Does Purchasing Power Parity hold between European countries?

—Investigation using non-linear STAR model

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Contents

Abstract

This paper investigates whether purchasing power parity (PPP) holds or not between each European country. PPP is a fundamental building block of international economics. The research of PPP not only can help economist understand exchange rate behaviour, but also assist with monetary maker to establish sensible exchange rate policies. For examining the PPP validity in euro, this paper starts at a general introduction of the exchange rate importance. The following is an in-depth overview of PPP studies and econometric technique developments since 1970s. We applied the non-linear Exponential Smooth Transition Autoregressive (ESTAR) for a new test (KSS test) and ADF test to the real exchange rates between 9 European countries. The results demonstrate the new test giving more support to PPP than that of ADF test. And while the linear ADF test can only reject a unit root in 6 cases, the new test is able to reject in 13 cases out of 36, which are in favour of PPP and offer evidences of non-linear mean reversion in real exchange rate

Keywords: Purchasing Power Parity; Unit Roots; Non-linearity; Euro area; Exponential Smooth Transition Autoregressive Model

Chapter I - Introduction

With the development of international trade, exchange rate plays a more important role in international financial market and commodity market than decades ago, since the foreign exchange rate market is the world's largest financial market and international trades depend on exchange rate. The exchange rate is usually defined as the rate at which one nation's currency can be exchanged for that of another (Dermot McAleese, 2004). Not only is the exchange rate study benefit to investors, but more importantly, assists to monetary makers. First, exchange rate is essential for a nation, as the exchange rate determines the level of imports and exports between countries. For example, if a domestic currency appreciates with respect to a foreign currency, imported goods will be cheaper in the domestic market and the foreign goods become more attractive to customers than local goods. Oppositely, the nation's goods grow to be more expensive in the international market and lose competitiveness, if the currency of that nation is strong in international market. This is the reason why China is still unwilling to appreciate its currency (RMB) under the United States heavy pressure. Second, exchange rate fluctuation has a direct impact on investors' returns, because the foreign exchange rates influence the local material costs, labour costs and profits of multinational companies. Moreover, exchange rates have strong connections with other economic variables, such as interest rates, inflation figures, and GDP. And other economic indicators that demonstrate the economic situation of one nation or one state have a significant impact on the movement of currency. These indicators, including employment reports, balance of trade and capital, manufacturing indices, consumer prices and retail sales, illustrate that a strong economy is often positively correlated with a strong currency. Therefore, it is inevitable to raise the questions such as how government structures its exchange rate policies to stabilize, and even strength its position in international market, how exchange rate adjustment influent the financial market and how much the impacts are, and how to forecast exchange rate to establish stable and prosperous domestic economy.

In order to understand exchange rate behaviour, a large number of economists have put much effort into study and develop *exchange rate determination theories*. Although exchange rate determination theories are foundations in international finance, it is still need to be developed and improved. The schools of exchange rate research are various, and the debates involve with many economic aspects. The main exchange rate determination theories are following: theory of international indebtedness, theory of purchasing power parity, theory of interest rate parity, monetary approach, portfolio approach, flexible price monetary approach, and sticky-price monetary approach. However, despite of various and profound researches of exchange rate, the financial crises are not rare in those decades. In 1992, the United Kingdom pound and Italian lira were attacked and, subsequently, forced out of the Exchange Rate Mechanism (ERM). At the end of 1994, Mexican peso crisis was caused by the sudden currency devaluation, and Mexican peso broke down in only 48 hours. After three year later, the Asian financial crisis, which started in Thailand due to cutting Thai baht fixed exchange rate to the United State Dollar, spread most of Southeast Asia and destroyed several Asian countries' economy. 1998 Russian financial crisis, result from Asian financial crisis, led Russian economy to recess again. And in this decade, Credit Crunch and European sovereign debt crisis become major concerns in economic study. The reasons why financial crises happen are various, including national economic structures, development of economic environment, fiscal monetary policy, exchange rate system, exchange rate mechanism and etc. It is undeniable that exchange rate misalignment, either appreciated or depreciated, costs a large number of labour and money to recover its economic losses. However, the monetary crises have happened at most areas in the world. From this point, it is necessary and important to study how to determine and regulate exchange rate. A majority of the researchers has focused on three explanatory variables impacted on exchange rate: price level, interest rate and balance of payment. From price level aspect, purchasing power parity (PPP) links movements in exchange rates to differences of price level between trading nations. PPP is drawing inspiration from the

Law of One Price, which holds that identical goods will be the same price in different markets when the prices are expressed in one currency (Krugman and Obstfeld, 2009). From this sense, PPP indicates that the nominal exchange rate between two currencies should be equalized for the ration of total price levels between the two countries, so that a given basket of goods will have same purchasing power in both countries (Taylor, 2004). After First World War, PPP was contributed to recover and stabilize exchange rate of several nations. To be specified, PPP was theoretical foundation concerning how the major currencies return to the Gold Standard, which suspended during the war. Moreover, it is mentioned before that exchange rate links almost every part of a nation's economy Taylor (2004) said that exchange policy is the central problem of exchange rate adjustment. It indicates that PPP will assists to find out what the equilibrium exchange rate is likely to be and what the standards is to determine whether the exchange rate is undervalued or overvalued. Besides, PPP also can verify the level and variation in real and nominal exchange rates so as to help government to rearrange and adjust exchange rate reasonably.

Although there have been remarkable researches keen on the PPP hypothesis and PPP examination, a limited number of economists focused on examining PPP theory for the euro zone. Therefore, there are at least two aspects where this paper can contribute to. First, since introduced the euro in 1999 January, it is not unproblematic to examine the real exchange rate behaviour of the euro over this period against long run. Even though economists have put much effort to overcome this obstacle, it is usually use a substitute method for the euro before its existence by using previous European countries data. Moreover, researches of real exchange rate in euro zone were only focus on whether PPP holds between the euro area and other major currencies or not. But it is essential to test if PPP holds within the euro area, since different European countries have different and unique economics. From this sense, examining PPP can also help European Central Bank (ECB) scrutinise its monetary policies. Second, regardless of Koedijk et al. (2004) and Schnatz (2002) studied real exchange rate within euro area, they both use the data of euro against Deutsche mark (DM), which limits their comparison between German real exchange rate and that of other European countries. Besides, in Koedijk et al.'s (2004) work, they collected the Consumer Price Index (CPI) against US dollar, but they employed the data to calculate real exchange rate of European countries against DM. From this point, this paper avoids this confusion by analysing real exchange rates between each particular European countries evading from other intermediary figures. In terms of their empirical analysis, they employed Seemingly Unrelated Regression (SUR) technique only for a linear test with PPP. The third interesting point of this paper is applied a new econometric technique propose by Kapetanios et al. (2003) to investigate the non-linear Smooth Transition Autoregressive (STAR) model.

The remainder of this thesis will be organized as follows: Chapter II gives a literature review, beginning with a description of development of PPP theory, followed by an examination of empirical studies of this realm and ending with a definition of terminologies that will be used in this thesis. Chapter III presents a series of econometric methods and models to be used in this thesis, including unit root test, STAR model, Augmented Dickey–Fuller (ADF) test and KSS test. Chapter IV introduces the data and relevant data background. And then I will analyze empirical researches and this contains the major part of this thesis. Chapter V summarises findings and recommendations for possible future work.

Chapter II - Literature Review

2.1 Theory development, stylized facts and methodology categorization

Dating back to 1910s, the most notorious advocate of the Purchasing Power Parity theory was the Swedish economist Gustav Cassel, who first defined and formally coined the term PPP in the "Economic Journal". It is a long history about PPP study and related research since 16^{th} Century (Taylor, 2006). From Keynesian economics in 1925 to Kenneth Rogoff (1996), PPP test has never discontinued validity. The theory of PPP is a core statement in international economics. PPP explains a long run relationship between exchange rate and price level in an open market. For nations with fixed exchange rates, PPP indicates what level the equilibrium exchange rates should be, and PPP implies variation level in real and nominal exchange rate under a floating exchange rate regime. Therefore PPP attracts some empirical research of exchange rate determination. However, PPP dose not usually hold in the short run and is normally not believed to hold in the short run by economists.

In general, the concept of PPP can be described by three main facets: the Law of One Price (LOP), absolute PPP and relative PPP. All these three concepts will be presented in subsequent sections.

2.1.1 The Law of One Price

The Law of One Price holds that the price of an identical internationally traded good should be same when the price is converted to common currency, since people could buy the goods from locations where the price is low and sell the goods to locations where the price is high to gain riskless profit, i.e. arbitrage. LOP holds only if the transactions costs can be ignored and the goods are traded and homogeneous. From LOP sense, this arbitrage would eliminate any differences between goods' price due to negligible external costs. And based on the laws of supply and demand relative to price, any price differential would dissipate over time. To be more specific, excess supply would decrease the price of goods and similarly excess demand would increase the price of goods. Eventually, there is no longer any potential for arbitrage. The equation of the law of one price is following:

$$S = A\frac{P}{P^*}$$

where S is the nominal spot exchange rate, P and P* are the prices for an identical good in the domestic and foreign country respectively and A is an arbitrary constant. However, LOP cannot be hold in many real business cases. First of all, there is a LOP violation, which is induced by transactions costs, such as transport cost, taxes, tariffs and duties and nontariff barriers (Taylor and Taylor, 2004). Engel and Rogers studied the price differentials between comparable goods in the United States and Canada. They found that the greater distance between cities would result in larger price differentials. In other words, transport costs cannot be negligible in most commercial environment. Furthermore, it is common that not all goods are tradable between countries or districts. For example, some services are particular in a unique place, and the value of services is hard to estimate. Besides, it is a dilemma that using producer price indices or consumer price indices for PPP test. But absolute PPP theory copes with partial obstacles.

2.1.2 Absolute Purchasing Power Parity

Absolute PPP applies general price index instead of the identify goods price, which is employed in the LOP. Therefore, the price differential will convert to same level, presented by one currency, over time. However, the description of price levels by price indices has inherent measurement problems. For example, identical comparable goods are probably not in the basket of goods. Although there are some flaws of absolute PPP, the CPI still is a plausible variable in PPP study. The equation for absolute PPP can be written as follows:

$$S = A\frac{P}{P^*}$$

Again S is the nominal exchange rate, A is an arbitrary constant and P and P* represents the price indices for the domestic and foreign country respectively.

