriate tax adjustment of the nominal interest rates. In this regard, I re-estimate the VAR-GARCH model for each country. This time, however, I use raw nominal interest rates without doing tax adjustment in the empirical estimations. The corresponding cumulated impulse responses are depicted in Figure 5[38].

It can be seen that the limited responses of interest rates are not due to the tax adjustment used. In particular, the responses of nominal interest rates of Australia, Japan, New Zealand and the United Kingdom are still below the corresponding inflation. One interesting thing to note is that according to Summers (1982), the theoretical response of nominal interest rates (without tax adjustment) to inflation ought to be within the range of 1.3 to 1.5. Comparing these theoretical values with the findings here, Switzerland once again fit well with the Fisher hypothesis. The cumulated responses of inflation and nominal interest rates become steady at 3.69%

[38] For clarity, the confidence intervals are omitted.

and 5.02%. This implies that inflation and nominal interest rates move in a ratio of 1 to 1.36, which ties closely with the suggested theoretical value. For Canada and Korea, the ratios are 1.15 and 1.18 respectively. Although they lie outside the theoretical range, the ratios are not far below either. Similar to the findings in the previous section, the responses of inflation and nominal interest rates for Germany and Mexico are limited when unadjusted nominal rates are used. The cumulated response of inflation and nominal rates are 3.23% and 3.02% for Germany, which corresponds to a ratio of 1 to 0.93. In the case of Mexico, the nominal interest rates stay below inflation with a ratio of 1 to 0.86.

In summary, the findings from the impulse response show that nominal interest rates and inflation have a positive relationship with each other. However, interest rates tend to react in less than one-to-one ratio upon an inflation shock. The evidence also shows that the limited response of interest rates is not due to the treatment of tax adjustments. Comparing the results when tax adjusted nominal interest rates or raw nominal interest rates are used in the empirical model, the findings for Canada, Korea and Switzerland are in favor of the Fisher hypothesis. While the findings for Germany and Mexico are a bit mixed, the results for Australia, Japan, New Zealand and the United Kingdom reject the Fisherian link.

3.4.4 Non-stationary Tax-Adjusted Nominal Interest Rates and Inflation

The findings of the prior sections are based on my preferred model of treating both tax-adjusted nominal interest rates and inflation as stationary and employ a VAR-GARCH model in levels as the empirical model. Due to the mixed findings on the unit root tests, I examine how the results will be changed if inflation and nominal rates are taken as non-stationary processes. If the time series are integrated of the same order, it is natural to check for the existence of cointegrating relationships between the variables. Table 14 shows the results when the Johansen (1991) method is applied. The results do not support any cointegrating relationships except Mexico for which the λ_{trace} statistics and the $\lambda_{\max}$ statistics both suggest the presence of one cointegrating vector between inflation and tax-adjusted nominal rates. The final column of Table 13 reports the coefficient of the cointegrating relationship after normalizing with respect to the tax-adjusted nominal rate. Even though inflation and tax-adjusted nominal rate are positively related, the size of the coefficient is only 0.7588, which is much less than the hypothesized value of 1. Hence, the evidence once again shows restricted response of nominal rates to inflation.

Since there is no cointegration between the time series for the other countries, I implement a first-differenced VAR model and conduct innovation analyses for these countries. Figure 6 depicts the cumulated impulse responses of inflation and tax-adjusted nominal rates upon an inflation shock. In all cases, nominal rates fail to match the predicted one-to-one relationship[39]. Though a first-differenced VAR model actually only represents the link between the change in inflation and tax-adjusted nominal interest rates, the findings can be regarded as a denial of the Fisher hypothesis.

3.5 Conclusion

The Fisher hypothesis is an important foundation in both theoretical economics and macroeconomic policies. It is therefore crucial to know if the hypothesis is valid in practice. In this paper, I extend my study to cover a sample of nine OECD countries. By using quarterly data of inflation and nominal interest rates for the last few decades, I examine the Fisher relationship by two main approaches.

First, I use a mean shift model and apply the BP method to estimate the structural breaks of tax-adjusted real interest rates. If there is a one-to-one relationship between inflation and tax-adjusted nominal interest rates, the real rates will remain stable over the entire sample period and no structural breaks can be detected. The findings are not supportive of the Fisherian link for all countries except Switzerland.

In order to examine the reasons behind these real rate shifts, I consider some of the factors which have been suggested by the literature. They include government expenditures, real oil prices, changes in US Fed regimes and the variation of inflation

[39] The confidence intervals are non-overlapping in all cases and the only exception is Switzerland when the time horizon is more than 36 quarters.

of respective country. Incorporating these factors into the mean shift model, I found that both government expenditures and real oil prices only have limited explanatory power to breaks in real rates. In contrast, changes in US Fed regimes or switches in inflation regimes of respective country both explain the breaks that have been found in most of the countries. Since it is imperative to know if major changes in real rates are due to unmatched movement in inflation, I implement a J-test comparing both regime models. The results suggest that the Fed regime model better explain the real rate shifts for Canada, Germany and Japan. On the other hand, switches in inflation regimes explain the shifts for Australia, Korea, Mexico and the United Kingdom.

In the second part of this paper, I study the dynamic relationship between inflation and tax-adjusted nominal interest rates by using a VAR-GARCH model. The results from the subsequent innovation analyses show that tax-adjusted nominal rates respond positively when a unit inflation shock is applied. With the exception of Canada, Korea and Switzerland, however, the responses tend to be small and are less than the hypothesized one-to-one relationship. The findings are robust when unadjusted nominal interest rates are used. Hence the results are not due to any inappropriate tax adjustments of the nominal rates.

Considering the overall results, Switzerland and Canada are the two countries that fit well with the Fisher hypothesis. On the other hand, the evidence for Australia, New Zealand and the United Kingdom is not supportive of it. The findings for the rest of countries are mixed. In conclusion, the evidence of the Fisher hypothesis is weak based on the findings in this paper.

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Table 3.1 Structural Breaks for Real Interest Rates

Australia

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	$SupF_T(5)$	$SupF_T(6)$	$SupF_T(7)$	$UD\max$	$WD\max$
13.49 *	26.22 *	28.62 *	25.81 *	22.35 *	24.08 *	19.23 *	28.62 *	54.53 *

$SupF_T(2\mid1)$	$SupF_T(3\mid2)$	$SupF_T(4\mid3)$	$SupF_T(5\mid4)$	$SupF_T(6\mid5)$	$SupF_T(7\mid6)$
25.58 *	29.51 *	19.04 *	7.56	1.53	1.40

Break Time	Regime	Mean
	R_1	0.94% **
$\widehat{T}_1$ 1971Q1 [70Q1 – 72Q2]	R_2	−6.48% *
$\widehat{T}_2$ 1976Q4 [76Q2 – 81Q1]	R_3	−1.46% **
$\widehat{T}_3$ 1982Q4 [82Q2 – 84Q2]	R_4	2.85% *
$\widehat{T}_4$ 1999Q2 [97Q1 – 03Q2]	R_5	0.60%

Canada

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	$SupF_T(5)$	$SupF_T(6)$	$SupF_T(7)$	$UD\max$	$WD\max$
13.31 *	14.83 *	20.51 *	30.05 *	25.80 *	21.58 *	18.55 *	30.05 *	53.43 *

$SupF_T(2\mid1)$	$SupF_T(3\mid2)$	$SupF_T(4\mid3)$	$SupF_T(5\mid4)$	$SupF_T(6\mid5)$	$SupF_T(7\mid6)$
28.43 *	18.48 *	9.13	1.79	2.13	0.82

Break Time	Regime	Mean
	R_1	1.03% *
$\widehat{T}_1$ 1971Q1 [63Q1 – 73Q2]	R_2	−1.71% *
$\widehat{T}_2$ 1981Q1 [80Q3 – 83Q4]	R_3	3.01% *
$\widehat{T}_3$ 1999Q1 [96Q2 – 01Q1]	R_4	0.35%

Germany

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	$SupF_T(5)$	$SupF_T(6)$	$SupF_T(7)$	$UD\max$	$WD\max$
9.82 **	13.09 *	11.50 *	8.50 *	7.10 *	5.70 **	4.96 **	30.05 *	53.43 *

$SupF_T(2\mid1)$	$SupF_T(3\mid2)$	$SupF_T(4\mid3)$	$SupF_T(5\mid4)$	$SupF_T(6\mid5)$	$SupF_T(7\mid6)$
18.34 *	5.41	1.93	1.02	0.30	0.64

Break Time	Regime	Mean
	R_1	−0.28%
$\widehat{T}_1$ 1981Q2 [78Q3 – 85Q3]	R_2	1.47% *
$\widehat{T}_2$ 2002Q4 [01Q1 – 06Q4]	R_3	−0.06%

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* , ** and [a] denote 1% , 5% and 10% significance level

Table 3.1 Structural Breaks for Real Interest Rates (cont'd)

Japan

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	$SupF_T(5)$	$SupF_T(6)$	$SupF_T(7)$	$UD\max$	$WD\max$
13.29 *	11.99 *	9.63 *	7.95 *	8.39 *	7.29 *	6.41 *	13.29 *	16.82 *

$SupF_T(2\mid1)$	$SupF_T(3\mid2)$	$SupF_T(4\mid3)$	$SupF_T(5\mid4)$	$SupF_T(6\mid5)$	$SupF_T(7\mid6)$
16.81 *	4.95	2.59	1.72	0.24	–

Break Time	Regime	Mean
$\hat{T}_1$ 1972Q4 [68Q2 – 74Q1]	R_1	0.19%
$\hat{T}_2$ 1980Q2 [80Q1 – 84Q2]	R_2	–5.76% *
	R_3	0.71% *

Korea

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	$SupF_T(5)$	$SupF_T(6)$	$SupF_T(7)$	$UD\max$	$WD\max$
6.29	30.89 *	40.63 *	30.28 *	24.29 *	20.58 *	17.93 *	40.63 *	62.72 *

$SupF_T(2\mid1)$	$SupF_T(3\mid2)$	$SupF_T(4\mid3)$	$SupF_T(5\mid4)$	$SupF_T(6\mid5)$	$SupF_T(7\mid6)$
54.78 *	36.65 *	1.35	–	–	–

Break Time	Regime	Mean
$\hat{T}_1$ 1981Q3 [81Q2 – 85Q2]	R_1	–0.30%
$\hat{T}_2$ 1987Q1 [85Q1 – 88Q3]	R_2	9.41% *
$\hat{T}_3$ 2000Q2 [99Q3 – 03Q1]	R_3	4.80% *
	R_4	0.78%[a]

Mexico

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	$SupF_T(5)$	$SupF_T(6)$	$SupF_T(7)$	$UD\max$	$WD\max$
23.37 *	6.16	5.16	3.77	3.61	5.08 **	5.66 *	23.37 *	23.37 *

$SupF_T(2\mid1)$	$SupF_T(3\mid2)$	$SupF_T(4\mid3)$	$SupF_T(5\mid4)$	$SupF_T(6\mid5)$	$SupF_T(7\mid6)$
5.54	3.72	5.80	5.73	4.59	–

Break Time	Regime	Mean
$\hat{T}_1$ 1988Q1 [87Q3 – 89Q4]	R_1	–24.80% *
	R_2	2.97% **

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* , ** and [a] denote 1% , 5% and 10% significance level

Table 3.1 Structural Breaks for Real Interest Rates (cont'd)

New Zealand

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	$SupF_T(5)$	$SupF_T(6)$	$SupF_T(7)$	$UD\max$	$WD\max$
39.83*	58.00*	42.40*	33.13*	31.28*	27.43*	23.25*	58.00*	74.35*

$SupF_T(2\mid 1)$	$SupF_T(3\mid 2)$	$SupF_T(4\mid 3)$	$SupF_T(5\mid 4)$	$SupF_T(6\mid 5)$	$SupF_T(7\mid 6)$
15.53*	1.64	2.35	3.84	0.20	–

Break Time	Regime	Mean
	R_1	−7.38%*
$\hat{T}_1$ 1986Q4 [86Q3 – 89Q1]	R_2	1.91%*
$\hat{T}_2$ 1999Q4 [97Q2 – 05Q2]	R_3	0.34%

Switzerland

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	$SupF_T(5)$	$SupF_T(6)$	$SupF_T(7)$	$UD\max$	$WD\max$
5.96	8.12**	5.30	4.35	4.23	3.38	2.92	8.12	10.41

$SupF_T(2\mid 1)$	$SupF_T(3\mid 2)$	$SupF_T(4\mid 3)$	$SupF_T(5\mid 4)$	$SupF_T(6\mid 5)$	$SupF_T(7\mid 6)$
6.80	0.97	0.74	0.69	–	–

Break Time	Regime	Mean
No break	R_1	−0.09%

The United Kingdom

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	$SupF_T(5)$	$SupF_T(6)$	$SupF_T(7)$	$UD\max$	$WD\max$
15.12*	19.96*	17.27*	14.69*	13.53*	11.54*	10.28*	19.96*	27.14*

$SupF_T(2\mid 1)$	$SupF_T(3\mid 2)$	$SupF_T(4\mid 3)$	$SupF_T(5\mid 4)$	$SupF_T(6\mid 5)$	$SupF_T(7\mid 6)$
23.72*	15.28*	15.28*	2.56	1.46	1.30

