TWO ESSAYS IN INTERNATIONAL FINANCE

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TWO ESSAYS IN INTERNATIONAL FINANCE

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Essay 1. An empirical study on whether Inflation Targeting matters to Purchasing Power Parity

1.1 Introduction

Inflation targeting (IT) is a new monetary strategy that central banks are interested in recent years. New Zealand firstly adopted IT in 1990. Compared to other monetary policies, IT is highly recommended for its ability to stable inflation rate and to maintain a lower volatility of real exchange rates in the long run based on several theoretical studies (Svensson, 2000; Mishkin and Schmidt-Hebbel, 2007; and Rose, 2007). The purpose of this essay is to empirically investigate whether IT affects the volatility of real exchange rates in the long-run. Purchasing Power Parity (PPP) is usually examined to study exchange rates volatility in the long-run.

PPP, foundation of international economics theories, has been studied and tested for decades. It is widely believed that the failure of PPP in early studies is due to the short span data employed. With a small sample size, univariate unit root tests tend to have low power. In the empirical studies of PPP, panel data methods are considered effective to improve test power. Sampled data are expanded cross-sectionally for recent floating exchange rates to capture additional information (Quah, 1992; Breitung and Mayer, 1994; and Abuaf and Jorion, 1990). Several studies adopted panel data methods have found supportive evidence of PPP for OECD countries (Lothian, 1998; Papell, 2002; and Taylor, 2003).

In addition, the validity of PPP using panel data methods is contingent upon an important assumption of cross-sectional dependence. A key assumption of previous panel methods is cross-sectional independence. As pointed out by O'Connell (1998), supportive evidence of PPP is overturned after considering cross-sectional dependence. However, the majority of existing empirical studies failed to explore this issue. Furthermore, the choice of price indices and base currencies are two other important issues that might explain the failure of PPP. Therefore, this essay attempts to investigate whether IT affects PPP for OECD countries using panel data methods and whether results might be influenced by those important issues proposed by previous studies.

Quarterly data of 19 OECD countries are sampled from 1974Q1 to 2009Q4. Different from previous studies that pooled countries into a group (ALL group), this essay further divides them into countries adopted IT (IT group) and countries not adopted IT (NIT group). IPS unit root tests (Im, Pesaran, and Shin, 2003) and CIPS unit root tests (Pesaran, 2007) are applied to panel data. Univariate unit root tests are also employed as benchmark. However, conclusions are drawn based on results from panel unit root tests because of their better test powers. For IT, ALL, and NIT groups, results are compared based on real exchange rates with CPI and PPI, five different base currencies, and with and without cross-sectional dependence assumption.

The rest of this essay is organized as follows: literature review and background on Inflation Targeting policy and Purchasing Power Parity are presented in the following section. The third section discusses econometric methodologies. Data description is discussed in section 4. In section 5, results are reported and analyzed. The final section concludes.

1.2 Literature Review

1.2.1 Inflation Targeting

Inflation targeting is a new monetary policy strategy that central banks are interested in recent years. The reason why they are searching for new monetary policy is mainly because existing monetary policies may not be suitable for current economic environment. Many countries experienced failures of their policies. One type of monetary policy, targeting exchange rate, was becoming impropriate since Bretton Woods system ended in early 1970's. Moreover, with the rapid development of financial markets, the relationship of money supply growth and price are becoming unstable. Consequently, the other type of monetary policy, targeting monetary supply growth, turns to be inefficiency. A growing number of researchers and policy makers are recommending target inflation since the early 1990's and this idea is supported by the theoretical models of Svensson (1997) and Ball (1997).

It is widely believed that the primary objective of monetary policy is to maintain a low and stable rate of inflation. It is important that a monetary policy framework can provide a credible nominal anchor that policy makers can use to tie down the price level. At the same time, it is required the sufficient flexibility responding to temporary shocks without undermining the credibility of the main goal. A key to a successful monetary policy is to have a strong nominal anchor, that is, a nominal variable can not only help central banks focus on the goal of long-run price stability but also keep it from the temptation or the political pressures to pursue short-run expansionary policies that are inconsistent with the long-run goal.

Under inflation targeting, it does not anchor the price level (P) but the expected rate of price increases (ΔP^e). According to Ramos-Francia (2008), inflation targeting can be viewed as a mechanism for moving the economy away from bad equilibrium (high-inflation equilibrium) to low inflation equilibrium. Five main features of inflation targeting listed by Mishkin (2000) that distinguish it from other monetary policy strategies are: "(i) the public announcement of medium-term numerical targets for inflation; (ii) an institutional commitment to price stability as the primary goal of monetary policy, to which other goals are subordinated; (iii) an information-inclusive strategy in which many variables, and not just monetary aggregates or the exchange rate, are used for deciding the setting of policy instruments; (iv) increased transparency of the monetary-policy strategy through communication with the public and the markets about the plans, objectives and decisions of the monetary authorities; and (v) increased accountability of the central bank for attaining its inflation objectives".

Compared to alternative nominal anchors, inflation targeting has several advantages. On the one hand, monetary targeting (targeting money supply growth) used to be considered as a credible nominal anchor. But the relationship between money and inflation became increasingly unstable with the development of financial markets innovations. However, under inflation targeting, the strategy does not depend on such a stable relationship only, but instead uses all available information to determine the best settings for the instruments of monetary policy. On the other hand, targeting exchange rate was another way to anchor monetary policy. It's hard for the pegging country to pursue its own monetary policy to response to shocks that are independent of those hitting the anchor country. However, inflation targeting enables monetary policy to focus on domestic considerations and to respond to shocks to the domestic economy.

In addition, under inflation targeting, a key feature is the public announcement of a numerical target. On the one hand, this targeting not only provides a nominal anchor but also offers a point that may anchor inflation expectations. Without a reference number, economic agents in the economy may have different expectations about inflation in the future. According to Bernanke et al. (1999), by setting same information across agents, inflation targeting is considered to be able to anchor inflation expectations more rapidly and durably than other strategies. On the other hand, since a defined numerical target is explicitly published, the transparency and accountability of central banks increase greatly. Therefore, the communication between authorities and economic agents is improved. According to Ramos-Francia (2008), agents are allowed to make a better-informed allocation of resources. Moreover, according to Ball and Mankiw(1995), the better communication could lead to less deviation of expectations, decreasing the volatility in relative prices so that reduce the level of inflation.

New Zealand firstly adopted inflation targeting in March 1990. Followed by it, several other industrial countries including Canada, United Kingdom, Sweden, Finland, and Australia have also shifted to this new monetary policy in 1990's. By 2009, there are almost thirty countries including a great number of industrial countries as well as several emerging economies have explicitly adopted an inflation target as their nominal anchor. The trend fascinates researchers to study whether inflation targeting makes a difference. Empirical studies always focus on two major questions. One is whether the overall macroeconomic performance improved after countries adopted inflation targeting. The other one is whether this is because of inflation targeting if the answer of first question is positive.

Generally, empirical studies provide positive supports for the first question that inflation targeting improves macroeconomic performance relative to countries without explicit inflation targeting (Roger and Stone (2005) reach this conclusion). Early studies by Ammer and Freeman (1995) and Freeman and Willis (1995) employ vector autoregression (VAR) models to examine real gross domestic product (GDP), price levels, and interest rates before and after the adoption of inflation targeting. Their sample only includes three and only three inflation targeting countries, New Zealand, Canada and the United Kingdom. Ammer and Freeman (1995) compare the actual inflation rates and ones that are forecasted based on their VARs model. They find that inflation fell by more than was predicted by the models in the early 1990s that means the new regime might work. Freeman and Willis (1995) find long-run interest rate fell after these three countries adopted IT but rates came back after a few years later. They argue that this occurrence could be the results of a rise in interest rates worldwide. But it also could be the indication that the effects of IT cannot last long on credibility of monetary policy.

Mishkin and Posen (1997) estimate VARs of core inflation, GDP growth, and short-run central bank rates for New Zealand, Canada and the United Kingdom. They find disinflation had already happened before countries adopted inflation targeting. This implied that IT might just have served to maintain a low inflation rate rather than to facilitate disinflation. They further study the question whether IT can help these countries to keep inflation rates down after the initial disinflation. They compare dynamic simulations with actual outcomes. They find that after the adoption of IT, the inflation and interest rate of these countries can remain below their counterfactuals but output cannot. Especially, actual inflation did not rise with the upswing in the business cycle, as it would have prior to IT. Laubach and Posen (1997) improve Mishkin and Posen (1997)'s method and find further evidence to support these results. Debelle (1997) include more countries in the sample, including the previous three in addition to Sweden, Finland, Spain and Australia. They find the decline in inflation rates and long-run bond rates in these countries but at the cost of a rise in unemployment rate. Corbo, Landerretche Moreno, and Schimidt-Hebbel (2001) find that inflation persistence has declined substantially among IT countries since the introduction of the new regime. Bernanke and others (1999) examine sacrifice ratios of IT countries. Sacrifice ratio measures the costs associated with slowing down economic output to change trends of inflation. It is defined as dollar cost of production loss is divided by percentage change in inflation. In their study, they fail to find the improvement of sacrifice ratio in industrialized IT countries. However, Corbo, landerretche, and Schmidt-Hebbel (2002) include more IT countries in their sample and find sacrifice rations are indeed improved after the adoption of IT. In addition, Hyvonen (2004), Vega and Winkelried (2005), IMF (2005), and Batini and Laxton (2006) find the supportive evidence that inflation levels, inflation persistence, and volatility are lower in IT countries than in Noninflation Targeting (NIT) countries.

Based on these empirical studies, Mishkin and Schmidt-Hebbel (2007) summarize four results, the first three are: "(i) inflation levels, inflation volatility, and interest rates have declined after countries adopted inflation targeting; (ii) Output volatility has not worsen after the adoption of inflation targeting; if anything, it has improved; (iii) Exchange rate pass-through seems to be attenuated by the adoption of inflation targeting". Roger and Stone (2005) reach the conclusion that the adoption of inflation targeting is associated with an improvement in overall economic performance.

However, results of these empirical studies also raise the second question that whether the improved macroeconomic measures are due to the adoption of IT. As summarized in Mishkin and Schmidt-Hebbel (2007), the fourth result is: "(iv) The fall in inflation levels and volatility, interest rates, and output volatility is part of a worldwide trend in the 1990s, and IT countries have not done better in terms of these variables or in terms of exchange rate pass-through than NIT such as Germany or the United States." As mentioned before, Debelle (1997) find a decline in inflation and long-run bond rate in IT countries. But Debelle also find a decline in inflation in some NIT countries. Therefore, it is difficult to conclude that the disinflation is a success of the IT regime. Moreover, Kahn and Parrish (1998) find the volatility of both nominal and real interest rate declined significantly after the adoption of IT. They argue that it might be the effects of IT regime but it might also be due to a more stable economic environment in the 1990s. Because they find the volatility of interest rates in United State, a NIT country, also declined. Cecchetti and Ehrmann (2000) compared nine IT countries and fourteen NIT countries, including developed and less developed. They find a decline in inflation rates is a general trend worldwide. It indicates that 1990s were a period providing a friendly environment to price stability. According to Mishkin and Schmidt-Hebbel (2002) and Gertler (2005), as an endogenous choice, they doubt that the adoption of inflation targeting can directly cause this better performance.

Mishkin and Schmidt-Hebbel (2007) explain these findings. The improved performance of some NIT countries, such as Germany or United State suggests a strong nominal anchor is a key to a successful monetary policy. As mentioned above, to target a strong nominal anchor, IT is a one way but not the only way. According to several studies, both Germany and United States were having a strong nominal anchor in 1990s. (see Bernanke and Mishkin, 1992; Mishkin and Posen, 1997; Bernake and others, 1999; Mishkin, 2000; Neumann and von Hagen, 2002). Consequently, empirical studies turn to focus on whether IT can strengthens the nominal anchor.

Chortareas, Stasavage, and Sterne (2002) find a negative relationship between policy transparency and average inflation. As mentioned above, a key feature of IT regime is the transparency. Their findings did provide supportive evidence that IT is able to decrease inflation. Mishkin and Schmidt-Hebbel (2007) summarize several empirical results. There is no strong evidence that an immediate decline in inflation happened after the adoption of inflation targeting. However, inflation persistence is always lower in IT countries than in for NIT countries. More importantly, inflation expectation seems to be more anchored for IT countries than for NIT countries. It suggests that inflation expectations react less to shocks to actual inflation for IT countries than NIT countries, especially in the long-run (Gurkaynak, Levin, and Swanson (2006); Levin, Natalucci, and Piger, 2004; Castelnuovo, Nicoletti-Altimari, and Palenzuela,2003) . Those empirical results indicate that inflation targeting did make a difference and strengthen nominal anchor as long as it has been employed for a while. Mishkin (2005) and Mishkin and Schmidt-Hebbel (2007) argue that even the nominal anchors are strong in some countries such as Germany and United States, they can be strengthen and bring even better performance if those countries adopt inflation targeting.

In summary, based on previous empirical studies, a strong nominal anchor is a key to a successful monetary policy. Targeting inflation can serve as a strong nominal anchor that is able to help a country improve the overall macroeconomic performance. Even if a country already employs another strong nominal anchor, IT is considered to strengthen the anchor to bring better performance.

This essay is motivated by one of the theoretical findings related to exchange rate. According to Svensson (2000), Mishkin and Schmidt-Hebbel (2007), and Rose (2007), IT is highly recommended for its ability to stable inflation rate and to maintain a lower volatility of real exchange rates in the long run based on several theoretical studies. Therefore, since long-run Purchasing Power Parity (PPP) related to the volatility of real exchange rate in the long-run, a question raises that whether inflation targeting matters for PPP.

1.2.2 Purchasing Power Parity

The concept of “the Purchasing Power Parity” was officially proposed by Cassel (1918). However, the idea of PPP employed in making policies can date back as early as the writings of scholars of the University of Salamanca in the fifteenth and sixteenth centuries. At that time, PPP had already used to discuss the relationship between exchange rate and prices (Taylor, 2003).

PPP simply indicates that a unit of currency should have same purchasing power in a foreign country as it in the domestic country, once it is converted into foreign currency at the nominal exchange rate between these two countries. Cassel (1918) was applying this concept as a tool to analyze exchange rate levels among the major industrialized countries. He argues that as long as almost free movement of good and comprehensive trade between two countries exists, the actual rate of exchange cannot deviate very much from this purchasing power parity. The purchasing power of each country is usually represented by the national price level, such as the consumer price index (CPI), or wholesale price index (WPI). It can be denoted as,

$$P_t = P_t^* / S_t \tag{1.1}$$

where P_t is the price level of the domestic country that represents the purchasing power of the domestic currency, P_t^* is the price level of the foreign country and S_t is the exchange rate. P_t^*/S_t is the price level of the domestic country in foreign currency and represents the purchasing power of foreign currency. If PPP holds, the purchasing power of one currency in two countries must be equal. Equation (1.1) represents absolute PPP. Relative PPP holds when changes in purchasing power parity are equalized across the two countries:

$$\frac{\Delta S_t}{S_{t-1}} + \frac{\Delta P_t}{P_{t-1}} = \frac{\Delta P_t^*}{p_{t-1}^*} \tag{1.2}$$

where $\Delta S_t = S_t - S_{t-1}, \Delta P_t = P_t - P_{t-1}$, and $\Delta P_t^* = P_t^* - P_{t-1}^*$. Since the parity asserts that the exchange at any time is determined by the change in the two relative price levels, Dornbusch (1987) also call it as “inflation theory of exchange rates”. To indicate the cause relationship between exchange rate and relative price level. It is more often expressed in logarithmic form:

$$s_t = p_t - p_t^* \tag{1.3}$$

PPP is used as a theory of exchange rate determination, in particular after the breakdown of Bretton Woods system in early 1970s (Taylor, 1995). It is also the foundation of monetary models and other models in international finance. Therefore, a great number of researchers are interested in empirical studies on PPP (Frenkel and Johnson, 1978).

To test the long-run relationship of PPP, empirical studies on the real exchange rate are always employed. The real exchange rate q_t is defined in logarithmic form as (a more detailed explanation of this form can be found in Econometric Methodologies part),

$$q_t = s_t - p_t + p_t^* \tag{1.4}$$

Early studies by Roll (1979) and Adler and Lehmann (1983) tested the null hypotheses that the real exchange rate follows a random walk against the alternative mean-reversion hypotheses. Roll

(1979) reported individual t statistic and Adler and Lehmann (1983) reported joint F statistic. However, the null hypothesis cannot be rejected in either case. Hakkio (1986) argues the failure of rejection on a random walk hypothesis cannot be believed to draw conclusion. Abuaf and Jorion (1990) also have the same opinion. They believe these test results reflect the poor power of the tests rather than evidence against PPP. As the introduction of unit root tests, a great number of empirical studies find evidence of PPP (Diebold, Husted, and Rush, 1991; Abauf and Jorion, 1990; Lothian, 1990; Lee, 1978; Officer, 1982; Frankel, 1986; Edison, 1987; Johnson, 1990; Kim, 1990; Glen, 1992). With abundance evidence of PPP, Froot and Rogoff (1995) declared it was a "fairly dull research topic" at that time.

However, since the breakdown of Bretton Woods system in early 1970s, most of recent empirical studies employed a short span data for the floating-rate and many of them failed to find evidence of PPP. This leaded to another wave of empirical studies on PPP. Researchers questioned about whether PPP still holds under floating rate regime. If not, those monetary model based on PPP as an assumption cannot be trusted any more. Frankel (1986, 1990) firstly point out that since researchers are examining a long-run relationship of PPP, it is inappropriate to use a data sample including just 15 years span data. This might result in low power of tests to reject the null hypothesis even if it is indeed false. Talyor (2003) explained the possibility of this lack of power issue. This idea was further be supported and examined by other researchers (Lothian, 1986, 1998a; Lothian and Taylor, 1996, 1997). Taylor (1995) and Froot and Rogoff (1995) employ more data with higher-powered techniques and find PPP does hold in the long run. They also find that real exchange exhibit mean reversion with a half-life of deviations of four to five years. It suggests expanding the size of samples used to test PPP is reasonable.

There are two ways to expand the sample size. One way is to use much longer time series, spanning a century or more. Several studies find evidence of PPP when the data period increases to hundreds of years (Frankel 1986, Lothian and Taylor 1994). However, it is a limitation that only some industrialized countries can be concentrated such as the United States, the United Kingdom and France. It is a challenge to collect a century or more data set for any country. There is another limitation that researcher are more interested in data period under floating exchange rate policy. Samples include data from fixed-rate period are not reasonable.

Alternatively, researchers have expended the data for the recent float cross-sectionally to exploit the additional information (Quah 1992, 1994; Breitung and Mayer, 1994; Abuaf and Jorion, 1990; MacDonald, 1996; and Oh, 1996). The early panel unit root test is proposed by Quah (1992, 1994) but it does not consider heterogeneity across groups such as individual specific effects and residual serial correlation. Levin and Lin (1992, 1993) and Levin, Lin and Chu (2002), denoted as LLC test, is more generally used. It allows for individual specific effects as well as heterogeneity across groups. Im, Pesaran and Shin (2003), denoted as IPS test, improves LLC test by allowing unbalanced panels, different convergence rates toward PPP and different serial correlation properties across groups. Recent studies have already found supportive evidence for long-run PPP by using Panel data methods (Lothian, 1998; Papell, 2002; Taylor, 2003; Taylor and Taylor, 2004).

Although supportive evidence of PPP is reported, there are several important issues related to the validity of PPP using panel data methods. These issues may affect results of PPP tests. One issue is the cross-sectional dependence across countries. It is widely recognized that these panel unit root tests have some flaws in terms of lack of power and size distortion in the presence of correlation among contemporaneous cross-sectional error terms (O'Connell, 1998). Both of LLC test and IPS test assume an independent relationship across countries. It is obvious the assumption cannot be hold in the real world. At least, real exchange rate of each country shares a common base currency. According to O'Connell (1998), failure to consider cross-sectional dependence might result in a huge increased significant level. It may in turn affect conclusion of the hypothesis test. Consequently, the supportive conclusion from LLC test and IPS test might not be reliable. By controlling for cross-sectional dependence, O'Connell (1998) reported the evidence of PPP turns to be insignificant. Although there are some limitations in his method, attention has been paid to the issue of cross-sectional dependence. Maddala and Wu (1999) proposed a new test statistic based on Fish's test (MW test). The behind principle of MW test is similar to IPS test. In contrast to IPS test, MW test statistic is related to p-value of OLS t-ratio statistic instead of relating to OLS t-ratio directly. Moreover, Maddala and Wu (1999) suggested a non-parametric bootstrap procedure for IPS test that can implicitly consider cross-sectional dependence issue. In their paper, they reported that IPS test and MW test are more powerful than LLC test by using the test procedure they proposed, particularly in small samples. Wu and Wu (2001) further supported Maddala and Wu (1999) results and improved the testing procedure by using seeming unrelated regression (SUR method) instead of OLS regression in non-parametric bootstrap procedure. They argue it can better capture the correlation relationship across countries. Both of their methods find supportive evidence of PPP after implicitly considering cross-sectional dependence. It suggests that cross-sectional dependence might not matter for PPP. However, there is no assurance that their method has completely solved this issue. Recently, a great number of panel unit root tests have been proposed to explicitly consider cross-sectional dependence (Phillips and Sul, 2003; Moon and Perron, 2004; Bai and Ng, 2004a; Pesaran, 2007). They assume that the process is driven by a group of common factors, so that it is possible to distinguish between the idiosyncratic component and the common component. Although there are differences among the methods proposed, their driving idea is similar. Pesaran (2007) proposed a cross-sectional augmented IPS test (CIPS test) that is based on IPS test. The feature of this test is to use cross-section averages of lagged levels as the common factor. The evidence of PPP from

CIPS test is not very significant compared to IPS test. It indicates that cross-sectional dependence does matter for PPP.

The second issue is the choice of base countries. Researcher have pointed out that inferences based on panel methods are sensitive to the choice of base countries, for example, the United States compared to Germany (Papell, 1997; Edison, Gagnon, and Melick, 1994). Jorion and Sweeney (1996), Wei and Parsley (1995) , and Papell (1997) find in a panel context, the evidence of PPP is stronger when the Deutch Mark, rather than US dollar, is used as the base currency. One explanation is the substantial real appreciation of dollar between 1980 and early 1985 and the subsequent depreciation until 1987. It resulted in a huge volatility of real exchange rate if use US dollar as base currency. Therefore, the choice of base currencies might be an issue matters for PPP.

The third issue is the choice of price indices. The price indices can be thought as the sum of a stationary tradable relative-price component and a nonstationary nontradable relative-price component (Engel, 2000; Ng and Perron, 1999). Early studies by Isard (1977) and Giovannini's (1988) find the correlation between deviations from PPP and highly disaggregated tradable goods price indices. According to Froot and Rogoff (1995), the real exchange rate depends on deviations from the law of one price in tradable goods, as well as on the relative price of tradable and nontradable goods within each country. They find that real exchange rate constructed using Producer Price Index (PPI) produce more support for PPP than that using Consumer Price Index (CPI). They argue that it is because PPI contains a higher proportion of tradable goods. Therefore, the choice of price indices is also considered to be an issue in empirical studies of long-run PPP.

Empirical studies of long-run PPP have involved plenty of issues and topics. Although it might not be completed in this literature review, several of the most important issues appeared in recent studies have already been included. The main purpose of my study is to examine whether IT could be another new issue matters to PPP. These important issues are also considered as benchmarks to indicate how significant effects of IT for PPP might be.

1.3 Econometric Methodologies

Tests of long-run relationship of PPP with panel data have often been based on an examination of the real exchange rate, which is defined as

$$q_{it} = s_{it} - p_{it} + p_t^* \tag{1.5}$$

where q_{it} is the real exchange rate of country i at time t, s_{it} is the nominal exchange rate for currency of country i per currency of foreign country at time t, p_{it} is the price index of country i at time t, and p_t^* is the price index of foreign country. All variable are in natural logarithms.