It is interesting to study the relationship between the law of one price and absolute Purchasing Power Parity. At first, the CPI indicates the fluctuation level of the prices of identical goods in a period. The price related to CPI includes many aspects, such as food, education, clothing, and transportation. Therefore, absolute PPP expands the bands of PPP so as to explain more general situation.

2.1.3 Relative Purchasing Power Parity

Similar to absolute PPP, relative PPP investigates the movements between exchange rates and prices. Moreover, the relative Purchasing Power Parity linked with inflation rate, exchange rate and interest rate. In other words, the determination of exchange rate or interest rate is necessary to consider the other two variables. To be more specific, the logarithm relationship between exchange rate and the price indices can be written as:

$$\ln S = \ln\left(A\frac{P}{P^*}\right) = \alpha + \ln P - \ln P^*$$

Clearly, the relative PPP is an improved version of the original PPP theory, but is more suitable for PPP empirical analysis.

While PPP do explain some relationships between exchange rate and price level, it is of importance to investigate and understand the limitations faced by PPP. One difficulty is to choose which price indices, like consumer price index, producer price index or wholesale price index, to measure PPP. Obviously, it is hard to make a reasonable comparison between identical goods in both countries, even if the goods can be compared. Moreover, there are also remaining some weaknesses of these price indices including be calculated on different base years and weights used by each country. And as mentioned before, some services are not tradable in the international market. All of these facts weaken the validity of PPP theory.

Another factor weakening PPP power is transaction costs. The transaction costs involving international market, including transport cost, taxes, tariffs and duties and nontariff barriers etc., impact on the price differentials and wear off arbitrage opportunities. But this does not imply that the market is inefficient. It only explains that the external cost hidden in price differentials must equal to the transaction cost.

In general, the fluctuation or adjustment of price level cannot keep pace with the change of economic structure, which will shock the exchange rate. In other words, economic structural change is independent of price level. For example, Mexican peso crisis, 1994, was caused by the change of monetary policy, and Mexican peso broke down in only 48 hours. Therefore, PPP cannot be an accurate predictor of real exchange rate, since the international movements caused by economic structural change influence the exchange rate.

Impediments to predicting future exchange rates, it is an important question about how to measure expected future price. As we know, the future price cannot be predicted accurately, due to like inflation, statistical errors, and policy uncertainty. Again, this is another factors would weaken PPP's ability to measure future exchange rate.

To sum up, all of these factors have negative impact on the accuracy and reliability of PPP theory to estimate exchange rate. However, the debate whether PPP holds or not has never ceased since the theory of PPP put forward in 1970s. While there has been an abundance of literature on the topic of PPP, it is still worthwhile to categorize past literatures to identify those stylized facts. First and foremost, the volatility of many financial market time series is not constant. It means there are periods when exchange rates seem tranquil alongside periods when market seems extreme volatile. This discovery of the time-varying nature of return fluctuations was attributed to Engle (1987). The second is that PPP usually holds in the long run. And this point can be drawing from early PPP studies that the null hypothesises were rejected when employed short-run data. Furthermore, not only does long span data increase the power of PPP tests, but also using more countries. At the same time, the debate on whether PPP should follow random walk hypothesis or mean reversion theory has never come to an end. Even if the real exchange rates illustrate mean reversion behaviour, the question remains on how long this reversion takes. In order to conquer this PPP puzzle, economists put forward the theory of nonlinear data generating process (DGP). Moreover, the non-linearity of real exchange rates has been proved by large quantity empirical studies. An in-depth literature review in next section will discuss with all of these stylized facts.

2.2 Review of empirical evidences

With the development of financial mathematics and econometrics, especially the techniques of financial time series, laid the foundation of further accurate studies of the theory of PPP, there are four major stages of PPP empirical study. The first empirical studies were focused on testing PPP of the null hypothesis. In 1970s and 1980s, the economists employed traditional econometric techniques, such as ordinary least squares and instrumental variables estimation, to test PPP holding or not. And the results of these researches were various due to different inflation level among those countries. It turned out that most of the early test rejected PPP hypothesis excepted hyperinflation economies (see e.g. Frenkel, 1978, 1981). And in terms of these evidence supporting PPP, it is perhaps because of relative stability of the US dollar or lack of a long enough span data to test the PPP hypothesis (Taylor, 2004). However, the first weakness of these early approaches is the failure to test for stationarity in the variables and conduct cointegration analysis. To be more specific, the standard regression analysis of real exchange rate would be spurious if the nominal exchange rate and relative prices are non-stationary. The second shortcoming is the assumption that nominal exchange rate and relative prices have a causal relationship. In practice, it is hard to measure the relationship between nominal exchange rate and relative prices, even if the price indices calculated with strict similar standards. Besides, the fluctuation of price levels does not keep pace with the change of exchange rates. At the end, the results pointed out that PPP does not hold continuously. The empirical evidences were conducted by Frenkel and Johnson, 1978 and Taylor, 1995.

Due the econometric technique absences, economists conducted a series research on PPP to overcome the shortcomings above. One major theory in that time was exchange rate overshooting, in which PPP is retained as a long-run equilibrium while allowing for significant short-run deviations because of sticky prices (Dornbusch, 1976). During this time, one theory suggested that real exchange rates should display mean reversion in the long-run. Oppositely, an alternative theory put forward that exchange rate follows a random walk (see e.g. Adler and Lehmann, 1983, Darby, 1983 and Hakkio, 1986) However, this branch of studies suffered from the low power of the tests, which resulted in many rejections of PPP. There were three main econometric techniques used to test null hypothesis of unit root, Dickey Fuller, Augmented Dickey–Fuller tests and variance ratios and fractional integration. In order to solve with this low power problem, long periods of data and more countries has been employed into the unit root test. Although it does increase the power of unit root test by using long span data, PPP theory still cannot be hold convincingly. Lothian and Taylor (2000) collected over two centuries exchange rates running test and found that PPP were supported by their data, while Cudding and Liang (2000) concluded contradictory findings, PPP does not hold, by choosing different lag orders and time trends with Lothian and Taylor’s work. Despite of this evidence, most of literatures supported PPP theory after applied panel data to test the series (see e.g. Mark, 1995, Jorion and Sweeney, 1996, and Papell, 1997). While these studies result in the favour of PPP, O’Connell (1998) pointed out that spurious rejections of a unit root can exist when cross-sectional dependence is unaccounted for.

Even if these studies strongly support PPP theory, Rogoff (1996) summarized the famous PPP puzzle: if the exchange rates are so volatile (i.e. they can change very quickly in the short term), why does it take such a long time for them to converge to the exchange rate predicted by the PPP? The nonlinear data generating process (DGP) is one of the most important explanations of PPP puzzle. The DGP demonstrates a region of unit root or near unit root behaviour approaching the equilibrium real exchange rate. In a linear process, the adjustment speed of PPP deviations is assumed to be constant over time. Particularly, this assumption would reduce the half-life of the reversion due to simple estimation of real exchange rate. Since the transaction costs involving with international arbitrage, Heckscher (1916) proposed a nonlinear adjustment. This sight mainly expressed formally and improved by later researchers (Beninga and Protopapadakis, 1988; Williams and Wright, 1991) around 1990s. This equilibrium conversion can be expressed by Threshold Autoregressive (TAR) model. It states that exchange rates would be influenced by other variables randomly, e.g. transaction costs, and would revert back toward the threshold, until the breached value equal to the threshold. Moreover, a number of empirical studies have documented that exchange rate behaviour can be well captured by the Smooth Transition Autoregressive (STAR) model of Grander and Teräsvlrta (1993; Taylor and Sarno, 1998; Sarantis, 1999). In next section, I will introduce the econometric techniques employed in this paper.

Chapter III - Methodology

3.1 Real Exchange Rates and Unit Root Test

Based on the early studies of PPP in 1980s, it is usually rejected the validity of PPP in the short-run. With the development of econometric techniques for non-stationary time series, a large number of experiment employed unit root and cointegration approaches on exchange rate so as to examine the validity of PPP theory in the long-run. According to PPP theory, the logarithmic real exchange rate may be presented as:

$$y_t = s_t - p_t + p_t^* \tag{3.1.1}$$

Where y_t is real exchange rate, s_t is the nominal exchange rate at time t (the domestic price of foreign currency), p_t is the domestic price level, p_t^* is the foreign price level. PPP states that the value of logarithm of real exchange rate should be equal to zero. From this point, if the exchange rates are relatively constant, then it is evidence supported PPP. Because, when the logarithm of real exchange rate equal to zero, the nominal exchange rate and relative national prices are at level consistent with PPP (Taylor, 2006). Moreover, under this condition, the time series of real exchange rates will be mean reverting, if the PPP holds. Thus the investigation of PPP is to test the null hypothesis of non-mean reversion against mean reversion. However, the early studies of Roll (1979) and Adler and Lehmann (1983) demonstrated that the real exchange rate follows a random walk. Subsequently, due to the introduction of unit root test, a number of researchers back on study of the long-run PPP using the new techniques. To begin with, the simplest model is random walk, which can be expressed as follow:

$$y_t = y_{t-1} + \varepsilon_t \tag{3.1.2}$$

where y_t is a time series and $\varepsilon_t \sim N(0, \sigma^2)$. According to the definition given by Hill et al (2008), a time series y_t is said to be *stationary* if its mean and variance are constant over time, and if the covariance between two values from the series depends only on the length of the time separating the two values, and not on the actual times at which the variables are observed. That is, the time series y_t is stationary if for all values, and every time period, it is true that:

$$E(y_t) \quad \text{(constant mean)} \tag{3.1.3}$$

$$var(y_t) = \sigma^2 \quad \text{(constant variance)} \tag{3.1.4}$$

$$cov(y_t, y_{t+s}) = cov(y_t, y_{t-s}) = \gamma_s \quad \text{(covariance depends on s, not t)} \tag{3.1.5}$$