Break Time	Regime	Mean
	R_1	−0.09%
$\hat{T}_1$ 1968Q1 [64Q2 – 70Q2]	R_2	−3.03%*
$\hat{T}_2$ 1973Q3 [66Q4 – 74Q1]	R_3	−8.26%*
$\hat{T}_3$ 1981Q2 [81Q1 – 84Q1]	R_4	1.35%*
$\hat{T}_4$ 2002Q1 [00Q4 – 07Q1]	R_5	−0.57%**

*, ** and [a] denote 1%, 5% and 10% significance level

Table 3.2 Structural Breaks of Real Interest Rates Controlled for Government Expenditure

Australia

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	$SupF_T(5)$	$SupF_T(6)$	$SupF_T(7)$	$UD\max$	$WD\max$
8.37	45.90*	50.48*	49.17*	38.65*	41.51*	38.38*	50.48*	98.80*

$SupF_T(2\mid 1)$	$SupF_T(3\mid 2)$	$SupF_T(4\mid 3)$	$SupF_T(5\mid 4)$	$SupF_T(6\mid 5)$	$SupF_T(7\mid 6)$
29.61*	36.58*	21.83*	5.60	1.46	1.20

Break Time

$\hat{T}_1$	$\hat{T}_2$	$\hat{T}_3$	$\hat{T}_4$
1972Q2	1977Q1	1983Q4	1999Q2
[71Q1 – 73Q1]	[76Q3 – 78Q4]	[82Q2 – 84Q4]	[97Q1 – 03Q2]

Government Expenditure Parameter: –0.1792

Canada

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	$SupF_T(5)$	$SupF_T(6)$	$SupF_T(7)$	$UD\max$	$WD\max$
12.66**	27.90*	18.49*	22.92*	19.86*	19.14*	16.25*	27.90*	43.34*

$SupF_T(2\mid 1)$	$SupF_T(3\mid 2)$	$SupF_T(4\mid 3)$	$SupF_T(5\mid 4)$	$SupF_T(6\mid 5)$	$SupF_T(7\mid 6)$
26.66*	8.64	1.10	1.25	–	–

Break Time

$\hat{T}_1$	$\hat{T}_2$
1981Q1	1999Q1
[80Q2 – 83Q3]	[96Q4 – 00Q4]

Government Expenditure Parameter: –0.4057

Germany

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	$SupF_T(5)$	$SupF_T(6)$	$SupF_T(7)$	$UD\max$	$WD\max$
11.80**	13.86*	11.79*	10.64*	8.66*	7.49*	7.98*	13.86*	20.54*

$SupF_T(2\mid 1)$	$SupF_T(3\mid 2)$	$SupF_T(4\mid 3)$	$SupF_T(5\mid 4)$	$SupF_T(6\mid 5)$	$SupF_T(7\mid 6)$
16.40*	7.99	1.90	1.78	2.65	1.78

Break Time

$\hat{T}_1$	$\hat{T}_2$
1981Q2	2002Q4
[78Q2 – 86Q1]	[00Q1 – 06Q2]

Government Expenditure Parameter: –0.1112

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* , ** and [a] denote 1% , 5% and 10% significance level

Table 3.2 Structural Breaks of Real Interest Rates Controlled for Government Expenditure (Cont'd)

Japan

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	$SupF_T(5)$	$SupF_T(6)$	$SupF_T(7)$	$UD\max$	$WD\max$
30.01*	11.04*	12.12*	10.07*	8.34*	7.98*	7.10*	30.01*	30.01*

$SupF_T(2\mid 1)$	$SupF_T(3\mid 2)$	$SupF_T(4\mid 3)$	$SupF_T(5\mid 4)$	$SupF_T(6\mid 5)$	$SupF_T(7\mid 6)$
19.88*	6.56	3.06	3.06	2.70	3.06

Break Time

$\widehat{T}_1$	$\widehat{T}_2$
1972Q1	1977Q2
[69Q2 – 72Q4]	[77Q1 – 80Q2]

Government Expenditure Parameter: 0.1019

Korea

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	$SupF_T(5)$	$SupF_T(6)$	$SupF_T(7)$	$UD\max$	$WD\max$
8.83	25.29*	16.87*	12.81*	10.97*	9.12*	9.01*	25.29*	32.43*

$SupF_T(2\mid 1)$	$SupF_T(3\mid 2)$	$SupF_T(4\mid 3)$	$SupF_T(5\mid 4)$	$SupF_T(6\mid 5)$	$SupF_T(7\mid 6)$
23.88*	23.59*	2.93	2.93	2.93	–

Break Time

$\widehat{T}_1$	$\widehat{T}_2$	$\widehat{T}_3$
1980Q4	1987Q1	1999Q2
[80Q2 – 85Q1]	[83Q4 – 90Q3]	[97Q4 – 08Q2]

Government Expenditure Parameter: –0.7408

Mexico

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	$SupF_T(5)$	$SupF_T(6)$	$SupF_T(7)$	$UD\max$	$WD\max$
4.35	7.28	5.42	4.42	7.16*	17.84*	15.02*	17.84*	40.39*

$SupF_T(2\mid 1)$	$SupF_T(3\mid 2)$	$SupF_T(4\mid 3)$	$SupF_T(5\mid 4)$	$SupF_T(6\mid 5)$	$SupF_T(7\mid 6)$
8.99	2.05	7.54	7.54	2.67	0.30

Break Time No break

Government Expenditure Parameter: 1.9778**

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* , ** and [a] denote 1% , 5% and 10% significance level

Table 3.2 Structural Breaks of Real Interest Rates Controlled for Government Expenditure

New Zealand

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	$SupF_T(5)$	$SupF_T(6)$	$SupF_T(7)$	$UD\max$	$WD\max$
11.83**	22.16*	8.56*	15.68*	14.98*	11.92*	14.35*	22.16*	36.95*

$SupF_T(2\mid1)$	$SupF_T(3\mid2)$	$SupF_T(4\mid3)$	$SupF_T(5\mid4)$	$SupF_T(6\mid5)$	$SupF_T(7\mid6)$
11.01*	0.89	0.89	1.12	0.19	−

Break Time

$\widehat{T}_1$	$\widehat{T}_2$
1987Q2	1990Q1
[85Q2 − 92Q2]	[88Q4 − 90Q3]

Government Expenditure Parameter: 0.5383**

The United Kingdom

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	$SupF_T(5)$	$SupF_T(6)$	$SupF_T(7)$	$UD\max$	$WD\max$
81.42*	27.90*	22.76*	17.54*	14.20*	12.40*	10.97*	81.42*	81.42*

$SupF_T(2\mid1)$	$SupF_T(3\mid2)$	$SupF_T(4\mid3)$	$SupF_T(5\mid4)$	$SupF_T(6\mid5)$	$SupF_T(7\mid6)$
8.98	8.98	6.93	6.93	2.10	1.31

Break Time

$\widehat{T}_1$
1980Q2
[79Q2 − 82Q1]

Government Expenditure Parameter: −1.3660*

*, ** and [a] denote 1%, 5% and 10% significance level

Table 3.3 Structural Breaks of Real Interest Rates Controlled for Real Oil Prices

Australia

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	$SupF_T(5)$	$SupF_T(6)$	$SupF_T(7)$	$UD\max$	$WD\max$
20.68 *	51.74 *	35.57 *	30.73 *	25.18 *	24.72 *	27.43 *	51.74 *	70.62 *

$SupF_T(2\mid1)$	$SupF_T(3\mid2)$	$SupF_T(4\mid3)$	$SupF_T(5\mid4)$	$SupF_T(6\mid5)$	$SupF_T(7\mid6)$
63.65 *	27.06 *	7.89	8.79	8.79	–

Break Time

$\hat{T}_1$	$\hat{T}_2$	$\hat{T}_3$
1971Q2	1976Q4	1981Q4
[69Q3 – 71Q4]	[76Q3 – 78Q4]	[79Q1 – 83Q2]

Oil Price Parameter: –0.0201 *

Canada

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	$SupF_T(5)$	$SupF_T(6)$	$SupF_T(7)$	$UD\max$	$WD\max$
31.86 *	15.88 *	22.64 *	44.13 *	32.15 *	29.52 *	25.96 *	44.13 *	78.47 *

$SupF_T(2\mid1)$	$SupF_T(3\mid2)$	$SupF_T(4\mid3)$	$SupF_T(5\mid4)$	$SupF_T(6\mid5)$	$SupF_T(7\mid6)$
24.01 *	23.46 *	11.80 *	2.86	2.86	–

Break Time

$\hat{T}_1$	$\hat{T}_2$	$\hat{T}_3$	$\hat{T}_4$
1971Q4	1979Q2	1984Q2	1996Q4
[66Q2 – 72Q1]	[77Q4 – 81Q3]	[80Q1 – 87Q2]	[93Q3 – 98Q1]

Oil Price Parameter: –0.0052

Germany

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	$SupF_T(5)$	$SupF_T(6)$	$SupF_T(7)$	$UD\max$	$WD\max$
7.26	10.47 *	32.53 *	27.71 *	39.81 *	36.16 *	27.28 *	39.81 *	81.89 *

$SupF_T(2\mid1)$	$SupF_T(3\mid2)$	$SupF_T(4\mid3)$	$SupF_T(5\mid4)$	$SupF_T(6\mid5)$	$SupF_T(7\mid6)$
15.69 *	1.75	1.91	1.96	1.75	2.43

Break Time

$\hat{T}_1$	$\hat{T}_2$
1979Q3	1989Q4
[78Q3 – 83Q3]	[87Q4 – 95Q1]

Oil Price Parameter: –0.0114 *

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* , ** and [a] denote 1% , 5% and 10% significance level

Table 3.3 Structural Breaks of Real Interest Rates Controlled for Real Oil Prices (Cont'd)

Japan

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	$SupF_T(5)$	$SupF_T(6)$	$SupF_T(7)$	$UD\max$	$WD\max$
12.98**	11.87*	9.65*	7.78*	8.54*	7.33*	6.33*	12.98*	17.13*

$SupF_T(2\mid 1)$	$SupF_T(3\mid 2)$	$SupF_T(4\mid 3)$	$SupF_T(5\mid 4)$	$SupF_T(6\mid 5)$	$SupF_T(7\mid 6)$
18.86*	3.42	2.33	1.41	0.65	–

Break Time

$\widehat{T}_1$	$\widehat{T}_2$
1972Q4	1980Q2
[68Q3 – 73Q4]	[80Q1 – 84Q1]

Oil Price Parameter: 0.0066

Korea

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	$SupF_T(5)$	$SupF_T(6)$	$SupF_T(7)$	$UD\max$	$WD\max$
4.24	26.03*	28.77*	25.99*	19.69*	16.57*	15.81*	28.77*	46.23*

$SupF_T(2\mid 1)$	$SupF_T(3\mid 2)$	$SupF_T(4\mid 3)$	$SupF_T(5\mid 4)$	$SupF_T(6\mid 5)$	$SupF_T(7\mid 6)$
43.44*	6.85	10.13	4.58	7.92	0.01

Break Time

$\widehat{T}_1$	$\widehat{T}_2$
1981Q3	1987Q1
[81Q1 – 85Q3]	[86Q3 – 88Q1]

Oil Price Parameter: –0.0391*

Mexico

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	$SupF_T(5)$	$SupF_T(6)$	$SupF_T(7)$	$UD\max$	$WD\max$
4.74	5.62	6.03	4.76	4.98	8.38*	7.48*	8.37	19.25*

$SupF_T(2\mid 1)$	$SupF_T(3\mid 2)$	$SupF_T(4\mid 3)$	$SupF_T(5\mid 4)$	$SupF_T(6\mid 5)$	$SupF_T(7\mid 6)$
5.76	5.08	1.74	1.97	–	–

Break Time No break

Oil Price Parameter: –0.0642

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*, ** and [a] denote 1%, 5% and 10% significance level

Table 3.3 Structural Breaks of Real Interest Rates Controlled for Real Oil Prices (Cont'd)

New Zealand

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	$SupF_T(5)$	$SupF_T(6)$	$SupF_T(7)$	$UD\max$	$WD\max$
24.61*	27.59*	18.31*	110.29*	20.85*	39.07*	37.23*	110.29*	196.14*

$SupF_T(2\mid1)$	$SupF_T(3\mid2)$	$SupF_T(4\mid3)$	$SupF_T(5\mid4)$	$SupF_T(6\mid5)$	$SupF_T(7\mid6)$
2.78	2.78	4.66	2.35	6.61	4.52

Break Time

$\widehat{T}_1$
$1986Q4$
$[86Q3-91Q1]$

Oil Price Parameter: -0.0264**

The United Kingdom

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	$SupF_T(5)$	$SupF_T(6)$	$SupF_T(7)$	$UD\max$	$WD\max$
25.21*	22.77*	23.59*	17.69*	14.15*	12.49*	11.32*	25.21*	36.42*