The form of PPP says that the nominal exchange rate and relative national prices all move together at a level consistent with PPP in the long run so that the logarithm of the real exchange rate should be identically equal to zero. Movements of the real exchange rate represent deviations from PPP. While there might be considerable short-run variance of q_{it}, a necessary condition for PPP to hold in the long run is that the real exchange rate q_{it} be stationary over time, that is the real exchange rate should be mean reverting. If q_{it} follows a stationary process, long-run PPP is said to be hold. If q_{it} contains a unit root, the deviations from PPP will persist indefinitely. In that case, it implies rejection of PPP in the long run. Therefore, the presence of a unit root in q_{it} indicates the failure of PPP in the long run. This parity is tested the null hypothesis of unit roots against the alternative of mean reversion.

In this study, I firstly employ some preliminary analysis, such as plots of long-run variance (LRV). The preliminary analysis provides a general idea for this topic. Secondly, augmented Dickey-Fuller tests and KPSS tests are employed as benchmarks for panel unit root tests. Thirdly, two panel unit root tests are then conducted. One is IPS panel unit root test with an assumption that individual time series are cross-sectionally independently distributed. Relative to IPS test, CIPS test assumes cross-sectional dependence.

1.3.1 Long-run Variance (LRV)

Let $\mathbf{Y}_t$ be an $(n \times 1)$ stationary and ergodic multivariate time series with $E[\mathbf{Y}_t] = \boldsymbol{\mu}$. $\mathbf{Y}_t$ depends on *K*-vector of parameters θ. Let $Y_t \equiv Y_t(\theta_0)$ where $\theta_0$is the true value of θ. According to central limit theorem for stationary and ergodic process, it states

$$\sqrt{T}(\overline{\mathbf{Y}} - \boldsymbol{\mu}) \xrightarrow{d} N\left(0, \sum_{j=-\infty}^{\infty} \boldsymbol{\Gamma_j}\right) \quad (1.6.a)$$

or

$$\overline{\mathbf{Y}} \sim N(\boldsymbol{\mu}, \frac{1}{\mathrm{T}} \sum_{j=-\infty}^{\infty} \boldsymbol{\Gamma_j}) \quad (1.6.b)$$

Hence, the long-run variance of $\mathbf{Y}_t$ is *T* times the asymptotic variance of $\overline{\mathbf{Y}}$:

$$lrv(\mathbf{Y}_t) = T \cdot avar(\overline{\mathbf{Y}}) = \sum_{j=-\infty}^{\infty} \boldsymbol{\Gamma_j} \quad (1.7)$$

Since $\Gamma_{-j} = \Gamma_j'$, $lrv(\mathbf{Y}_t)$ may be alternatively expressed as

$$lrv(\mathbf{Y}_t) = \boldsymbol{\Gamma_0} + \sum_{j=1}^{\infty}(\boldsymbol{\Gamma_j} + \boldsymbol{\Gamma_j'}) \quad (1.8)$$

$lrv(\mathbf{Y}_t)$ is denoted as $\boldsymbol{\Omega}$.

To estimate long-run variance $\boldsymbol{\Omega}$, in the econometric literature, it is generally using a consistent estimator $\hat{\theta}$ to estimate $\hat{Y}_t$ for a consistent estimate of $\boldsymbol{\Omega}$. $\widehat{\boldsymbol{\Omega}}$ obtained from methods following this idea are often referred to as heteroskedasticity and autocorrelation consistent (HAC) covariance matrix estimators. There are several approaches to estimating $\boldsymbol{\Omega}$. The Nonparametric kernel approach (Andrews, 1991; Newey-west, 1987) is employed in this study. It estimates $\boldsymbol{\Omega}$ by taking a weighted sum of the sample autocovariances of the observed data.

The classic of kernel HAC covariance matrix estimators in Andrews (1991) may be written as Equation (1.9):

$$\widehat{\Omega} = \frac{T}{T-K}\sum_{j=-\infty}^{\infty} k(j/b_T)\cdot \hat{\Gamma}(j) \tag{1.9}$$

where the sample autocovariances $\hat{\Gamma}(j)$ are given by

$$\hat{\Gamma}(j) = \frac{1}{T}\sum_{t=j+1}^{T} \hat{Y}_t\, \hat{Y}_{t-j}' \qquad j \geq 0 \tag{1.10.a}$$

$$\hat{\Gamma}(j) = \hat{\Gamma}(-j)' \qquad j < 0 \tag{1.10.b}$$

K is a symmetric kernel function that, among other conditions, is continuous at the origin and satisfies $|k(x)| \leq 1$ for all x with $k(0) = 1$, and $b_T > 0$ is a bandwidth parameter. The leading $T/(T-K)$ term is an optical correction for degrees-of-freedom associated with the estimation of the *K* parameters in θ. The kernel HAC estimator is determined by the choice of a kernel function and a value for the bandwidth parameter.

In this study, two methods of nonparametric kernel are used. They are Andrew (1991) and Newey and West (1987). Both of methods choose Bartlett kernel function, that is

$$k(x) = \begin{cases} 1-|x| & \text{if } |x| \leq 1 \\ 0 & \text{otherwise} \end{cases} \tag{1.11}$$

The difference is the choice of bandwidth parameter. The bandwidth b_T is used to determine the weights for the variance sample autocovarinces in (1.9). The optimal bandwidths may be written in the form (1.12):

$$b_T = \gamma T^{1/(2q+1)} \tag{1.12}$$

Automatic bandwidth selection methods are used. It indicates that the optimal bandwidth is estimated from the data instead of specifying a priori. Estimators for γ from both methods may be written as:

$$\hat{\gamma}(q) = c_k \hat{\alpha}(q)^{1/(2q+1)} \tag{1.13}$$

where q is determined by the selection of kernel function, that is 1 for Bartlett kernel function, the constant c_k depend on properties of the selected kernel, and $\hat{\alpha}(q)$ is an estimator of $\alpha(q)$, a measure of the smoothness of the spectral density at frequency zero that depends on the autocovariances $\Gamma(j)$. Substituting into (1.12) , the resulting estimator for the optimal automatic bandwidth is giving by,

$$\hat{b}_T^* = c_k(\hat{\alpha}(1)T)^{1/3} \tag{1.14}$$

Both of the Andrews and Newey-West estimators require an estimator of $\alpha(q)$, or $\alpha(1)$ in this study.They offer alternative methods for forming these estimates. The Andrews (1991) method estimate $\alpha(q)$ parametrically fitting a simple parametric time series model to the original data, then deriving the autocovariances parameter $\Gamma(j)$ and corresponding $\alpha(q)$ implied by the estimated model. Newey-West employ a nonparametric approach to estimating $\alpha(q)$. Andrews computes parametric estimates of the generalized derivatives of p in individual elements, then aggregates the estimates into a single measure. In contrast, Newey and West aggregate early, forming linear combinations of the autocovariance matrics, then use the scalar results to compute nonparametric estimators of the Parzen smoothness measures. In addition, a weight vector w that is used to determine $\alpha(q)$ must be determined. Newey-West leaves open the choice of w, but Andrew suggests $w_s = 1$ for all s. Time series econometric software EViews is used to do the estimations. For details of Andrew and Newey-West methods, refer to Andrew (1991), Newey-West(1987), or Eview7.0 User Guide II.

1.3.2 Univariate unit root test: Augmented Dickey-Fuller (ADF) test

The ADF test involves regressing the first-difference of a variance on a constant, its lagged level, and k lagged first difference. The real exchange rate is calculated as,

$$q_i = s_i - p + p^* \tag{1.15}$$

where q_i is the real exchange rate of country i, s_i be the nominal exchange rate for currency of country i per currency of foreign country, p^* is the price index of country i at time t, and p is the price index of foreign country. All variable are in natural logarithms. The regression representation is showed as,

$$\Delta q_t = \alpha + \beta q_{t-1} + \sum_{i=1}^{k} \gamma_i \Delta q_{t-i} + \varepsilon_t \tag{1.16}$$

where q_t is the real exchange rate. A time trend normally is not included in (1.16), for it would not be consistent with long-run purchasing power parity. The null hypothesis of a unit root is rejected in favor of the alternative of level stationary if α is significantly different from zero. The lag length k is determined by Hall's (1994) general-to-specific method recommended by Campbell and Perron (1991). Started with a upper bound, k_{max}, on k. If the last included lag is significant, choose $k = k_{max}$. If not, reduce k by 1 unit the last lag becomes significant. If no lags are significant, set $k = 4$ in this study.

1.3.3 Univariate unit root test: The Kwiatkowski, Phillips, Schmidt, and Shin (KPSS) Test

Different from ADF test with a null hypothesis of a unit root, KPSS test assumes there is a stationary process under the null. Followed by KPSS (1992), the KPSS statistic is based on residuals from the OLS regression defined as follow,

$$q_t = x_t' \delta + \varepsilon_t \tag{1.17}$$

The KPSS statistic is defined as:

$$\varphi_{\varepsilon} = \sum_{t} S(t)^{2} / (T^{2} f_{0}) \tag{1.18}$$

where f_0 is an estimator of the residual spectrum at frequency zero and where $S(t)$ is a cumulative residual function:

$$S(t) = \sum_{r=1}^{t} \hat{\varepsilon}_{r} \tag{1.19}$$

based on the residuals from Equation (1.17). The number of lags truncation in the KPSS test is selected automatically by Newey and West Bandwidth using Barlett Kernal Spectral estimation method. The null hypothesis of stationarity is rejected if the test statistic is greater than the critical value.

1.3.4 Panel unit root test: IPS test (Im, Pesaran and Shin 2003)

Let q_{it} be the real exchange rate for country i, where $i = 1,2, \dots N$ and$t = 1,2, \dots T$ with N countries in the panel, and T time series observations. q_{it} follows ADF representation:

$$\Delta q_{it} = \alpha_{i} + \beta_{i} q_{it-1} + \sum_{\mathrm{j=1}}^{\mathrm{k_i}} \gamma_{ij} \Delta q_{it-j} + \varepsilon_{it} \tag{1.20}$$

where Δq_{it} is the first difference of the logarithm of the real exchange rate for country i at time t $(i = 1,2, \dots N)$, $k_i$is the lag length selected for country i , and ε_{it} is the regression error. The null hypothesis of unit roots under IPS test, $\mathrm{H}_0\colon \beta_i = 0$ for all i is tested against the alternative hypothesis of stationary, $\mathrm{H}_1\colon \beta_j < 0 \;\; j = 1,2, \dots N$, which allows for different convergence rate toward PPP across countries. The rejection of the null hypothesis implies the null hypothesis is rejected for $N_1 < N$. It indicates the evidence of stationary series existing in the group.

According to IPS (2003), the IPS statistic $\bar{z}$ is defined as,

$$\bar{z} = \frac{\sqrt{N}(\bar{t} - E(\bar{t}))}{\sqrt{Var(\bar{t})}} \tag{1.21}$$

where $\bar{t} = \frac{1}{N}\sum_{i=1}^{N} t_i$, with mean $E(\bar{t})$ and variance $Var(\bar{t})$. t_i is the t-ratio of the least square estimate of β_i from individual ADF regression (Equation (1.15)). $\bar{z}$ has an asymptotic standardized normal distribution and it relies on very large samples.

IPS test is based on individual ADF regression. Since an appropriate ADF regression can correct for serial correlation in the data, IPS test also corrects serial correlation automatically, and allow for heterogeneity at the same time. To get the critical values, followed by Maddala and Wu (1999) and Wu and Wu (2001), a non-parametric bootstrap procedure is employed. In this way, it can implicitly consider cross-section dependence and fix the bias of distribution due to small sample size. The detailed bootstrap procedure can be found in Appendix.

1.3.5 Panel unit root test: CIPS test (Pesaran 2007)

To test the long-run relationship (Equation (1.15)), the following regression is considered:

$$\Delta q_{it} = \alpha_i + \beta_i q_{i,t-1} + e_{it} \tag{1.22}$$

where Δq_{it} is the first difference of the logarithm of the real exchange rate for country i at time t $(i = 1,2, \dots N)$, and e_{it} is an error term that is allowed to be serially correlated and has a single common factor structure:

$$e_{it} = \gamma_i f_t + \varepsilon_{it} \tag{1.23}$$

where f_t is an unobserved common factor, γ_i is the individual factor loading and ε_{it} is a white noise idiosyncratic error.

For the unit root null hypothesis considered by Pesaran(2007), he proposes a test based on the t-ratio of the least square estimate β_{it} in the following cross-sectionally augmented Dickey-Fuller (CADF) regression for each cross-sectional unit,

$$\Delta q_{it} = \alpha_i + \beta_i q_{it-1} + \sum_{j=1}^{k_i} \gamma_{ij} \Delta q_{it-j} + c_i \bar{q}_{t-1} + \sum_{j=0}^{k_i} d_{ij} \Delta \bar{q}_{i,t-j} + \varepsilon_{it} \quad (1.24)$$

where $\bar{q}_t = \frac{1}{N}\sum_{i=1}^{N} q_{it}$, $\Delta\bar{q}_{it} = \frac{1}{N}\sum_{i=1}^{N} \Delta q_{it}$, $k_i$is the lag length selected for country i , and ε_{it} is the regression error. According to Pesaran (2007), the cross-sectional averages of Δq_{it} and q_{it-1} are included into Equation (1.24) as a proxy for the unobserved common factor f_t. Under Equation (1.24), the null hypothesis, $H_0: \beta_i = 0$ for all i is tested against the heterogeneous alternative, $H_1: \beta_1 < 0, \dots, \beta_{N_0} < 0, N_0 < N$, in the whole panel set. In line with IPS (2003), Pesaran proposes the CIPS test,

$$\text{CIPS} = \frac{1}{N}\sum_{i=1}^{N} \text{CADF}_i \quad (1.25)$$

where $CADF_i$ is the CADF statistic for the ith cross-sectional unit in Equation (1.24). The distribution of the CIPS statistic is shown to be nonstandard even for large N. Therefore, a bootstrap procedure is needed to get critical values.

1.3.6 Non-parametric Bootstrap procedure

The bootstrap method used in this study is the residual bootstrap, that is, I will be resampling from the residuals. In parametric bootstrap, error terms are draw from the estimated residuals that are assumed following the parametric normal distribution. In this study, since the distribution of estimated residuals is unknown due to small sample property, non-parametric bootstrap is preferred, that is, residuals assuming to follow the uniform distribution. In my study, p-values from non-parametric and parametric bootstraps are very close. P-values from non-parametric bootstrap are reported only.

1.3.6.1 Bootstrap procedure for IPS test

Step 1: Estimate the following system equations using seemingly unrelated regression (SUR) method. Then the estimation of coefficient values $\gamma_{i,j}$ and the bootstrap sample of the residuals ε_t^0=[$\varepsilon_{1,t}^0$, $\varepsilon_{2,t}^0$,…, $\varepsilon_{N,t}^0$] are obtained.

$$\Delta q_{i,t} = \alpha_i + \beta_i q_{i,t-1} + \sum_{j=1}^{k_i} \gamma_{i,j} \Delta q_{i,t-j} + \varepsilon_{i,t}^0 \qquad i = 1,2, \dots N \quad t = 1,2, \dots T \quad (1.26)$$

where $\Delta q_{i,t}$ has a unit root under the null hypothesis, $\Delta q_{i,t-j} = q_{i,t} - q_{i,t-j}$, and k_i is the lag length selected for regression in IPS test for country i.

Step 2: As suggested by Maddala and Wu (1999), residuals are resampled as a vector (with the cross-section index fixed) instead of resampling separately for each country. They argue that since there are cross-correlations among residuals, in this way, the contemporaneous correlation can be preserved. An integer h between 1 to H is generated with equal probability. $H = T - \max(k_i) - 2$ for $i = 1,2 \dots N$. For each country, the total observations in original sample are T. To construct their lagged, difference, or lagged difference variables, $\max(k_i) + 2$ observations turn to be missing. Therefore, there are $T - \max(k_i) - 2$ observations for residuals after regression. Once h is generated, a row of fitted residuals ε_1^0=[$\varepsilon_{1,h}^0$, $\varepsilon_{2,h}^0$,…, $\varepsilon_{N,h}^0$] is used as ε_1^* . Repeating this process $T + 50$ times, a bootstrap sample of the error terms $\varepsilon_t^*, t = 1,2, \dots T, T + 1, \dots T + 50$ is generated.

Step 3: Choose the initial values of $q_{i,t}^*$. Under H_0 that $\beta_i = 0$, the real exchange series follow random walk. The data generating process of bootstrap sample $q_{i,t}^*$ is showed as

$$\Delta q_{i,t}^* = \sum_{j=1}^{k_i} \hat{\gamma}_{i,j} \Delta q_{i,t-j}^* + \varepsilon_{i,t}^* \qquad (1.27)$$

The initial values of $q_{i,t}^*$ are obtained by block resampling from the actual $\{q_{i,t}\}$ as described in Berkowitz and Kilian (1996). An integer m is generated between 1 to M. $M = T - \max(k_i)$ $i =$

$1,2 \dots N$. Once m is generated, a row of the first initial value$q_0 = [q_{1,m}, q_{2,m}, \dots, q_{N,m}]$ is used as q_0^*. k_i is the lag length of country i. For each country, select k_i+1 adjacent data points from $q_{i,m}$ to represent the first k_i+1 initial values of the bootstrap sample. For example, for country 1, initial values are $q_{1,m}, q_{1,m+1}, \dots, q_{1,m+k_i}, q_{1,m+k_i+1}$. ε_{it}^* is the bootstrap sample generated from step 2. $\hat{\gamma}_{i,k_i}$s are the SUR estimates obtained from step 1. Drop the first 50 observations to avoid start-up effects.

Step 4: Compute the t value of estimations of ρ_i from ADF regressions for each group separately and construct the $\bar{t}$ statistic.

$$\Delta q_{i,t}^* = \delta_i + \rho_i q_{i,t-1}^* + \sum_{j=1}^{k_j} \theta_{i,j} \Delta q_{i,t-j}^* + \mu_{i,t}^* \qquad (1.28)$$

Step 5: Repeat previous steps 5,000 times to derive the empirical distribution of $\bar{t}$ statistic.

Step 6: Estimate the p value of $\bar{t}$ based on the estimated distribution and make a decision of hypothesis test.

1.3.6.2 Bootstrap procedure for CIPS test

Step 1: Estimate the following system equations using seemingly unrelated regression (SUR) method. Then the estimation of coefficient values $\gamma_{i,j}$ and the bootstrap sample of the residuals ε_t^0=[$\varepsilon_{1,t}^0$, $\varepsilon_{2,t}^0$,…, $\varepsilon_{N,t}^0$] are obtained.

$$\Delta q_{i,t} = \alpha_i + \beta_i q_{i,t-1} + \sum_{j=1}^{k_i} \gamma_{i,j} \Delta q_{i,t-j} + c_i \bar{q}_{t-1} + \sum_{j=0}^{k_i} d_{i,j} \Delta \bar{q}_{i,t-j} + \varepsilon_{i,t}^0$$

$$i = 1,2, \dots . N \quad t = 1,2, \dots T \qquad (1.29)$$

where $\Delta q_{i,t}$ has a unit root under the null hypothesis, $\Delta q_{i,t-j} = q_{i,t} - q_{i,t-j}$, and k_i is the lag length selected for regression in IPS test for country i.

Step 2: As suggested by Maddala and Wu (1999), residuals are resampled as a vector (with the cross-section index fixed) instead of resampling separately for each country. They argue that since there are cross-correlations among residuals, in this way, the contemporaneous correlation can be preserved. An integer h between 1 to H is generated with equal probability. $H = T - \max(k_i) - 2$ for $i = 1,2 \dots N$. For each country, the total observations in original sample are T. To construct their lagged, difference, or lagged difference variables, $\max(k_i) + 2$ observations turn to be missing. Therefore, there are $T - \max(k_i) - 2$ observations for residuals after regression. Once h is generated, a row of fitted residuals ε_1^0=[$\varepsilon_{1,h}^0$, $\varepsilon_{2,h}^0$,…, $\varepsilon_{N,h}^0$] is used as ε_1^* . Repeating this process $T + 50$ times, a bootstrap sample of the error terms $\varepsilon_t^*, t = 1,2, \dots T, T + 1, \dots T + 50$ is generated.

Step 3: Choose the initial values of $q_{i,t}^*$. Under H_0 that $\beta_i = 0$, the real exchange series follow random walk. The data generating process of bootstrap sample $q_{i,t}^*$ is showed as

$$\Delta q_{i,t}^* = \sum_{j=1}^{k_i} \hat{\gamma}_{i,j} \Delta q_{i,t-j}^* + \varepsilon_{i,t}^* \tag{1.30}$$

The initial values of $q_{i,t}^*$ are obtained by block resampling from the actual $\{q_{i,t}\}$ as described in Berkowitz and Kilian (1996). An integer m is generated between 1 to M. $M = T - \max(k_i)\;\; i = 1,2 \dots N$. Once m is generated, a row of the first initial value$q_0 = [q_{1,m}, q_{2,m}, \dots, q_{N,m}]$ is used as q_0^*. k_i is the lag length of country i. For each country, select k_i+1 adjacent data points from $q_{i,m}$ to represent the first k_i+1 initial values of the bootstrap sample. For example, for country 1, initial values are $q_{1,m}, q_{1,m+1}, \dots, q_{1,m+k_i}, q_{1,m+k_i+1}$. ε_{it}^* is the bootstrap sample generated from step 2. $\hat{\gamma}_{i,k_i}$s are the SUR estimates obtained from step 1. Drop the first 50 observations to avoid start-up effects.

Step 4: Compute the t value of estimations of ρ_i from ADF regressions for each group separately and construct the $\bar{t}$ statistic.

$$\Delta q_{i,t}^{*} = \delta_i + \rho_i q_{i,t-1}^{*} + \sum_{j=1}^{k_j} \theta_{i,j} \Delta q_{i,t-j}^{*} + n_i \overline{q}_{t-1}^{*} + \sum_{j=0}^{k_i} m_{i,j} \Delta \overline{q}_{i,t-j}^{*} + \mu_{i,t}^{*} \quad (1.31)$$

Step 5: Repeat previous steps 5,000 times to derive the empirical distribution of $\bar{t}$ statistic.

Step 6: Estimate the p value of $\bar{t}$ based on the estimated distribution and make a decision of hypothesis test.

1.4 Data Descriptions

Quarterly data of 19 OECD countries are sample from 1974Q1 to 2009Q4. Bilateral real exchange rates are constructed using Consumer Price Index (CPI) and Producer Price Index (PPI). CPI and PPI approximately represent nontradable and tradable goods separately. The end of period quarterly nominal exchange rate (per US dollar), CPI, and PPI are obtained from DataStream and International Monetary Fund's International Financial Statistics. Countries are Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Ireland, Italy, Japan, the Netherlands, New Zealand, Norway, Spain, Sweden, Switzerland, the United Kingdom, and the United States. For PPI panel, only 15 countries are included. They are Australia, Austria, Canada, Denmark, Finland, Germany, Ireland, Italy, Japan, the Netherlands, New Zealand, Norway, Spain, Switzerland, the United Kingdom, and the United States. This is determined by the availability of PPI. For countries in the European and Monetary Union (EMU), the period starts from 1974:Q1 to 1998Q2 because of nominal exchange rate unavailability after the adoption of Euros. EMU countries are Austria, Belgium, Finland, France, Germany, Ireland, Italy, the Netherlands, and Spain. To investigate whether IT affects PPP, countries are classified into different groups based on whether their central banks adopt IT. The nine countries that engage in IT are New Zealand, Canada, the United Kingdom, Sweden, Finland, Australia, Spain, Switzerland and Norway. More information about Inflation Targeting countries are summarized in Table 1-1. Furthermore, since many studies point out the problem of choosing the US dollar as the numeraire, real exchange rates are alternatively defined with respect to the US dollar, Deutch mark, Canadian dollar, Japanese yen, and Swiss franc.