The unit root test is used to test for the stationary of a time series. If there is a unit root, then the series is not stationary. Among the unit root techniques used to test the real exchange rates, the Dickey – Fuller test (DF) and the Augmented Dickey – Fuller test (ADF) are most famous. Expanding the random walk model, the non-augmented Dickey Fuller regressions are presented as:

$$y_t = \alpha y_{t-1} + \varepsilon_t \tag{3.1.6}$$

$$y_t = \varphi + \alpha y_{t-1} + \varepsilon_t \tag{3.1.7}$$

$$y_t = \varphi + \alpha y_{t-1} + \beta\left(t - \frac{T}{2}\right) + \varepsilon_t \tag{3.1.8}$$

Where Equation 3.1.6 has neither intercept nor trend, Equation 3.1.7 has intercept but no trend, Equation 3.1.8 has intercept and trend. When the linear trend is deterministic or stochastic, intercept is the drift. And the differences between deterministic and stochastic process is that the former is mean-reverting whereas the latter is not. If the null hypothesis: $H_0: \alpha = 1$ is rejected, the series is stationary or integrated of order 0, i.e. I (0). The main purpose to understand whether a time series is stationary or not before running a regression is because it is possible to run a *spurious regression*, or non-sense regression, which happens when regressing a stochastic trend on another stochastic time series and resulting in a meaningless high goodness of fit (Murphy and

Izzeldin, 2010). The situation of high R^2 but extremely low Durbin-Watson statistics was described by Box and Newbold (1971), and Granger and Newbold (1974) as spurious regression. In 2006, Taylor summarized that "under weak additional assumptions and according to certain statistical theorems", the autoregressive formula of real exchange rate with a *p*th order can be written as:

$$y_t = \varphi_0 + \sum_{j=1}^{p} \varphi_j y_{t-1} + \varepsilon_t \qquad (3.1.9)$$

Where ε_t is a white-noise disturbance, if we set $\varepsilon_t = 0$ for all *t*, then the real exchange rate will be mean-reverting due to no shocks drive its fluctuation. When y^* is the long-run equilibrium level of real exchange rate, then putting the total values of real exchange rate to the y^*, Equation 3.1.9 yields:

$$y^* = \frac{\varphi_0}{1-\sum_{j=1}^{p} \varphi_j} \qquad (3.1.10)$$

Therefore, if the long-run equilibrium stands over time, then $\sum_{j=1}^{p} \varphi_j < 1$ must be hold. And when $\sum_{j=1}^{p} \varphi_j = 1$, all shocks impact on the real exchange rate will be perpetual, since the unit root exists. Besides, the situation of $\sum_{j=1}^{p} \varphi_j > 1$ is not often taken into account, because the real exchange rate would be explosive. Thus, we can rewrite Equation 3.1.9 as:

$$\Delta y_t = \varphi + \gamma y_{t-1} + \sum_{s=1}^{m} \Psi_s \Delta y_{t-s} + v_t \qquad (4)$$

where $\gamma = \sum_{j=1}^{p} \varphi_j - 1$, and $\Delta y_t = y_t - y_{t-1}$. This equation is a typical augmented Dicky-Fuller equation. And the hypothesis is written as:

$$H_0: \sum_{j=1}^{p} \varphi_j = 1, \text{or}, H_0: \gamma = 0 \text{ (there is a unit root, the series is non} - \text{stationary)}$$

$H_1: \sum_{j=1}^{p} \varphi_j < 1, or, H_0: \gamma < 0$ (there is no unit root, the series is stationary)

Rejection of the null hypothesis $H_0: \gamma = 0$ is tantamount to rejection of the null hypothesis that the real exchange rate does not follow mean reversion behaviour. Besides, in order to make sure the errors are not correlated, ADF test is preferred.

3.2 STAR Model

While ADF offered an effective approach to test the stationarity of the real exchange rate, a large number of literatures have failed to reject the null hypothesis of a unit root, which states that the time series of real exchange is non-stationary. Some studies found that the real exchange rates may experience different regimes in the long run, which could imply permanent movements of real exchange rate (Edison and Kloveland, 1987). Moreover, Edison and Kloveand indicate that adjusting for "general equilibrium" shocks could reject the null hypothesis of unit root in long-run exchange rate, and then support the PPP theory. Kapetanois et al. (2003) summarized that there are two branches of investigators looking for alternative approaches to test unit root. The two branches economists are willing to solve the low power problem with ADF. The first one is using panel data or long-run exchange rate sets for ADF test. While Abuaf and Jorion (1990) show that panel data do hence the ADF test power to an upper level, all data set may experience different regimes during the periods, especially EU countries after Bretton Woods system breaking down, which can be found in a number of studies. Moreover, I will demonstrate and explain this phenomenon in next section in details. The second branch is developing AR or ARMA models such as frictional integration and non-linear transition dynamics to verify the PPP theory. Researchers have found that TAR and one unique sub-branch was trying to establish non-linear model to cope with the regimes issues (see example Enders and Granger, 1998). The most successful and famous model is TAR model. In 1983, Tang proposed this non-linear model to study real exchange rate. The thresholds in TAR model can explain and depict two patterns of exchange rates behaviour. According to Tang's work, the TAR model can be presented as:

$$y_t = \begin{cases} a_0 + a_1 y_{t-1} + u_t & \text{if } z_{t-d} \leq c, \\ b_0 + b_1 y_{t-1} + u_t & \text{if } z_{t-d} \geq c, \end{cases} \tag{3.2.1}$$

where z_{t-d} is the transition variable, in real exchange rate study $z_{t-d} = y_{t-d}$. The delay lag d is usually unknown, and we can estimate it by ADF test or least-squares approach. Parameter c is the "threshold", which is to identify two different regimes: one is when transition variable $z_{t-d} \leq c$, named low regime, the other is transition variable $z_{t-d} \geq c$. Besides, variable a and b adjust the change of real exchange rate in its last period value. From this point, TAR model offers a new method to depict the real change rate experience from one regime to another regime, and this is more accurate to describe the real exchange rate in reality. The TAR model has been modified since the beginning of this century. There is a new technique using unit root test against TAR model for PPP test. At the same time, Ozaki (1978) put forward the Exponential Smooth Transition Autoregressive (ESTAR) in 1978. As following, I will introduce this technique, employed in this paper, in details. First of all, a typical STR model can be written as:

$$y_t = \alpha \tilde{y}_t + \varphi' \tilde{y}_t F(z_{t-d};\ \gamma, c) + u_t \tag{3.2.2}$$

where $\tilde{y}_t = (1, y_{t-1}, \dots, y_{t-p}, \omega_{t-1}, \dots, \omega_{t-p})$, ω_t is a vector of exogenous variables, u_t is a white noise, $u_t \sim N(0, \sigma^2)$, and similarly variable z_{t-d} is the transition variable. Without the exogenous variables, ω_t, then $\tilde{y}_t = (1, y_{t-1}, \dots, y_{t-p})$, and $z_{t-d} = y_{t-d}$, then Equation 3.2.2 is Smooth Transition Autoregressive (STAR) model, expressing as following:

$$y_t = \alpha_0 + \sum_{j=1}^{p} \alpha_j y_{t-j} + \left(\varphi_0 + \sum_{j=1}^{p} \varphi_j y_{t-j}\right) F(y_{t-d};\ \gamma, c) + u_t \tag{3.2.3}$$

The delay lag $d \in 1,2, \ldots, d_{max}$ of variable y_{t-d}, and $1 \leq d \leq r$ for $r = \max(p, q)$. And in this paper, it is only considering the case that p = q. Variable c is the threshold, which can be deterministic and/or stochastic variable. The variable γ enables function F to be different over time and determine the smoothness of this model , and $F(\cdot)$ is at least fourth-order. Economists have developed two forms of STAR model: one is Exponential Smooth Transition Autoregressive (ESTAR) model, the other is Logistic Smooth Transition Autoregressive (LSTAR) model. Since this paper focus on ESTAR mostly, I will introduce this model thoroughly. According to Granger and Teräsvirta (1993) research, the transition function $F(\cdot)$ of LSTAR model can be presented as:

$$F(y_{t-d}; \gamma, c) = [1 + \exp(-\gamma(y_{t-d} - c))]^{-1} \quad \gamma > 0 \qquad (3.2.4)$$

When $y_{t-d} = c$, the function $F(\cdot)$ is asymmetric around threshold c. From this point, it means that there are two different dynamic process of variable y_t, while the value of y_t is above c or the value of y_t below c. Assume Equation 3.2.3 is presented as:

$$y_t = (\alpha_0 + \beta_0 y_{t-1})(1 - F(y_{t-d}; \gamma, c)) + (\alpha_1 + \beta_1 y_{t-1})F(y_{t-d}; \gamma, c) + \varepsilon_t \quad (3.2.5)$$

Then the function $F(\cdot)$ would be depicted as Fig 1

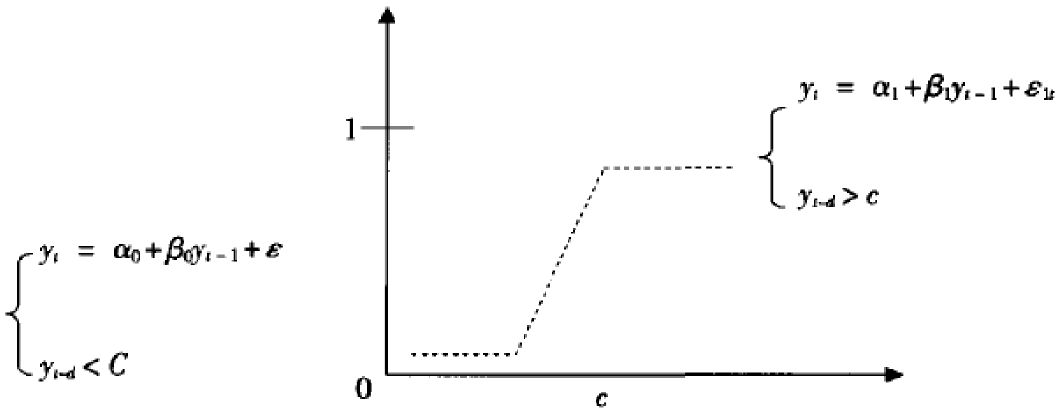

Fig. 1 LSTAR model

The X axis is the value of y_{t-d}, and the Y axis is the value of the function $F(\cdot)$. We can see switch regime behaviour of the time series go through from one regime to another regime. For example, when the effectiveness of government policies is increasing positively, then the exchange rate or interest rate will show the behaviour in Fig. 1.