$SupF_T(2\mid1)$	$SupF_T(3\mid2)$	$SupF_T(4\mid3)$	$SupF_T(5\mid4)$	$SupF_T(6\mid5)$	$SupF_T(7\mid6)$
20.49*	7.94	7.94	5.11	0.95	0.95

Break Time

$\widehat{T}_1$	$\widehat{T}_2$
$1970Q3$	$1980Q2$
$[65Q2-71Q1]$	$[80Q1-83Q2]$

Oil Price Parameter: -0.0182*

*, ** and [a] denote 1%, 5% and 10% significance level

Table 3.4 Structural Breaks of Real Interest Rates Controlled for Fed Regimes

Australia

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	$SupF_T(5)$	$SupF_T(6)$	$SupF_T(7)$	$UD\max$	$WD\max$
8.51[a]	5.29	9.83*	9.89*	9.08*	7.68*	6.90*	9.89**	18.21*

$SupF_T(2\mid1)$	$SupF_T(3\mid2)$	$SupF_T(4\mid3)$	$SupF_T(5\mid4)$	$SupF_T(6\mid5)$	$SupF_T(7\mid6)$
9.88**	16.86*	9.65	4.40	1.59	0.97

Break Time

$\widehat{T}_1$	$\widehat{T}_2$	$\widehat{T}_3$
1973Q1	1983Q4	1999Q2
[63Q4 – 75Q2]	[82Q1 – 90Q2]	[95Q4 – 02Q2]

Canada

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	$SupF_T(5)$	$SupF_T(6)$	$SupF_T(7)$	$UD\max$	$WD\max$
8.78[a]	13.86*	9.91*	7.39*	6.07**	5.68**	4.71**	13.86*	17.77*

$SupF_T(2\mid1)$	$SupF_T(3\mid2)$	$SupF_T(4\mid3)$	$SupF_T(5\mid4)$	$SupF_T(6\mid5)$	$SupF_T(7\mid6)$
7.25	3.67	2.23	1.08	1.84	0.63

Break Time

$\widehat{T}_1$
1999Q1
[90Q4 – 08Q2]

Germany

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	$SupF_T(5)$	$SupF_T(6)$	$SupF_T(7)$	$UD\max$	$WD\max$
8.68[a]	6.38	5.29	5.31	4.35	3.86	3.16	8.68[a]	8.68[a]

$SupF_T(2\mid1)$	$SupF_T(3\mid2)$	$SupF_T(4\mid3)$	$SupF_T(5\mid4)$	$SupF_T(6\mid5)$	$SupF_T(7\mid6)$
3.02	2.46	2.22	0.94	0.94	0.16

Break Time

$\widehat{T}_1$
2002Q4
[98Q4 – 08Q2]

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* , ** and [a] denote 1% , 5% and 10% significance level

Table 3.4 Structural Breaks of Real Interest Rates Controlled for Fed Regimes (Cont'd)

Japan

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	$SupF_T(5)$	$SupF_T(6)$	$SupF_T(7)$	$UD\max$	$WD\max$
2.65	2.30	2.71	2.73	3.31	3.07	2.61	3.31	6.95

$SupF_T(2\mid 1)$	$SupF_T(3\mid 2)$	$SupF_T(4\mid 3)$	$SupF_T(5\mid 4)$	$SupF_T(6\mid 5)$	$SupF_T(7\mid 6)$
3.58	5.83	5.83	5.83	1.19	0.58

Break Time No Break

Korea

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	$SupF_T(5)$	$SupF_T(6)$	$SupF_T(7)$	$UD\max$	$WD\max$
1.31	12.54*	9.22*	9.25*	10.22*	8.57*	7.61*	12.54**	20.50*

$SupF_T(2\mid 1)$	$SupF_T(3\mid 2)$	$SupF_T(4\mid 3)$	$SupF_T(5\mid 4)$	$SupF_T(6\mid 5)$	$SupF_T(7\mid 6)$
24.19*	7.52	7.52	4.17	0.75	0.64

Break Time

$\widehat{T}_1$	$\widehat{T}_2$
1981Q3	2000Q2
[80Q2 – 08Q2]	[98Q2 – 04Q1]

Mexico

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	$SupF_T(5)$	$SupF_T(6)$	$SupF_T(7)$	$UD\max$	$WD\max$
1.47	3.65	3.00	2.33	3.52	5.02**	4.47**	5.02	11.53

$SupF_T(2\mid 1)$	$SupF_T(3\mid 2)$	$SupF_T(4\mid 3)$	$SupF_T(5\mid 4)$	$SupF_T(6\mid 5)$	$SupF_T(7\mid 6)$
6.07	2.42	8.82	8.82	1.44	1.44

Break Time No Break

New Zealand

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	$SupF_T(5)$	$SupF_T(6)$	$SupF_T(7)$	$UD\max$	$WD\max$
8.94^a	4.89	4.25	6.11^a	7.61*	7.38*	7.64*	8.94^a	19.66*

$SupF_T(2\mid 1)$	$SupF_T(3\mid 2)$	$SupF_T(4\mid 3)$	$SupF_T(5\mid 4)$	$SupF_T(6\mid 5)$	$SupF_T(7\mid 6)$
2.82	4.49	2.24	2.12	1.13	1.13

Break Time

$\widehat{T}_1$
1982Q3
[78Q1 – 86Q1]

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* , ** and [a] denote 1% , 5% and 10% significance level

Table 3.4 Structural Breaks of Real Interest Rates Controlled for Fed Regimes (Cont'd)

The United Kingdom

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	$SupF_T(5)$	$SupF_T(6)$	$SupF_T(7)$	$UD\max$	$WD\max$
3.90	3.52	6.90**	9.13*	8.04*	8.08*	6.99*	9.13^{a}	18.30*

$SupF_T(2\mid1)$	$SupF_T(3\mid2)$	$SupF_T(4\mid3)$	$SupF_T(5\mid4)$	$SupF_T(6\mid5)$	$SupF_T(7\mid6)$
9.12^{a}	15.76*	15.76*	3.89	3.89	0.62

Break Time

$\widehat{T}_1$	$\widehat{T}_2$	$\widehat{T}_3$	$\widehat{T}_4$
$1969Q1$	$1974Q1$	$1981Q2$	$1988Q1$
$[66Q1-72Q1]$	$[68Q3-74Q2]$	$[81Q1-88Q1]$	$[85Q2-92Q1]$

*, ** and ^{a} denote 1%, 5% and 10% significance level

Table 3.5 Structural Breaks for Inflation

Australia

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	$SupF_T(5)$	$SupF_T(6)$	$SupF_T(7)$	$UD\max$	$WD\max$
11.43**	39.33*	47.28*	38.85*	43.99*	36.92*	32.09*	47.28*	88.25*

$SupF_T(2\mid 1)$	$SupF_T(3\mid 2)$	$SupF_T(4\mid 3)$	$SupF_T(5\mid 4)$	$SupF_T(6\mid 5)$	$SupF_T(7\mid 6)$
52.77*	15.82*	9.93	8.96	5.58	–

Break Time	Regime	Mean
$\hat{T}_1$ 1972Q4 [72Q1 – 73Q2]	R_1	2.92%*
$\hat{T}_2$ 1977Q4 [76Q1 – 80Q4]	R_2	13.29%*
$\hat{T}_3$ 1990Q4 [90Q1 – 92Q2]	R_3	8.22%*
	R_4	2.56%*

Canada

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	$SupF_T(5)$	$SupF_T(6)$	$SupF_T(7)$	$UD\max$	$WD\max$
9.29**	63.98*	58.24*	50.12*	46.14*	46.04*	36.44*	63.98*	104.28*

$SupF_T(2\mid 1)$	$SupF_T(3\mid 2)$	$SupF_T(4\mid 3)$	$SupF_T(5\mid 4)$	$SupF_T(6\mid 5)$	$SupF_T(7\mid 6)$
18.03*	42.28*	20.90*	4.67	–	–

Break Time	Regime	Mean
$\hat{T}_1$ 1964Q4 [62Q3 – 67Q1]	R_1	1.60%*
$\hat{T}_2$ 1972Q2 [71Q1 – 72Q3]	R_2	3.69%*
$\hat{T}_3$ 1982Q3 [82Q2 – 84Q3]	R_3	9.54%*
$\hat{T}_4$ 1991Q1 [89Q2 – 92Q2]	R_4	4.67%*
	R_5	1.96%*

Germany

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	$SupF_T(5)$	$SupF_T(6)$	$SupF_T(7)$	$UD\max$	$WD\max$
24.12*	22.63*	16.76*	18.58*	17.03*	15.42*	12.73*	24.12*	34.93*

$SupF_T(2\mid 1)$	$SupF_T(3\mid 2)$	$SupF_T(4\mid 3)$	$SupF_T(5\mid 4)$	$SupF_T(6\mid 5)$	$SupF_T(7\mid 6)$
8.22	4.17	3.92	4.45	2.08	2.44

Break Time	Regime	Mean
$\hat{T}_1$ 1982Q4 [79Q3 – 85Q2]	R_1	4.46%*
	R_2	2.01%*

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*, ** and [a] denote 1%, 5% and 10% significance level

Table 3.5 Structural Breaks for Inflation (Cont'd)

Japan

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	$SupF_T(5)$	$SupF_T(6)$	$SupF_T(7)$	$UD\max$	$WD\max$
26.32 *	21.97 *	25.86 *	22.69 *	24.54 *	21.33 *	19.95 *	26.32 *	51.35 *

$SupF_T(2\mid 1)$	$SupF_T(3\mid 2)$	$SupF_T(4\mid 3)$	$SupF_T(5\mid 4)$	$SupF_T(6\mid 5)$	$SupF_T(7\mid 6)$
23.48 *	4.92	3.00	–	–	–

Break Time	Regime	Mean
$\widehat{T}_1$ 1981Q2 [81Q2 – 92Q2]	R_1	6.55% *
$\widehat{T}_2$ 1993Q3 [91Q2 – 96Q4]	R_2	1.85% *
	R_3	0.08%

Korea

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	$SupF_T(5)$	$SupF_T(6)$	$SupF_T(7)$	$UD\max$	$WD\max$
44.61 *	32.47 *	25.25 *	24.54 *	21.40 *	17.83 *	14.89 *	44.61 *	44.61 *

$SupF_T(2\mid 1)$	$SupF_T(3\mid 2)$	$SupF_T(4\mid 3)$	$SupF_T(5\mid 4)$	$SupF_T(6\mid 5)$	$SupF_T(7\mid 6)$
11.75 *	11.75 *	2.42	2.42	2.17	–

Break Time	Regime	Mean
$\widehat{T}_1$ 1981Q3 [81Q2 – 83Q2]	R_1	19.52% *
$\widehat{T}_2$ 1987Q1 [83Q1 – 88Q1]	R_2	2.76% *
$\widehat{T}_3$ 1998Q1 [97Q1 – 02Q2]	R_3	6.52% *
	R_4	2.88% *

Mexico

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	$SupF_T(5)$	$SupF_T(6)$	$SupF_T(7)$	$UD\max$	$WD\max$
455.19 *	619.37 *	274.10 *	282.36 *	261.61 *	218.60 *	185.42 *	619.37 *	794.07 *

$SupF_T(2\mid 1)$	$SupF_T(3\mid 2)$	$SupF_T(4\mid 3)$	$SupF_T(5\mid 4)$	$SupF_T(6\mid 5)$	$SupF_T(7\mid 6)$
22.37 *	17.07 *	5.04	1.28	–	–

Break Time	Regime	Mean
$\widehat{T}_1$ 1988Q1 [87Q4 – 88Q2]	R_1	99.71% *
$\widehat{T}_2$ 1999Q1 [99Q1 – 07Q4]	R_2	20.99% *
$\widehat{T}_3$ 2001Q2 [00Q3 – 02Q3]	R_3	8.45% *
	R_4	4.33% *

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* , ** and [a] denote 1% , 5% and 10% significance level

Table 3.5 Structural Breaks for Inflation (Cont'd)

New Zealand

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	$SupF_T(5)$	$SupF_T(6)$	$SupF_T(7)$	$UD\max$	$WD\max$
45.27 *	34.12 *	41.56 *	24.93 *	21.10 *	18.98 *	20.36 *	45.27 *	64.16 *

$SupF_T(2\|1)$	$SupF_T(3\|2)$	$SupF_T(4\|3)$	$SupF_T(5\|4)$	$SupF_T(6\|5)$	$SupF_T(7\|6)$
19.03 *	7.51	7.51	7.51	4.06	6.60

Break Time	Regime	Mean
$\hat{T}_1$ 1987Q2 [87Q1 – 92Q1]	R_1	−7.38% *
$\hat{T}_2$ 1990Q4 [89Q3 – 92Q4]	R_2	1.91% *
	R_3	0.34% *

The United Kingdom

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	$SupF_T(5)$	$SupF_T(6)$	$SupF_T(7)$	$UD\max$	$WD\max$
11.93 **	19.91 *	22.39 *	24.18 *	19.26 *	16.45 *	14.15 *	24.18 *	43.00 *

$SupF_T(2\|1)$	$SupF_T(3\|2)$	$SupF_T(4\|3)$	$SupF_T(5\|4)$	$SupF_T(6\|5)$	$SupF_T(7\|6)$
19.15 *	27.00 *	4.23	4.23	0.89	–