1.5 Results

1.5.1 Preliminary Analysis

1.5.1.1 Inflation performance for sampled countries

Figure 1-1 illustrates the pattern of annual inflation for individual nine IT countries before and after the adoption of inflation targeting. In contrast, Figure 1-2 shows the annual inflation pattern for the other ten NIT countries. The plots are based on quarterly consumer price index (CPI) over 1974-2009.

Visual inspection of plots for IT countries suggests that annual inflations had a big improvement after the adoption of inflation targeting. A significant decline of each IT country happened and annual inflation rate was relatively stable after the initial decline. The relatively low inflation was maintained. According to Mishkin and Schmidt (2007), IT countries have been successful in meeting their targets during sampled years. It suggests the possibility that the improvement of inflation is due to IT. However, it turns to uncertainty after the examination of NIT countries. The pattern of annul inflation for NIT countries is quite similar to IT countries. A big decline of annual inflation rate happened in the late 1980s or the early 1990s. Then NIT countries also kept a low inflation rate relative to that in early 1970. The volatility of annual inflation is bigger than IT countries though. This phenomenon is consistent with ideas of several researchers. They argue that the improved economic performance reflect a general tendency of all countries. It is because of the stable economic environment in 1990s rather than inflation targeting policy (see section 1.2.1 for more details). Therefore, further studies are needed.

1.5.1.2 Long-run Variance Plots

Another preliminary analysis provides a stylized comparison for the volatility of real exchange rate between IT group and NIT group in a long-run. According to Svensson (2000), under IT, countries are able to lower volatility of real exchange rate at a long horizon. To examine this idea, long-run Variance (LRV) of real interest rate for IT and NIT group over 1990 to 1998 are estimated and compared. Two data sets are employed including real exchange rate based on US dollar with CPI and PPI. Two methods of estimating nonparametric kernel are used including Newey and West (1987) and Andrew (1991). Both of methods choose Bartlett kernel function. The difference is the choice of bandwidth (see section 1.3.1 for more detail).

Figure 1-3 to Figure 1-6 illustrate the pattern of long-run variance of real exchange rate for IT group and NIT group with different estimation methods and data sets. Figure 1-3 and Figure 1-4 present results from Newey-West's method with CPI and PPI, separately. Figure 1-5 and Figure 1-6 present results from Andrew's method with CPI and PPI, separately. The stylized fact is strong and consistent to Svensson (2000). The general pattern is similar across different cases. In early 1990s, both IT group and NIT group have a great decline in LRV of real exchange rate based on U.S dollar. It suggests a comfortable economic environment during that period. However, it is obvious that long-run variance for NIT group is generally greater than that of IT group over years after 1990 when countries were beginning to adopt inflation targeting. Plots from Newey-west method are smoother. Under Andrew's method, although LRVs of both groups fluctuate greatly over years, their patterns are still keeping. Moreover, PPI data provide a stronger pattern than CPI under either method.

1.5.2 Univariate Unit root tests

ADF and KPSS tests are conducted as benchmark to panel unit root tests. The crucial difference between ADF and KPSS tests is their opposite hypothesis. For ADF tests, PPP holds when the null hypothesis of a unit root is rejected. In contrast to KPSS tests, PPP fails to hold when the null hypothesis of stationary is rejected. CPI and PPI are used to measure real exchange rates and five base currencies are considered including USD, US Dollar; DM, Deutch Mark; JPY, Japanese Yen; SWF, Swiss Franc; CAD, Canadian Dollars.

Table 1-2 and Table 1-3 summarize the results from ADF tests. The lag length is determined by Hall's (1994) general-to-specific method recommended by Campbell and Perron (1991). It starts from lag 4 (see section 1.3.2 for details about lag selection). For most cases and countries, the null hypothesis of a unit root cannot be rejected at the 5 percent significant level that means PPP does not hold. For CPI, rejection rates for IT countries and NIT countries are relatively even and both are extremely low. None of cases can be rejected in US and CAD case. With JPY case, only two cases in IT countries can be rejected. None can be rejected in NIT countries. In contrast, with DM case, only one case in NIT countries can be rejected. None can be rejected in IT countries. With SWF cases, the null hypothesis of a unit root is rejected in two out of nine and three out of nine in IT countries and NIT countries separately. For PPI, rejection rates for IT countries and NIT countries are slightly higher. Moreover, there is at least one case can be rejected in IT countries, that is, one case with DM case, two cases with US, JPY, and CAD cases, and three cases with SWF. For NIT countries, the null hypothesis of a unit root can only be rejected in one out of nine with DM and in five out of nine SWF case.

Table 1-4 and Table 1-5 present the results from KPSS tests. The lag length is selected automatically by Newey and West Bandwidth using Barlett Kernal Spectral estimation method (see section 1.3.3 for details about lag selection). For most cases, the null hypothesis of stationary can be rejected at the 5 percent significant level that means PPP does not hold. This is consistent with ADF tests. Moreover, rejection rates for NIT countries are higher than that in IT countries in both CPI and PPI cases. It provides some evidence that PPP holds better in IT countries than NIT countries. When compare CPI and PPI cases cross tables, rejection rates for PPI cases are obviously higher than that for CPI cases. This is consistent with Froot and Rogoff (1995) in that PPI better represents tradable good prices and always find stronger evidence of PPP than CPI. Refer to different base currencies, most cases can be rejected using JPY. For other cases, the rejection rates are relatively even in general. However, for individual cases, it happened that the null can be rejected with one base currency and failed to be rejected with another base currency. This finding is consistent with previous studies that base currency matters to PPP.

In sum, results from ADF and KPSS tests are used as preliminary analysis because the power of univariate unit root tests is very low. However, it still reveals some interesting findings. Firstly, slightly more supportive evidence of PPP can be found in IT countries than NIT countries. Secondly, PPI cases generally provide more solid evidence of PPP than CPI cases. Thirdly, the choice of base currencies does matter to PPP. Lastly, the summarized regularities are more obvious by using KPSS tests. Therefore, more powerful tests such as panel unit root tests have to be performed.

1.5.3 Panel Unit root tests

For IT, ALL, and NIT groups, results from IPS tests and CIPS tests are compared based on real exchange rates with CPI and PPI, five different base currencies, and with and without cross-sectional dependence assumption (Table 1-6 and Table 1-7). The lag length for each country is determined based on Bayesian Information Criterion (BIC). The maximum lag for each country starts from lag 4. P-values are taken from nonparametric bootstrap procedure (see section 1.3.6 for details). The null hypothesis is rejected at 5% significant level is p-value is smaller than 5%.

The first question to investigate is whether there is supportive evidence of PPP in IT group. Based on 20 combinations of different issues, the answer is positive. The rejection rate of null hypothesis of a unit root for IT group is 19 out of 20 at 5% significant level. In contrast, the rejection rate for NIT group is only 4 out of 20. The rejection rate for ALL group is 9 out of 20 that ranks in the middle. Moreover, under different cases, nonparametric bootstrapped p-values are generally smaller for IT group than that for ALL group. NIT group usually provides largest p-values. It means the possibility to reject null hypothesis for NIT group is lower than ALL group and IT group. These results suggest that the probability of evidence of PPP appeared in IT group is largest. The regularity of this finding is not affected by choices of price indices and base countries as well as cross-sectional dependence assumption.

Secondly, results are compared cross tables to examine whether real exchange rate with PPI provides stronger evidence for PPP than CPI. According to Froot and Rogoff (1995), the real exchange rate depends on deviations from the law of one price in tradable goods, as well as on the relative price of tradable and nontradable goods within each country. Since PPI contains a higher proportion of tradable goods, real exchange rates with PPI should reflect mean reverting features of PPP better than that with CPI. Therefore, evidence of PPP is expected to be stronger in PPI groups. Based on my results, except for IT group, ALL and NIT groups follows this pattern. Under the 20 cases, each of CPI and PPI employs to 10 cases. For NIT group, although only one case with PPI can be rejected, there are 6 out of 10 cases for PPI with lower p-values than CPI. It suggests a higher possibility to find favorable evidence of PPP for real exchange rates with PPI. As the CPI and PPI are employed for ALL group, this pattern is more obvious. 9 out of 20 cases can be rejected, among which 6 cases from exchange rates with PPI. Moreover, there are 7 out of 10 cases for PPI with lower p-values than CPI. While it comes to IT group, the null hypothesis of PPP is always rejected in spite of price indices.

Thirdly, results are compared between IPS tests and CIPS tests to explore the issue of cross-sectional dependence. The null hypothesis can be rejected almost every case in terms of IT group. It suggests the validity of PPP for IT countries cannot be influenced by the assumption of cross-sectional dependence. However, for NIT and All groups, the case is different. For NIT group, two out of three cases that can be rejected in IPS tests but failed to be rejected in CIPS tests. All ten cases in CIPS tests have an increased p-values compared to cases in IPS tests. It indicates that the possibility to reject the null hypothesis under CIPS tests decreased. For All group, the effects of the cross-sectional dependence are more obvious. The null hypothesis of five out of six cases can be rejected in IPS test while they cannot be rejected in CIPS test. Seven out of ten cases in CIPS tests have an increase in p-values compared to cases in IPS tests. These results provide more empirical evidence for O'Connell (1998) that the validity of PPP can be greatly affected by the assumption of cross-sectional dependence. However, for IT group, on the other hand, the null hypothesis of unit roots can always be rejected.

Fourth, except IT group, results from All and NIT groups might be related to the choice of base currencies. Real exchange rates that use European countries as base countries provide a slightly better results that PPP holds. This is consistent with finding from Papell (1997). However, they depend on whether cross-sectional dependence is captured. In sum, IT related to the validity of PPP and IT even outweighs other issues proposed by previous studies when it comes to PPP.

1.6 Conclusion

This is the first empirical study on whether Inflation Targeting (IT) policy is related to the validity of long-run Purchasing Power Parity (PPP). Quarterly data for 19 OECD countries under floating rate period are sampled. Bilateral real exchange rates are constructed with two price indices and five base currencies. In addition to IPS tests, CIPS tests that consider cross-sectional dependence are also employed. In contrast to previous panel studies that usually examine OECD countries as a whole, this essay further classifies them into IT and NIT groups depending on whether the country adopted Inflation Targeting Monetary Policy in the sampled period.

Based on the results from two panel unit root tests, the evidence of PPP is very strong for IT group no matter any other issue is considered. It suggests IT outweighs other issues when it comes to PPP. For other groups, results are consistent with previous studies. The choices of price indices and base currencies as well as cross-sectional dependence are related to the validity of PPP in different degrees. These results match the theoretical findings. In contrast to other monetary policy, central banks under IT are able to adjust inflation rate and real exchange rate more stable in the long run in response to shocks from rest of the world. Countries adopted IT are expected to have a more stable real exchange rate movement in the long run (Svensson, 2000; Mishkin and Schmidt-Hebbel, 2007; and Rose, 2007).

The implications of this essay are very intriguing. The initial purpose of authorities to adopt IT might not be to keep PPP hold for this country. However, based on the findings, IT is unexpectedly related to the validity of PPP. Supportive evidence of PPP can always be found in countries adopted IT. Moreover, under the effect of IT, issues that could explain the failure of PPP turn to be unimportant. Therefore, compared to previous studies on PPP, this essay provides a new aspect to explore topics related to PPP.

Table 1-1 Inflation targeting countries

Countries	Year of Adoption	Previous Anchor	Current Target Values	Target Variable
Australia	1993	None	2%-3%	CPI
Canada	1991	None	2%+/-1%	CPI
Finland	1993	None	2%	CPI
New Zealand	1990	None	1%-3%	CPI
Norway	2001	Exchange rate	2.5%+/-1%	CPI
Spain	1994	None	2%	CPI
Sweden	1993	Exchange rate	2%+/-1%	CPI
Switzerland	2000	Money Supply	< 2%	CPI
United Kingdom	1992	Exchange rate	2%+/-1%	CPI (HICP)

*Source:*Petursson (2004), Mishkin and Schmidt (2007), Roger (2010) and central banks websites HICP: Harmonised Index of Consumer Prices.

Table 1-2 ADF tests of real exchange rate with CPI

	Currencies				
Inflation Targeting Countries	US	DM	JPY	SWF	CAD
Australia	-2.170	-2.177	-2.267	-2.605	-2.493
Canada	-2.053	-2.216	-2.427	-2.782	#
Finland	-2.541	-2.485	-1.699	-2.217	-2.685
New Zealand	-2.467	-2.750	-2.802	-3.852*	-2.433
Norway	-2.397	-2.180	-2.747	-2.074	-2.731
Spain	-2.190	-2.273	-2.425	-2.831	-1.874
Sweden	-2.487	-2.182	-2.229	-2.078	-2.554
Switzerland	-2.853	-2.598	-2.922*	#	-2.782
United Kingdom	-2.825	-2.418	-2.998*	-3.228*	-2.526
Noninflation Targeting Countries					
Austria	-2.415	-1.936	-2.550	-4.481*	-1.896
Belgium	-2.110	-2.014	-1.966	-1.920	-2.033
Denmark	-2.337	-1.821	-2.326	-3.168*	-2.505
France	-2.704	-2.904*	-1.791	-2.526	-2.316
Germany	-2.598	#	-2.264	-2.598	-2.216
Ireland	-2.467	-1.412	-2.552	-2.376	-1.819
Italy	-2.559	-1.759	-2.380	-2.414	-1.893
Japan	-2.609	-2.264	#	-2.922*	-2.515
Netherlands	-2.740	-1.013	-1.956	-1.858	-2.426
United States	#	-2.598	-2.609	-2.853	-2.053

*Note:**Indicates rejection of the null hypothesis at the 5% level of significant. Critical Values from MacKinnon (1991) at the 5% level of significant is -2.86. # indicates that the test statistics is not computed. USD, US Dollar; DM, Deutch Mark; JPY, Japanese Yen; SWF, swiss Franc; CAD, Canadian Dollars.

Table 1-3 ADF tests of real exchange rate with PPI

	Currencies				
Inflation Targeting Countries	US	DM	JPY	SWF	CAD
Australia	-2.258	-2.605	-2.358	-3.283*	-2.171
Canada	-2.533	-2.433	-2.669	-3.362*	#
Finland	-3.151*	-1.788	-2.160	-2.487	-3.092*
New Zealand	-1.879	-2.686	-1.908	-2.153	-1.896
Norway	-0.383	-1.676	-0.923	-0.831	-0.521
Spain	-2.483	-2.301	-2.564	-3.059*	-2.520
Switzerland	-3.029*	-4.757*	-3.279*	#	-3.362*
United Kingdom	-2.558	-2.083	-3.093*	-2.570	-2.423
Noninflation Targeting Countries					
Austria	-2.179	-1.114	-2.348	-3.168*	-2.641
Denmark	-2.221	-3.080*	-2.374	-2.438	-2.591
Germany	-2.381	#	-2.810	-4.757*	-2.433
Ireland	-2.422	-1.649	-2.539	-2.613	-2.641
Italy	-1.860	-1.731	-2.293	-2.170	-1.989
Japan	-2.488	-2.810	#	-3.013*	-2.498
Netherlands	-1.927	-1.751	-2.577	-3.465*	-2.272
United States	#	-2.381	-2.488	-3.029*	-2.533

*Note:**Indicates rejection of the null hypothesis at the 5% level of significant. Critical Values from MacKinnon (1991) at the 5% level of significant is -2.86. # indicates that the test statistics is not computed. USD, US Dollar; DM, Deutch Mark; JPY, Japanese Yen; SWF, swiss Franc; CAD, Canadian Dollars.

Table 1-4 KPSS tests of real exchange rates with CPI

	Currencies				
Inflation Targeting Countries	US	DM	JPY	SWF	CAD
Australia	0.827*	0.583*	0.703*	0.889*	0.159
Canada	0.904*	0.343	0.684*	0.706*	#
Finland	0.299	0.802*	0.869*	0.522*	0.384
New Zealand	0.488*	0.226	0.343	0.161	0.674*
Norway	0.360	0.231	0.605*	0.835*	0.472
Spain	0.416	0.494*	0.603	0.273	0.594*
Sweden	0.985*	0.521*	1.008*	1.354*	0.290
Switzerland	0.406	0.987*	0.386	#	0.674*
United Kingdom	0.932*	0.260	0.234	0.164	0.946*
Noninflation Targeting Countries					
Austria	0.475*	1.069*	0.882*	0.396	0.595*
Belguim	0.581*	0.544*	0.961*	0.941*	0.510*
Denmark	0.631*	0.573*	0.398	0.510*	0.657*
France	0.473*	0.503*	0.970*	0.967*	0.504*
Germany	0.604*	#	0.970*	0.987*	0.540*
Ireland	0.699*	0.439	0.734*	0.650*	0.827*
Italy	0.434	0.354	0.688*	0.599*	0.758*
Japan	0.886*	0.970*	#	0.386	0.684*
Netherlands	0.513*	0.732*	1.025*	1.129*	0.565*
United States	#	0.604*	0.506*	0.631*	0.491*

Note: *Indicates rejection of the null hypothesis at the 5% level of significant. Critical Values from KPSS (1992) at the 5% level of significant is 0.463. # indicates that the test statistics is not computed.

Table 1-5 KPSS tests of real exchange rates with PPI

	Currencies				
Inflation Targeting Countries	US	DM	JPY	SWF	CAD
Australia	0.160	0.598*	0.602*	0.332	0.127
Canada	0.169	0.619*	0.600*	0.244	#
Finland	0.202	0.211	0.543*	0.878*	0.171
New Zealand	1.447*	0.467*	0.746*	1.537*	1.765*
Norway	0.602*	1.190*	0.572*	0.711*	0.706*
Spain	0.288	0.480*	1.001*	0.434	0.335
Switzerland	0.202	0.211	0.543*	#	0.244
United Kingdom	1.618*	0.718*	0.736*	1.330*	1.570*
Noninflation Targeting Countries					
Austria	0.521*	1.626*	1.393*	1.230*	0.365
Denmark	0.480*	0.581*	0.489*	0.980*	0.665*
Germany	0.545*	#	1.068*	0.211	0.619*
Ireland	0.460	0.478*	1.144*	0.440	0.507*
Italy	0.606*	0.672*	0.369	0.492*	0.790*
Japan	0.585*	1.068*	#	0.543*	0.600*
Netherlands	0.498*	0.497*	1.067*	0.485*	0.559*
United States	#	0.545*	0.585*	0.453	0.375

*Note:**Indicates rejection of the null hypothesis at the 5% level of significant. Critical Values from KPSS (1992) at the 5% level of significant is 0.463. # indicates that the test statistics is not computed.

Table 1-6 Panel unit root tests of real exchange rate with CPI

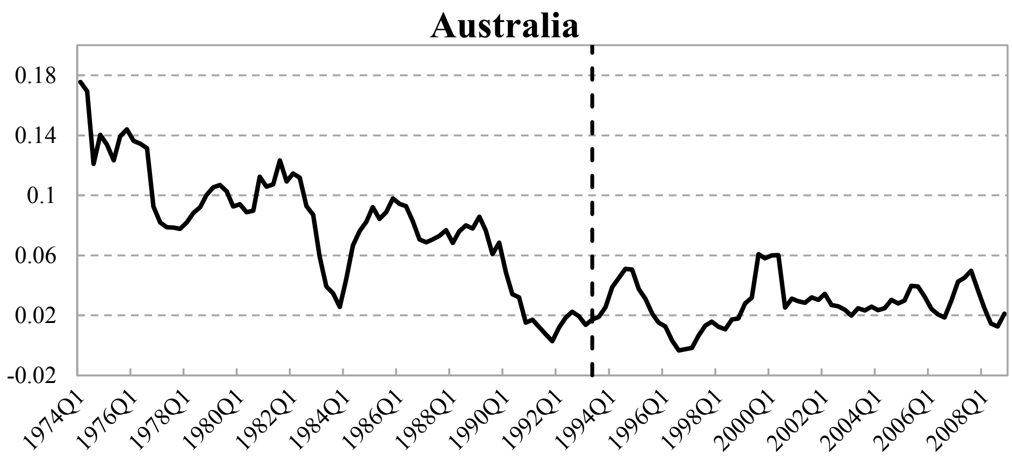
	IPS			CIPS		
Currencies	$\bar{t}_{IT}$	$\bar{t}_{ALL}$	$\bar{t}_{NIT}$	$\bar{t}_{IT}$	$\bar{t}_{ALL}$	$\bar{t}_{NIT}$
USD	-2.407	-2.189	-1.841	-2.319	-2.054	-1.860
	(0.001)	(0.069)	(0.307)	(0.248)	(0.405)	(0.402)
DM	-2.378	-2.244	-2.228	-2.683	-2.521	-2.511
	(0.002)	(0.059)	(0.002)	(0.025)	(0.035)	(0.036)
JPY	-2.578	-2.260	-2.252	-2.899	-2.390	-1.834
	(0.007)	(0.052)	(0.067)	(0.010)	(0.222)	(0.520)
SWF	-2.914	-2.681	-2.532	-2.752	-2.376	-1.874
	(0.001)	(0.001)	(0.002)	(0.040)	(0.211)	(0.731)
CAD	-2.531	-2.369	-1.949	-2.76	-2.319	-1.661
	(0.002)	(0.039)	(0.203)	(0.020)	(0.177)	(0.849)

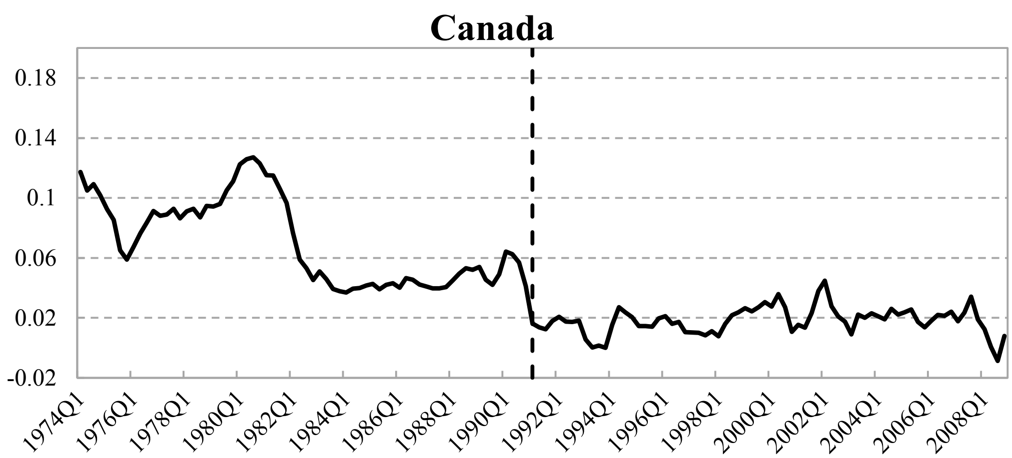
Notes: Subscripts IT, ALL, and NIT represent Inflation Targeting (IT), all, Noninflation Targeting (NIT) countries, respectively. Numbers in parentheses are p-values taken from the nonparametric bootstraps. CPI, Consumer Price Index; USD, US Dollar; DM, Deutch Mark; JPY, Japanese Yen; SWF, swiss Franc; CAD, Canadian Dollars; IPS, Im, Pesanran and Shin; CIPS, Cross-sectionally augmented version of IPS. P values are reported in parentheses.