Similarly, the transition function $F(\cdot)$ of the ESTAR model is

$$F(y_{t-d};\ \gamma, c) = [1 - \exp(-\gamma(y_{t-d} - c)^2)] \qquad \gamma > 0 \qquad (3.2.6)$$

This transition function is symmetric around $(y_{t-1} - c)$ and admits the limits,

$$F(y_{t-d};\ \gamma, c) \to 1 \text{ as } |y_{t-d} - c| \to +\infty, \qquad (3.2.7)$$

$$F(y_{t-d};\ \gamma, c) \to 1 \text{ as } |y_{t-d} - c| \to 0. \qquad (3.2.8)$$

Use Equation 3.2.5 for ESTAR model, it can be graphed as Fig.2.

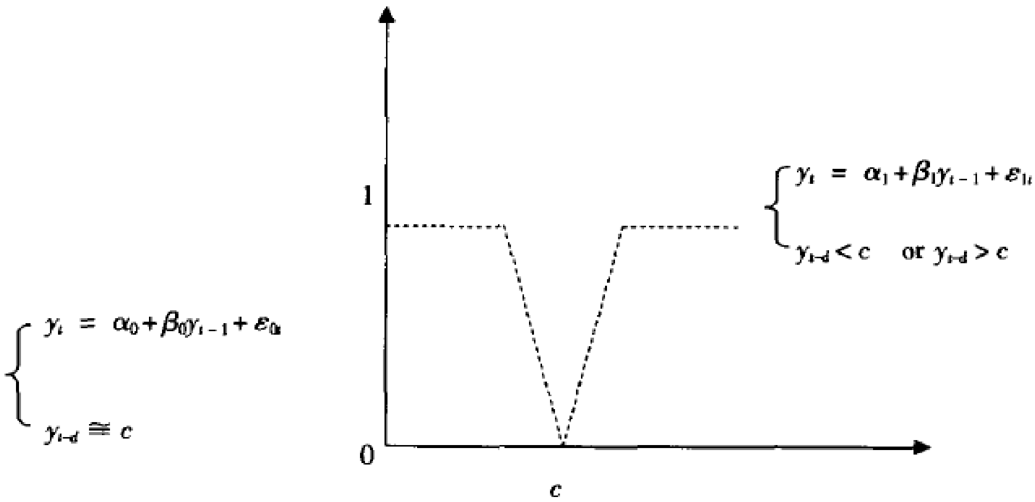

Fig. 2 ESTAR model

Moreover, Van Dijk, Teräsvirta and Franses (2002) point out that ESTAR model is much better suitable for some certain conditions than that of LSTAR model due to the symmetry of ESTAR model. However, the weakness of ESTAR model is that no matter whether $|y_{t-d} - c| \to +\infty$ or $|y_{t-d} - c| \to 0$, the function $F(\cdot)$ will towards a constant (0 or 1). Therefore, when $F(\cdot)$ equals to 1, the ESTAR model will become an AR form (i.e. $y_t = \sum_{j=1}^{p}(\alpha_j + \varphi_j)y_{t-j} + u_t$. In the same way, as $F(\cdot)$ is 1, the ESTAR will be a unit root process, $y_t = \sum_{j=1}^{p}\alpha_j y_{t-j} + u_t$. Obviously, it is necessary to test the non-linearity of ESTAR model before using it for further test. To sum up, LSTAR and ESTAR models have different patterns to describe the time series. There are two significant dissimilar behaviours of LSTAR model, while there are same tracks of ESTAR model. For example, the mean reversion of real exchange rate over equilibrium exchange rate is not so much distinguishable with the mean reversion of the real exchange rate below the equilibrium exchange rate. Besides, because it is unknown to choose which models to employ into the test, a selection approach of two models is needed and essential.

3.3 Testing for STAR Model

The first thing for testing the STAR model is to identify whether the time series for test is linear or not. According to Equation 3.2.2, the null hypothesis of linearity corresponds to $H_0 : \varphi' = 0$. However, the variable $\gamma, \text{and } c$ cannot be identified by the null. On the other hand, if the null hypothesis was $H_0 : \gamma = 0$ or $H_0 : c = 0$, φ' and c or γ and c, respectively ,cannot be identified under the null hypothesis. In 1988, Luukkonen, Saikkonen and Teräsvirta found that the function $F(\cdot)$ can be instead of a Taylor series approximation, and the null hypothesis would be $H_0' : \gamma = 0$. To begin with, the following will introduce the linearity test both for LSTAR and ESTAR model separately. For LSTAR linearity test, we can us first order Taylor approximation as:

$$y_t = \beta'\tilde{y}_t + \gamma\varphi'\tilde{y}_t y_{t-d} + u_t \tag{3.3.1}$$

where $\beta' = (\beta'_{i,0}, \beta'_{i,1}, \dots, \beta'_{i,p})$, $i = 0, 1$, then the null hypothesis is $H''_0 : \beta_1 = 0$, which can be testes directly. However, Luukkonen et al. (1988) noticed that the test above (named LM_1) will be invalid when the coefficient of y_{t-d} is same. Under this situation, they propose using a third order Taylor expansion to build an auxiliary regression, which can be written as:

$$y_t = \beta'_1\tilde{y}_t + \beta'_2\bar{y}_t y_{t-d} + \beta'_3\bar{y}_t y^2_{t-d} + \beta'_4\bar{y}_t y^3_{t-d} + u_t \qquad (3.3.2)$$

where $\bar{y}_t = (y_{t-1}, \dots, y_{t-p})$, and the null hypothesis is: $H''_0 : \beta_2 = \beta_3 = \beta_4 = 0$, which can be tested by Lagrange Multiplier principle. Under this null the LM test corresponds to χ^2 of freedom as $3(p+1)$.

The linear test for ESTAR model is similar. Saikkonen and Luukkonen (1988) proposed the auxiliary regression can be presented as:

$$y_t = \beta'_1\tilde{y}_t + \beta'_2\bar{y}_t y_{t-d} + \beta'_3\bar{y}_t y^2_{t-d} + u_t \qquad (3.3.3)$$

Alternatively, the null hypothesis is $H''_0 : \beta_2 = \beta_3 = 0$. Because of there are two inflection points of the $F(y_{t-d};\, \gamma, c) = [1 - \exp(-\gamma(y_{t-d} - c)^2)] \quad \gamma > 0$, Escribano and Jordä (1999) suggest the first order Taylor expansion cannot describe all behaviours of $F(\cdot)$. Thus, they propose using second order Taylor approximation:

$$y_t = \beta'_1\tilde{y}_t + \beta'_2\bar{y}_t y_{t-d} + \beta'_3\bar{y}_t y^2_{t-d} + \beta'_4\bar{y}_t y^3_{t-d} + \beta'_5\bar{y}_t y^4_{t-d} + u_t \qquad (3.3.4)$$

Escribano and Jordä claim that this approach improves the linear test power, however, there are not sufficient evidences supporting this point.

The second procedure for test STAR model is to select the transition function between LSTAR and ESTAR models. According to Equation 3.3.2, the selection between these two models can be expressed by following sequence of null hypothesis:

$$H_{03}: \beta_4 = 0,$$

$$H_{02}: \beta_3' = 0 \mid \beta_4' = 0,$$

$$H_{01}: \beta_2' = 0 \mid \beta_3' = \beta_4' = 0.$$

Then we can compare with the p-value for the F test of these null hypotheses: if the p-value of H_{02} is less than that of the H_{01}, H_{03}, then we choose ESTAR. Otherwise, we select LSTAR. Other selection method is based on Equation 3.3.4 for testing the null hypothesises:

$H_{0E}: \beta_3' = \beta_5' = 0,$

$H_{0L}: \beta_2' = \beta_4' = 0$

If the p-value for F test of H_{0E} is smaller than that of H_{0L}, then we choose ESTAR model instead of LSTAR model else we select the LSTAR model. In conclusion, these selection approaches are only suitable for identical STAR models. In other words, the approaches cannot be generalized for all STAR models. Moreover, Lundbergh and Teräsvirta claim that conditional heteroskedasticity may reduce the power of the testing. And in 2007, Pavlidis et al. improves the size and power of linearity LM tests by employing Heteroskedasticity Consistent Covariance Matrix Estimators (HCCME) and the Wild Bootstrap.

In 2003, Kapetanios, Shin and Snell (KSS) (2003) develop a new technique for the null hypothesis with a unit root against an alternative of a stationary ESTAR process, which is the major test in this paper. Based on Equation 3.2.2, assuming d = 1, c = 0 the ESTAR model can be written as following,

$$y_t = \beta y_{t-1} + \theta y_{t-1}(1 - \exp(-\gamma y_{t-1}^2) + u_t \qquad (3.3.5)$$

When $\rho = \beta - 1$, Equation 3.3.5 can be rewrite as:

$$\Delta y_t = \rho y_{t-1} + \theta y_{t-1}(1 - \exp(-\gamma y_{t-1}^2) + u_t \qquad (3.3.6)$$

where θ is positive, which determines the speed of mean reversion. Kapetanios et al.