Break Time	Regime	Mean
$\hat{T}_1$ 1969Q4 [65Q4 – 70Q1]	R_1	3.28% *
$\hat{T}_2$ 1981Q2 [80Q4 – 88Q4]	R_2	13.29% *
$\hat{T}_3$ 1991Q2 [90Q2 – 96Q2]	R_3	6.01% *
	R_4	2.86% *

* , ** and [a] denote 1% , 5% and 10% significance level

Table 3.6 Structural Breaks of Real Interest Rates Controlled for Inflation

Australia

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	$SupF_T(5)$	$SupF_T(6)$	$SupF_T(7)$	$UD\max$	$WD\max$
149.00 *	357.77 *	388.31 *	337.50 *	272.2 *	239.48 *	204.57 *	388.31 *	600.21 *

$SupF_T(2\mid 1)$	$SupF_T(3\mid 2)$	$SupF_T(4\mid 3)$	$SupF_T(5\mid 4)$	$SupF_T(6\mid 5)$	$SupF_T(7\mid 6)$
193.51 *	224.47 *	92.04 *	16.28 *	9.85	4.53

Break Time

$\widehat{T}_1$	$\widehat{T}_2$	$\widehat{T}_3$	$\widehat{T}_4$	$\widehat{T}_5$
$1969Q2$	$1976Q4$	$1981Q4$	$1991Q3$	$1997Q2$
$[65Q2-70Q1]$	$[76Q1-77Q2]$	$[81Q2-82Q4]$	$[91Q2-91Q4]$	$[97Q1-98Q1]$

Inflation Parameter: -0.8677*

Canada

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	$SupF_T(5)$	$SupF_T(6)$	$SupF_T(7)$	$UD\max$	$WD\max$
8.04 [a]	37.08 *	44.72 *	32.31 *	50.88 *	47.14 *	48.57 *	50.88 *	125.02 *

$SupF_T(2\mid 1)$	$SupF_T(3\mid 2)$	$SupF_T(4\mid 3)$	$SupF_T(5\mid 4)$	$SupF_T(6\mid 5)$	$SupF_T(7\mid 6)$
39.30 *	41.80 *	8.16	6.11	6.11	0.86

Break Time

$\widehat{T}_1$	$\widehat{T}_2$	$\widehat{T}_3$
$1975Q3$	$1992Q1$	$2001Q2$
$[72Q4-76Q2]$	$[91Q2-96Q1]$	$[99Q4-04Q3]$

Inflation Parameter: -0.2120*

Germany

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	$SupF_T(5)$	$SupF_T(6)$	$SupF_T(7)$	$UD\max$	$WD\max$
22.47 *	11.25 *	14.33 *	6.24 **	15.31 *	14.32 *	20.80 *	22.47 *	53.55 *

$SupF_T(2\mid 1)$	$SupF_T(3\mid 2)$	$SupF_T(4\mid 3)$	$SupF_T(5\mid 4)$	$SupF_T(6\mid 5)$	$SupF_T(7\mid 6)$
24.77 *	0.81	1.61	2.34	2.34	0.42

Break Time

$\widehat{T}_1$	$\widehat{T}_2$
$1979Q3$	$1995Q4$
$[75Q3-79Q4]$	$[95Q2-03Q3]$

Inflation Parameter: -0.7165

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* , ** and [a] denote 1% , 5% and 10% significance level

Table 3.6 Structural Breaks of Real Interest Rates Controlled for Inflation (Cont'd)

Japan

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	$SupF_T(5)$	$SupF_T(6)$	$SupF_T(7)$	$UD\max$	$WD\max$
73.97 *	172.14 *	293.23 *	703.44 *	720.43 *	1327.88 *	1962.11 *	1962.11 *	5050.98 *

$SupF_T(2\mid1)$	$SupF_T(3\mid2)$	$SupF_T(4\mid3)$	$SupF_T(5\mid4)$	$SupF_T(6\mid5)$	$SupF_T(7\mid6)$
29.95 *	21.86 *	4.63	2.03	2.03	2.03

Break Time

$\hat{T}_1$	$\hat{T}_2$	$\hat{T}_3$
1970Q3	1984Q3	1992Q4
[67Q1 – 71Q2]	[79Q3 – 86Q1]	[91Q4 – 94Q1]

Inflation Parameter: -0.9471*

Korea

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	$SupF_T(5)$	$SupF_T(6)$	$SupF_T(7)$	$UD\max$	$WD\max$
22.03 *	56.76 *	25.87 *	131.52 *	342.71 *	296.44 *	250.98 *	342.71 *	687.53 *

$SupF_T(2\mid1)$	$SupF_T(3\mid2)$	$SupF_T(4\mid3)$	$SupF_T(5\mid4)$	$SupF_T(6\mid5)$	$SupF_T(7\mid6)$
34.46 *	9.70	9.40	7.77	0.97	–

Break Time

$\hat{T}_1$	$\hat{T}_2$
1982Q1	1998Q3
[81Q1 – 83Q2]	[96Q3 – 99Q4]

Inflation Parameter: -0.9409*

Mexico

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	$SupF_T(5)$	$SupF_T(6)$	$SupF_T(7)$	$UD\max$	$WD\max$
40.27 *	141.57 *	57.31 *	30.37 *	32.99 *	29.99 *	37.98 *	141.57 *	181.51 *

$SupF_T(2\mid1)$	$SupF_T(3\mid2)$	$SupF_T(4\mid3)$	$SupF_T(5\mid4)$	$SupF_T(6\mid5)$	$SupF_T(7\mid6)$
46.60 *	2.20	2.37	0.95	2.20	2.20

Break Time

$\hat{T}_1$	$\hat{T}_2$
1990Q2	2001Q2
[89Q4 – 91Q2]	[01Q1 – 05Q1]

Inflation Parameter: -0.5407*

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* , ** and [a] denote 1% , 5% and 10% significance level

Table 3.6 Structural Breaks of Real Interest Rates Controlled for Inflation (Cont'd)

New Zealand

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	$SupF_T(5)$	$SupF_T(6)$	$SupF_T(7)$	$UD\max$	$WD\max$
16.78*	49.93*	79.45*	63.51*	45.87*	151.87*	151.62*	151.87*	390.31*

$SupF_T(2\mid 1)$	$SupF_T(3\mid 2)$	$SupF_T(4\mid 3)$	$SupF_T(5\mid 4)$	$SupF_T(6\mid 5)$	$SupF_T(7\mid 6)$
90.90*	8.65	8.22	8.22	8.22	0.35

Break Time

$\hat{T}_1$	$\hat{T}_2$
$1985Q2$	$1991Q2$
$[82Q3-85Q4]$	$[90Q1-92Q3]$

Inflation Parameter: -0.9158

The United Kingdom

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	$SupF_T(5)$	$SupF_T(6)$	$SupF_T(7)$	$UD\max$	$WD\max$
13.47*	62.12*	38.20*	34.89*	30.37*	28.49*	24.37*	62.12*	79.64*

$SupF_T(2\mid 1)$	$SupF_T(3\mid 2)$	$SupF_T(4\mid 3)$	$SupF_T(5\mid 4)$	$SupF_T(6\mid 5)$	$SupF_T(7\mid 6)$
83.67*	18.18*	12.39*	0.80	–	–

Break Time

$\hat{T}_1$	$\hat{T}_2$	$\hat{T}_3$	$\hat{T}_4$
$1966Q2$	$1972Q4$	$1992Q3$	$2001Q1$
$[63Q3-69Q4]$	$[70Q2-73Q1]$	$[92Q2-95Q1]$	$[98Q1-02Q3]$

Inflation Parameter: -0.9426*

*, ** and [a] denote 1%, 5% and 10% significance level

Table 3.7 Structural Breaks of Real Interest Rates Controlled for Inflation Regimes

Australia

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	$SupF_T(5)$	$SupF_T(6)$	$SupF_T(7)$	$UD\max$	$WD\max$
11.59**	16.85*	14.41*	13.15*	10.87*	9.59*	9.47*	16.85*	24.39*

$SupF_T(2\mid1)$	$SupF_T(3\mid2)$	$SupF_T(4\mid3)$	$SupF_T(5\mid4)$	$SupF_T(6\mid5)$	$SupF_T(7\mid6)$
18.71*	9.14	4.50	2.76	0.55	–

Break Time

$\hat{T}_1$	$\hat{T}_2$
1983Q4	1999Q2
[79Q1 – 91Q1]	[97Q2 – 01Q4]

Canada

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	$SupF_T(5)$	$SupF_T(6)$	$SupF_T(7)$	$UD\max$	$WD\max$
9.26**	15.32*	13.40*	11.01*	9.61*	7.96*	6.93*	15.32*	20.70*

$SupF_T(2\mid1)$	$SupF_T(3\mid2)$	$SupF_T(4\mid3)$	$SupF_T(5\mid4)$	$SupF_T(6\mid5)$	$SupF_T(7\mid6)$
13.14*	6.50	1.37	3.72	0.32	0.89

Break Time

$\hat{T}_1$	$\hat{T}_2$
1983Q3	2001Q1
[78Q1 – 97Q3]	[98Q4 – 03Q4]

Germany

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	$SupF_T(5)$	$SupF_T(6)$	$SupF_T(7)$	$UD\max$	$WD\max$
16.43*	7.79	9.53*	7.38*	5.64**	4.78	4.15	16.43*	16.43*

$SupF_T(2\mid1)$	$SupF_T(3\mid2)$	$SupF_T(4\mid3)$	$SupF_T(5\mid4)$	$SupF_T(6\mid5)$	$SupF_T(7\mid6)$
2.82	1.02	0.87	0.64	0.02	–

Break Time

$\hat{T}_1$
2002Q4
[00Q4 – 08Q2]

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* , ** and [a] denote 1% , 5% and 10% significance level

Table 3.7 Structural Breaks of Real Interest Rates Controlled for Inflation Regimes (Cont'd)

Japan

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	$SupF_T(5)$	$SupF_T(6)$	$SupF_T(7)$	$UD\max$	$WD\max$
15.18 *	8.96 **	6.56	6.12 **	5.22	5.00 **	4.44 **	15.18 *	15.18 *

$SupF_T(2\mid1)$	$SupF_T(3\mid2)$	$SupF_T(4\mid3)$	$SupF_T(5\mid4)$	$SupF_T(6\mid5)$	$SupF_T(7\mid6)$
4.31	4.17	4.17	2.50	1.52	0.80

	$\widehat{T}_1$
Break Time	1969Q1
	[58Q2 – 74Q2]

Korea

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	$SupF_T(5)$	$SupF_T(6)$	$SupF_T(7)$	$UD\max$	$WD\max$
4.91	4.71	3.10	2.75	2.33	2.01	1.76	4.91	6.04

$SupF_T(2\mid1)$	$SupF_T(3\mid2)$	$SupF_T(4\mid3)$	$SupF_T(5\mid4)$	$SupF_T(6\mid5)$	$SupF_T(7\mid6)$
2.95	0.35	0.64	0.78	0.99	0.50

Break Time No Break

Mexico

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	$SupF_T(5)$	$SupF_T(6)$	$SupF_T(7)$	$UD\max$	$WD\max$
0.48	3.53	2.51	2.05	2.93	2.87	3.75	3.75	9.65

$SupF_T(2\mid1)$	$SupF_T(3\mid2)$	$SupF_T(4\mid3)$	$SupF_T(5\mid4)$	$SupF_T(6\mid5)$	$SupF_T(7\mid6)$
6.76	1.02	1.52	1.52	1.24	1.66

Break Time No Break

New Zealand

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	$SupF_T(5)$	$SupF_T(6)$	$SupF_T(7)$	$UD\max$	$WD\max$
5.31	3.31	4.23	7.46 *	8.69 *	9.16 *	7.65 *	9.16	20.74 *

$SupF_T(2\mid1)$	$SupF_T(3\mid2)$	$SupF_T(4\mid3)$	$SupF_T(5\mid4)$	$SupF_T(6\mid5)$	$SupF_T(7\mid6)$
2.86	6.92	1.61	2.38	4.53	0.20

Break Time No Break

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* , ** and [a] denote 1% , 5% and 10% significance level

Table 3.7 Structural Breaks of Real Interest Rates Controlled for Inflation Regimes (Cont'd)

The United Kingdom

$SupF_T(1)$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	$SupF_T(5)$	$SupF_T(6)$	$SupF_T(7)$	$UD\max$	$WD\max$
3.08	1.79	4.16	8.79 *	7.58 *	7.47 *	5.76 *	8.79	16.92 *

$SupF_T(2\|1)$	$SupF_T(3\|2)$	$SupF_T(4\|3)$	$SupF_T(5\|4)$	$SupF_T(6\|5)$	$SupF_T(7\|6)$
6.74	7.03	7.03	3.04	0.49	0.72