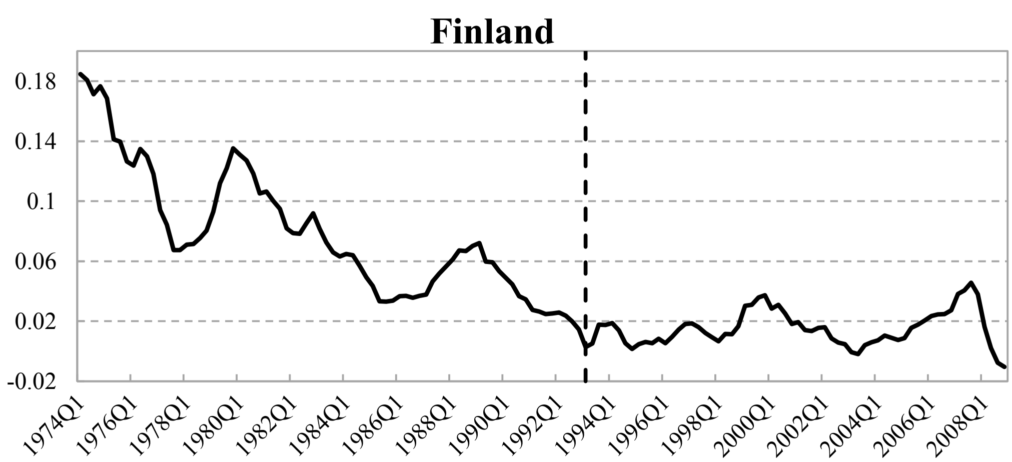
Table 1-7 Panel unit root tests of real exchange rate with PPI

	IPS			CIPS		
Currencies	$\bar{t}_{IT}$	$\bar{t}_{ALL}$	$\bar{t}_{NIT}$	$\bar{t}_{IT}$	$\bar{t}_{ALL}$	$\bar{t}_{NIT}$
USD	-2.206	-2.092	-2.024	-2.709	-2.436	-2.427
	(0.005)	(0.058)	(0.142)	(0.019)	(0.150)	(0.238)
DM	-2.477	-2.288	-2.032	-3.149	-2.896	-2.594
	(0.005)	(0.004)	(0.050)	(0.000)	(0.001)	(0.104)
JPY	-2.364	-2.341	-2.358	-2.776	-2.377	-2.309
	(0.010)	(0.043)	(0.072)	(0.022)	(0.217)	(0.351)
SWF	-3.309	-2.942	-2.206	-2.779	-2.454	-2.354
	(0.000)	(0.000)	(0.017)	(0.030)	(0.124)	(0.277)
CAD	-2.336	-2.312	-1.933	-2.837	-2.733	-2.305
	(0.006)	(0.024)	(0.184)	(0.005)	(0.008)	(0.201)

Notes: Subscripts IT, ALL, and NIT represent Inflation Targeting (IT), all, Noninflation Targeting (NIT) countries, respectively. Numbers in parentheses are p-values taken from the nonparametric bootstraps. PPI, Producer Price Index; USD, US Dollar; DM, Deutch Mark; JPY, Japanese Yen; SWF, swiss Franc; CAD, Canadian Dollars; IPS, Im, Pesanran and Shin; CIPS, Cross-sectionally augmented version of IPS. P values are reported in parentheses.







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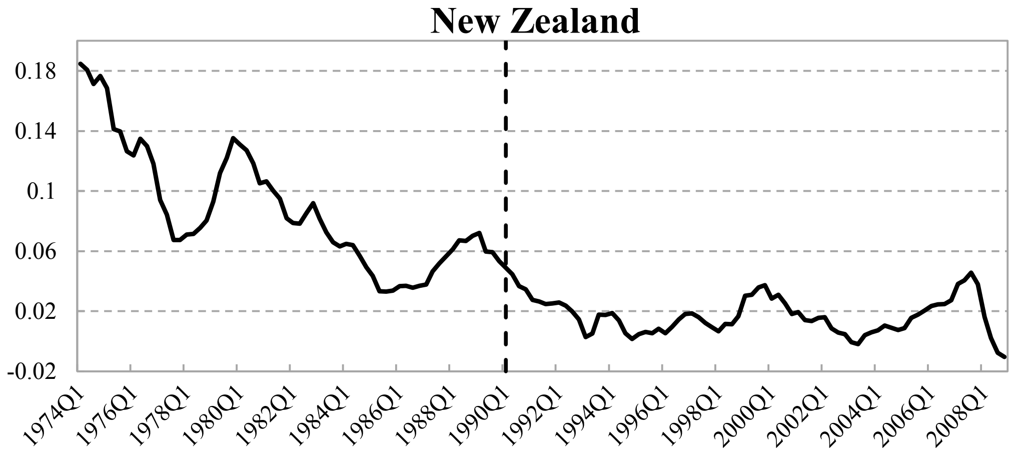

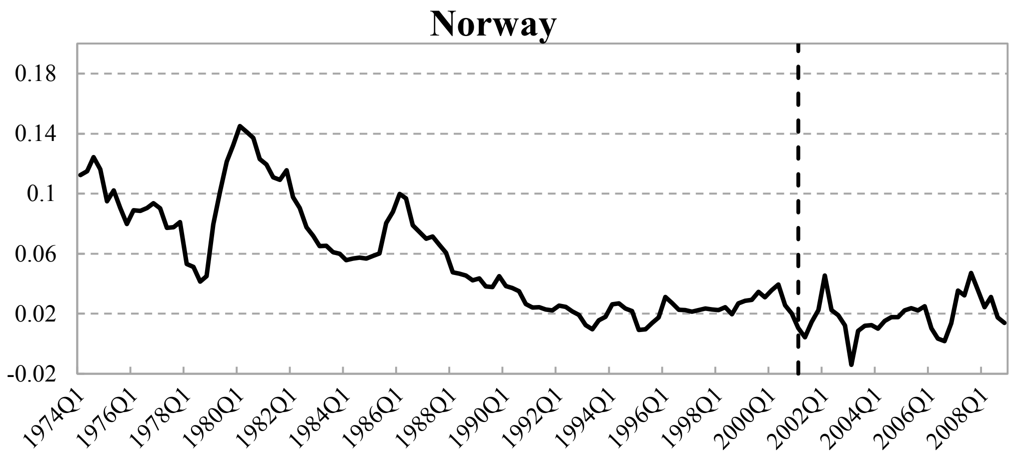

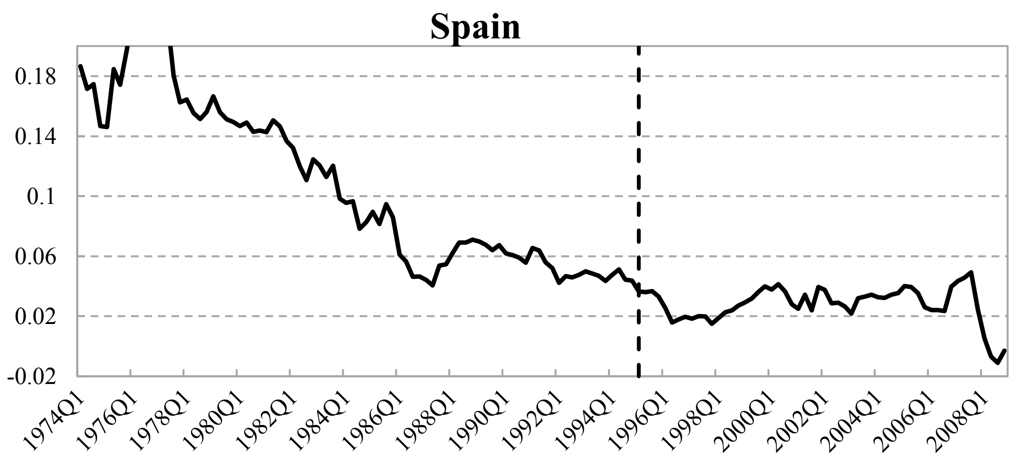

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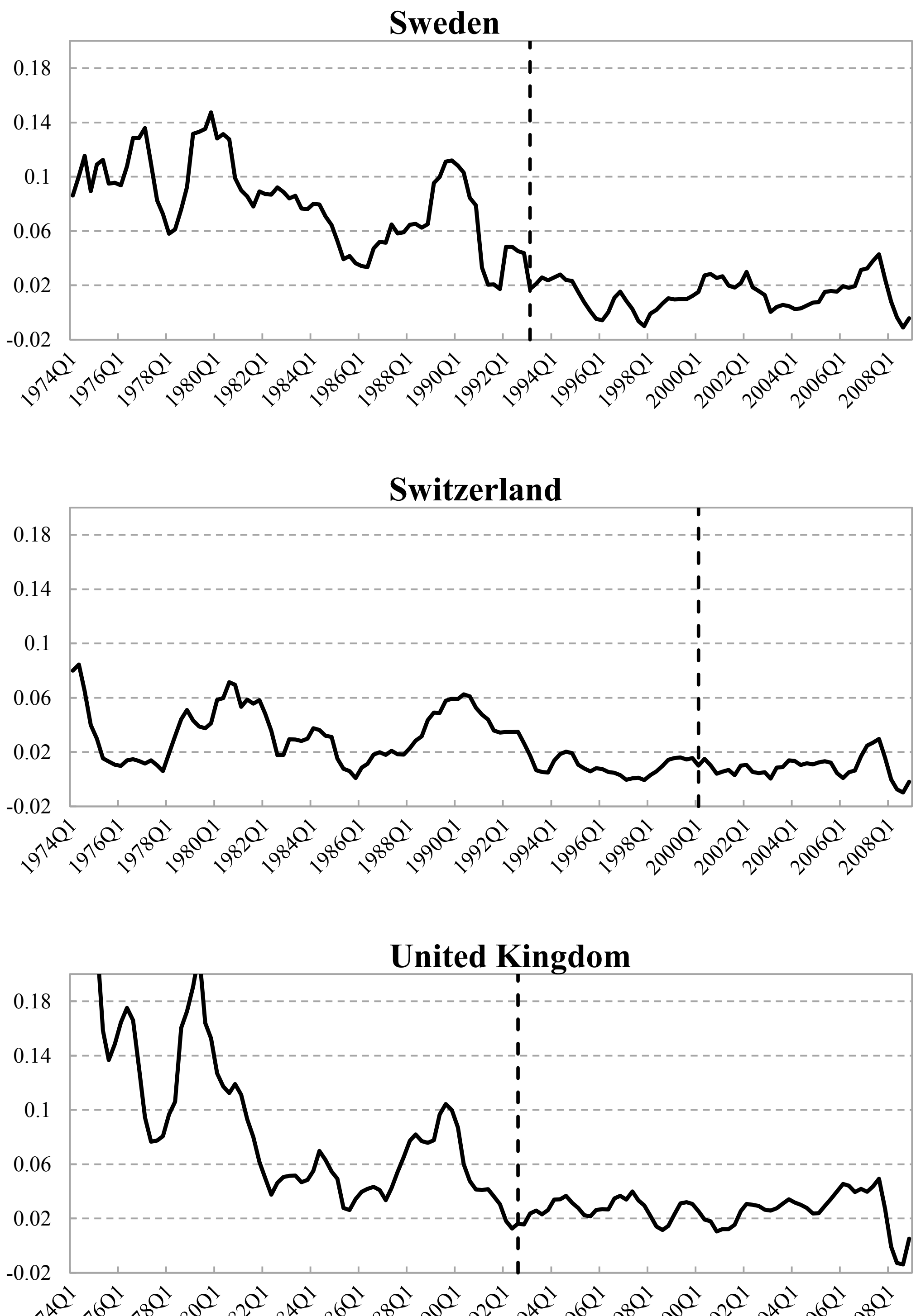
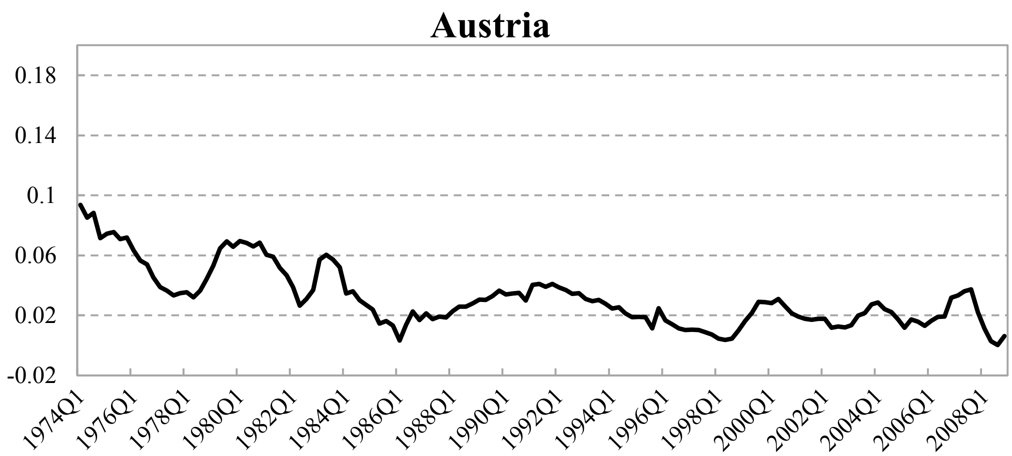
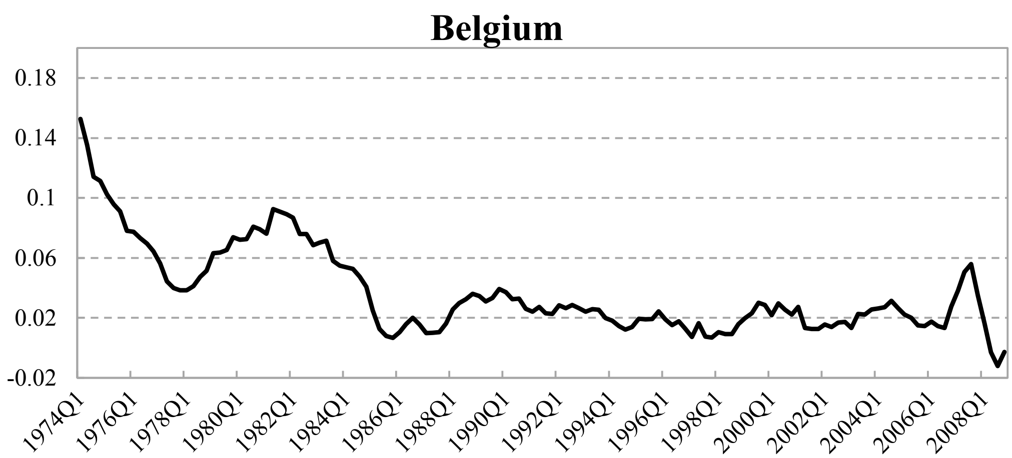
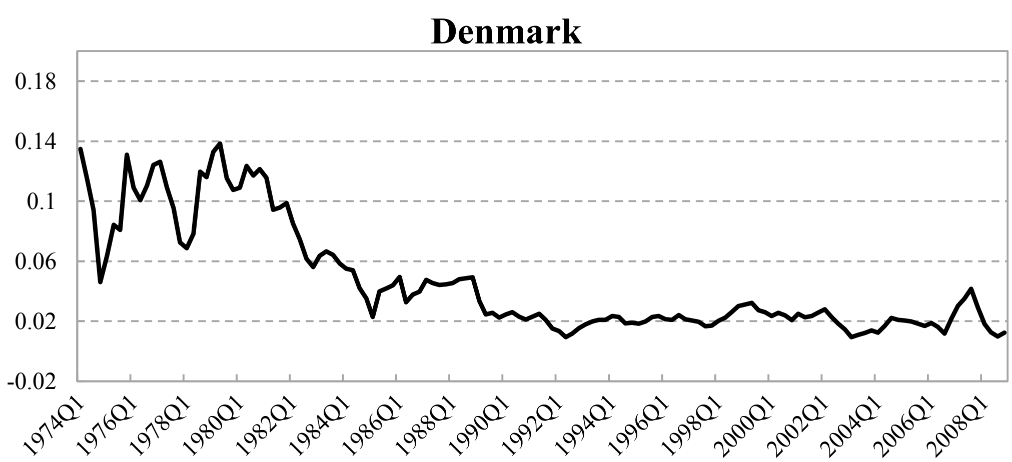


Figure 1-1 Annual inflation rates for IT countries







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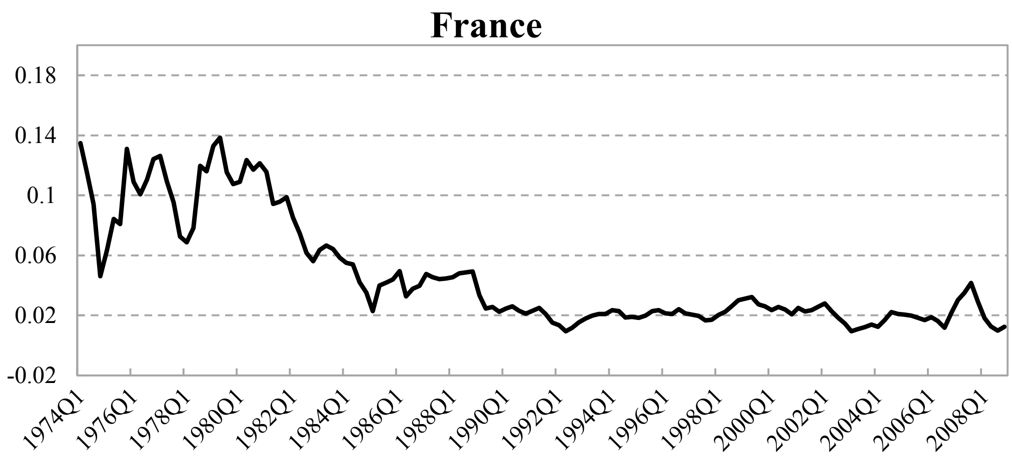

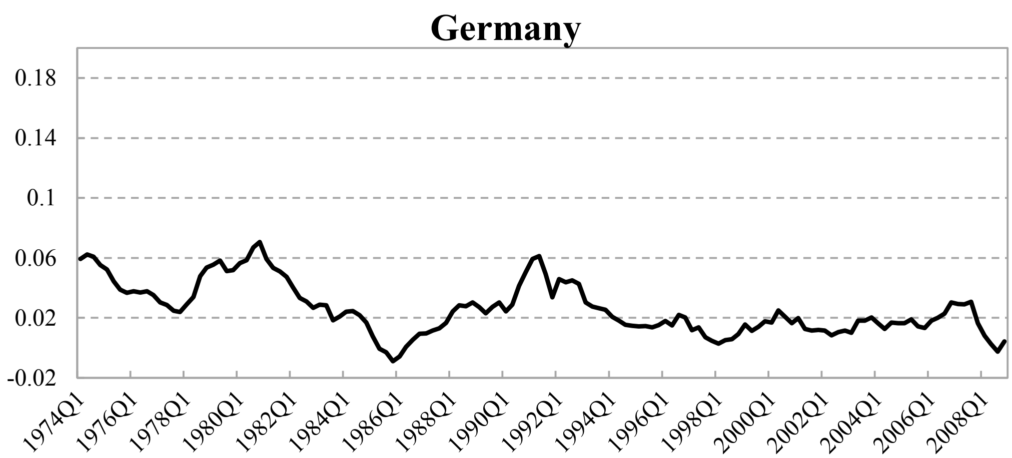

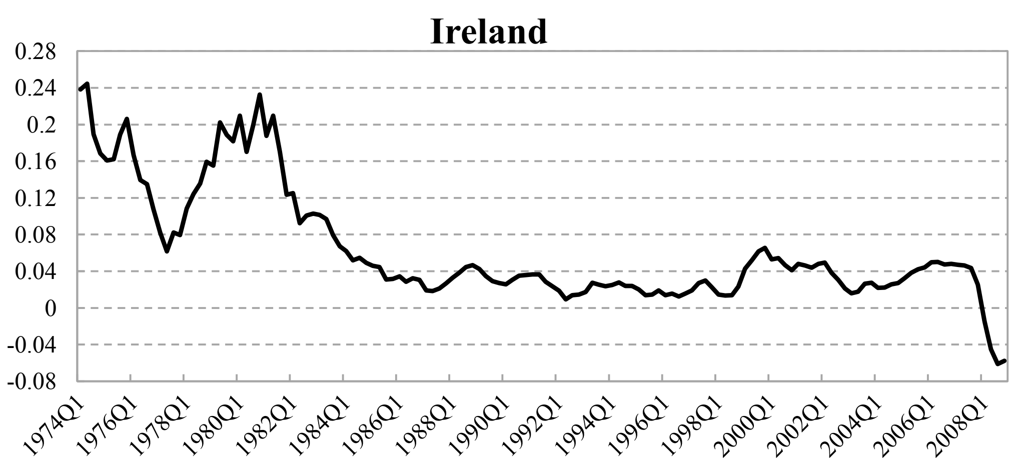

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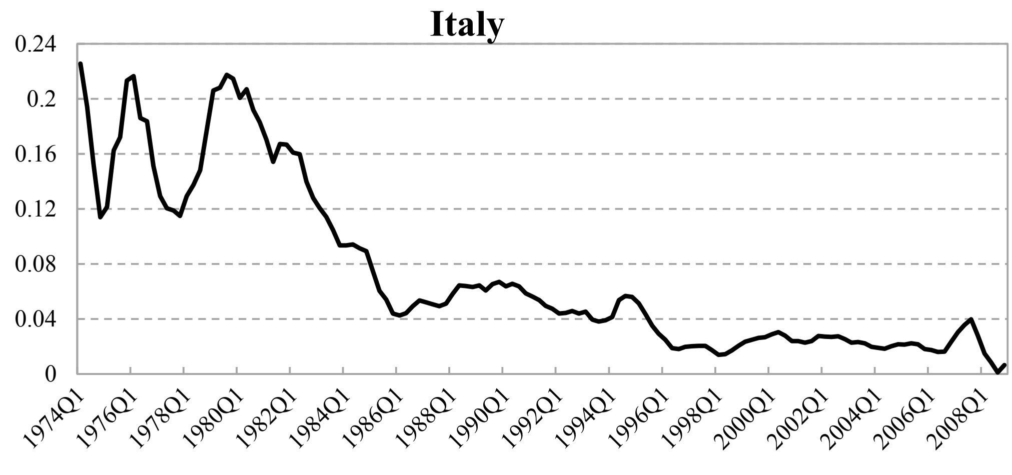

Italy
0.24
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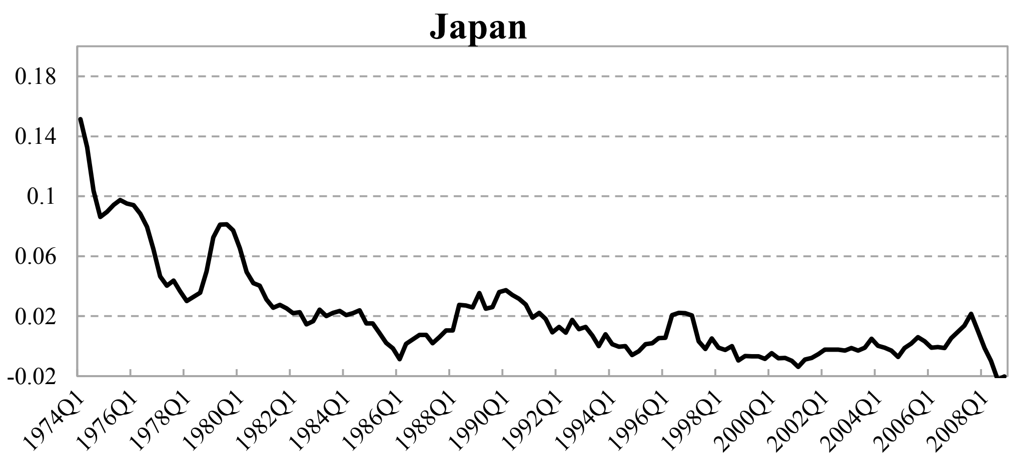
1974Q1 1976Q1 1978Q1 1980Q1 1982Q1 1984Q1 1986Q1 1988Q1 1990Q1 1992Q1 1994Q1 1996Q1 1998Q1 2000Q1 2002Q1 2004Q1 2006Q1 2008Q1



Japan
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The Netherlands
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1974Q1 1976Q1 1978Q1 1980Q1 1982Q1 1984Q1 1986Q1 1988Q1 1990Q1 1992Q1 1994Q1 1996Q1 1998Q1 2000Q1 2002Q1 2004Q1 2006Q1 2008Q1