(2003) propose a null hypothesis that $\rho = 0$ and $\theta = 0$, which implies time series y_t follows a linear process with unit root. Imposing$\rho = 0$, Equation 3.3.6 yeilds:

$$\Delta y_t = \theta y_{t-1}(1 - \exp(-\gamma y_{t-1}^2) + u_t \qquad (3.3.7)$$

Now the test for null hypothesis only needs to be considered the variableγ. Therefore, the null hypothesis is:

$H_0 : \gamma = 0,$

$H_1 : \gamma > 0.$

Clearly, it is difficult to test the null hypothesis for γ directly without the consideration of θ. This problem can be solved by using the first order Taylor series approximation to Equation 3.3.7. The new equation would be

$$\Delta y_t = \delta y_{t-1}^3 + \varepsilon_t \qquad (3.3.8)$$

In a more general case when deterministic components exists, the Equation 3.3.8 is given by

$$\Delta y_t^* = \sum_{j=1}^{p} a_j \Delta y_{t-j}^* + \delta y_{t-1}^{*3} + \varepsilon_t \qquad (3.3.9)$$

From this equation, testing $H_0 : \gamma = 0$ corresponds to testing for the null$\delta = 0$ agianst$\delta < 0$. And *t*-statistic for the null l$\delta = 0$ agianst$\delta < 0$ can be given by

$$t_{NL} = \frac{\hat{\delta}}{s.e.(\hat{\delta})}, \qquad (3.3.10)$$

where $\hat{\delta}$ can be obtained by OLS estimation, and $s.e.(\hat{\delta})$ is the standard error of $\hat{\delta}$. Based on this test, Kapetanios et al. (2003) test the real exchange rate of 11 OECD countries against US dollar by using quarterly data from 1957 to 1998. They found that the ADF cannot reject the null for a unit root process in any of the testing countries at 5% significance level, whereas KSS test rejected 6 cases giving support to PPP. And more successful examples can be found in these studies of Hasan (2004), Chortareas and Kapetanios (2002), and Liew, Baharumshah and Chong (2004), which applied KSS approach for testing the real exchange rate of India, Japan and Asian respectively. In next section, I will explain the data collection and processing in order to employ KSS test for each European countries.

Chapter IV - Findings and Evaluation

In this paper, the emprical analysis consists with three major parts. The first part is data description and explaination for nine european countries. For investigating the real exchange rate behaviours within each selected countries, I collect a dataset of nominal exchange rates against US Dollar and consumer price index (CPI) of Austria, Belguim, France, Germany, Greece, Italy, Netherlands, Portugal and Spain from Janurary 1957 to April 2011. The frequency of the exchange rate data are monthly, and the exchange rates are period average value of official rate. The reason why choosing the official rate rather than market rate is that to establish a relative same comparison foundation between each pair as well as to investigate the level of influence from government monetary policies. Besides, all of the nominal exchange rates and CPI data, including the CPI data of the US, are from International Financial Statistics (IFS). It is necessary to point out that some countries' CPI or nominal exchange rate are not continious from 1957 to 2011, for example, the Unified German CPI before Janurary 1991 is unavailble in the dataset. In this situation, the CPI of Germany for the period 1957-2011 is computed by the West Germany and Unified Germany by same foundation data drawing from Janurary 1991 to December 1991. Unfortunately, Finland is not include in the investigation of this paper due to CPI data is not availale before January 1995. Furthermore, in order to obtain real exchang rate between each countries, the first step is to collect all 9 countries' nominal exchange rate against US dollar. Since the euro is introduced in 1999 to replace each countries' currencies, I used Euro/US dollar ratio and (currency of identified countries)/Euro ratio to calculate the exchange rate of selected country against US dollar. The procedure can be presented as following:

$$\frac{R_X}{R_{US}} = \frac{R_X}{R_{EU}} * \frac{R_{EU}}{R_{US}}$$

where Rx is the nominal exchange rate of testing country, and R_{US} and R_{EU} is the nominal exchange rate of the US and Euro, respectively.

The second step is to compute the real exchange rate of each European country. Based on the PPP theory, the real exchange rate can be written as:

$$R^* = R\frac{CPI}{CPI^*}$$

Finally, there are 36 pairs of countries for the real exchange rate investigation. And all the real exchange rates are transferred into logrism for PPP test.

The second part of this chapter is test the null hypothesis for unit root to examine the PPP validity by using Augmented Dickey–Fuller (ADF) test. Moreover, the ADF test can be used to test whether the time series of real exchange rate has a trend and/or a intercept, as well as to determine the delay lag for later KSS test.

The last part is using KSS test for ESTAR model to investigate if PPP holds within the euro area. This part aims to using more powerful econometric technique, KSS test, to prove that the theory of PPP can be hold in the long-run. And other purpose is to compare the test power between ADF test and KSS test as well as identify the linearity of the time series of real exchange rate.

4.1 Real Exchange Rate between European Countries

Since PPP theory has been popularized by a large number of profound economic researches, it becomes an important and interesting topic that whether PPP holds in the European countries. Although economists have put much effort into PPP research, few of them focused on the issue that if the real exchange rate is sensible between each European countries, even if the PPP holds when one European country currency against other major currencies. From this point, this paper provides an alternative view to examine the PPP by using real exchange rate between each country. As there are 9 counties and 36 pairs of them, a clear and feasible way to demonstrate and compare with them is to depict the real exchange rate of one country against that of the others as one set. Fig. 3 is one example of the 9 sets of all 36 graphs. The others graphs will show in Appendix 1. Fig.3 is real exchange rates of Austria against other 8 European countries: Belgium, France, Germany, Greece, Italy, Netherlands, Portugal, and Spain, respectively. From Fig.3, these eight graphs can be categorized as there types. The first type is the graph of Austria against Belgium (AB), which illustrates a clear declined trend from 1957 to 1995. After 1995, it shows a relative stationary process. The second one has two parts: a decreasing trend, after a short stable period, stopped at a medium level and then fluctuating around the level, typically Austria vs. Greece, Italy, Portugal and Spain. However, it is needed to point out that although the real exchange rate of Austria against France (AF) experiences similar process, it is more stable in somewhat level than the others of this typical behaviour. The third type of the real exchange rate behaviour is stable until 1970s, and then it rises sharply before dropping at the beginning of 1985. Before summarizing the reasons why real

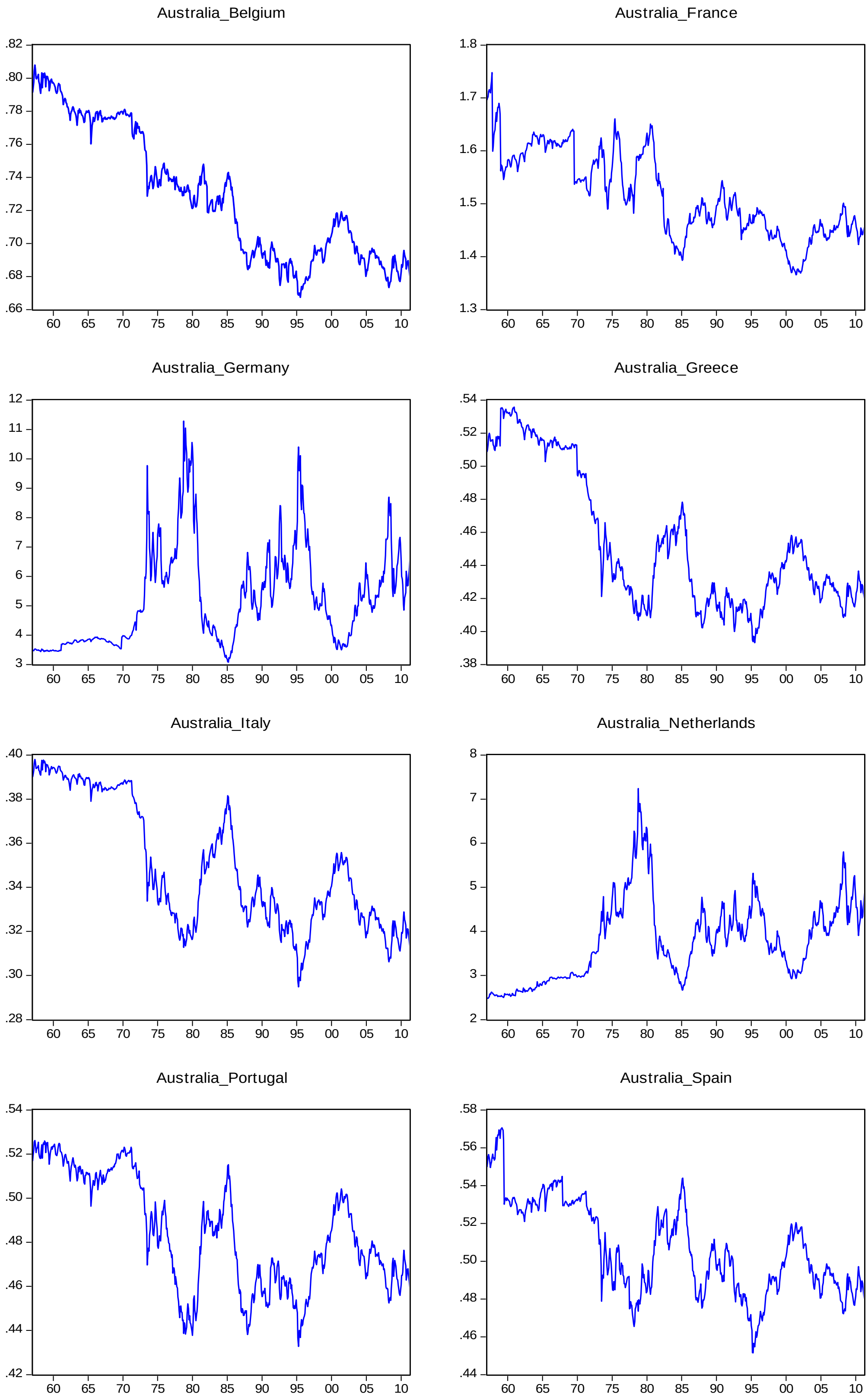

Fig.3 Real exchange rates of Austria against other 8 European countries: Belgium, France, Germany, Greece, Italy, Netherlands, Portugal, and Spain

exchange rates behave as demonstrated, which will be discussed and explained in next section, it is important to take a close examination of these graph and to discover the relationship between them as far as I can.

Moving to Belgium, except with two similar patterns discussed above, there are more different cases, which should be noticed. For Belgium vs. France, and Spain correspondingly, the real exchange rates increase for 4years approximately, and then follow a big falling until 1965. However, the left parts are different: the real exchange rate of Belgium against Spain (BS) has two steady routes which are separated at 1977, while that of Belgium versus France (BF) is non-stationary process. Although the exchange rate behaviour between Belgium and Greece (BGr) is similar with the second part of BS, the beginning is more stable than that of BS after a short arising.