Break Time No Break

* , ** and [a] denote 1% , 5% and 10% significance level

Table 3.8 J-Test: Fed Regime vs. Inflation Regime

Australia					
H_0:	Fed Regime	4.4719*	H_0:	Inflation Regime	3.9200*
H_1:	Inflation Regime		H_1:	Fed Regime	
Canada					
H_0:	Fed Regime	4.2445*	H_0:	Inflation Regime	3.2789*
H_1:	Inflation Regime		H_1:	Fed Regime	
Germany					
H_0:	Fed Regime	0.0344	H_0:	Inflation Regime	3.9333*
H_1:	Inflation Regime		H_1:	Fed Regime	
Japan					
H_0:	Fed Regime	1.6614[a]	H_0:	Inflation Regime	6.6405*
H_1:	Inflation Regime		H_1:	Fed Regime	
Korea					
H_0:	Fed Regime	3.4436*	H_0:	Inflation Regime	0.5411
H_1:	Inflation Regime		H_1:	Fed Regime	
Mexico					
H_0:	Fed Regime	4.8157*	H_0:	Inflation Regime	-1.8289[a]
H_1:	Inflation Regime		H_1:	Fed Regime	
New Zealand					
H_0:	Fed Regime	0.9761	H_0:	Inflation Regime	2.1429**
H_1:	Inflation Regime		H_1:	Fed Regime	
The United Kingdom					
H_0:	Fed Regime	3.6400*	H_0:	Inflation Regime	2.5809*
H_1:	Inflation Regime		H_1:	Fed Regime	

*, ** and [a] denote 1%, 5% and 10% significance level

Table 3.9 Summary of Factors Explaining Breaks in Real Interest Rates

Country	Break Time of Real Interest Rates				
Australia	71Q1	76Q4	82Q4		99Q2
	π	Fed / π			OP
Canada	71Q1		81Q1		99Q2
	G / Fed / π		Fed		
Germany			81Q1		02Q4
			Fed / π		
Japan	72Q4		80Q2		
	Fed		Fed / π		
Korea			81Q3	87Q1	00Q2
			π	Fed / π	OP / π
Mexico				88Q4	
				G / OP / Fed / π	
New Zealand				86Q4	99Q4
				π	OP / Fed / π
The United Kingdom	68Q1	73Q3	81Q2		02Q1
	G / π	G / OP / π	π		G / OP / Fed / π

G, π, OP and Fed denote government expenditures, inflation regimes, real oil prices and US Fed regimes respectively; the reported break times for real interest rates are obtained from the BP method

Table 3.10 Unit Root Tests

	ADF		KPSS		LP	
Country	i_{tax}	π	i_{tax}	π	i_{tax}	π
Australia	-1.40	-2.41	0.42	0.36	-5.56	-5.47
Canada	-2.40	-2.06	0.37	0.37	-4.94	-5.68
Germany	-2.24	-2.12	0.54	0.47	-4.90	-3.92
Japan	-0.90	-2.76	1.59	0.88	-6.30	-7.12
Korea	-0.78	-3.82	1.26	0.85	-6.12	-6.65
Mexico	-1.90	-2.91	0.82	0.76	-9.65	-15.80
New Zealand	-2.11	-2.95	0.73	0.99	-6.20	-8.68
Switzerland	-2.22	-2.79	0.64	0.59	-6.46	-4.40
UK	-2.57	-2.87	0.38	0.38	-6.08	-5.69
Critical Value	-3.46 (1%)		0.74 (1%)		-6.94 (1%)	
	-2.88 (5%)		0.46 (5%)		-6.24 (5%)	
	-2.57 (10%)		0.35 (10%)		-5.96 (10%)	

LP denotes the Lumsdaine and Papell (1997) unit root test allowing for two breaks in intercept; the null hypothesis is the unit root process

i_{tax}, and πrepresent the tax-adjusted nominal interest rate and inflation

Table 3.11 Multivariate Ljung-Box Test (VAR Model)

Country	Q_4	Q_8	Q_{12}	Q_4^2	Q_8^2	Q_{12}^2
Australia	4.90	20.46	39.27	79.51*	117.21*	152.97*
Canada	4.57	16.26	29.54	101.47*	125.04*	133.93*
Germany	3.40	11.40	24.29	41.28*	60.01*	72.55*
Japan	4.99	17.93	38.29	25.12*	27.07	30.28
Korea	4.28	24.85	50.47	49.24*	95.24*	124.62*
Mexico	6.16	23.71	34.23	30.50*	38.44	44.82
New Zealand	7.19	24.78	42.13	23.19**	114.20*	125.95*
Switzerland	5.31	18.38	22.14	46.84*	54.00*	68.21*
The United Kingdom	3.08	18.50	37.52	48.91*	135.03*	172.91*

* , ** denote 1% and 5% significance level ; standardized residuals and their squares are used for the tests

Table 3.12 Estimation Results of VAR-GARCH Models

		Australia		Canada		Germany	
		π	i_{tax}	π	i_{tax}	π	i_{tax}
π_{t-1}		0.2373*	0.0110	0.3844*	0.0380	0.2455*	0.0682*
π_{t-2}		0.1964*	0.0049	0.0516	0.0088	-0.0924	-0.0123
π_{t-3}		0.0707	0.0158	0.0792	0.0184	-0.0018	0.0183
π_{t-4}		0.2249*	-0.0126	0.3574	0.0191	0.5590*	-0.0144
π_{t-5}						-0.1693	-0.0522*
π_{t-6}							
π_{t-7}							
π_{t-8}							
π_{t-9}							
$i_{tax,t-1}$		1.8355*	1.0881*	0.2779	1.2634*	0.5559	1.3583*
$i_{tax,t-2}$		-0.7134	-0.1398	-0.2938	-0.4480*	0.5528	-0.3006
$i_{tax,t-3}$		-0.4342	0.1225	0.3086	0.0691	-1.0667	-0.1473
$i_{tax,t-4}$		-0.4884	-0.1294	-0.2656	0.0179	-0.1025	0.002
$i_{tax,t-5}$						0.3234	0.0216
$i_{tax,t-6}$							
$i_{tax,t-7}$							
$i_{tax,t-8}$							
$i_{tax,t-9}$							
μ		0.0034	0.0018*	0.0042	0.0011	0.0018	0.0018**
c_{11}	c_{12}	0.0139*	0.0003	0.0176*	0.0005	0.0101*	0.0002
0	c_{22}	0.0000	0.0006	0.0000	0.0000	0.0000	0.0000
a_{11}	a_{12}	0.4270*	0.0121	-0.4407*	-0.0995*	0.5875*	0.0529*
a_{21}	a_{22}	-1.7973*	0.3967	0.8962*	0.5738*	-0.3864	0.3875*
b_{11}	b_{12}	0.7118*	-0.0078	0.3881	-0.0361	-0.5486*	-0.0288**
b_{21}	b_{22}	0.6832*	0.9048*	-0.294	0.8365*	0.1131	0.8814*

*, ** denote 1% and 5% significance levels

Table 3.12 Estimation Results of VAR-GARCH Models (Cont'd)

		Japan		Korea		Mexico	
		π	i_{tax}	π	i_{tax}	π	i_{tax}
π_{t-1}		-0.0330	0.0024	0.1921*	0.0062	0.3523	-0.0725
π_{t-2}		0.1978*	-0.0002	-0.002	0.0125	0.1243	0.1004
π_{t-3}		0.0000	-0.0035	0.1878	-0.0101	0.2557	0.0027
π_{t-4}		0.4638*	0.0050	0.1701	-0.0031	-0.1251	0.1147
π_{t-5}		-0.0413	-0.0085**	0.0504	-0.0009	0.1225	-0.0348
π_{t-6}				-0.0859	-0.0016	-0.4166	-0.0209
π_{t-7}				-0.1335	-0.0167	0.2514	-0.0036
π_{t-8}						0.0804	0.0779
π_{t-9}							
$i_{tax,t-1}$		0.9514	1.2081*	1.3928*	1.1308*	1.0365	1.0525*
$i_{tax,t-2}$		0.2106	-0.1405	-0.8080	-0.0733	-1.5061	-0.7035
$i_{tax,t-3}$		1.7389	0.0536	0.7677	-0.2172	0.7917	0.6719
$i_{tax,t-4}$		-3.6542	-0.0639	-0.8276	0.2603	-0.2655	-0.5201
$i_{tax,t-5}$		1.1247	-0.0595	0.2830	-0.1341	-0.0199	0.3063
$i_{tax,t-6}$				0.5699	0.1605	0.3827	-0.1600
$i_{tax,t-7}$				-0.9430	-0.1060	-0.1047	0.1268
$i_{tax,t-8}$						-0.2124	-0.0991
$i_{tax,t-9}$							
μ		-0.0005	0.0001	0.0042	-0.0001	-0.0009	0.0132
c_{11}	c_{12}	0.0052	-0.0001	0.0000	0.0000	0.0031	-0.0013
0	c_{22}	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
a_{11}	a_{12}	0.5002*	0.0009	0.2576*	0.0340*	0.8102*	0.1265*
a_{21}	a_{22}	0.7849**	0.1288*	0.9731	1.5915*	1.8784*	1.4356*
b_{11}	b_{12}	0.8734*	0.0020*	0.9240*	-0.0226*	0.5463*	-0.1427*
b_{21}	b_{22}	-0.1193	0.9734*	-1.6523*	0.2486*	-0.7330*	0.4825*

*, ** denote 1% and 5% significance levels

Table 3.12 Estimation Results of VAR-GARCH Models (Cont'd)

		New Zealand		Switzerland		The United Kingdom	
		π	i_{tax}	π	i_{tax}	π	i_{tax}
π_{t-1}		0.4924*	0.0621*	0.1890	0.0090	0.3002*	0.0226
π_{t-2}		0.0519	-0.0244	0.1336	-0.0079	0.0846	-0.0163
π_{t-3}		0.1366	0.0174	-0.1800	0.0114	-0.0611	-0.0038
π_{t-4}		0.1879	-0.0117	0.5478*	0.0188	0.4695*	-0.0042
π_{t-5}		-0.0632	-0.0394	-0.2806	-0.0009	-0.2262	-0.0024
π_{t-6}						0.026	0.0295*
π_{t-7}						-0.0018	0.0073
π_{t-8}						0.2694	-0.0049
						-0.0571	-0.0022
$i_{tax,t-1}$		1.5987	1.1948*	-0.5334	1.3825*	1.5282*	1.2587*
$i_{tax,t-2}$		-0.7135	-0.3306	2.2512**	-0.2237	-1.2966	-0.3398
$i_{tax,t-3}$		-1.5386	0.0412	-0.4501	-0.0905	0.2766	-0.0019
$i_{tax,t-4}$		0.7603	-0.1366	-0.9596	-0.3683	-0.6699	0.1584
$i_{tax,t-5}$		0.0976	0.1863**	0.1172	0.2318**	-0.2307	-0.2374
$i_{tax,t-6}$						0.9163	0.124
$i_{tax,t-7}$						0.3227	-0.1193
$i_{tax,t-8}$						-1.726	0.0643
						0.8399	0.0228
μ		-0.0006	0.0016	0.0022	0.0004	0.0099	0.0016
c_{11}	c_{12}	0.0071*	0.0003*	0.0039*	0.0002	0.0019	0.0003
0	c_{22}	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
a_{11}	a_{12}	0.1959*	-0.0500*	0.3751*	0.0066	0.4231*	0.007
a_{21}	a_{22}	2.7024*	0.7390*	0.2801	0.3354*	-1.4833*	-0.0958*
b_{11}	b_{12}	0.8619*	0.0085*	0.8889*	-0.0077*	0.8599*	-0.0273*
b_{21}	b_{22}	-1.9768*	0.6766*	-0.0138	0.9334*	0.9556*	1.0115*

*, ** denote 1% and 5% significance levels

Table 3.13 Multivariate Ljung-Box Test (VAR-GARCH Model)

Country	Q_4	Q_8	Q_{12}	Q_4^2	Q_8^2	Q_{12}^2
Australia	10.09	24.46	35.93	11.02	27.81	38.55
Canada	5.90	15.38	31.21	16.50	32.67	45.22
Germany	10.03	19.68	35.65	14.73	28.53	40.09
Japan	14.46	28.64	52.54	6.12	17.29	24.63
Korea	14.21	36.13	50.33	16.06	33.74	51.98
Mexico	16.95	29.53	31.15	19.56	33.87	50.52
New Zealand	5.58	17.44	34.52	5.66	28.91	37.37
Switzerland	14.18	35.24	42.98	13.13	24.16	48.14
The United Kingdom	6.41	15.81	25.82	8.56	17.53	26.28