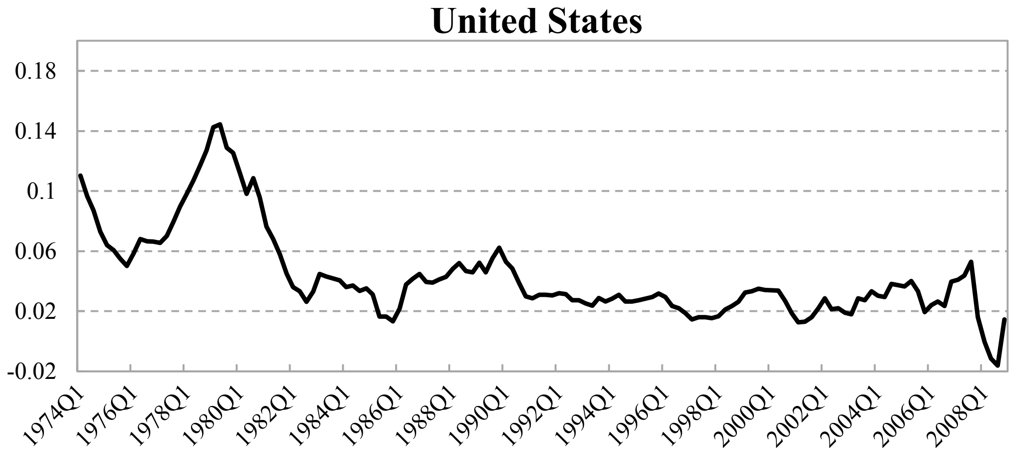

Figure 1-2 Annual inflation rates for NIT countries

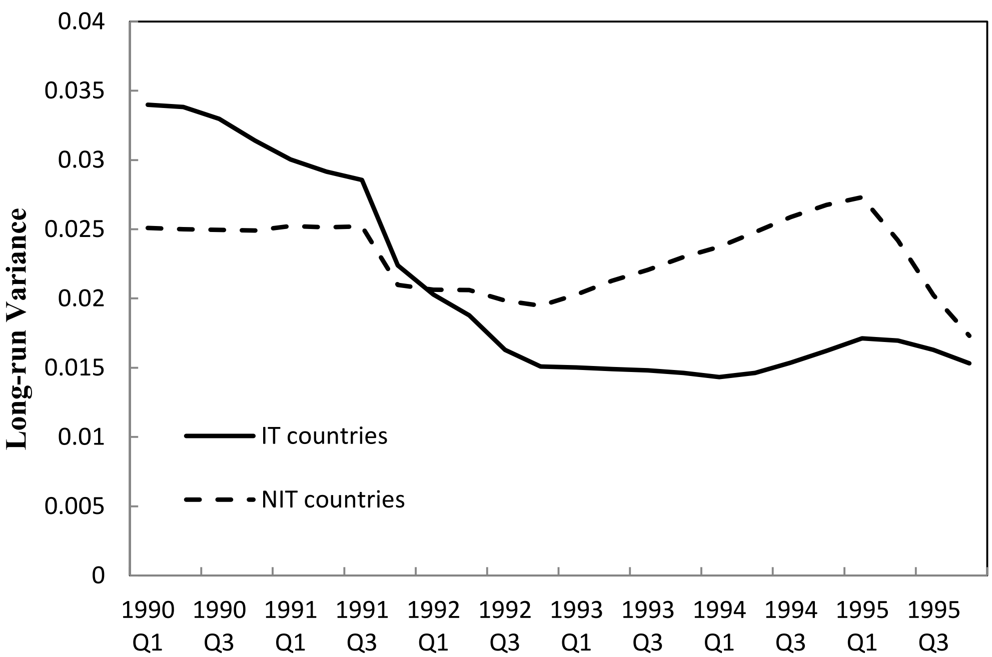

Figure 1-3 LRV of real exchange rate with CPI based on Newey-West method

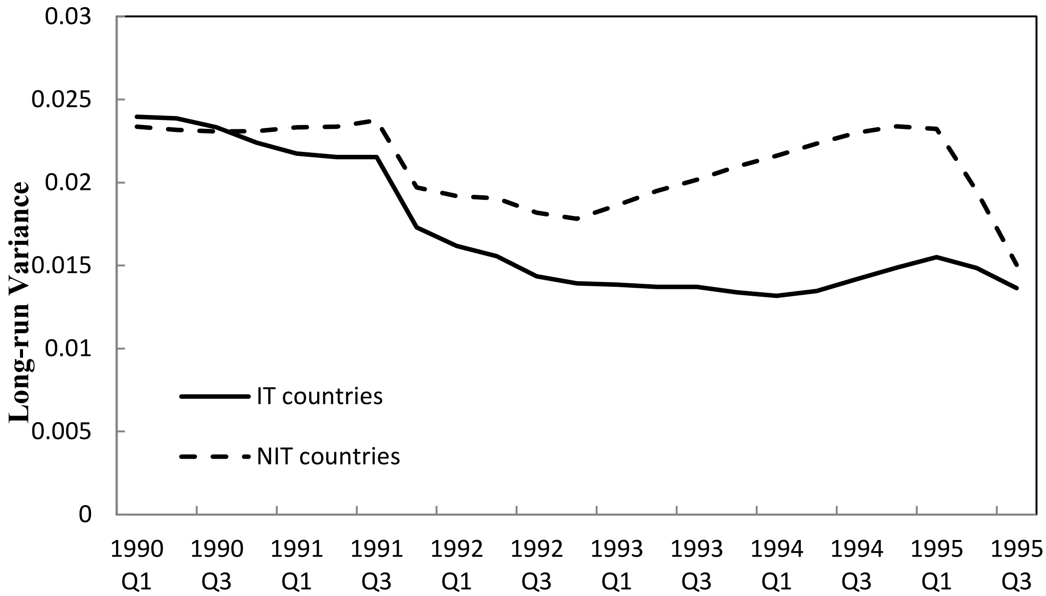

Figure 1-4 LRV of real exchange rate with PPI based on Newey-West method

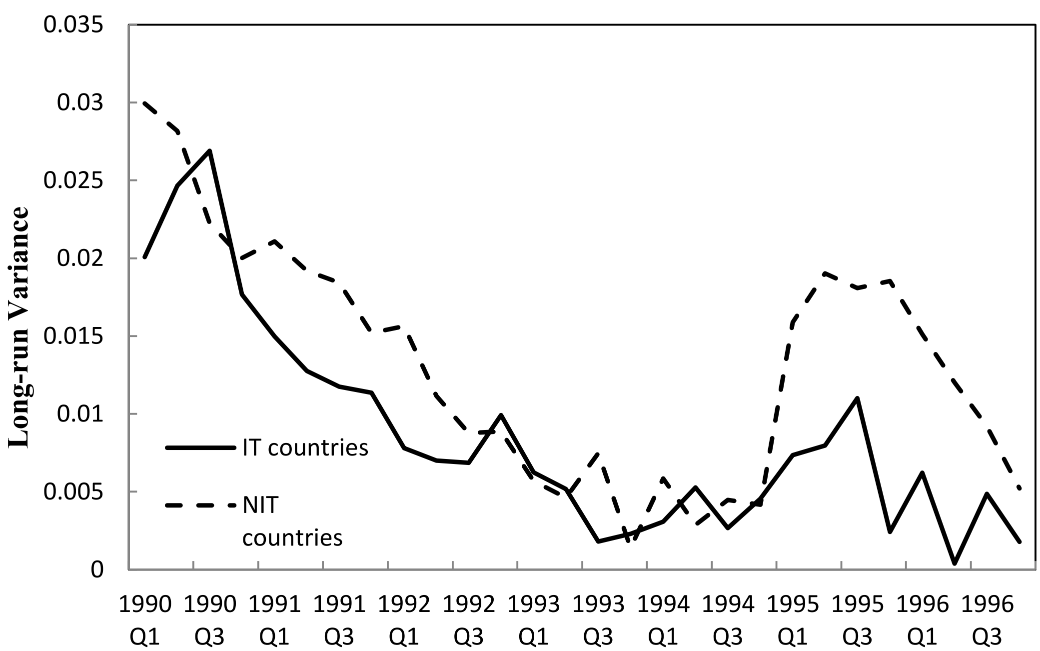

Figure 1-5 LRV of real exchange rate with CPI based on Andrew's method

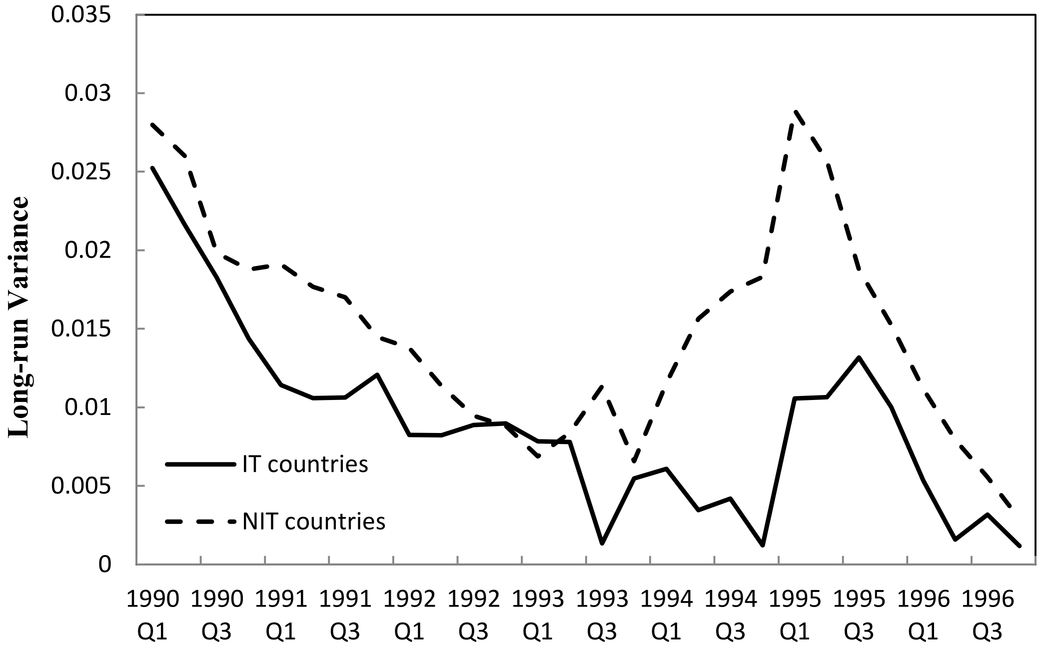

Figure 1-6 LRV of real exchange rate with PPI based on Andrew's method

Essay 2. An empirical study on whether Inflation Targeting matters to Real Interest Rate Parity

2.1 Introduction

With the development of financial markets, the degree of market integration is increasing greatly in recent years. The validity of Real Interest Rate Parity (RIP) serves as an indicator to examine whether countries are highly integrated or not. Frankel (1979) proposed the real interest rate differential model to examine this parity. Capitals always flow to countries with higher returns. As foreign capitals accumulated in countries with higher interest rate, the amount of domestic currency is relatively decreased so that leads to an appreciation of domestic currency. Therefore, the difference between interest rates of two countries is equal to the expected change in exchange rate. The model implied that RIP holds in the long run when exchange rate achieves its long-run equilibrium. The relationship between real interest rate differentials and real exchange rate is further confirmed by several early studies (Shafer and Loopesko, 1983 and Sachs, 1985). Essay One illustrates the validity of PPP is contingent upon Inflation Targeting (IT). Since RIP requires PPP as an assumption, this essay further investigates whether IT affects RIP using same panel data methods. On the other hand, compared to alternative monetary policies, several theoretical studies also pointed out the stability effects of IT on real interest rates in the long-run in addition to that on both inflation rates and real exchange rates (Kahn and Parrish, 1998; Svensson, 2000; and Mishkin and Schmidt-Hebbel, 2007).

Moreover, the investigation of RIP is important for two reasons. The validity of RIP suggested the equalization of real rates of return that has been employed as a key assumption in monetary models to determine exchange rates (Frenkel, 1976; Bilson, 1978; Flood and Marion, 1982; and Mussa, 1982). Another reason is the importance of policy implications. In an open economy, real interest rates influence economy activities through saving and investment behaviors. Policies increasing domestic savings directly cannot effectively increase the rate of capital when RIP holds (Feldstein, 1999). The power of monetary authorities to adjust interest rates is limited in the long run. Therefore, empirical studies on RIP have always been popular.

In addition, the validity of RIP using panel data methods might be related to several other issues proposed by previous studies. The first issue is the measure of real interest rates (Mishkin, 1984a,b; Cumby and Obstfeld, 1984; and Dutton, 1993). Real interest rates depends on deviations from the law of one price in goods markets across countries. Compared to nontradable goods, prices of tradable goods more accurately reflect the deviations. Therefore, to construct interest rate, it is more appropriate to use tradable goods index or price indices containing higher weights on tradable goods. Dutton (1993) and Kim (2006) find supportive evidence of RIP when real interest rates are measured in terms of only tradable goods relative to nontradable goods price index. Although tradable goods price indices are not available in the dataset of this essay, according to Froot and Rogoff (1995), Producer Price Index (PPI) can approximately represent tradable goods price index for a higher proportion of tradable goods compared to Consumer Price Index (CPI). The second issue is the assumption of cross-sectional dependence of panel unit root tests. Previous panel methods assume cross-sectional independence. As pointed out by O'Connell (1998), supportive evidence of PPP is overturned after considering cross-sectional dependence. This issue still exists when it comes to testing the validity of RIP, for PPP is an assumption of RIP. However, the majority of existing empirical studies failed to explore this issue. According to Camarero (2009), cross-sectional dependence has only been taken into account of RIP testing in very recent years. Thirdly, the choice of base currencies might explain the failure of PPP (Papell, 1997; Edison, Gagnon, and Melick, 1994). The huge volatility of U.S. dollar values that happened in 1980s might result in inaccurate conclusions on failure of PPP or RIP when U.S. dollar used as a base currency. Therefore, this essay attempts to investigate whether IT affects RIP for OECD countries using panel data methods and whether results might be influenced by those important issues proposed by previous studies.

Quarterly data of 11 OECD countries are sampled from 1974Q1 to 2011Q3. Different from previous studies that pooled countries into a group (ALL group), this essay further divides them into countries adopted IT (IT group) and countries not adopted IT (NIT group). The weak form of RIP is also tested after removing common time effects. IPS unit root tests (Im, Pesaran, and Shin, 2003) and CIPS unit root tests (Pesaran, 2007) are applied to panel data. Univariate unit root tests are also employed as benchmark. However, conclusions are drawn based on results from panel unit root tests because of their better test power. For IT, ALL, and NIT groups, results are compared based on real exchange rates with CPI and PPI, U.S. dollar and Duetch Marks, and with and without cross-sectional dependence assumption.

The rest of this essay is organized as follows: literature review and background on Real Interest Rate Parity are presented in the following section. The third section discusses econometric methodologies. Data description is discussed in section 4. In section 5, results are reported and analyzed. The final section concludes.

2.2 Literature review

2.2.1 Real Interest rate Parity (RIP)

Real interest parity differential (RID) model introduced by Frankel (1979) implied that real interest parity (RIP) holds in the long run when real exchange rates reaches its long-run equilibrium. It is also an important determinant in explaining exchange rate movement.

Real interest parity (RIP) relies upon four parity conditions: Fisher equation for domestic country and foreign country, Purchasing Power Parity (PPP), and Uncovered Interest rate Parity (UIP). The intuition behind Fisher equation is the relationship between nominal and real interest rates, through inflation, and the percentage change in the price level between two time periods. For example, suppose someone buys a \$1 bond with the nominal interest rate i_t in period *t*. He can redeem the bond in period *t*+1, and receive $\$(1 + i_t)$. But if there is price inflation between period *t* and *t*+1, the real value he receives from the bond is,

$$(1 + r_{t+1}) = (1 + i_t)/\,(1 + \pi_{t+1}) \tag{2.1}$$

where r_{t+1} is the real interest rate in period *t*+1 and π_{t+1} is the inflation rate between period *t* and *t*+1. Suppose that both real interest rates and the inflation rate are fairly small, this relationship can be approximately defined as,

$$r_{t+1} = i_t - \pi_{t+1} \tag{2.2}$$

Therefore, based on Fisher equation, the real interest rate of one country for one period is written in the form as,

$$r_{t+1}^{e} = i_t - \pi_{t+1}^{e} \tag{2.3}$$

where r_t^e is the one-period real interest rate expected for the bond maturing at time *t*+1, i_t is the nominal interest rate from holding the one-period bond from *t* to *t*+1, and π_{t+1}^e is the inflation rate from *t* to *t+1*, expected by the agents in the market at time *t*. The real interest rate defined above is more precisely referred to as the *ex ante* real interest rate, that is unobservable. In the same manner, the real interest rate of a foreign country for one period is defined as,

$$r_{t+1}^{*e} = {i_t}^{*} - \pi_{t+1}^{*e} \tag{2.4}$$

where r_t^{*e} is the one-period real interest rate of the foreign country expected for the bond maturing at time t+1, $i_t{}^*$ is the nominal interest rate of the foreign country from t to t+1, and π_{t+1}^{*e} is the inflation rate of foreign country from t to t+1 expected at time t.

Uncovered Interest rate Parity (UIP) indicates the relationship of real interest rates between two countries and their exchange rate. Suppose someone buys a \$1 bond with the nominal interest rate i_t in domestic market at time t. He can redeem the bond in period t+1, and receive $\$(1 + i_t)$. In another way, assuming the spot exchange rate is S_t (1 foreign currency exchanging for \$ S_t), he can exchange his \$1 for $1/S_t$ foreign currency and buy $1/S_t$ bond with the nominal interest rate i_t^* in foreign market at time t. At time t+1, he can receive $(1 + i_t^*)/S_t$ foreign currency. He can change to $S_{t+1}^e(1 + i_t^*)/S_t$ dollar. Under the assumption with no-arbitrage condition, there should be no difference from investing in domestic market and foreign market. Therefore, UIP can be represented as,

$$(1 + i_t) = \frac{S_{t+1}^e}{S_t}(1 + i_t^*) \tag{2.5}$$

where S_{t+1}^e is exchange rate at time t+1 expected at time t. By approximation, this relationship can be denoted as,

$$i_t - i_t^* = s_{t+1}^e - s_t \tag{2.6}$$

where s_{t+1}^e and s_t are the natural logarithm of S_{t+1}^e and S_t, separately.

Purchasing Power Parity (PPP) indicates the relationship of the exchange rate between two countries and their national price levels (See section 1.2.2 for more details). PPP is denoted as,

$$s_{t+1}^e - s_t = \Delta p_{t+1}^e - \Delta p_{t+1}^{*e} \tag{2.7}$$

where $\Delta p_{t+1}^{e} = \pi_{t+1}^{e}$, $\Delta p_{t+1}^{*e} = \pi_{t+1}^{*e}$, and p is the natural logarithm of the price level, e and *, respectively refer to an expected and foreign value. Based on (2.6) and (2.7),

$$i_t - i_t{}^{*} = \Delta p_{t+1}^{e} - \Delta p_{t+1}^{*e} \tag{2.8}$$

Together with (2.2) and (2.3), *ex ante* Real Interest rate Parity (RIP) is denoted as,

$$r_{t+1}^{e} = r_{t+1}^{*e} \tag{2.9}$$

Therefore, deviations from *ex ante* RIP can be defined as v where,

$$r_{t+1}^{e} - r_{t+1}^{*e} = v_{t+1} \tag{2.10}$$

Assuming expectations concerning inflation are formed rationally,

$$\Delta p_{t+1} = \Delta p_{t+1}^{e} + \omega_{t+1} \tag{2.11.a}$$

$$\Delta p_{t+1}^{*} = \Delta p_{t+1}^{*e} + \omega_{t+1}^{*} \tag{2.11.b}$$

where ω is the forecast error that is serially uncorrelated with a zero mean. The *ex post* RIP can be written as,

$$r_{t+1} - r_{t+1}^{*} = \varepsilon_{t+1} \tag{2.12}$$

where ε is the deviations from ex post RIP and is a composite term incorporating v and $\omega - \omega^{*}$. $r_{t+1} - r_{t+1}^{*}$ is called real interest rate differential (RID). In general, RIP holds as a long-run equilibrium condition if the real interest differential, ε_{t+1}, is mean reverting over time.

2.2.2 Empirical literature for RIP

The empirical studies on long-run RIP are quite abundant and diverse. Early studies of RIP include Mishkin (1984a,b), Cumby and Obstfeld (1984), and Cumby and Mishkin (1986). They employ classic OLS regression and barely find evidence of RIP. In addition, the results are robust with respect to countries and price deflators. Fuijii and Chinn (2002) have able to find supportive evidence for weak RIP in OECD countries using panel data. Moreover, the traditional time-series unit root tests have also not been able to provide satisfactory results (Meese and Rogoff, 1988; Edison and Pauls,1993) This outcome can be explained by a commonly accepted idea that the power of these tests tends to be very low when the root is close to one, especially in small samples (Shiller and Perron, 1985).

To improve the test power, Moosa and Bhatti (1996) recommend a series of alternative univariate unit root tests that are more powerful than the conventional ADF tests and find more promising results. Another method is to increase data set sample. Lothian (2000) uses annual data on real interest rate differentials over the long period 1791 to 1992 but results are mixed. Other researchers try to improve the power of unit root tests by expanding the data cross-sectionally to exploit the additional information. The early panel unit root test is proposed by Quah (1992, 1994) but it does not consider heterogeneity across groups such as individual specific effects and residual serial correlation. Levin and Lin (1992, 1993) and Levin, Lin and Chu (2002), denoted as LLC test, is more generally used. It allows for individual specific effects as well as heterogeneity across groups. Im, Pesaran and Shin (2003), denoted as IPS test, improves LLC test by allowing unbalanced panels, different convergence rates toward PPP and different serial correlation properties across groups. Maddala and Wu (1999) proposed a new test statistic based on Fish's test, denoted as MW test. The behind principle of MW test is similar to IPS test. In contrast to IPS test, MW test statistic is related to p-value of OLS t-ratio statistic instead of relating to OLS t-ratio directly. A number of panel data studies provide favorable evidence for long -run RID. Wu and Chen (1998) employ three panel unit root tests, LLC, IPS, and MW test, to examine the stationarity of real interest differentials. Their finds support long-run RIP. Holmes (2002) tests for long-run *ex post* RIP among major European Union over different periods using IPS test. In general, the evidence of RIP is strong. Baharumshah *et al*. (2005) find supportive evidence based on LLC, IPS, and MW test. Although Taylor and Sarno (1998) issued an important warning for spurious interpretations of finding with panel data, it is wildly believed that these econometric procedures are more powerful and efficient than ordinary methods when panel data are used.

However, it is widely recognized that these panel unit root tests have some flaws in terms of lack of power and size distortion in the presence of correlation among contemporaneous cross-sectional error terms (O'Conell, 1998). Both of LLC test and IPS test assume an independent relationship across countries. It is obvious the assumption cannot be true in the real world. At least, real interest rate differentials are constructed with one base country. According to O'Connell (1998), failure to consider cross-sectional dependence might result in a huge increased significant level. It may in turn affect conclusion of the hypothesis test. Consequently, the supportive conclusion from LLC test and IPS test might not be reliable.

To deal with the problem of cross-section dependence, first, Levin, Lin and Chu (2002) suggest computing the test removing the cross-section mean. Their idea is cross-section dependence is driven by one common factor with the same effect for all individuals in the panel data set. The second method is to implicitly accommodate general forms of cross-section dependence. Maddala and Wu (1999) propose a non-parametric bootstrap procedure to capture contemporaneous correlation of error terms. Wu and Wu (2001) further supported Maddala and Wu (1999) results and improved the testing procedure by using seeming unrelated regression (SUR method) instead of OLS regression in non-parametric bootstrap procedure.