For the real exchange rates of France versus other eight countries, two groups of countries are necessary to be mentioned. The first groups are France vs. Greece (FGr), France vs. Italy (FI), France vs. Portugal (FP), and France vs. Spain (FS). If we put all four graphs together, we will discover that a large part of them is same, and even some segments are overlapped. However, the value of real exchange rates for the group is from 0.24 to 0.40, which is not so close to 1.00. Excluded two cases discussed before (AF and BF), the France vs. Germany (FGm) and France vs. Netherlands (FN) have similar behaviours: arising slowly for the period 1957-1971, after that time, the fluctuations for both of them is similar.

In terms of Germany, the tracks of different groups of real exchange rates against other countries are more similar than that mentioned before. As demonstrated before, Austria vs. Germany (AGm), BGm, and FGm have same processes, which are increasing slowly, and then fluctuating since 1970. Moreover, the cases of Germany against Greece, Portugal, and Spain have particular alike routes, which have not ever seen before. At the beginning, the real exchange rates increase fluctuately, and then go down deeply following a short stable period with a bit of arising, sequentially, fluctuate after 1970 approximately. For Germany vs. Netherlands, the whole process can be separated as three parts in different periods. All these parts are relative stationary within each period. The first part ends around the year of 1973, whereas the second is from 1975 to 1995, and the left is the third part. Close scrutiny of this pair of countries, if we use first order difference or de-mean the original data, it would be stationary over the time.

In the comparisons between Greece and others countries, except for three groups with alike process in each group, the other two cases are different with any in this Greece set. For the real exchange rate of Greece vs. Italy (GrI), the increasing and decreasing are both sharply. Moreover, it seems that the constant period do not exist during the whole time. Another special case in this set is Greece vs. Netherlands (GrN), which is similar with other cases for other countries against Greece. The behaviours of Greece vs. Portugal (GrP) and Spain (GrS), respectively, do not have big differences between each other. There is an interesting point in this set for GrI, GrP and GrS. From 1957 to 1959, there is a big drop with all three cases. At the same time, one drastic increasing appears among AGr, BGr and FGr. According to the economic history of Spain and Europe, this big drop results from the “Stabilization Plan” of Spain, and Spain joined IMF in 1959. The purpose of this plan is to stabilize area economy, so the depreciation and appreciation appear at same time. This phenomenon will be explained in next section. Besides, it is easier to discover the similarity between AGr and BGr by comparing AGr with BGr together.

Taking account for Italy, we can see that the first half of the set (AI, BI, GmI) is alike. Except for partially different at the beginning, GrI also can be included in the group of AI, BI and GmI. In terms of Italy vs. Portual and Spain, correspongdingly, the trend and fluctuation in different periods are quite similar. However, there is an obvious drop in the graph of Italy vs. Spain in 1959.This phenomenon is also because of the “Stabilization Plan” in Spain at that time.

The behaviours of real exchange rate for Netherlands against others are one of the most important parts in all graphs. At the first glance, it is not difficult to discover that most graphs in this Netherlands set are very similar with each other, especially for Austria vs. Netherlands (AN), BN, FN, GrN and IN. With a close and careful examine, we can see that the last two (Netherlands against Portugal, and Netherlands against Spain) are mirror images of the first group (AN, BN FN, GrN and IN). Besides, I have already plotted the graphs of Portugal vs. Netherlands and Spain vs. Netherlands, and it turns out that these two pairs are indeed same like the others. As Germany vs. Netherlands has been discussed above, it would not be talked about more in here.

The last sets are Portugal against others and Spain against others. Avoiding introducing all the graphs repeatedly, it is the best way to study Portugal vs. Spain only. There is also a big shock around 1959 due to the same reason of “Stabilization Plan”. And after the fluctuation, which lasts from 1960 to 1993, the real exchange rate is at a constant level with minor rise and fall.

In order to summarize all the behaviours acceptable and reasonable, it is necessary to investigate the history of European monetary integration involving with exchange rates in the European Monetary Union (EMU). At beginning, it is worthwhile to pay attention to the Bretton Woods system, which was established in 1944. The Bretton Woods system has much influence not only in North America, but also in the Europe. It identified the obligation for each member country to adopt a monetary policy that tying with its own currency to the US dollar so as to stabilize the exchange rate and enables the International Monetary Fund (IMF) to manage temporary imbalances of payments. After Bretton Woods system collapsed in 1971, there are two main events in 1970s. The first is the Smithsonian Agreement signed at the end of 1971, which proposed an expansion of the limits of exchange rate from 1% to 2.25%. At the same time, members of the European Economic Community (EEC) agreed with a more restricted band of exchange rate floating ratio at 1.125%, named “snake in the tunnel”, in order to maintain the stable situation within the EEC. And in March 1979, Exchange Rate Mechanism (ERM) took place of the Smithsonian Agreement, but the purpose of both regimes is same: establishing stable monetary zone. Therefore, the real exchange rate between most of European countries experienced a relative stable period from 1975 to 1990. At the beginning of 1990s, the European currency crisis enforced the Italian lira and British pound to leave ERM due to the strong appreciation of Deutsche Mark. However, the Euro introduced by Economic and Monetary Union (EMU) of the European Union indeed stabilized the exchange rate in euro zone, which can be seen from all of the graphs in Appendix 1 since 1999.

In conclusion, the behaviour of real exchange rate in euro area studied in this paper can be categorized as four periods. From 1957 to 1971, it is a stable period due to economic reconstruction after World War II. The second period is the decade of 1970s, which is the time economists and monetary makers trying to establish a new stable monetary system. The following typical period is beginning at the time of the ERM establishment and partially fails in 1992 due to the European currency crisis. The latest stage is from 1999 until now, because of the euro formally introduced. Moreover, all these four phases can be found in most of the graphs in Appendix 1, which demonstrate the mean revision behaviour obviously, or at least the PPP holds in most of the pairs of these nine countries over the time. In next two sections, the question that whether PPP holds or not will be verified by ADF test and KSS test.

4.2 Unit Root Test

The results of ADF test and its explanation will be discussed in this section. Table 1 is the summary of the univariate ADF unit root test for all real exchange rates from January 1957 to April 2011. The columns of table 1 present the ADF test statistic, Prob-value, estimated parameters and the summary of the trend and intercept existence for all time series. The ADF t-statistic yields from raw data by the ADF test with trend and intercept in order to identify whether the series of real exchange rate has trend and/or intercept or not. At the same time, the ADF test is employed to investigate the delay lag *d* for the following KSS test. The selection criteria and significance testing procedure is based on the null of a linear model, which can be estimated by ADF test (Ng and Perron, 1995). The criteria that determine whether there is trend and/or intercept in series refers to the significance of trend and intercept. From table 1, there are 10 samples have both trend and intercept, and no samples with trend but without intercept. 5 samples have neither trend nor intercept. The other 21 series are only with significant intercept. Table 1 indicates that only three series (Austria against France, Belgium against France, and Belgium against Portugal) are stationary due to rejection of ADF test at the 5% significance level, which does not support PPP convincingly. At the 10% significance level, the ADF still rejects only 6 out of 36 cases (another three are Austria vs. Spain, Belgium vs. Germany, and Belgium vs. Spain). This finding may result from the low power of univariate ADF test. From other respect, it indicates that linear AR model cannot test PPP efficiently. Therefore, the non-linear model would be more powerful and suitable for exchange rate investigation than linear model, which can be proved in next section.

Table 1
Augmented Dickey-Fuller tests of real exchange rates

Country	ADF	p-value	Delay lags	Trend	Intercept
AB	-2.4642	0.3460	1	yes	yes
AF	**-3.9853***	0.0096	1	yes	yes
AGm	-3.0583	0.1174	1	no	yes
AGr	-1.8523	0.6779	1	no	no
AI	-2.2377	0.4672	1	no	yes
AN	-2.6505	0.2580	1	no	yes
AP	-2.4572	0.3495	1	no	yes
AS	**-3.3628****	0.0574	1	yes	yes
BF	**-3.7516***	0.0197	1	no	yes
BGm	**-3.1565****	0.0943	1	yes	yes
BGr	-1.9121	0.6470	1	no	no
BI	-2.1683	0.5060	1	yes	yes
BN	-2.8062	0.1955	1	no	yes
BP	**-3.6326***	0.0279	1	yes	yes
BS	**-3.2877****	0.0692	1	yes	yes
FGm	-2.6579	0.2548	1	yes	yes
FGr	-2.8463	0.1812	1	no	yes
FI	-2.9087	0.1603	1	no	yes
FN	-2.8987	0.1636	1	no	yes
FP	-3.0941	0.1085	1	no	yes
FS	-3.1187	0.1028	1	no	yes
GmGr	-2.4834	0.3363	1	no	yes
GmI	-2.5264	0.3151	1	no	yes
GmN	-3.0442	0.1210	1	no	yes
GmP	-2.6040	0.2787	1	no	yes
GmS	-2.5451	0.3062	1	no	yes
GrI	-1.6118	0.7876	12	no	no
GrN	-2.8678	0.1735	1	no	yes
GrP	-1.6784	0.7599	12	no	no
GrS	-1.9693	0.6164	6	no	yes
IN	-2.7128	0.2317	1	no	yes
IP	-2.5920	0.2842	1	yes	yes

Table 1 (*continued*)

Country	ADF	p-value	Delay lags	Trend	Intercept
IS	-2.6452	0.2603	1	yes	yes
NP	-2.3075	0.4288	1	no	no
NS	-2.4121	0.3728	1	no	yes
PS	-2.9246	0.1553	1	no	yes

Note: The trend and intercept existence are determined by their p-value in ADF test with trend and intercept. The delay lag is chose from the one with smallest p-value. Test critical values of 5% significance level and 10% level are -3.416768 and -3.130731 respectively. In all cases * and ** denote significance at 5% and 10% level.

4.3 KSS Test

From the results of ADF test above, the unit root behaviour exits in most cases. In order to conquer this problem, the KSS test is applied in this section to examine the power for both ADF test and KSS test. This section consists with two parts: the first part introduces the data processing for KSS test, and the other part will compare the result of KSS test with that of ADF test.