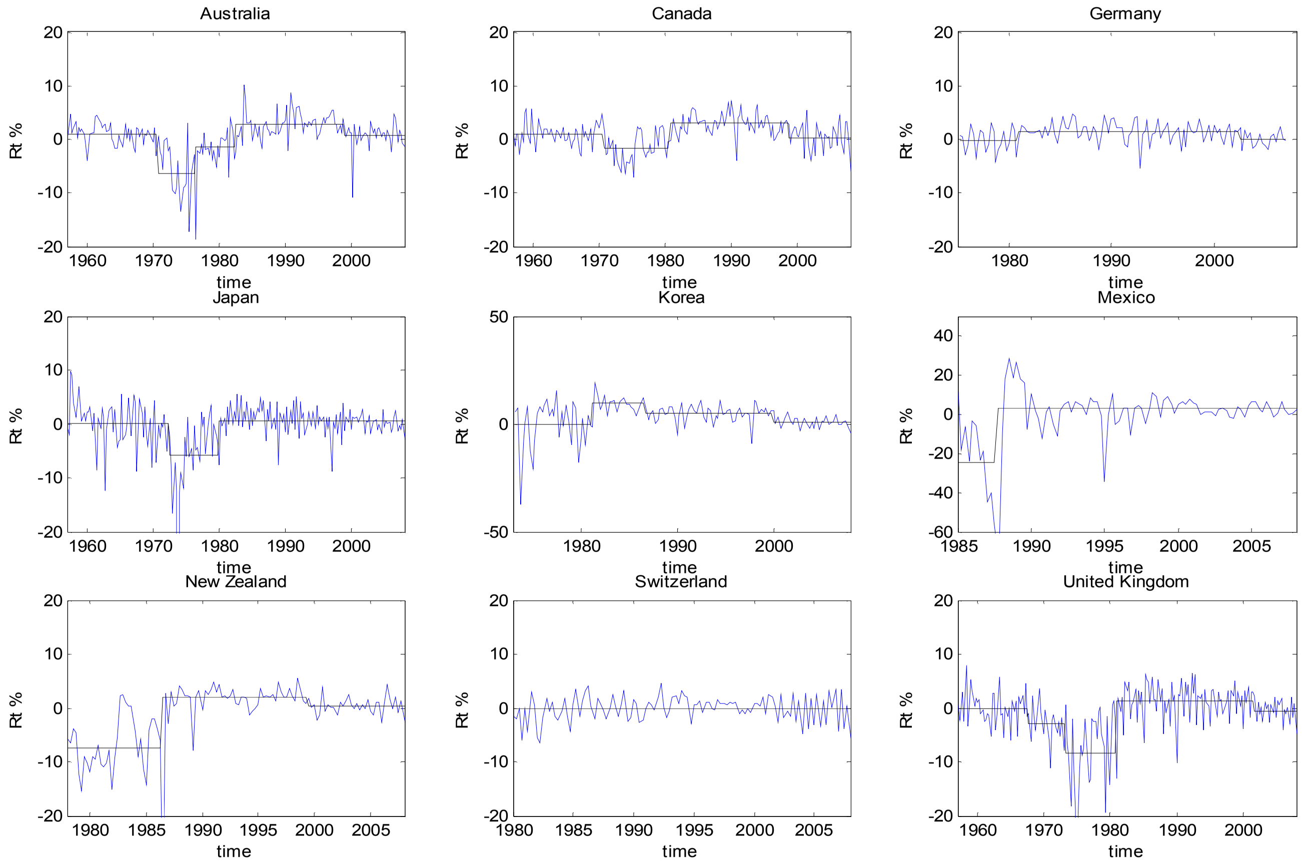
* , ** denote 1% and 5% significance level ; standardized residuals and their squares are used for the tests

Table 3.14 Cointegration Tests

Country	Number of Cointegrating Eqt	λ_{trace}	$\lambda_{\max}$	β_{π}
Australia	r = 0	17.14	12.86	-
	r ≤ 1	4.28	4.28	-
Canada	r = 0	19.55	14.00	-
	r ≤ 1	5.55	5.55	-
Germany	r = 0	16.92	10.31	-
	r ≤ 1	6.61	6.61	-
Japan	r = 0	17.51	15.41	-
	r ≤ 1	2.10	2.10	-
Korea	r = 0	18.54	16.40	-
	r ≤ 1	2.15	2.15	-
Mexico	r = 0	22.78**	20.02**	0.7588*
	r ≤ 1	2.76	2.76	-
New Zealand	r = 0	10.47	6.68	-
	r ≤ 1	3.79	3.79	-
Switzerland	r = 0	18.80	14.57	-
	r ≤ 1	4.23	4.23	-
The United Kingdom	r = 0	17.04	11.50	-
	r ≤ 1	5.54	5.54	-

* , ** denote 1% and 5% significance level

Figure 3.1 Structural Breaks of Real Interest Rate



Rt denotes the tax-adjusted real interest rate

Figure 3.2 Structural Breaks of Inflation

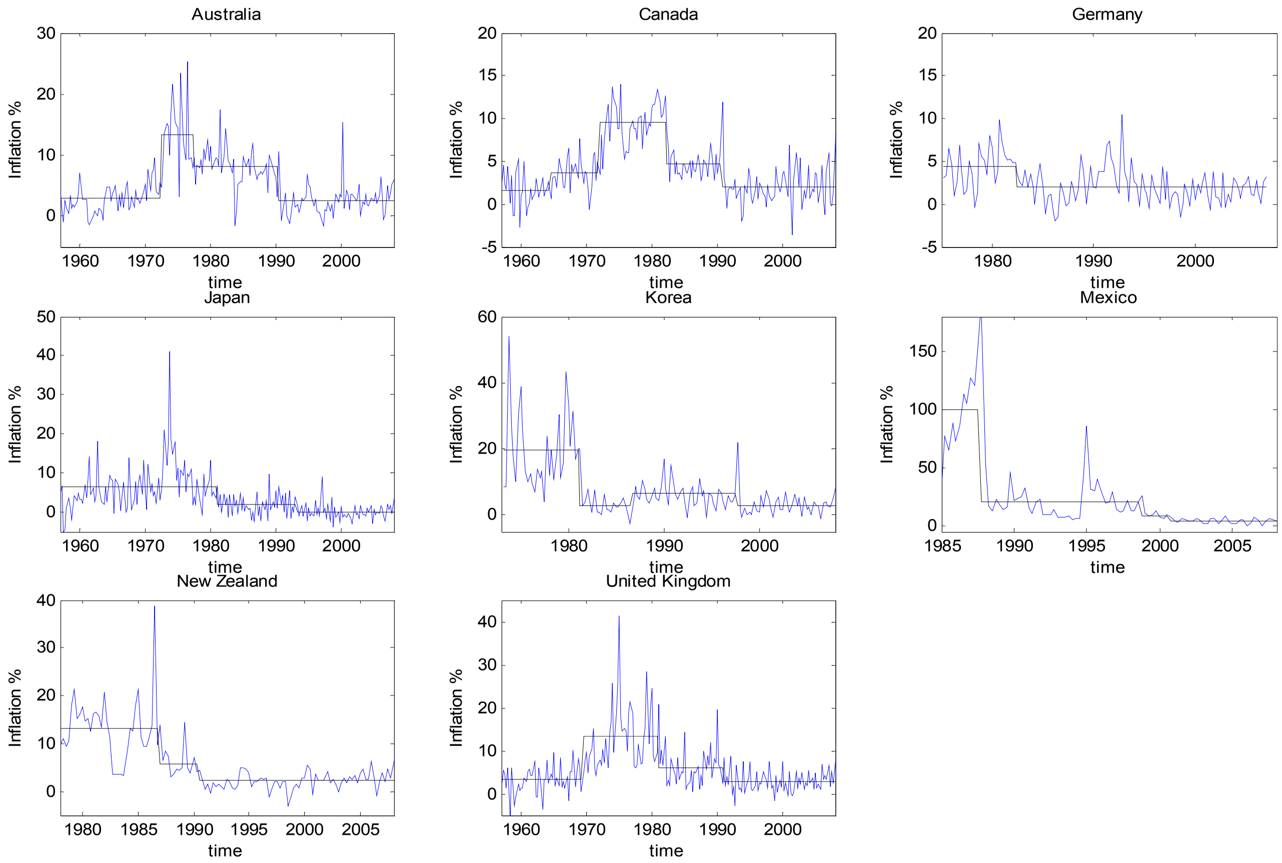
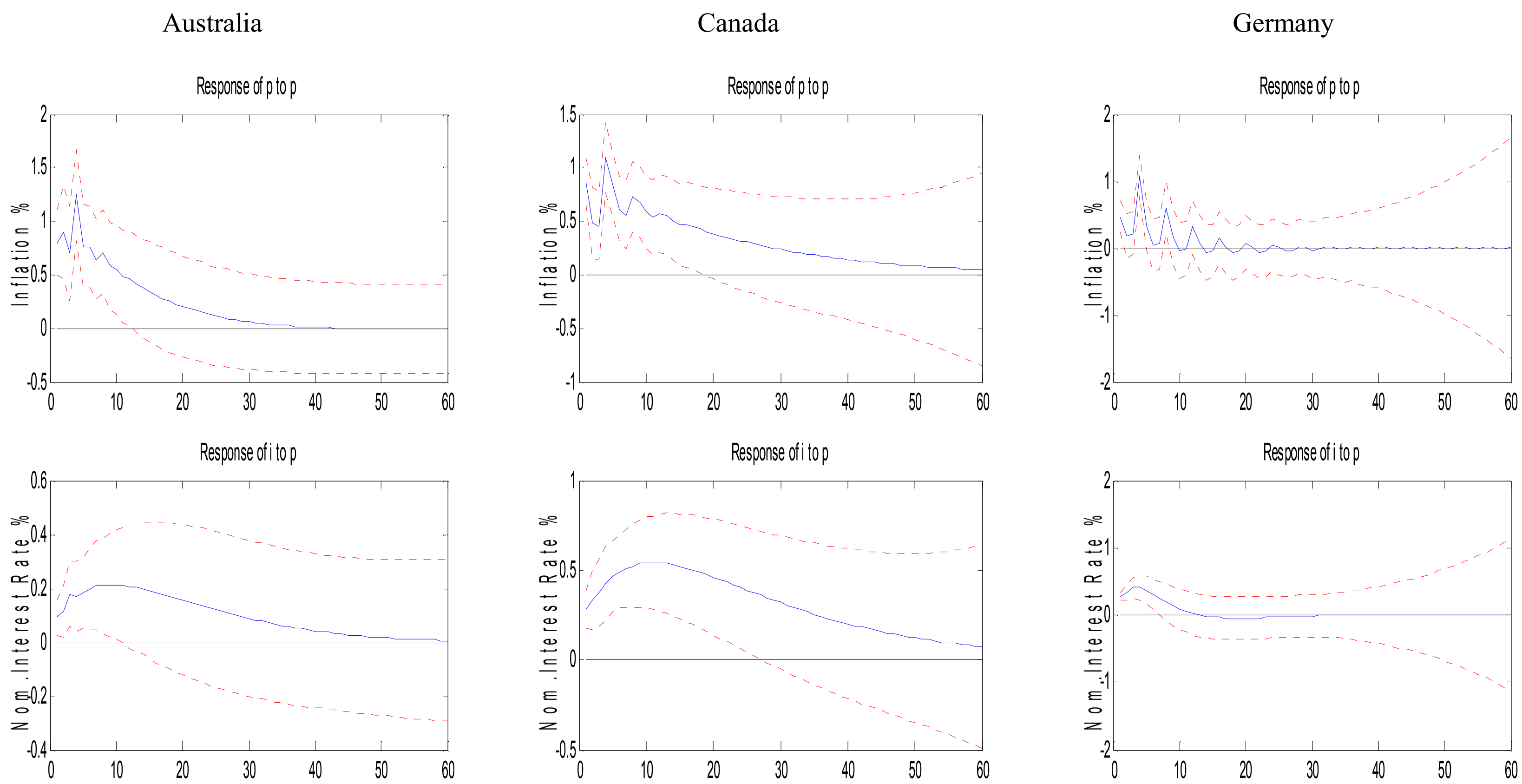
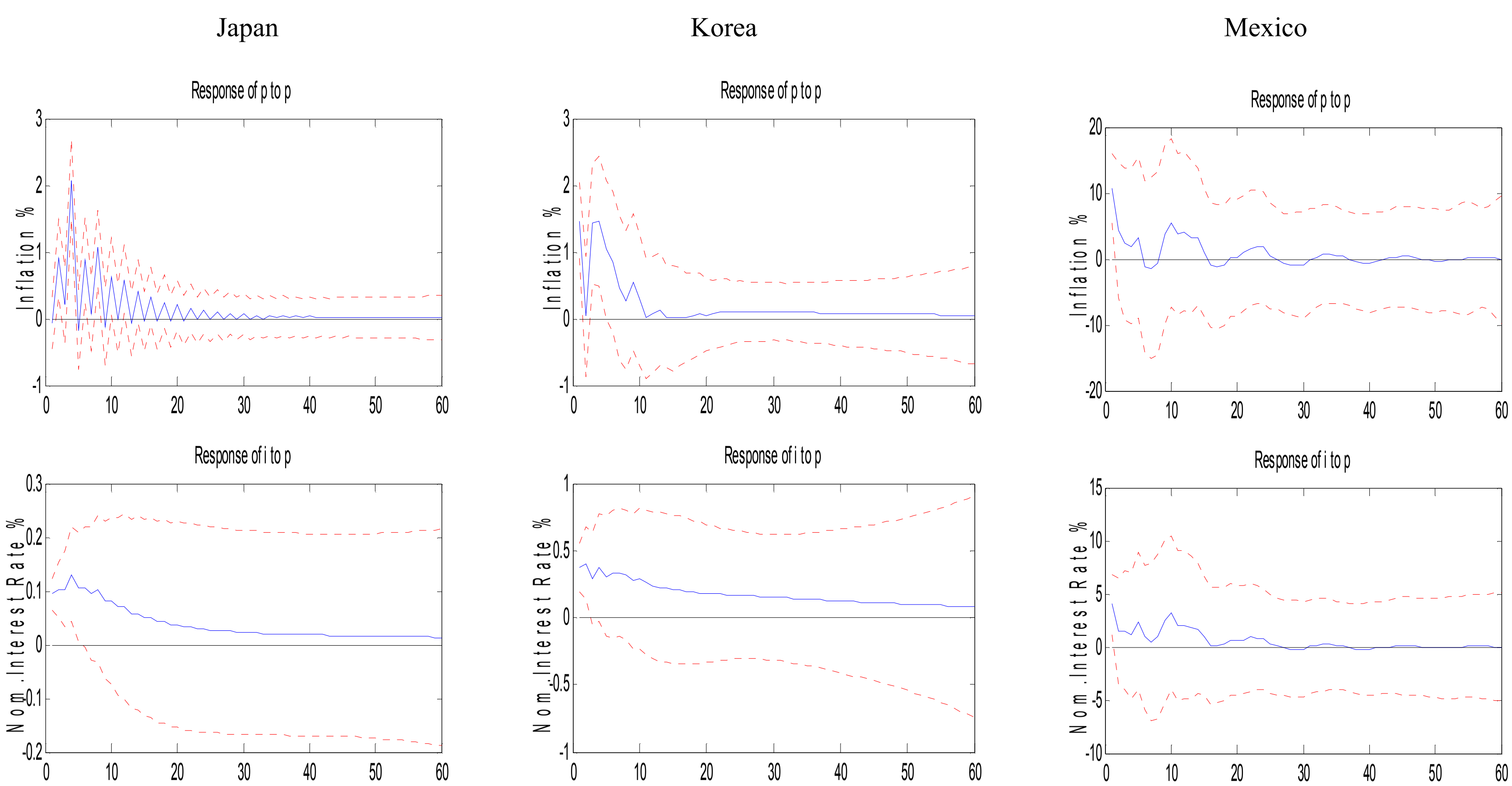