More recently, a great number of panel unit root tests have been proposed to explicitly consider cross-sectional dependence (Phillips and Sul, 2003; Moon and Perron, 2004; Bai and Ng, 2004a; Pesaran, 2007). They assume that the process is driven by a group of common factors, so that it is possible to distinguish between the idiosyncratic component and the common component. Although there are differences among the methods proposed, their driving idea is similar. Phillips and Sul (2003), Moon and Perron (2004), and Pesaran (2007) focus on the extraction of the common factors that generate the cross-correlations in the panel to assess the non-stationarity of the series. While in Bai and Ng (2004) the non-stationarity of the series can come from the common factors, the idiosyncratic component or both. Moreover, Phillips and Sul (2003) and Pesaran (2007) consider the existence of one common factor in contrast to multiple common factors considered in Bai and Ng (2004 and Moon and Perron (2004). Several studies are unable to find supportive evidence based on these panel unit root tests. Singh and Banerjee (2006) study for long-run real interest convergence in emerging markets using Pesaran (2007) test. Their results suggest that real interest rates in the emerging markets show some convergence in the long run but real interest parity does not hold. Camarero (2009) employ Bai and Ng (2004) test for real interest parity among the 19 OECD countries over 1978 to 2006. They are unable to find evidence of RIP. It indicates that cross-sectional dependence may matter for RIP.

Except the issue of cross-section dependence, another important issue to understand RID is the measure of the real interest rate (Cumby and Obstfeld, 1984; Mishkin, 1984a,b; Duntton, 1993). If all of the goods in the consumption basket are perfectly arbitraged, then an overall consumption deflator, such as consumer price index (CPI), is an appropriate measure of the real interest rate. However, the results of tests using CPI based real interest rates are very mixed (see Cumby and Obstfeld, 1984; Mark,1985;Chinn and Frankel, 1995; Wu and Chen, 1998; Fountas and Wu, 1999; and Fujii and Chinn, 2001 for details). In empirical studies of PPP, the choice of price index is an issue because general price indices contain the prices of both tradable and nontradable goods. Since whether RIP holds is based on the assumption of PPP, Cumby and Obstfel (1984) argue the rejection of RIP might be primarily due to rejection of Purchasing Power Parity using general price indices. Under the assumption of perfect arbitrage in the goods market, the interest rates measured in terms of the whole consumption basket may not be appropriate. Instead, international financial theory implies that for international comparisons, the appropriate measure of real interest rate is one defined in terms of tradable goods prices alone. Duntton (1993) employs a tradable goods component to construct the real interest rates for five countries and shows that real rate parity is supported if the real interest rate is appropriately measured in term of tradable goods. Kim (2006) employs panel unit root tests to examine RIP by contrasting real interest rates across tradable and nontradable good. He also finds strong evidence of RIP based on tradable good price indices. It suggests the measure of the real interest rate matters for RIP. According to Froot and Rogoff (1995), in empirical studies of PPP, real exchange rate based on Producer Price index (PPI) produce more supportive evidence than that based on CPI. They argue PPI contains a higher proportion of tradable goods. Therefore, CPI and PPI can be considered as an approximation to nontradable and tradable goods price, separately.

Empirical studies of long-run RIP have involved plenty of issues and topics. Although it might not be completed in this literature review, several of the most important issues appeared in recent studies have already been included. The main purpose of my study is to examine whether IT could be another new issue matters for RIP. These important issues are also considered as benchmarks to indicate how significant effects of IT for RIP might be.

2.3 Econometric Methodologies

Real Interest rate Parity (RIP) involves both Uncovered Interest rate Parity (UIP) and Purchasing Power Parity (PPP). For panel data, UIP between two countries can be written as,

$$i_{it} - i_t^* = s_{it+1} - s_{it} + \varepsilon_{it} \tag{2.13}$$

where i_{it} is the nominal exchange rate for country *i* at time *t*, i_t^* is the nominal exchange rate for base country at time *t*, s_{it} is the natural logarithm of exchange rate between country *i* and base country (country *i*'s price of base country), and ε_{it} is an error term from expectation errors, which is assumed to be white noise. $\varepsilon_{it} = E(s_{it+1}|I_t) - s_{it+1}$ and $E(\cdot\,|I_t)$ is the conditional expectations operator based on the information at time *t*.

Based on PPP,

$$s_{it} = p_{it} - p_t^* \tag{2.14}$$

where p_{it} is the natural logarithm of the price level in country i and p_t^* is the natural logarithm of the price level in base country. Combine Equation (2.13) and (2.14), the Real Interest rate Differential is,

$$r_{it} - r_t^* = \varepsilon_{it} \tag{2.15}$$

where $r_{it} = i_{it} - (p_{it+1} - p_{it})$ and $r_t^* = i_t^* - (p_{t+1}^* - p_t^*)$ (See section 2.2.1 for more details on derivation of RIP). The form of RIP implies that under the assumption of no arbitrage, real interest rates for comparable securities should be equal across countries. Movements of the differentials ε_{it} represent deviations from RIP. While there might be considerable short-run variance of ε_{it}, a necessary condition for RIP to hold in the long run is that ε_{it} be stationary over time, that is the differentials should be mean reverting. If ε_{it} follows a stationary process, long-run RIP is said to be hold. If ε_{it} contains a unit root, the deviations from RIP will persist indefinitely. In that case, it implies rejection of RIP in the long run. Hence, the presence of a unit root in ε_{it} indicates the failure of RIP in the long-run. This parity is tested the null hypothesis of unit roots against the alternative of mean reversion.

In this study, I firstly estimate the long-run variance of real interest rates over years and plot their values. They provide a stylized fact for RID. Secondly, augmented Dickey-Fuller test is employed as a benchmark for panel unit root tests. Thirdly, the two panel unit root tests are then employed. One is Im-Pesaran-Shin (IPS) test (2003). This procedure assumes that the individual time series are cross-sectionally independently distributed. In contrast to IPS test, the other one, cross-sectionally augmented version of IPS (CIPS) test (2007), considers cross-sectional dependence. For each unit root tests, I also test data after removal of common specific-time effects.

2.3.1 Long-run Variance

Let $\mathbf{Y}_t$ be an $(n \times 1)$ stationary and ergodic multivariate time series with $E[\mathbf{Y}_t] = \boldsymbol{\mu}$. $\mathbf{Y}_t$ depends on *K*-vector of parameters θ. Let $Y_t \equiv Y_t(\theta_0)$ where $\theta_0$is the true value of θ. According to central limit theorem for stationary and ergodic process, it states

$$\sqrt{T}(\bar{\mathbf{Y}} - \boldsymbol{\mu}) \xrightarrow{\boldsymbol{d}} N\left(0, \textstyle\sum_{j=-\infty}^{\infty} \boldsymbol{\Gamma_j}\right) \tag{2.16.a}$$

or

$$\bar{\mathbf{Y}} \sim N(\boldsymbol{\mu}, \tfrac{1}{\mathrm{T}} \textstyle\sum_{j=-\infty}^{\infty} \boldsymbol{\Gamma_j}) \tag{2.16.b}$$

Hence, the long-run variance of $\mathbf{Y}_t$ is T times the asymptotic variance of $\bar{\mathbf{Y}}$:

$$lrv(\mathbf{Y}_t) = T \cdot avar(\bar{\mathbf{Y}}) = \textstyle\sum_{j=-\infty}^{\infty} \boldsymbol{\Gamma_j} \tag{2.17}$$

Since $\Gamma_{-j} = \Gamma_j'$, $lrv(\mathbf{Y}_t)$ may be alternatively expressed as

$$lrv(\mathbf{Y}_t) = \boldsymbol{\Gamma_0} + \textstyle\sum_{j=1}^{\infty} (\boldsymbol{\Gamma_j} + \boldsymbol{\Gamma_j'}) \tag{2.18}$$

$lrv(\mathbf{Y}_t)$ is denoted as $\boldsymbol{\Omega}$.

To estimate long-run variance $\boldsymbol{\Omega}$, in the econometric literature, it is generally using a consistent estimator $\hat{\theta}$ to estimate $\hat{Y}_t$ for a consistent estimate of $\boldsymbol{\Omega}$. $\widehat{\boldsymbol{\Omega}}$ obtained from methods following this idea are often referred to as heteroskedasticity and autocorrelation consistent (HAC) covariance matrix estimators. There are several approaches to estimating $\boldsymbol{\Omega}$. The Nonparametric kernel approach (Newey-west, 1987; Andrews, 1991) is employed in this study. It estimates $\mathbf{\Omega}$ by taking a weighted sum of the sample autocovariances of the observed data.

The classic of kernel HAC covariance matrix estimators in Andrews (1991) may be written as,

$$\widehat{\Omega} = \frac{T}{T-K} \sum_{j=-\infty}^{\infty} k(j/b_T) \cdot \widehat{\Gamma}(j) \tag{2.19}$$

where the sample autocovariances $\widehat{\Gamma}(j)$ are given by

$$\widehat{\Gamma}(j) = \frac{1}{T} \sum_{t=j+1}^{T} \widehat{Y}_t \, \widehat{Y}'_{t-j} \qquad j \geq 0 \tag{2.20.a}$$

$$\widehat{\Gamma}(j) = \widehat{\Gamma}(-j)' \quad j < 0 \tag{2.20.b}$$

K is a symmetric kernel function that, among other conditions, is continuous at the origin and satisfies $|k(x)| \leq 1$ for all x with $k(0) = 1$, and $b_T > 0$ is a bandwidth parameter. The leading $T/(T - K)$ term is an optical correction for degrees-of-freedom associated with the estimation of the *K* parameters in θ. The kernel HAC estimator is determined by the choice of a kernel function and a value for the bandwidth parameter.

In this study, two methods of nonparametric kernel are used including Newey and West (1987) and Andrew (1991). Both of methods choose Bartlett kernel function, that is

$$k(x) = \begin{cases} 1 - |x| & \text{if } |x| \leq 1 \\ 0 & \text{otherwise} \end{cases} \tag{2.21}$$

The difference is the choice of bandwidth parameter. The bandwidth b_T is used to determine the weights for the variance sample autocovariances in (2.19). The optimal bandwidths may be written in the form (2.22):

$$b_T = \gamma T^{1/(2q+1)} \tag{2.22}$$

Automatic bandwidth selection methods are used. It indicates that the optimal bandwidth is estimated from the data instead of specifying a priori. Estimators for γ from both methods may be written as:

$$\hat{\gamma}(q) = c_k \hat{\alpha}(q)^{1/(2q+1)} \tag{2.23}$$

where q is determined by the selection of kernel function, that is 1 for Bartlett kernel function, the constant c_k depend on properties of the selected kernel, and $\hat{\alpha}(q)$ is an estimator of $\alpha(q)$, a measure of the smoothness of the spectral density at frequency zero that depends on the autocovariances $\Gamma(j)$. Substituting into Equation (2.22), the resulting estimator for the optimal automatic bandwidth is giving by,

$$\hat{b}_T^* = c_k(\hat{\alpha}(1)T)^{1/3} \tag{2.24}$$

Both of the Andrews and Newey-West estimators require an estimator of $\alpha(q)$, or $\alpha(1)$ in this study.They offer alternative methods for forming these estimates. The Andrews (1991) method estimate $\alpha(q)$ parametrically fitting a simple parametric time series model to the original data, then deriving the autocovariances parameter $\Gamma(j)$ and corresponding $\alpha(q)$ implied by the estimated model. Newey-West employ a nonparametric approach to estimating $\alpha(q)$. Andrews that computes parametric estimates of the generalized derivatives of p in individual elements, then aggregates the estimates into a single measure. In contrast, Newey and West aggregate early, forming linear combinations of the autocovariance matrics, then use the scalar results to compute nonparametric estimators of the Parzen smoothness measures. In addition, a weight vector w that is used to determine $\alpha(q)$ must be determined. Newey-West leaves open the choice of w, but Andrew suggests $w_s = 1$ for all s. EViews time series econometric software is used to do the estimations. For details of Andrew and Newey-West methods, refer to Andrew (1991), Newey-West(1987), or Eview7.0 User Guide II.

2.3.2 Univariate unit root test: Augmented Dickey-Fuller (ADF) test

The ADF test involves regressing the first-difference of a variance on a constant, its lagged level, and k lagged first difference. The real interest rate differential is calculated as,

$$\varepsilon_t = r_t - r_t^* \tag{2.25}$$

where ε_t is the differential of real interest rate between two countries, $r_t$and r_t^* are real interest rate of two country, separately. The regression representation is showed as,

$$\Delta\varepsilon_t = \alpha + \beta\varepsilon_{t-1} + \sum_{i=1}^{k} \gamma_i \,\Delta\varepsilon_{t-i} + \mu_t \tag{2.26}$$

where ε_t is the differential. The null hypothesis of a unit root is rejected in favor of the alternative of level stationary if α is significantly different from zero. The lag length k is determined by Hall's (1994) general-to-specific method recommended by Campbell and Perron (1991). Started with a upper bound, k_{max}, on k. In this study, k_{max} is 10 , If the last included lag is significant, choose $k = k_{max}$. If not, reduce k by 1 unit the last lag becomes significant. If no lags are significant, set $k = 10$ in this study.

2.3.3 Univariate unit root test: The Kwiatkowski, Phillips, Schmidt, and Shin (KPSS) Test

Different from ADF test with a null hypothesis of a unit root, KPSS test assumes there is a stationary process under the null. Followed by KPSS (1992), the KPSS statistic is based on residuals from the OLS regression defined as follow,

$$q_t = x_t'\delta + \varepsilon_t \tag{2.27}$$

The KPSS statistic is defined as:

$$\varphi_\varepsilon = \sum_t S(t)^2 / (T^2 f_0) \tag{2.28}$$

where f_0 is an estimator of the residual spectrum at frequency zero and where $S(t)$ is a cumulative residual function:

$$S(t) = \sum_{r=1}^{t} \hat{\varepsilon}_r \tag{2.29}$$

based on the residuals from Equation (2.27). The number of lags truncation in the KPSS test is selected automatically by Newey and West Bandwidth using Barlett Kernal Spectral estimation method. The null hypothesis of stationarity is rejected if the test statistic is greater than the critical value.

2.3.4 Panel unit root test: IPS test (Im, Pesaran and Shin 2003)

Let ε_{it} be the interest rate differential of country i and base country, where $i = 1,2,\ldots N$ and $t = 1,2,\ldots T$ with N countries in the panel, and T time series observations. ε_{it} follows ADF representation:

$$\Delta\varepsilon_{it} = \alpha_i + \beta_i\varepsilon_{it-1} + \sum_{\mathrm{j}=1}^{\mathrm{k_i}} \gamma_{ij}\Delta\varepsilon_{it-j} + \mu_{it} \tag{2.30}$$

where $\Delta\varepsilon_{it}$ is the first difference of the interest rate differentials of country i and base country at time t $(i = 1,2,\ldots N)$, $k_i$is the lag length selected for country i , and μ_{it} is the regression error. The null hypothesis of unit roots under IPS test, $\mathrm{H_0}: \beta_i = 0$ for all i is tested against the alternative hypothesis of stationary, $\mathrm{H_1}: \beta_j < 0 \ j = 1,2,\ldots N$, which allows for different convergence rate toward PPP across countries. The rejection of the null hypothesis implies the null hypothesis is rejected for $N_1 < N$. It indicates the evidence of stationary series existing in the group.

According to IPS (2003), the IPS statistic $\bar{z}$ is defined as,

$$\bar{z} = \frac{\sqrt{N}(\bar{t} - E(\bar{t}))}{\sqrt{Var(\bar{t})}} \tag{2.31}$$

where $\bar{t} = \frac{1}{N}\sum_{i=1}^{N} t_i$, with mean $E(\bar{t})$ and variance $Var(\bar{t})$. t_i is the t-ratio of the least square estimate of β_i from individual ADF regression (Equation (2.30)). $\bar{z}$ has an asymptotic standardized normal distribution and it relies on very large samples. IPS test is based on individual ADF regression. Since an appropriate ADF regression can correct for serial correlation in the data, IPS test also correct serial correlation automatically, and allow for heterogeneity at the same time.

However, IPS test does not consider cross-section dependence. To fix this problem, a simple method suggested by Levin and Lin (1992) is to remove the common specific-time effect of group before do the regression, that is, the cross-section mean.

$$\varepsilon_{it}' = \varepsilon_{it} - \bar{\varepsilon}_t \tag{2.32}$$

where $\bar{\varepsilon}_t = \sum_{i=1}^{N} \varepsilon_{it} / N$ and ε_{it}' is the real interest rate differentials between country i and base country without common specific-time effects. Then, ε_{it}' instead of ε_{it} is used in previous estimations. To get the critical values, followed by Maddala and Wu (1999) and Wu and Wu (2001), a non-parametric bootstrap procedure is employed. In this way, it can implicitly consider cross-section dependence and fix the bias of distribution due to small sample size. The detailed bootstrap procedure can be found in Appendix.

2.3.5 Panel unit root test: CIPS test (Pesaran 2007)

To test the long-run relationship (Equation (2.25)), the following regression is considered:

$$\Delta\varepsilon_{it} = \alpha_i + \beta_i \varepsilon_{i,t-1} + e_{it} \tag{2.33}$$

where Δq_{it} is the first difference of the logarithm of the real exchange rate for country i at time t $(i = 1,2, \dots N)$, and e_{it} is an error term that is allowed to be serially correlated and has a single common factor structure:

$$e_{it} = \gamma_i f_t + \mu_{it} \tag{2.34}$$

where f_t is an unobserved common factor, γ_i is the individual factor loading and μ_{it} is a white noise idiosyncratic error.

For the unit root null hypothesis considered by Pesaran(2007), he proposes a test based on the t-ratio of the least square estimate β_{it} in the following cross-sectionally augmented Dickey-Fuller (CADF) regression for each cross-sectional unit,

$$\Delta\varepsilon_{it} = \alpha_i + \beta_i\varepsilon_{it-1} + \sum_{j=1}^{k_i}\gamma_{ij}\Delta\varepsilon_{it-j} + c_i\bar{\varepsilon}_{t-1} + \sum_{j=0}^{k_i} d_{ij}\Delta\bar{\varepsilon}_{i,t-j} + \mu_{it} \tag{2.35}$$

where $\bar{\varepsilon}_t = \frac{1}{N}\sum_{i=1}^{N}\varepsilon_{it}$, $\Delta\bar{\varepsilon}_{it} = \frac{1}{N}\sum_{i=1}^{N}\Delta\varepsilon_{it}$, $k_i$is the lag length selected for country i , and μ_{it} is the regression error. According to Pesaran (2007), the cross-sectional averages of $\Delta\varepsilon_{it}$ and $\Delta\varepsilon_{it-1}$ are included into Equation (2.35) as a proxy for the unobserved common factor f_t. Under Equation (2.35), the null hypothesis, $H_0: \beta_i = 0$ for all i is tested against the heterogeneous alternative, $H_1: \beta_1 < 0, \ldots, \beta_{N_0} < 0, N_0 < N$, in the whole panel set. In line with IPS (2003), Pesaran proposes the CIPS test,

$$\text{CIPS} = \frac{1}{N}\sum_{i=1}^{N}\text{CADF}_i \tag{2.36}$$

where $CADF_i$ is the CADF statistic for the ith cross-sectional unit in Equation (2.35). The distribution of the CIPS statistic is shown to be nonstandard even for large N. Therefore, a bootstrap procedure is needed to get critical values.

2.3.6 Non-parametric Bootstrap procedure

The bootstrap method used in this study is the residual bootstrap, that is, I will be resampling from the residuals. In parametric bootstrap, error terms are draw from the estimated residuals that are assumed following the parametric normal distribution. In this study, since the distribution of estimated residuals is unknown due to small sample property, non-parametric bootstrap is preferred, that is, residuals assuming to follow the uniform distribution. In my study, p-values from non-parametric and parametric bootstraps are very close. P-values from non-parametric bootstrap are reported only.

2.3.6.1 Bootstrap procedure for IPS test

Step 1: Estimate the following system equations using seemingly unrelated regression (SUR) method. Then the estimation of coefficient values $\gamma_{i,j}$ and the bootstrap sample of the residuals μ_t^0=[$\mu_{1,t}^0$, $\mu_{2,t}^0$,…, $\mu_{N,t}^0$] are obtained.

$$\Delta\varepsilon_{i,t} = \alpha_i + \beta_i \varepsilon_{i,t-1} + \sum_{j=1}^{k_i} \gamma_{i,j} \Delta\varepsilon_{i,t-j} + \mu_{i,t}^0 \quad i = 1,2, \dots N \quad t = 1,2, \dots T \quad (2.37)$$

where $\Delta\varepsilon_{i,t}$ has a unit root under the null hypothesis, $\Delta\varepsilon_{i,t-j} = \varepsilon_{i,t} - \varepsilon_{i,t-j}$, and k_i is the lag length selected for regression in IPS test for country i.

Step 2: As suggested by Maddala and Wu (1999), residuals are resampled as a vector (with the cross-section index fixed) instead of resampling separately for each country. They argue that since there are cross-correlations among residuals, in this way, the contemporaneous correlation can be preserved. An integer h between 1 to H is generated with equal probability. $H = T - \max(k_i) - 2$ for $i = 1,2 \dots N$. For each country, the total observations in original sample are T. To construct their lagged, difference, or lagged difference variables, $\max(k_i) + 2$ observations turn to be missing. Therefore, there are $T - \max(k_i) - 2$ observations for residuals after regression. Once h is generated, a row of fitted residuals μ_1^0=[$\mu_{1,h}^0$, $\mu_{2,h}^0$,…, $\mu_{N,h}^0$] is used as μ_1^* . Repeating this process $T + 50$ times, a bootstrap sample of the error terms $\mu_t^*, t = 1,2, \dots T, T + 1, \dots T + 50$ is generated.

Step 3: Choose the initial values of $\varepsilon_{i,t}^*$. Under H_0 that $\beta_i = 0$, the real exchange series follow random walk. The data generating process of bootstrap sample $\varepsilon_{i,t}^*$ is showed as

$$\Delta\varepsilon_{i,t}^{*} = \sum_{j=1}^{k_i} \hat{\gamma}_{i,j} \Delta\varepsilon_{i,t-j}^{*} + \mu_{i,t}^{*} \tag{2.38}$$

The initial values of $\mu_{i,t}^{*}$ are obtained by block resampling from the actual $\{\mu_{i,t}\}$ as described in Berkowitz and Kilian (1996). An integer m is generated between 1 to M. $M = T - \max(k_i)$ $i = 1,2 \dots N$. Once m is generated, a row of the first initial value $\varepsilon_0 = [\varepsilon_{1,m}, \varepsilon_{2,m}, \dots, \varepsilon_{N,m}]$ is used as ε_0^{*}. k_i is the lag length of country i. For each country, select ε_i+1 adjacent data points from $\varepsilon_{i,m}$ to represent the first k_i+1 initial values of the bootstrap sample. For example, for country 1, initial values are $\varepsilon_{1,m}, \varepsilon_{1,m+1}, \dots, \varepsilon_{1,m+k_i}, \varepsilon_{1,m+k_i+1}$. μ_{it}^{*} is the bootstrap sample generated from step 2. $\hat{\gamma}_{i,k_i}$s are the SUR estimates obtained from step 1. The first 50 observations are dropped to avoid start-up effects.

Step 4: Compute the t value of estimations of ρ_i from ADF regressions for each group separately and construct the $\bar{t}$ statistic.

$$\Delta\varepsilon_{i,t}^{*} = \delta_i + \rho_i \varepsilon_{i,t-1}^{*} + \sum_{j=1}^{k_j} \theta_{i,j} \Delta\varepsilon_{i,t-j}^{*} + v_{i,t}^{*} \tag{2.39}$$

Step 5: Repeat previous steps 5,000 times to derive the empirical distribution of $\bar{t}$ statistic.