Kapetanios et al. (2003) recommend that using de-meaned and/or de-trended data would accommodate stochastic processes and high volatile series. Moreover, modelling the variables of trend and intercept in a non-linear model is not direct and feasible. Therefore, the de-meaned and/or de-trended data processing is necessary before starting KSS test. According to the procedure presented by Kapetanios et al. (2003, p. 364), the de-mean data can be obtained through following steps. Assuming one series has nonzero mean, then the series can be expressed as:

$$y_t = \alpha + x_t$$

then residual series x_t is the de-meaned data, due to $x_t = y_t - \alpha$, and α is the mean of the raw series y_t. Similarly, we can write a series with trend and intercept as:

$y_t = \alpha + \beta t + x_t$

where βt is the time trend, and α is intercept. Thus, series x_t is the de-meaned and de-trended data, because $x_t = y_t - \alpha - \beta t$. According to Equation 3.3.9, $\Delta y_t^* = \sum_{j=1}^{p} a_j \Delta y_{t-j}^* + \delta y_{t-1}^{*3} + \varepsilon_t$, using the delay lag estimated in the ADF test, we can conduct the autoregression of Equation 3.3.9 to obtain the t-statistic for the null of linear unit root, i.e. t_{NL}. Table 2 summarizes the results of ADF tests and KSS tests for 36 samples. As discussed above, the ADF test can only reject a unit root in three cases at the 5% significance level, although it can reject three more cases at the 10% significance level. In terms of KSS test, it can reject the null of 9 cases at the 5% significance level, and another 4 cases at the 10% significance level. Therefore, KSS test rejects the null much more than ADF test, which indicates that KSS test improves the power of unit root test. Furthermore, it is also interesting to note that the *t*-statistic for $s.e.(\hat{\delta})$ is larger than 5, which may imply that ESTAR model could not be the best choice for the series to conduct unit root test and modelling. Alternatively, since lack of the stage for model selection test before, the results also show that not every sample can be modelling very well by ESTAR model. In terms of economic concerns, the graphs of real exchange rates between each countries also illustrates the time series is not always symmetric from one regime to another. Therefore, the exploration of PPP theory within euro area can be continued to study in the future.

Table 2
Unit root test results for 36 samples

Series	Coefficient	Std. Error	t_{NL}	ADF	p-ADF	Trend	Intercept
AB	-37.2050	12.1727	-3.0564	-2.4642	0.3460	yes	yes
AF	-6.3442	1.4703	**-4.3150***	**-3.9853***	0.0096	yes	yes
AGm	-0.0034	0.0006	**-6.1324***	-3.0583	0.1174	no	yes
AGr	-0.0158	0.0013	-1.1873	-1.8523	0.6779	no	no
AI	-4.2612	2.2598	-1.8856	-2.2377	0.4672	no	yes
AN	-0.0058	0.0014	**-4.0076***	-2.6505	0.2580	no	yes
AP	-10.8456	3.7835	**-2.8666****	-2.4572	0.3495	no	yes
AS	-32.6605	8.2908	**-3.9394***	**-3.3628****	0.0574	yes	yes
BF	-3.42E-05	8.33E-05	-0.4108	**-3.7516***	0.0197	no	yes
BGm	-8.70E-05	2.44E-05	**-3.5653***	**-3.1565****	0.0943	yes	yes
BGr	-0.0003	0.0005	-0.4971	-1.9121	0.6470	no	no
BI	-0.0002	0.0007	-0.3142	-2.1683	0.5060	yes	yes
BN	-6.29E-05	3.55E-05	-1.7705	-2.8062	0.1955	no	yes
BP	-0.0001	0.0003	-0.3808	**-3.6326***	0.0279	yes	yes
BS	-0.0002	0.0004	-0.4969	**-3.2877****	0.0692	yes	yes
FGm	-0.0003	0.0001	**-3.2883****	-2.6579	0.2548	yes	yes
FGr	-0.0034	0.0052	-0.6503	-2.8463	0.1812	no	yes
FI	-0.0059	0.0085	-0.6970	-2.9087	0.1603	no	yes
FN	-0.0002	0.0001	-1.4136	-2.8987	0.1636	no	yes
FP	-0.0018	0.0042	-0.4305	-3.0941	0.1085	no	yes
FS	-0.0020	0.0040	-0.5033	-3.1187	0.1028	no	yes
GmGr	-8.6469	2.5777	**-3.3545****	-2.4834	0.3363	no	yes
GmI	-11.3610	3.7845	**-3.0020***	-2.5264	0.3151	no	yes
GmN	-2.0326	0.3678	**-5.5269***	-3.0442	0.1210	no	yes
GmP	-0.3759	0.09430	**-3.9860***	-2.6040	0.2787	no	yes
GmS	-7.3655	2.2263	**-3.3084****	-2.5451	0.3062	no	yes
GrI	-8.88E-05	0.0002	-0.3816	-1.6118	0.7876	no	no
GrN	-2.75E-05	1.32E-05	-2.0765	-2.8678	0.1735	no	yes
GrP	8.91E-05	0.0001	0.6288	-1.6784	0.7599	no	no
GrS	-0.6129	0.4036	-1.5184	-1.9693	0.6164	no	yes
IN	-0.0005	0.0001	**-4.2734***	-2.7128	0.2317	no	yes

IP	-1.08E-05	5.80E-05	-0.1857	-2.5920	0.2842	yes	yes

Table 2 (*continued*)

Series	Coefficient	Std. Error	t_{NL}	ADF	p-ADF	Trend	Intercept
IS	-2.40E-03	6.99E-05	-0.3440	-2.6452	0.2603	yes	yes
NP	-0.0632	0.0383	-1.6483	-2.3075	0.4288	no	no
NS	-2.7621	1.1567	-2.3879	-2.4121	0.3728	no	yes
PS	-5.02E-05	0.0002	-0.3280	-2.9246	0.1553	no	yes

Note: The trend and intercept existence are determined by their p-value in ADF test with trend and intercept. Test critical values of 5% significance level and 10% level are -3.416768 and -3.130731 respectively. In all cases * and ** denote significance at 5% and 10% level. The critical value of t_{NL} is in Appendix 2

Chapter V - Conclusion

The debate of Purchasing Power Parity (PPP) has never been ceased since Gustav Cassel formally introduced this theory. This paper intends to investigate whether PPP holds between each European country, especially after the economic integration in Europe by using a recent econometric technique, KSS test. The results from the empirical analysis in this paper provide economists as well as monetary makers with an alternative aspect to think and employ PPP theory.

Refer to the overview of PPP theory by Taylor and Taylor (2004), not only included major events related to PPP in this paper, but more importantly, it also summarized recent empirical approaches and evidences selectively. Together with the PPP history and the economic principles behind it, it builds a solid foundation for further empirical investigation for PPP. Have understood the weakness of one theory, we can conduct our research more objectively. For example, although PPP can explain some exchange rate behaviours, such as exchange rate movements and conversion, one of its flaws is that PPP cannot be hold in the long-run. This is drawing from PPP theory that exchange rate reverting to the equilibrium level is time consuming. Moreover, it is critical to recognize what research have been done and where can be explored. Therefore, in the literature review, it first briefly summarized the development of PPP theory. Based on the theoretical knowledge, it discussed the weaknesses of PPP that inaccurate price level calculation, transaction costs, and government policies all can erode the power of PPP. And we noticed that early studies are focused on simple univariate linear model, due to the absence of advanced econometric techniques. Therefore, these early studies show that the PPP cannot be hold as it rejected unit root test in most cases. Thus, researchers have put much effort into enhancing the power of unit root tests. As argued before, there are two main branches. One is to study the cointegration of exchange rate, and the other is trying to establish more delicate

Autoregressive (AR) model for exchange rate analysis. In this paper, we are focusing on the latter one by applying non-linear model to examine the real exchange rate behaviour. The Smooth Transition Autoregressive (STAR) model is more suitable for real exchange rate study proved by abundance empirical evidences. In contrast to previous works, we employed a non-linear process to test the validity of PPP. And the empirical results prove that the non-linear STAR model enlarge the valid parameter of PPP. Furthermore, a new test for unit root was introduced by Kapetanios, Shin, and Snell in 2003, named KSS test. Recently, many researchers have been paying attention to examine various datasets and improve the power of KSS test (see e.g. Hasan, 2004; Chortareas and Kapetanios, 2002; and Liew, Baharumshah and Chong, 2004). In this paper, we also use the KSS test for our samples in order to compare the test power of ADF test. From this point, this paper is different from other previous study for PPP within euro area.

Except with the advantage of recent powerful econometric technique, there is also a unique perspective to examine the PPP in euro area. Based on the literature review and combined with all theoretical economic knowledge, we found that there are few economists devote into the study of PPP between each European countries, especially for non-linear model. Thus, this is a valuable opportunity to study whether PPP holds within each country or not, especially after the introduction of Euro.

We found evidence in favour of PPP between each European country by applied KSS test. There are over one third samples (13 out of 36) rejected the null of unit root, which give strong supporting to PPP theory. In terms of ADF tests, it rejected only 6 cases at the 10% significance level, which is much less than that of the KSS tests. In sum, the non-linear STAR model and KSS test demonstrate more power than linear AR model and ADF test for PPP support. Beyond this, there are four potential area can be studied in the future. During the process of graphs summarize, I noticed that some sample can be divided into subsample to conduct ESTAR model test. The first reason is that the nature of ESTAR model is to explain the differences when time series experiences from one regime to another symmetric. It is common to know not all samples will behaviour symmetric routes. From this discussion, it would be interesting if we can use several subsamples to examine the STAR model as well as add one procedure for model selection, which will enhance both model and t-statistic test power. The third finding is also during the graph summary. As I mentioned before, the different order of comparing countries will result in not only different graphs but also distinctive series. For example, Netherlands against Portugal will yield a different graph and a different series if we switch them as Portugal against Netherlands. This point can be test the issue whether that switch would impact on the result of unit root test. Finally, as all our test is univariate, it could be extended to test multivariate situation for error correction model (Kapetanios el at., 2003).