Figure 3.3 Impulse Responses: VAR-GARCH Model



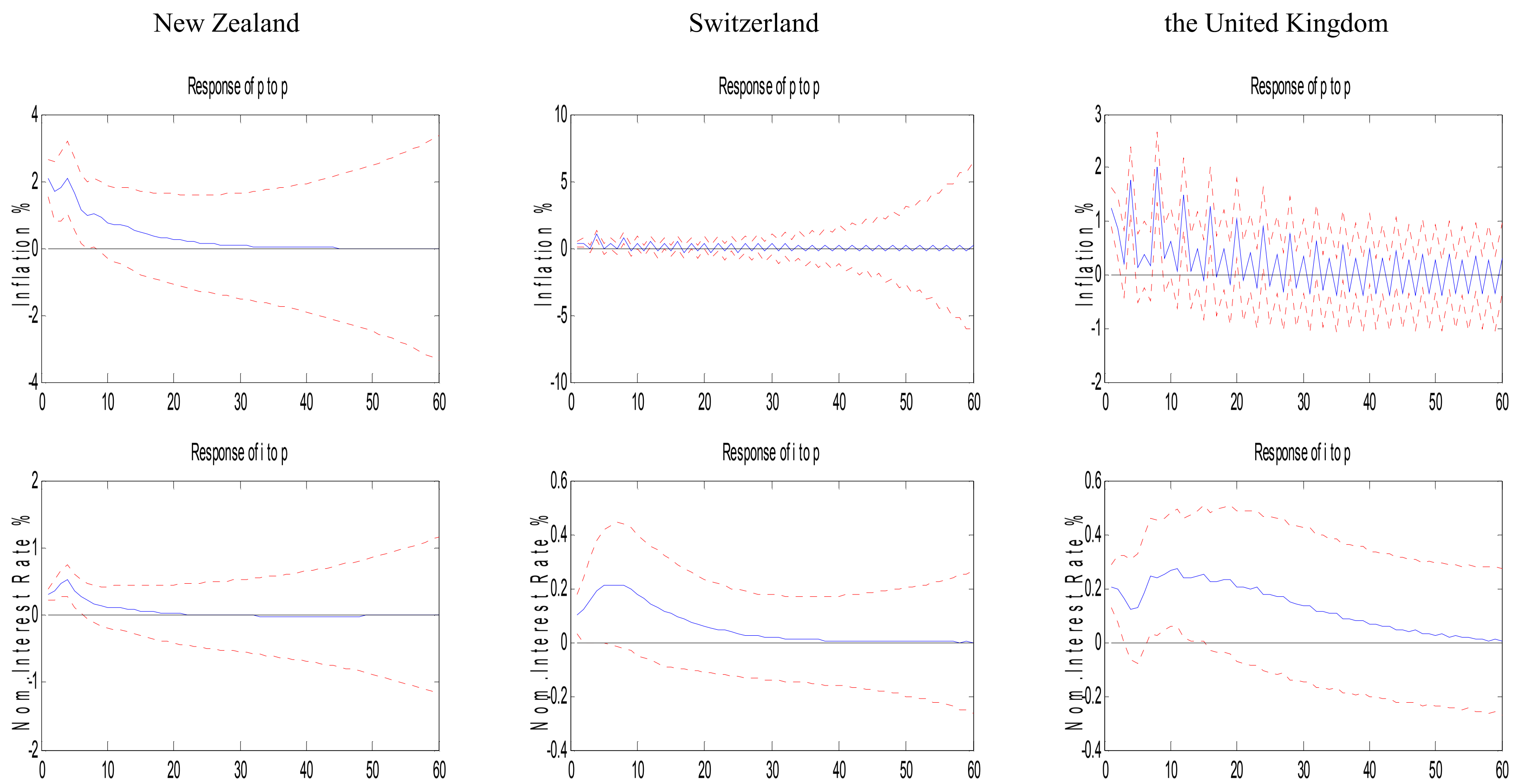
Note: the broken lines represent the 95% confidence interval based on 1000 replications

Figure 3.3 Impulse Responses: VAR-GARCH Model (Cont'd)



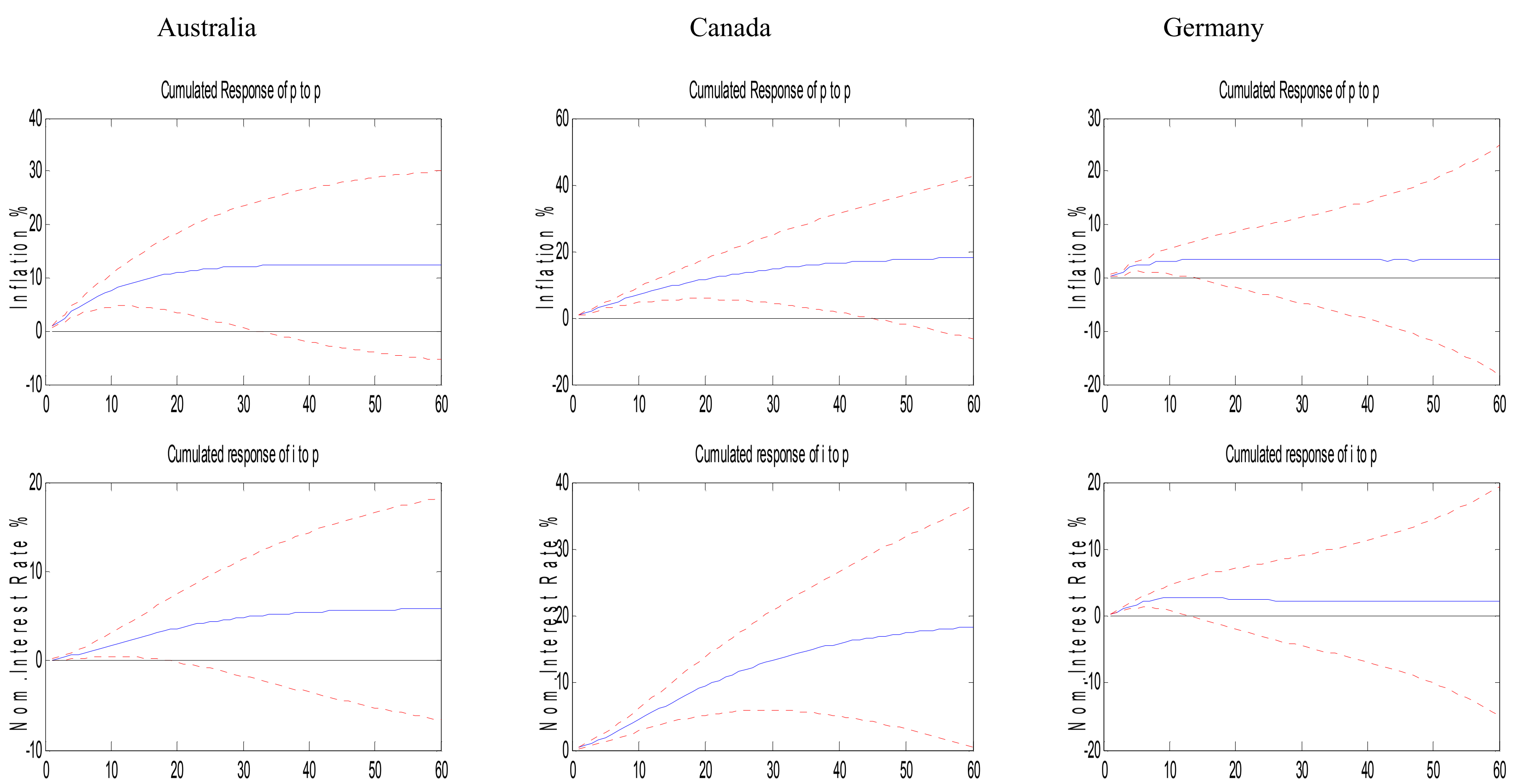
Note: the broken lines represent the 95% confidence interval based on 1000 replications

Figure 3.3 Impulse Responses: VAR-GARCH Model (Cont'd)



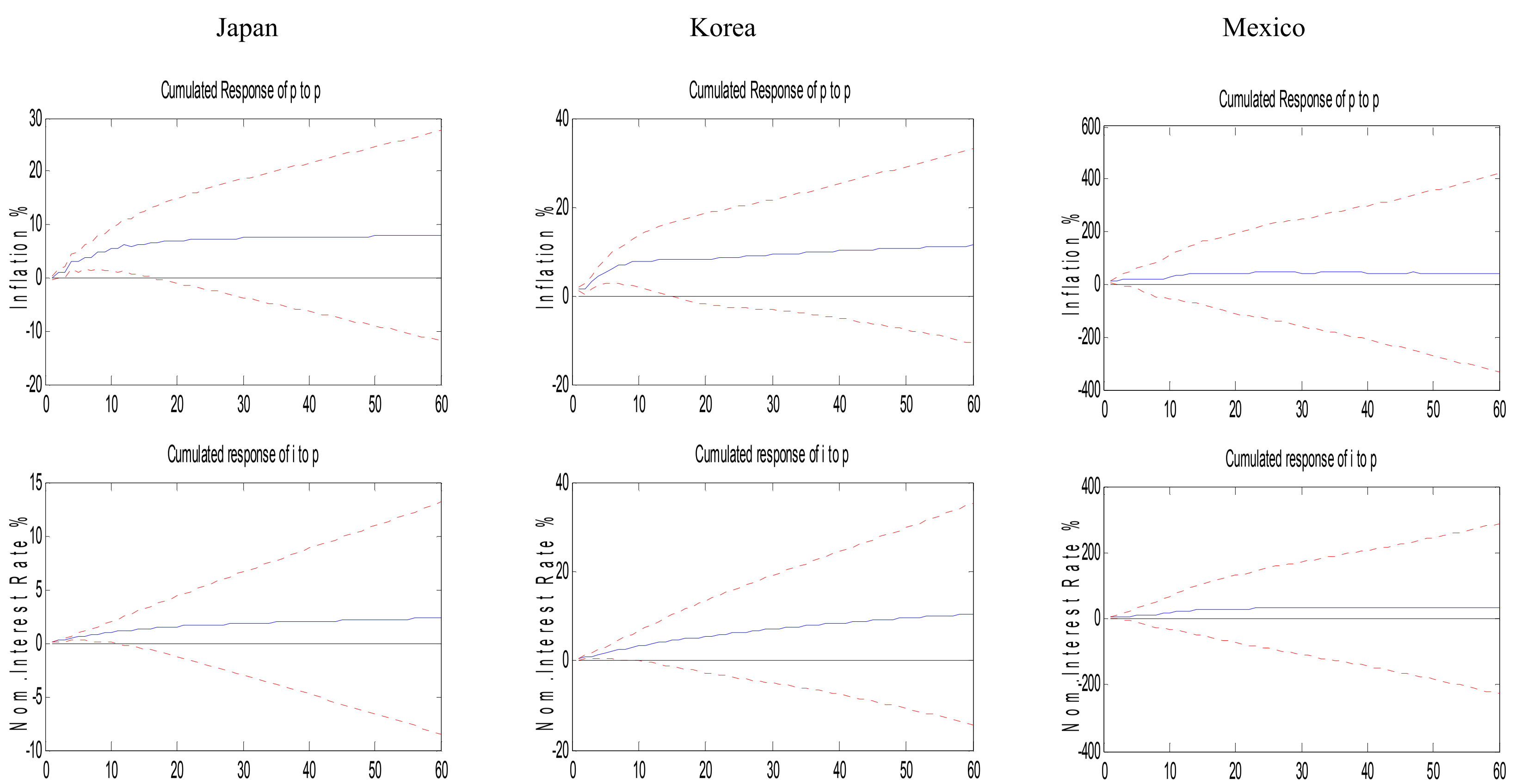
Note: the broken lines represent the 95% confidence interval based on 1000 replications