Step 6: Estimate the p value of $\bar{t}$ based on the estimated distribution and make a decision of hypothesis test.

2.3.6.2 Bootstrap procedure for CIPS test

Step 1: Estimate the following system equations using seemingly unrelated regression (SUR) method. Then the estimation of coefficient values $\gamma_{i,j}$ and the bootstrap sample of the residuals μ_t^0=[$\mu_{1,t}^0$, $\mu_{2,t}^0$,…, $\mu_{N,t}^0$] are obtained.

$$\Delta\varepsilon_{i,t} = \alpha_i + \beta_i \varepsilon_{i,t-1} + \sum_{j=1}^{k_i} \gamma_{i,j} \Delta\varepsilon_{i,t-j} + c_i \bar{\varepsilon}_{t-1} + \sum_{j=0}^{k_i} d_{i,j} \Delta\bar{\varepsilon}_{i,t-j} + \mu_{i,t}^0$$

$$i = 1,2, \dots . N \quad t = 1,2, \dots T \qquad (2.40)$$

where $\Delta\varepsilon_{i,t}$ has a unit root under the null hypothesis, $\Delta\varepsilon_{i,t-j} = \varepsilon_{i,t} - \varepsilon_{i,t-j}$, and k_i is the lag length selected for regression in CIPS test for country i.

Step 2: As suggested by Maddala and Wu (1999), residuals are resampled as a vector (with the cross-section index fixed) instead of resampling separately for each country. They argue that since there are cross-correlations among residuals, in this way, the contemporaneous correlation can be preserved. An integer h between 1 to H is generated with equal probability. $H = T - \max(k_i) - 2$ for $i = 1,2 \dots N$. For each country, the total observations in original sample are T. To construct their lagged, difference, or lagged difference variables, $\max(k_i) + 2$ observations turn to be missing. Therefore, there are $T - \max(k_i) - 2$ observations for residuals after regression. Once h is generated, a row of fitted residuals μ_1^0=[$\mu_{1,h}^0$, $\mu_{2,h}^0$,…, $\mu_{N,h}^0$] is used as μ_1^* . Repeating this process $T + 50$ times, a bootstrap sample of the error terms $\mu_t^*, t = 1,2, \dots T, T + 1, \dots T + 50$ is generated.

Step 3: Choose the initial values of $\varepsilon_{i,t}^*$. Under H_0 that $\beta_i = 0$, the real exchange series follow random walk. The data generating process of bootstrap sample $\varepsilon_{i,t}^*$ is showed as

$$\Delta\varepsilon_{i,t}^* = \sum_{j=1}^{k_i} \hat{\gamma}_{i,j} \Delta\varepsilon_{i,t-j}^* + \mu_{i,t}^* \qquad (2.41)$$

The initial values of $\mu_{i,t}^*$ are obtained by block resampling from the actual $\{\mu_{i,t}\}$ as described in Berkowitz and Kilian (1996). An integer m is generated between 1 to M. $M = T - \max(k_i)$ $i = 1,2 \dots N$. Once m is generated, a row of the first initial value ε_0 $= [\varepsilon_{1,m}, \varepsilon_{2,m}, \dots, \varepsilon_{N,m}]$ is used as ε_0^*. k_i is the lag length of country i. For each country, select ε_i+1 adjacent data points from $\varepsilon_{i,m}$ to represent the first k_i+1 initial values of the bootstrap sample. For example, for country 1, initial values are $\varepsilon_{1,m}, \varepsilon_{1,m+1}, \dots, \varepsilon_{1,m+k_i}, \varepsilon_{1,m+k_i+1}$. μ_{it}^* is the bootstrap sample generated from step 2. $\hat{\gamma}_{i,k_i}$s are the SUR estimates obtained from step 1. The first 50 observations are dropped to avoid start-up effects.

Step 4: Compute the t value of estimations of ρ_i from ADF regressions for each group separately and construct the $\bar{t}$ statistic.

$$\Delta\varepsilon_{i,t}^{*} = \delta_i + \rho_i\varepsilon_{i,t-1}^{*} + \sum_{j=1}^{k_j}\theta_{i,j}\Delta\varepsilon_{i,t-j}^{*} + n_i\bar{\varepsilon}_{t-1}^{*} + \sum_{j=0}^{k_i} m_{i,j}\Delta\,\bar{\varepsilon}_{i,t-j}^{*} + v_{i,t}^{*} \quad (2.42)$$

Step 5: Repeat previous steps 5,000 times to derive the empirical distribution of $\bar{t}$ statistic.

Step 6: Estimate the p value of $\bar{t}$ based on the estimated distribution and make a decision of hypothesis test.

2.4 Data Description

Quarterly data are sampled from 1974Q1 to 2011Q3 for 11 OECD countries including Belgium, Canada, France, Germany, Italy, Japan, New Zealand, Spain, Sweden, the United Kingdom, and the United States. Three-month Treasury bill rates are used as the nominal interest rates. It is a short-term risk-free government bonds with a relatively fixed maturity across countries. It is considered to be more accurate than other rates that can be used by International arbitrageurs to compare their expected returns at home and abroad. Data for annual inflation are constructed from the Consumer Price Index (CPI) and Producer Price Index (PPI) as proxies for prices of nontradable and tradable goods, separately. The end of period quarterly three-month Treasury bill rates, CPI, and PPI are obtained from DataStream and International Monetary Fund's International Financial Statistics. Compared to the data set used in Essay One, eight countries are excluded due to the availability of three-month Treasury bill rates. Three-month Treasury bill rates of several included countries are not in full sample either. They are Germany (1975Q3-2007Q3), Italy (1977Q1:2011Q3), New Zealand (1978Q1:2011Q3), Spain (1979Q1:2011Q3).

For PPI panel, France is excluded from NIT group due to the availability of PPI. PPI of Italy (1981Q1:2011Q3) and Belgium (1980Q1:2011Q3) are not in full sample either.

Countries are classified based on whether their central banks adopt IT. Five countries that engage in IT are New Zealand, Canada, the United Kingdom, Sweden, and Spain. More information about Inflation Targeting countries are summarized in Table 2-1. Furthermore, since many studies point out the problem of choosing the US dollar as the numeraire, real interest rates are alternatively defined with respect to Deutch mark. I use the annualized, *ex post* real interest rates in my empirical investigation that is the expected inflation rate is approximate by actual inflation rate. The annualized, ex post interest rate differentials are plotted in Figure 2-1 to Figure 2-4.

2.5 Results

2.5.1 Preliminary Analysis

The preliminary analysis provides a stylized comparison for the volatility of real interest rates differentials (RID) between IT group and NIT group in a long run. According to Svensson (2000), under IT, countries are able to lower volatility of real interest rate at a long horizon. To examine this idea, long-run Variance (LRV) of RID for IT and NIT group over 1990 to 1998 are estimated and compared. Two data sets are employed including real interest rates differentials to United States with CPI and PPI. Two methods of estimating nonparametric kernel are used including Newey and West (1987) and Andrew (1991). Both of methods choose Bartlett kernel function. The difference is the choice of bandwidth (see section 2.3.1 for more details).

Figure 2-5 to Figure 2-8 illustrate the pattern of long-run variance of real interest rate differentials for IT group and NIT group with different estimation methods and data sets. Figure 2-4 and Figure 2-5 present results from Newey-West's method with CPI and PPI, separately. Figure 2-7 and Figure 2-8 present results from Andrew's method with CPI and PPI, separately.

The stylized fact is very strong and consistent to Svensson (2000). The pattern is very similar across different cases. In early 1990s, both IT countries and NIT countries have a great decline in LRV of real interest rates differentials to United States. It suggests a comfortable economic environment during that period. However, it is obvious that long-run variance for NIT group is generally greater than IT group at any time after 1990 when countries were beginning to adopt Inflation Targeting. The gap between two groups is more obvious when PPI data is employed.

2.5.2 Univariate Unit root tests

ADF and KPSS tests are conducted as benchmark to panel unit root tests. The crucial difference between ADF and KPSS tests is their opposite hypothesis. For ADF tests, PPP holds when the null hypothesis of a unit root is rejected. In contrast to KPSS tests, PPP fails to hold when the null hypothesis of stationary is rejected. CPI and PPI are used to measure real exchange rates. U.S dollar and Deutch Mark are used as base currencies.

Table 2-2 reports results of univariate ADF tests for real interest rates differentials series for CPI and PPI. The lag length is determined by Hall's (1994) general-to-specific method recommended by Campbell and Perron (1991). It starts from lag 10 (see section 2.3.2 for details about lag selection). For most cases, the null hypothesis of a unit root cannot be rejected at the 5 percent significant level that means RIP does not hold. For CPI, rejection rates overall are relatively low and there are not huge difference between IT group and NIT group. Only Belgium in NIT group can be rejected for differentials to US case and also only United Kingdom in IT group for differentials to DM case. For PPI, rejection rates are overall improved. It is obvious that rejection rates for IT group are higher than NIT group. In particular, four out of nine cases can be rejected for differentials to US case, among which three out of four are in IT group. In contrast, for differential to DM case, two out of nine cases can be rejected and both of them are in IT group.

Table 2-3 reports results from KPSS tests. The lag length is selected automatically by Newey and West Bandwidth using Barlett Kernal Spectral estimation method (see section 2.3.3 for details about lag selection). For most cases, the null hypothesis of stationary can be rejected at the 5 percent significant level that means RIP does not hold. This is consistent with ADF tests. Moreover, rejection rates for NIT countries are obvious higher than that in IT countries in both CPI and PPI cases. It indicates that PPP holds better in IT countries than NIT countries. Rejection rates are generally even between CPI and PPI cases, and US and DM cases. It suggests that choices of price indices and base currencies may not affect the validity of RIP.

In sum, results from ADF and KPSS tests are used as preliminary analysis because the power of these type tests is very low. However, there are still some interesting findings. Firstly, there is obviously more supportive evidence of PPP in IT countries than NIT countries by KPSS tests. Secondly, from ADF tests, choices of price indices and base currencies are related to the validity of RIP to different extent. However, it turns to be unimportant factors based on KPSS tests. This point is not very consistent between two univarite root tests. Therefore, more powerful tests such as panel unit root tests have to be performed.

2.5.3 Panel Unit root tests

For IT, ALL, and NIT groups, results from IPS and CIPS tests are compared based on real interest rates differentials with CPI and PPI, base currencies of U.S. dollar and Duetch Mark, and with and without cross-sectional dependence assumption (Table 2-4). The lag length for each country is determined by Hall's (1994) general-to-specific method recommended by Campbell and Perron (1991). The maximum lag of each country starts from lag 10 (see section 2.3.4 and 2.3.5 for details about lag selection).The p-values are taken from the nonparametric bootstraps (see section 2.3.6 for details). The null hypothesis is rejected at 5% significant level if p-value is less than 5%.

The first question to explore is whether there is solid evidence of RIP in IT group. Based on 12 combinations of different issues, the answer is positive. The rejection rate of the null hypothesis of a unit root for IT group is 12 out of 12 at 5% significant level. In contrast, the rejection rate for NIT group is 0 out of 12. For all group, the rejection rate for ALL group 9 out of 12 that ranks in the middle. Moreover, under different cases, nonparametric bootstrapped p-values are generally smaller for IT group than that for ALL group. NIT group receives largest p-values broadly. It means that the possibility to reject null hypothesis for NIT group is lower than ALL group and IT group. These results suggest that the probability of evidence of RIP appeared in IT group is largest. The regularity of this finding does not matter to choices of price indices and base currencies as well as cross-sectional dependence assumption.

Secondly, results are compared cross CPI cases and PPI cases to examine whether PPI cases provides stronger evidence for RIP than CPI cases. According to Froot and Rogoff (1995), the real exchange rate depends on deviations from the law of one price in tradable goods, as well as on the relative price of tradable and nontradable goods within each country. Since PPI contains a higher proportion of tradable goods, real exchange rates with PPI should reflect mean reverting features of PPP better than that with CPI. Since RIP requires PPP as an assumption, it is expected that PPI cases would provide better results that RIP holds than CPI cases. Based on my results, except for IT group, ALL and NIT groups follows this pattern. Under 12 cases, each of CPI and PPI employs to 6 cases. For NIT group, although none of the null hypothesis can be rejected, there are 3 out of 6 for PPI with lower p-values than CPI. It suggests at least there is not less evidence of RIP for interest rates with PPI. For ALL group, this pattern is more obvious. 9 out of 12 cases can be rejected, among which 6 cases from interest rates with PPI. Moreover, there are 6 out of 6 cases for PPI with lower p-values than CPI. This finding is consistent with Dutton (1993) and Kim (2006). They find strong evidence of RIP when interest rate is constructed in term of tradable goods price. The results are somewhat affected by cross-sectional dependence assumption. However, the null hypothesis of RIP is always rejected in spite of price indices.

Thirdly, results are compared between IPS and CIPS tests to explore the issue of cross-sectional dependence. For IT group, the null hypothesis can be rejected in almost every case. It suggests that the assumption of cross-sectional dependence might not be important in terms of IT group. However, for NIT and ALL groups, the case is different. Refer to NIT group, three out of four cases have a p-value either higher than or very close to cases in CIPS tests. It indicates that the possibility to reject the null hypothesis under CIPS tests decreased. For All group, the evidence for the cross-sectional dependence is much more obvious. The null hypothesis of one out of four cases can be rejected in IPS test but failed to be rejected in CIPS test. The rest three also have an increase in p-values, although their conclusions are not turned over by CIPS. The results provide more empirical evidence to support O'connell (1998) that international relationship parities can be greatly affected by the assumption of cross-sectional dependence. However, for IT group, the null hypothesis of unit roots can always be rejected.

This study also considers cases after removing common time effects across countries to test a weaker version of RIP. Results are reported in Table 2-5. Cross-sectional demeaned data are used to measure a common time effect in the unit root regression. The justification for this method is that most of the co-movements of real interest rate differentials are due to a single common source of variance, that is, variations in base country. The information captured by demeaned data is the variations from cross-sectional mean. It better reflects the movements of sampled countries without effects of the movement of base country. This is considered as a weak form for RIP. RIP holds in the long-run if the real interest differential is cross-sectional mean reverting instead of long-run mean reverting. Based on results from IPS tests, the stronger evidence of RIP can be found in IT, NIT and All groups in that p-values are decreased generally relative to p-values obtained from regular version of RIP. In contrast to results from original data, results from demeaned data are very close regardless of the choice of base countries. It suggests the common time effects caused by base country have been removed.

2.6 Conclusion

In Essay one, the relationship between IT and PPP has been empirically examined. Since PPP is one of assumptions of RIP, this essay further studies whether Inflation Targeting (IT) policy is related to the validity of long-run Real Interest Rate Parity (RIP). Quarterly data for 11 OECD countries under floating rate period are sampled. Real interest rate differentials are constructed with two price indices and two base currencies. In addition to IPS tests, CIPS tests that consider cross-sectional dependence are also employed. In contrast to previous panel studies that usually examine OECD countries as a whole, this essay further classifies them into IT and NIT groups depending on whether the country adopted Inflation Targeting Monetary Policy in the sampled period.

Similar to findings from Essay one, the evidence of RIP is very strong for IT group based on two panel unit root tests in spite of any other issue. It suggests IT outweighs other issues when it comes to RIP. For other groups, this pattern is changed. Results are consistent with previous studies in that the choices of price indices and base currencies as well as cross-sectional dependence are related to the validity of RIP to different extent. These results match the theoretical findings. In contrast to other monetary policy, central banks under IT are able to adjust inflation rate, real exchange rate as well as real interest rates more stable in the long run in response to shocks from rest of the world. Countries adopted IT are expected to have a more stable real interest rates movement in the long run (Kahn and Parrish, 1998; Svensson, 2000; and Mishkin and Schmidt-Hebbel, 2007).

The implications of this essay are very intriguing. The initial purpose of authorities to adopt IT might not be to keep RIP hold for this country. However, based on the findings, IT is unexpectedly related to the validity of RIP. Supportive evidence of RIP can always be found in countries adopted IT. Moreover, under the effect of IT, issues that could explain the failure of RIP turn to be unimportant. Therefore, compared to previous studies on RIP, this essay provides a new aspect to explore topics related to PPP.

Table 2-1 Inflation targeting countries

Countries	Year of Adoption	Previous Anchor	Current Target Values	Target Variable
Canada	1991	None	2%+/-1%	CPI
New Zealand	1990	None	1%-3%	CPI
Spain	1994	None	2%	CPI
Sweden	1993	Exchange rate	2%+/-1%	CPI
United Kingdom	1992	Exchange rate	2%+/-1%	CPI (HICP)

*Source:*Petursson (2004), Mishkin and Schmidt (2007), Roger (2010) and central banks websites
HICP: Harmonised Index of Consumer Prices

Table 2-2 ADF tests of real interest rate differentials

	CPI		PPI	
Inflation Targeting Countries	USD	DM	USD	DM
Canada	-1.616	-2.250	-3.342*	-2.385
New Zealand	-2.627	-2.592	-2.277	-2.730
Sweden	-1.735	-1.547	-1.611	-1.720
Spain	-2.452	-0.985	-3.407*	-2.860*
United Kingdom	-1.980	-2.912*	-4.248*	-3.006*
Noninflation Targeting Countries				
Belguim	-2.947*	-1.029	-2.220	-0.959
France	-2.478	-1.079	#	#
Germany	-2.046	#	-2.297	#
Italy	-2.414	-1.631	-2.226	-1.062
Japan	-2.057	-2.360	-3.114*	-2.364
United States	#	-2.207	#	-2.297

*Note:**Indicates rejection of the null hypothesis at the 5% level of significant. Critical Values from MacKinnon (1991) at the 5% level of significant is -2.86. # indicates that the test statistic is not computed. USD, U.S. dollars; DM, Deutch Marks.

Table 2-3 KPSS tests of real interest rate differentials

	CPI		PPI	
Inflation Targeting Countries	US	DM	US	DM
Canada	0.233	0.241	0.466*	0.551*
New Zealand	0.398	0.484*	0.269	0.367
Sweden	0.432	0.430	0.362	0.308
Spain	1.298*	1.095*	1.926*	0.862*
United Kingdom	0.165	0.248	0.169	0.233
Noninflation Targeting Countries				
Belguim	0.586*	0.550*	0.316	0.167
France	0.633*	0.180	#	#
Germany	1.671*	#	1.049*	#
Italy	1.847*	1.342*	1.651*	1.371*
Japan	1.200*	0.952*	0.577*	0.503*
United States	#	0.517*	#	0.556*

*Note:**Indicates rejection of the null hypothesis at the 5% level of significant. Critical Values from KPSS (1992) at the 5% level of significant is 0.463. # indicates that the test statistic is not computed

Table 2-4 Panel unit root tests of real interest rate differentials

	IPS			CIPS		
CPI	$\bar{t}_{IT}$	$\bar{t}_{ALL}$	$\bar{t}_{NIT}$	$\bar{t}_{IT}$	$\bar{t}_{ALL}$	$\bar{t}_{NIT}$
USD	-2.6244	-2.2353	-2.0181	-3.1785	-2.2431	-1.8446
	(0.0036)	(0.0134)	(0.1442)	(0.0012)	(0.0766)	(0.3894)
DM	-2.4117	-2.0385	-1.6612	-3.0381	-2.2543	-2.3017
	(0.0156)	(0.0606)	(0.3828)	(0.0018)	(0.0782)	(0.0570)
PPI						
USD	-2.9770	-2.6659	-2.2771	-3.1248	-2.3560	-1.6267
	(0.0020)	(0.0034)	(0.0772)	(0.0000)	(0.0120)	(0.3256)
DM	-2.5400	-2.1537	-1.6708	-3.1133	-2.5308	-1.9969
	(0.0040)	(0.0232)	(0.3734)	(0.0010)	(0.0304)	(0.3008)

Notes: Subscripts IT, ALL, and NIT represent Inflation Targeting (IT), all, Noninflation Targeting (NIT) countries, respectively. Numbers in parentheses are p-values taken from the nonparametric bootstraps CPI, Consumer Price Index; PPI, Producer Price Index; USD, US Dollar; DM, Deutch Mark; IPS, Im, Pesanran and Shin; CIPS, Cross-sectionally augmented version of IPS.

Table 2-5 IPS tests of real interest rate differentials without common time effects

CPI	$\bar{t}_{IT}$	$\bar{t}_{ALL}$	$\bar{t}_{NIT}$
USD	-2.8935	-2.2869	-1.9324
	(0.0006)	(0.0034)	(0.1338)
DM	-2.9113	-2.2653	-2.0139
	(0.0006)	(0.0046)	(0.1028)
PPI			
USD	-3.0790	-2.4000	-1.8870
	(0.0000)	(0.0004)	(0.2244)
DM	-2.9182	-2.3108	-1.8690
	(0.0002)	(0.0002)	(0.2058)

Notes: Subscripts IT, ALL, and NIT represent Inflation Targeting (IT), all, Noninflation Targeting (NIT) countries, respectively. Numbers in parentheses are p-values taken from the nonparametric bootstraps CPI, Consumer Price Index; PPI, Producer Price Index; USD, US Dollar; DM, Deutch Mark.