Figure 3.4 Cumulated Impulse Responses: VAR-GARCH Model



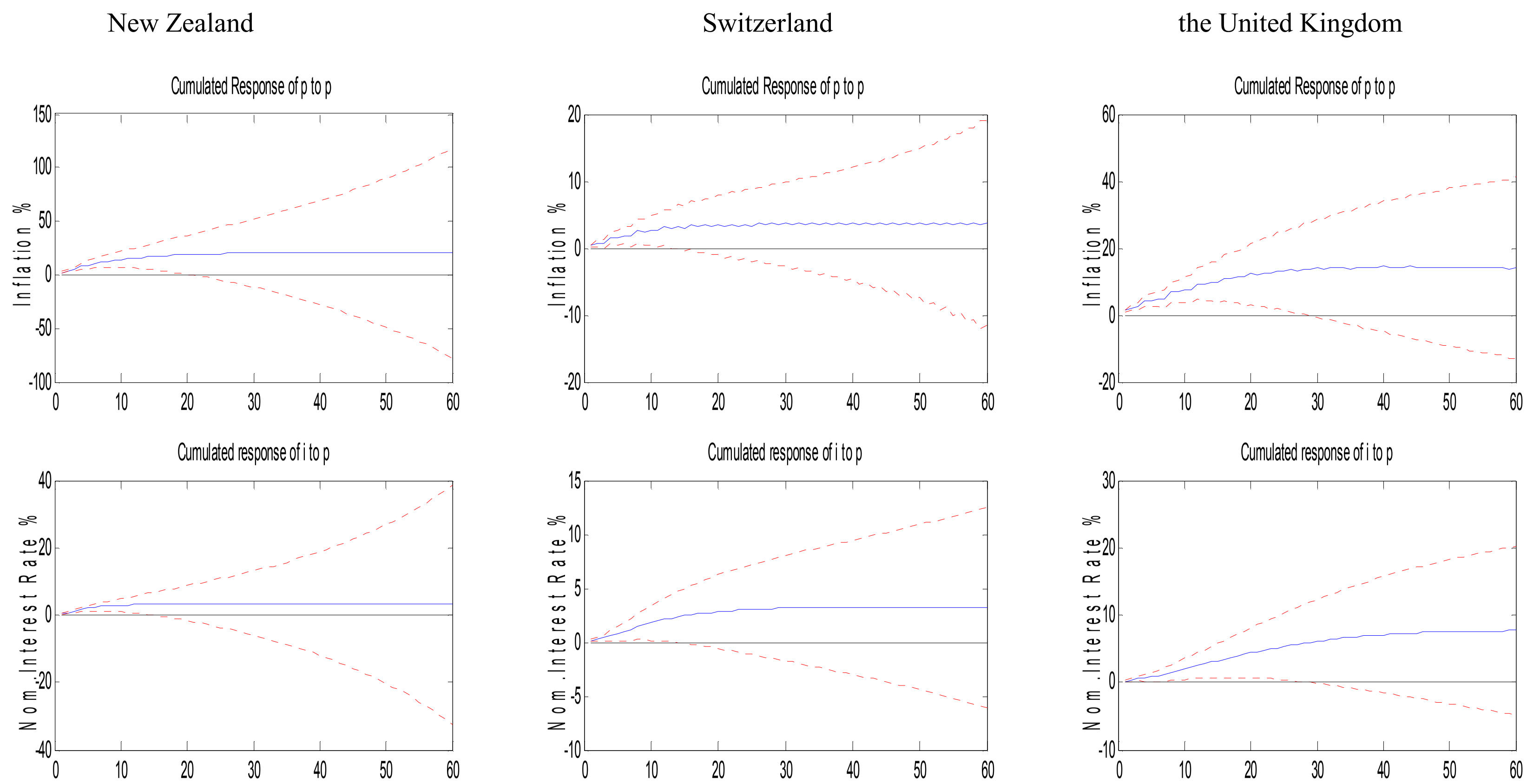
Note: the broken lines represent the 95% confidence interval based on 1000 replications

Figure 3.4 Cumulated Impulse Responses: VAR-GARCH Model (Cont'd)



Note: the broken lines represent the 95% confidence interval based on 1000 replications

Figure 3.4 Cumulated Impulse Responses: VAR-GARCH Model (Cont'd)



Note: the broken lines represent the 95% confidence interval based on 1000 replications

Figure 3.5 Cumulated Impulse Responses: Inflation and Unadjusted Nominal Interest Rates

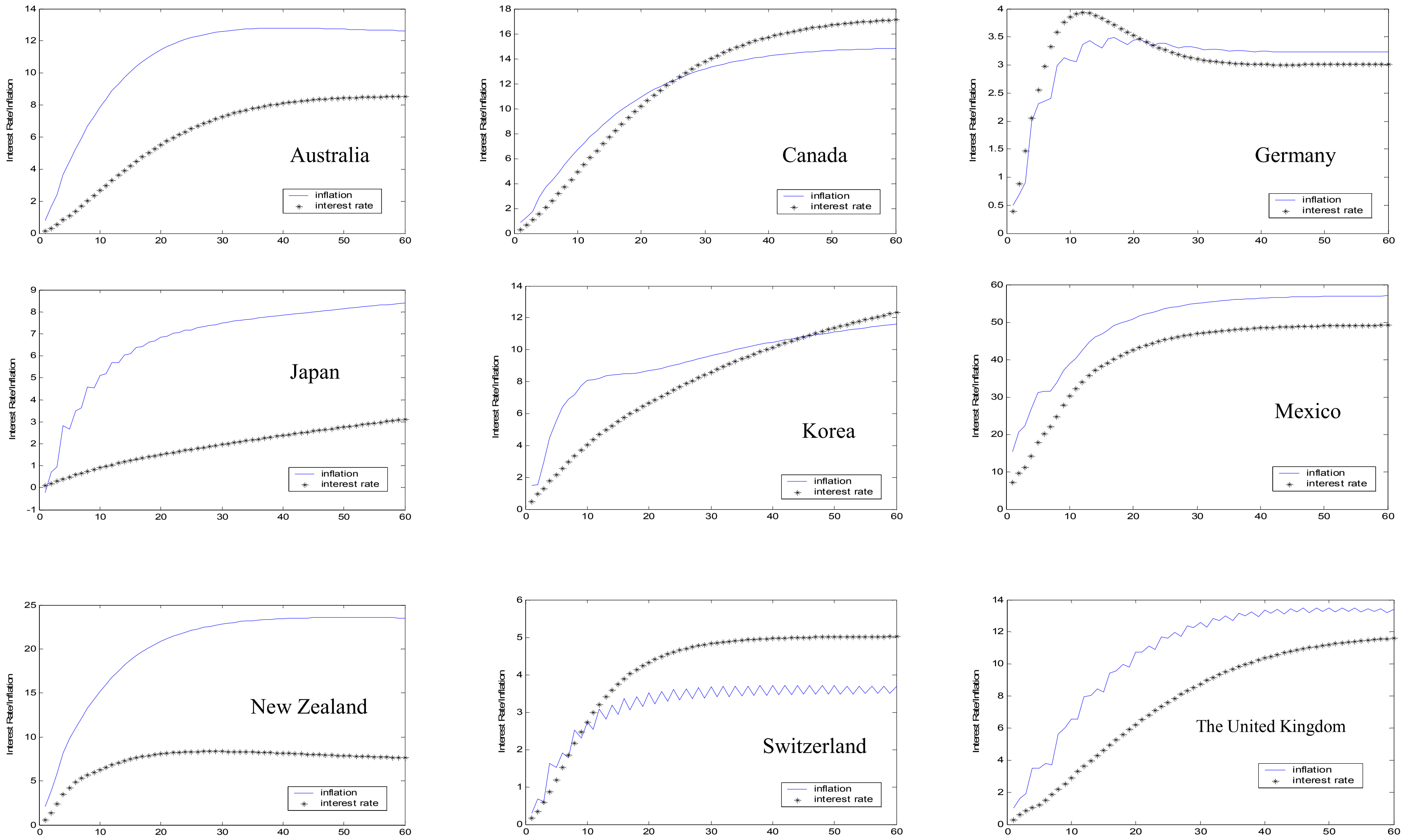
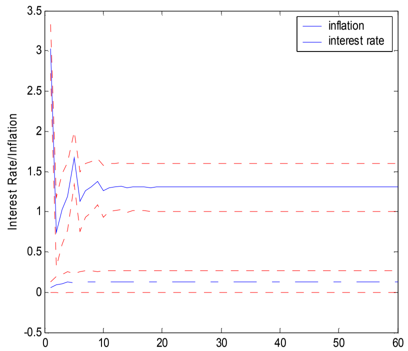
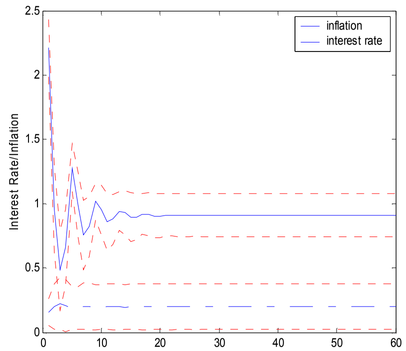


Figure 3.6 Cumulated Impulse Response: First-Differenced VAR Model

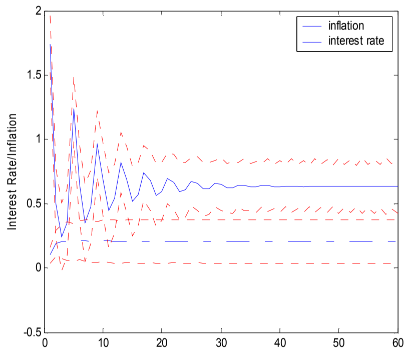
Australia



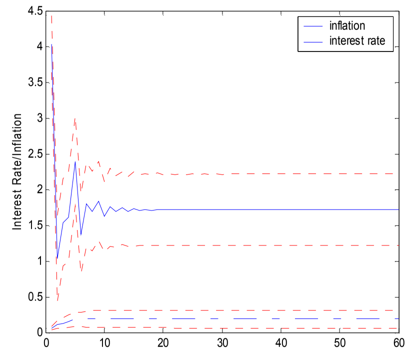
Canada



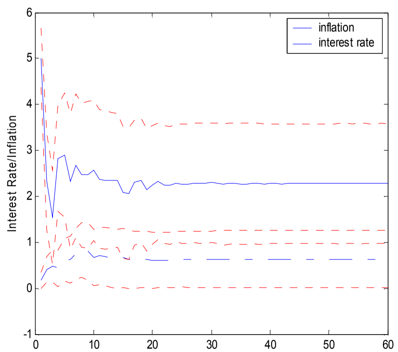
Germany



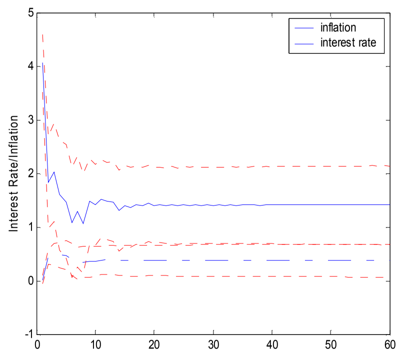
Japan



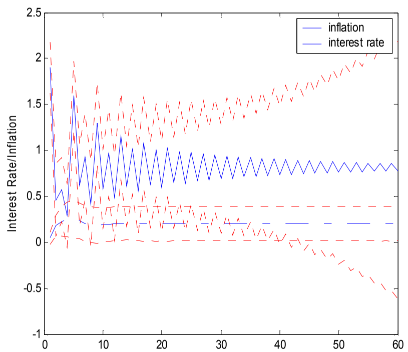
Korea



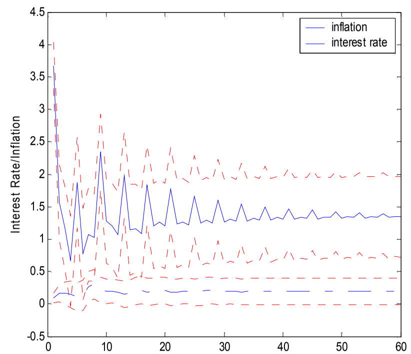
New Zealand



Switzerland



The United Kingdom



Note: the broken lines represent the 95% confidence interval based on 1000 replications