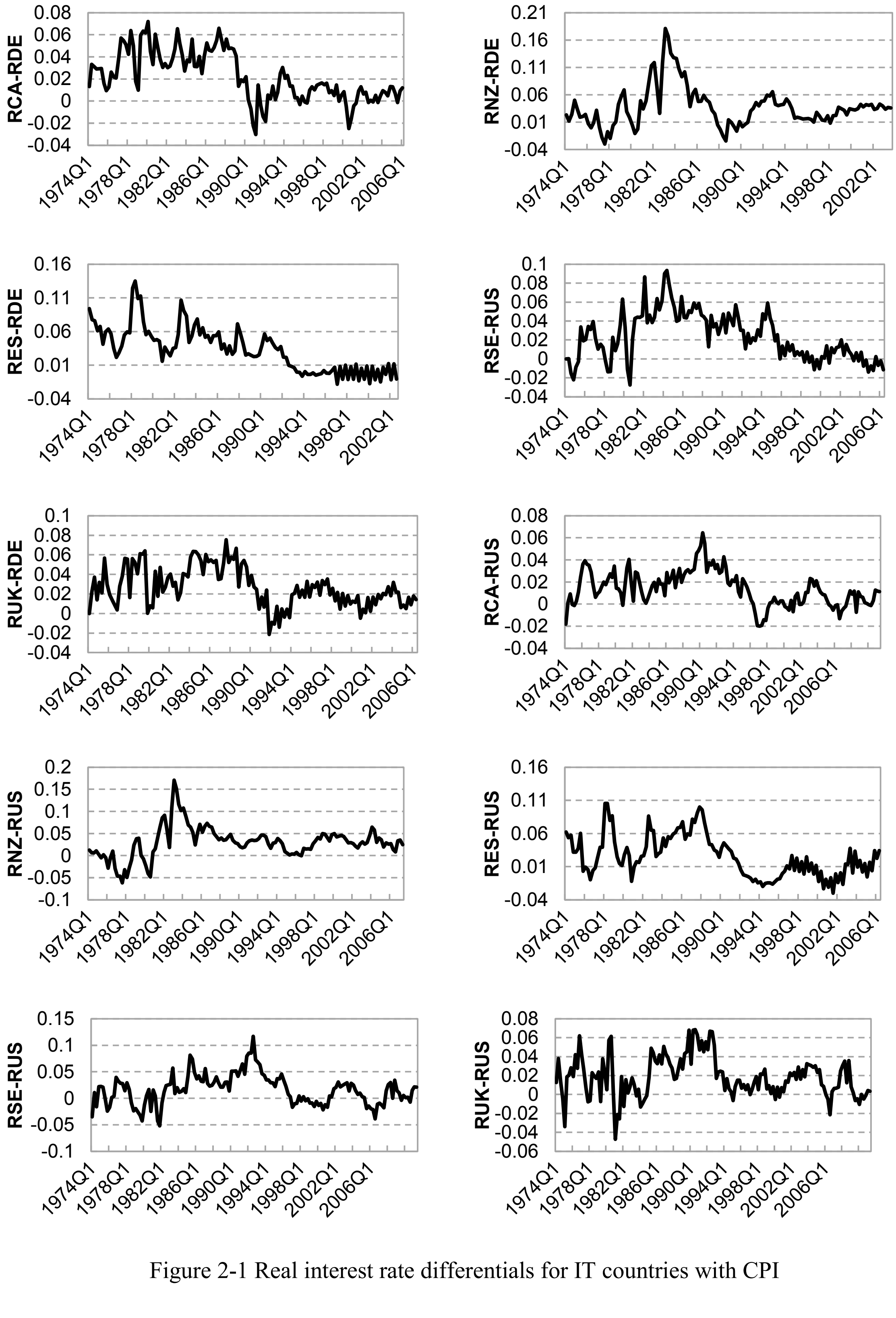

Figure 2-1 Real interest rate differentials for IT countries with CPI

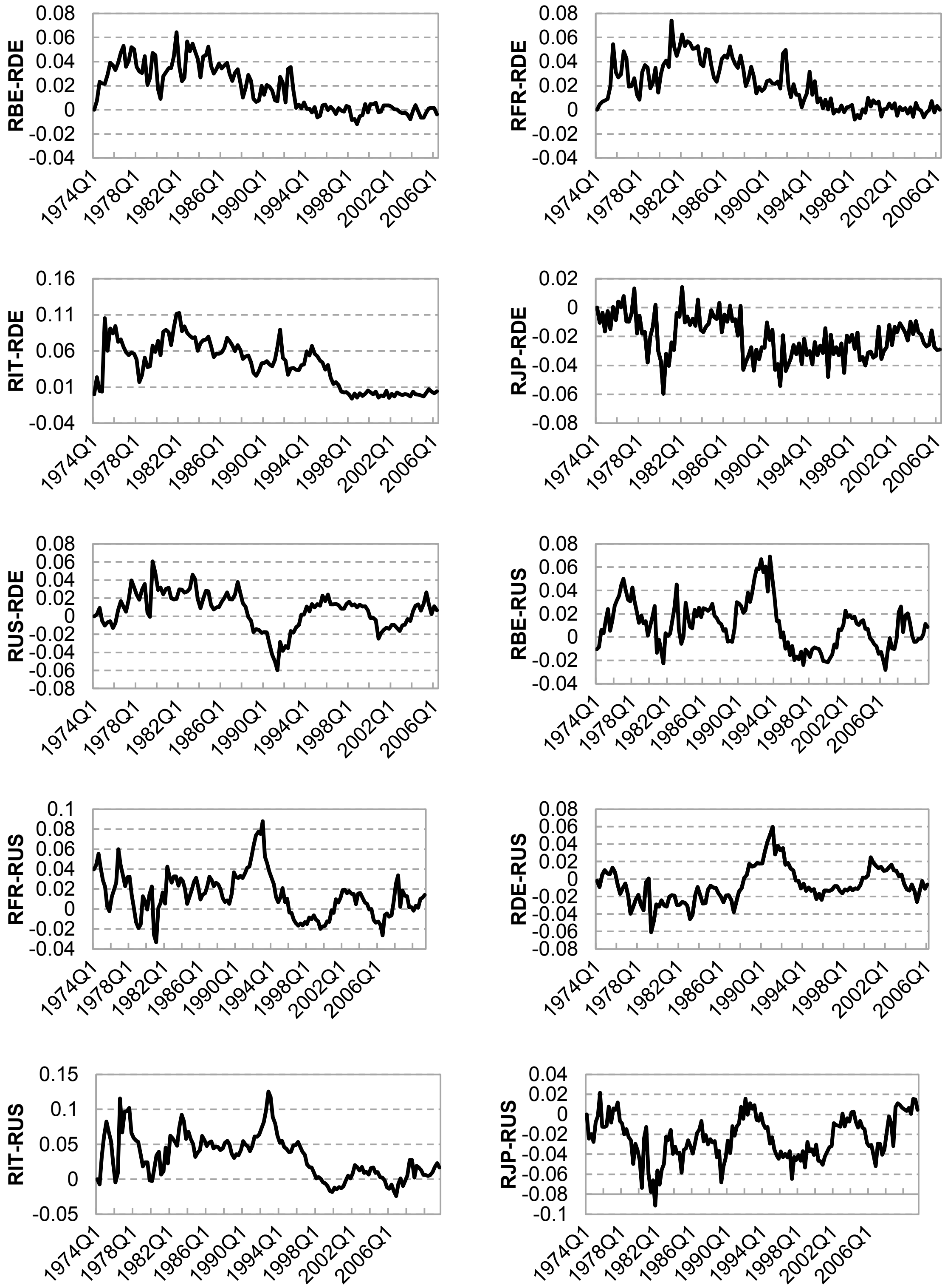

Figure 2-2 Real interest rate differentials for NIT countries with CPI

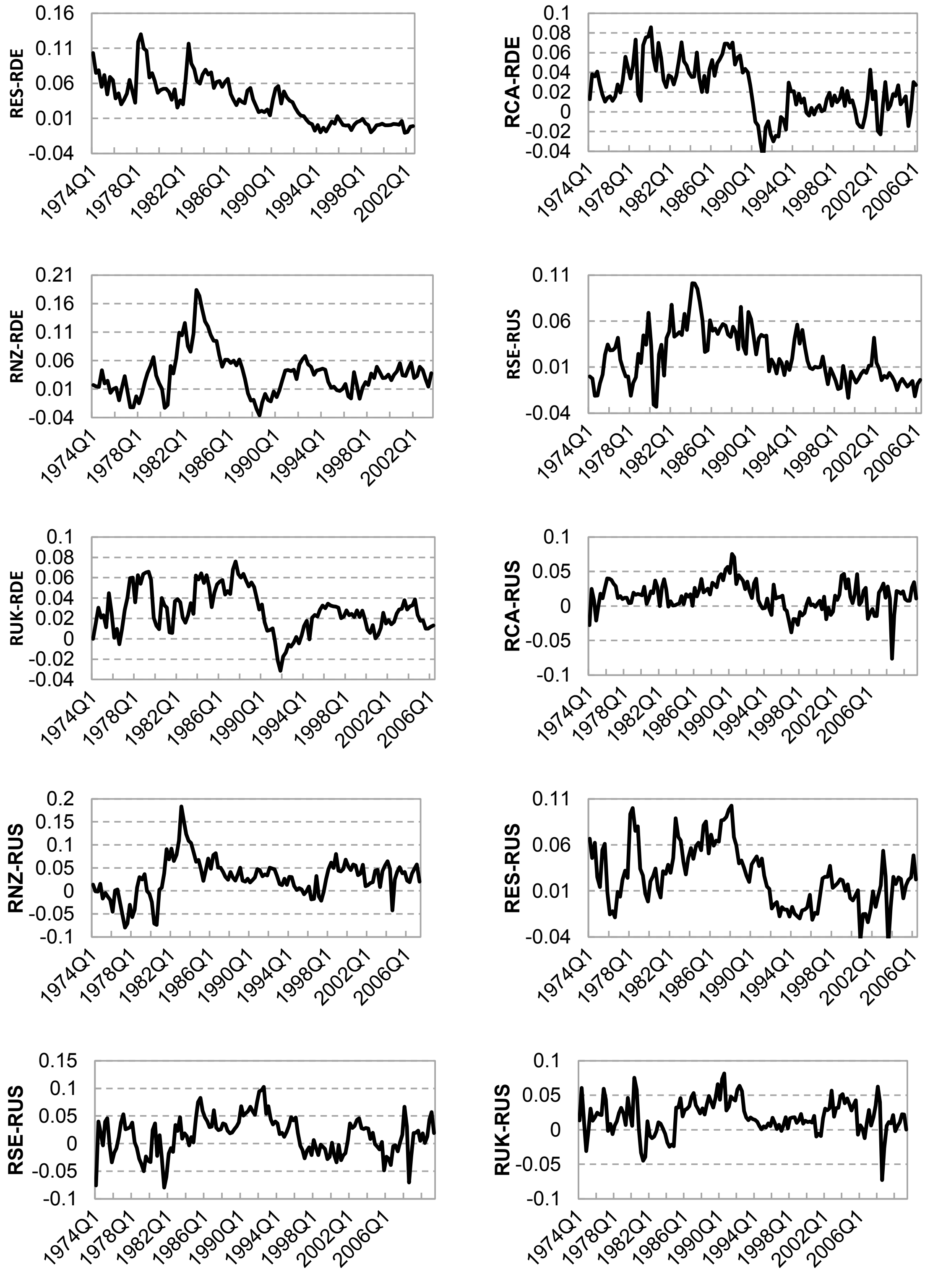

Figure 2-3 Real interest rate differentials for IT countries with PPI

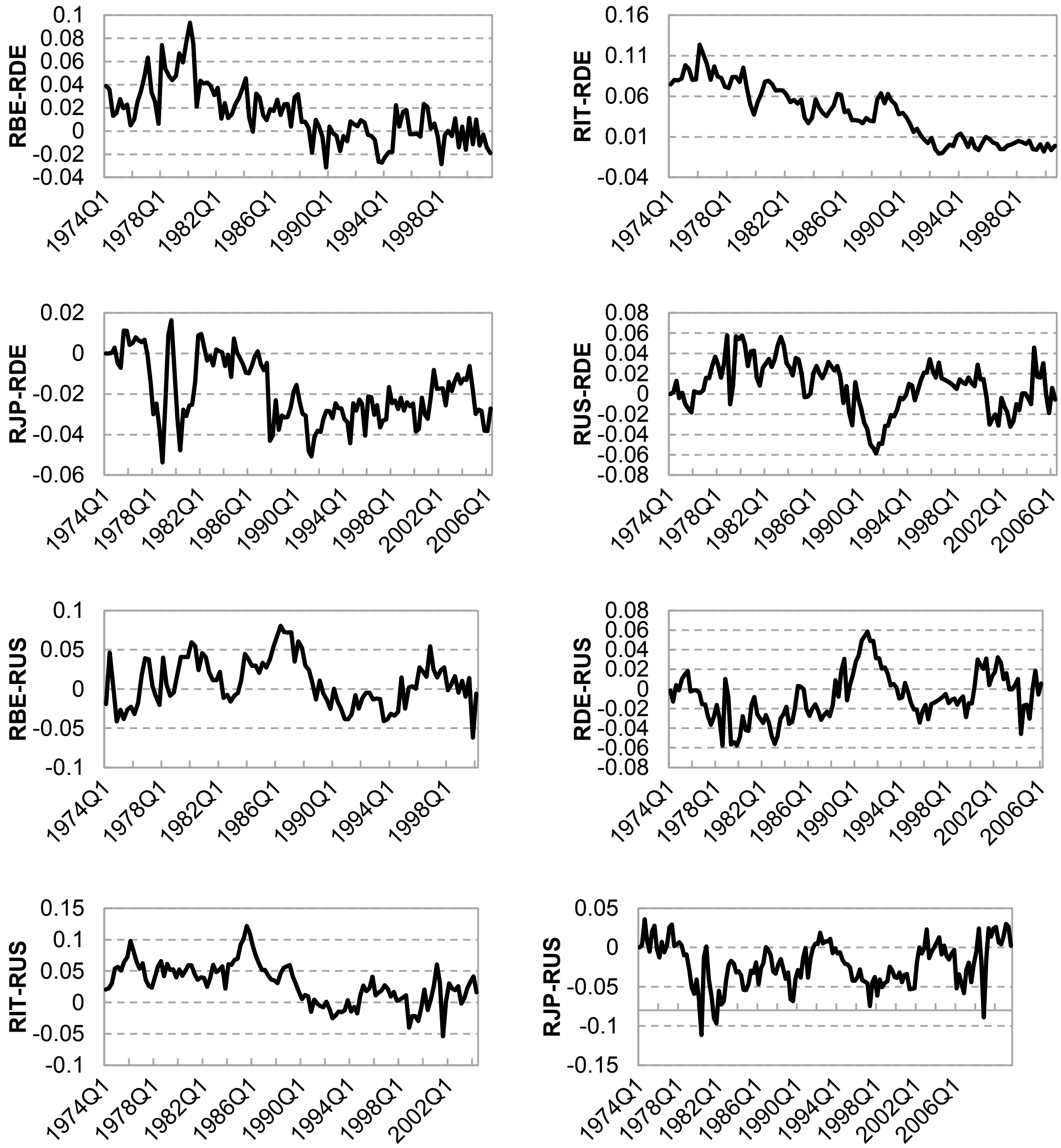

Figure 2-4 Real interest rate differentials for NIT countries with PPI

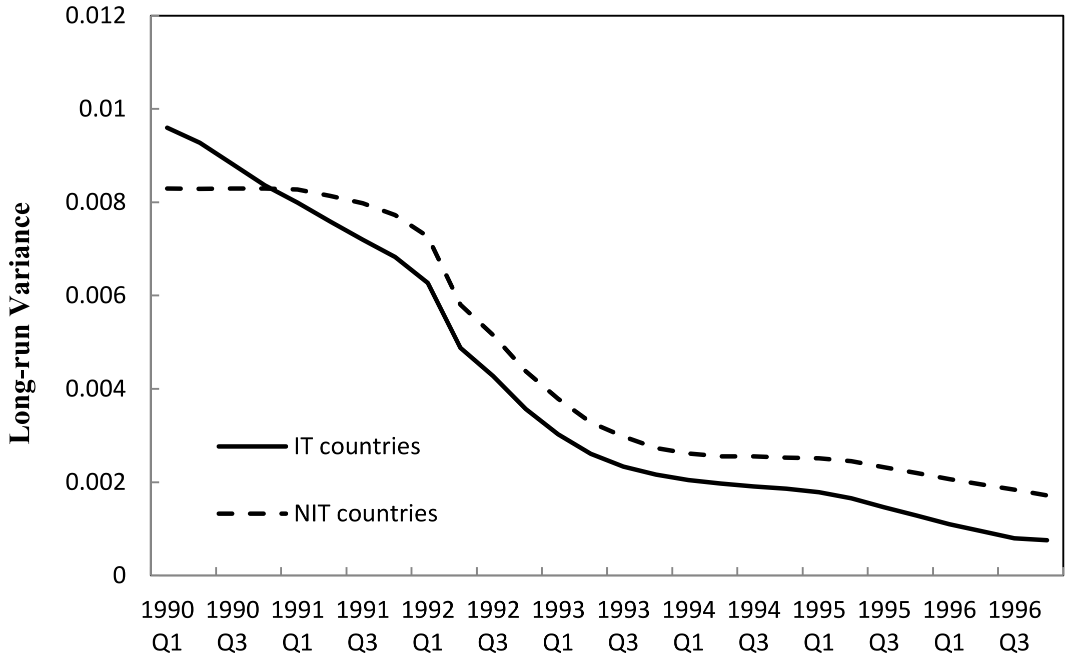

Figure 2-5 LRV of real interest rate differentials with CPI based on Newey-West method

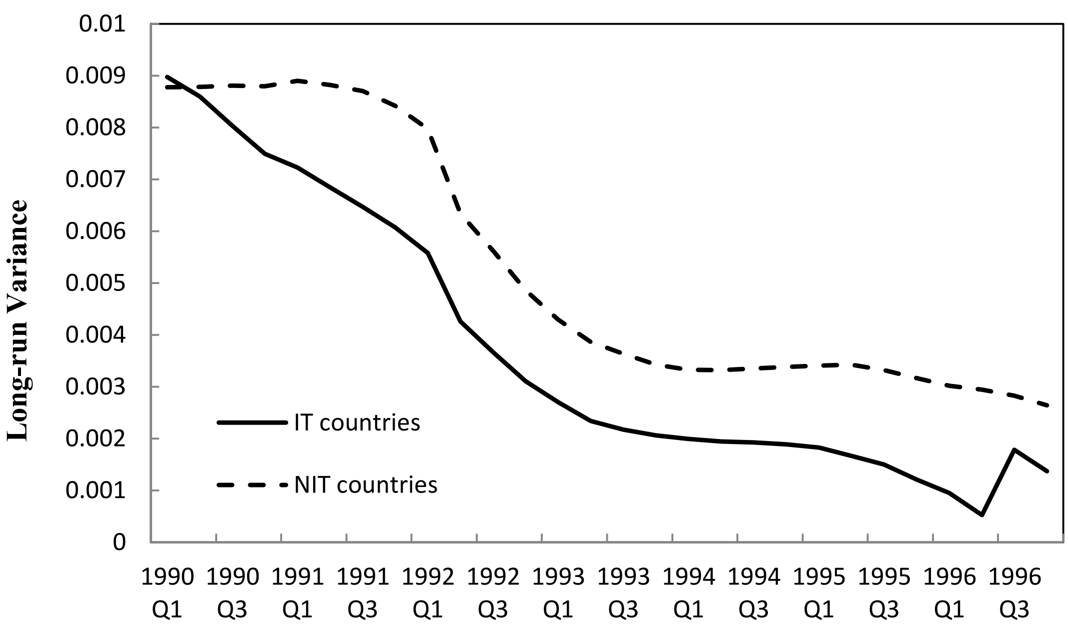

Figure 2-6 LRV of real interest rate differentials with PPI based on Newey-West method

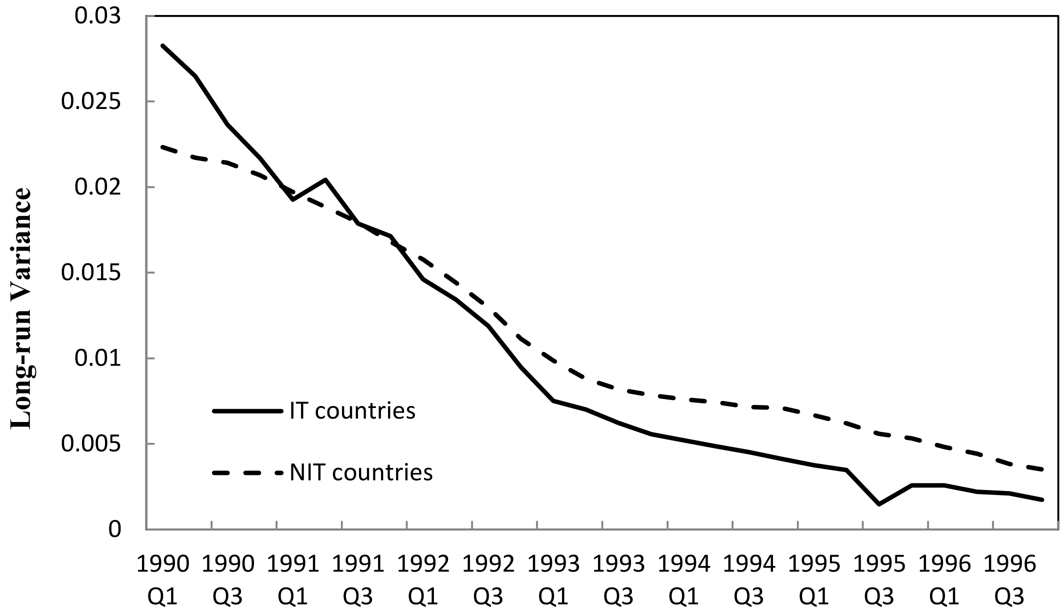

Figure 2-7 LRV of real interest rate differentials with CPI based on Andrew's method

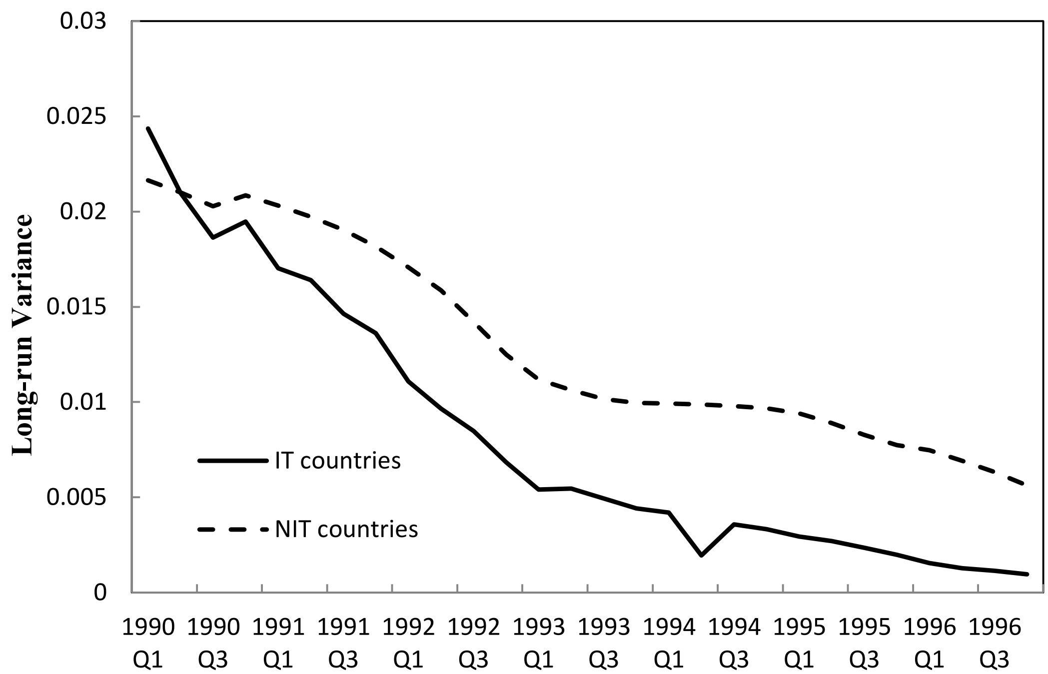

Figure 2-8 LRV of real interest rate differentials with PPI based on Andrew's method

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VITA

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Scope and Method of Study:

This dissertation empirically investigates whether Inflation Targeting (IT) policies are related to the validity of Purchasing Power Parity (PPP) and Real Interest Rate Parity (RIP). Each Essay examines each parity with same logic and test methods. In empirical studies of PPP and RIP, several issues have been discussed including choices of price indices and base currencies as well as cross-sectional dependence assumption. PPP and RIP are considered to be contingent upon those factors. This study further explores whether those issues are still important to PPP and RIP when it comes to IT. Quarterly data of 19 OECD countries are sampled under floating rates regime. Different from previous studies that pooled countries into a group (ALL group), this essay further divides them into countries adopted IT (IT group) and countries not adopted IT (NIT group). IPS unit root tests (Im, Pesaran, and Shin, 2003) and CIPS unit root tests (Pesaran, 2007) are applied to panel data. P-values are taken from nonparametric bootstrap procedure. For IT, ALL, and NIT groups, results are compared based on real exchange rates with CPI and PPI, five different base currencies, and with and without cross-sectional dependence assumption.

Findings and Conclusions:

Results from both essays are consistent. The evidence of PPP and RIP is very strong for IT group no matter what other issue is considered. It suggests IT outweighs other issues when it comes to PPP and RIP. For ALL and NIT groups, results are consistent with previous studies. The choices of price indices and base currencies as well as cross-sectional dependence are related to the validity of PPP and RIP to different extent. Moreover, these empirical results match the theoretical findings. Compared to other monetary policies, IT has the ability to adjust inflation rates, real exchange rate, and real interest rate more stable in the long run in response to shocks from rest of the world. IT is highly recommend for its stability effects on those macroeconomic variables. The implications of this study are very intriguing. The initial purpose of authorities to adopt IT might not be to keep PPP or RIP hold for this country. However, based on the findings, IT is unexpectedly related to the validity of PPP and RIP. Supportive evidence can always be found in countries adopted IT. Moreover, under the effect of IT, issues that could explain the failure of PPP or RIP turn to be unimportant. Therefore, compared to previous studies, this study provides a new aspect to explore topics related to PPP and RIP.

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