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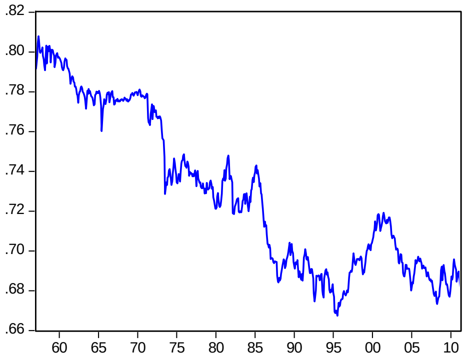
Appendix

Appendix 1 Nine sets graphs of real exchange rate between nine European country

Australia_Belgium



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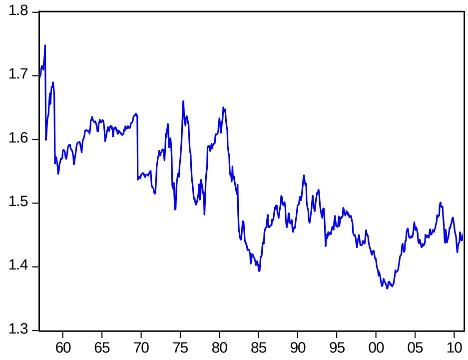

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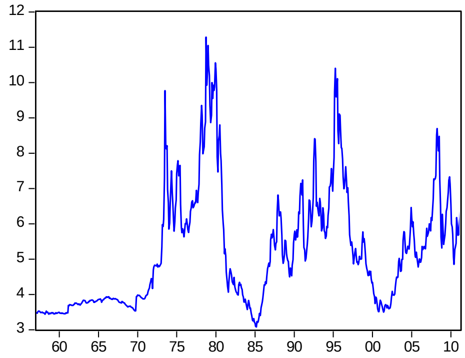

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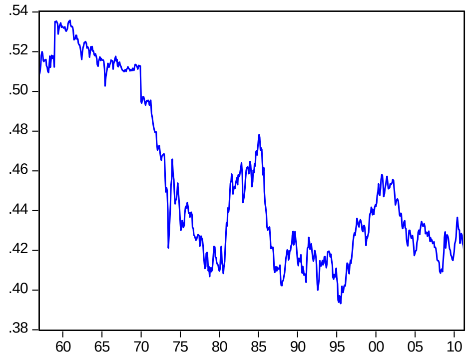

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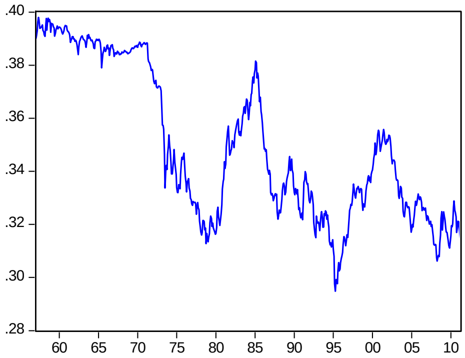

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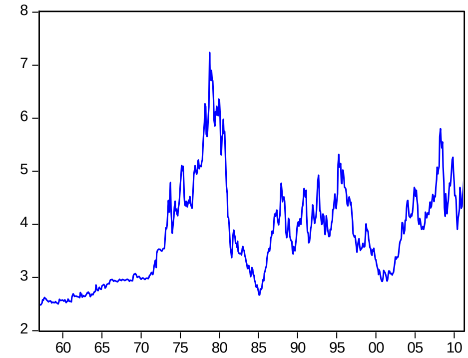

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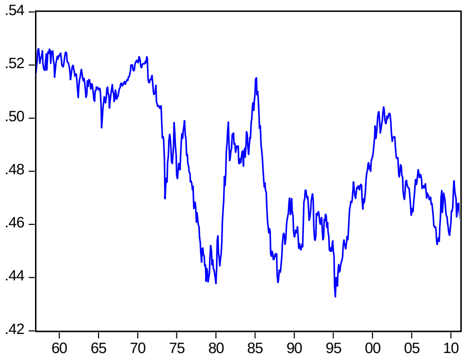

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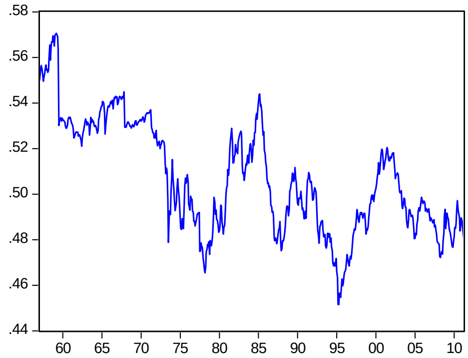

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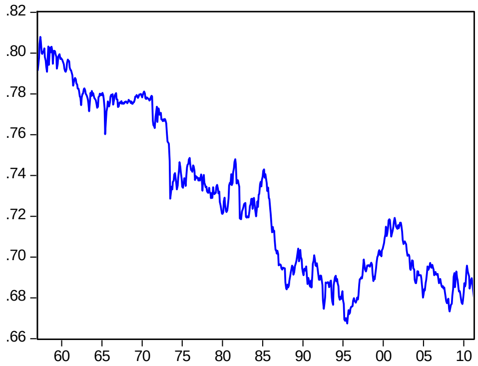

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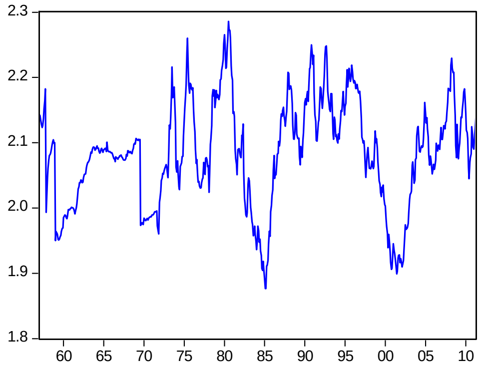

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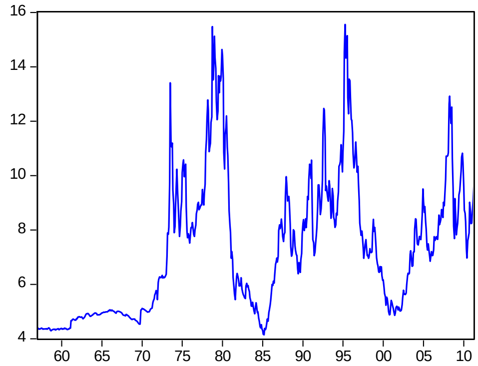

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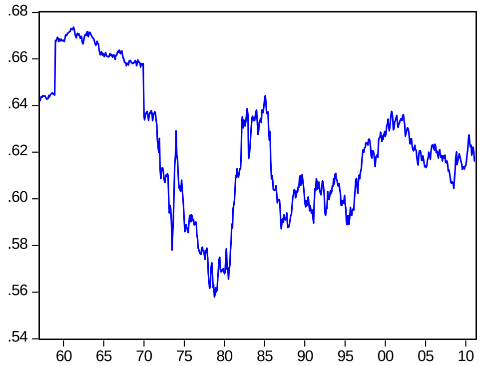

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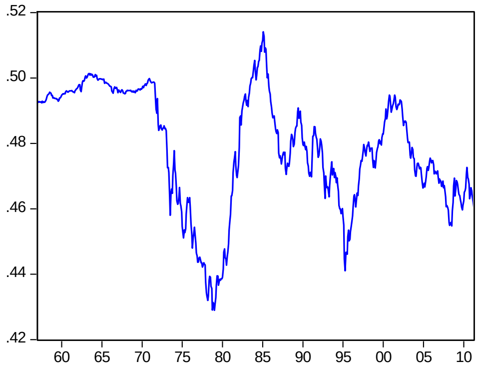

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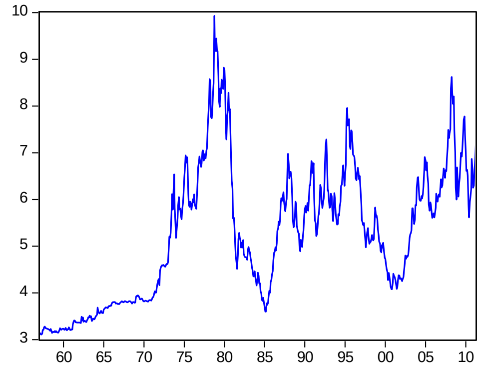

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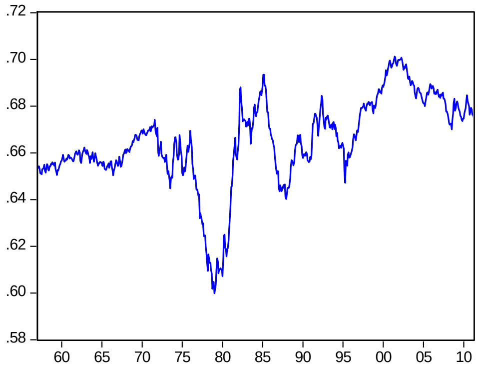

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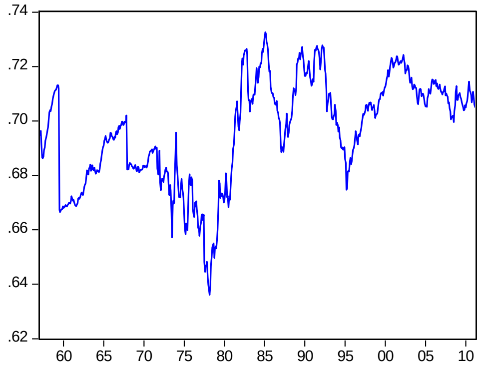

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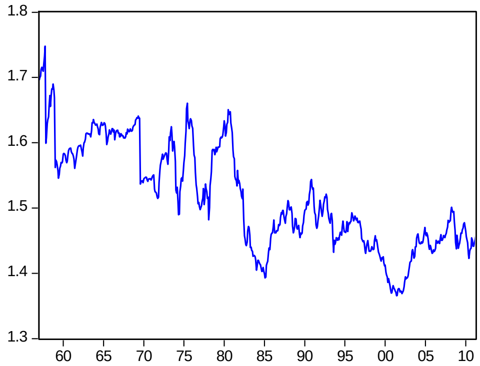

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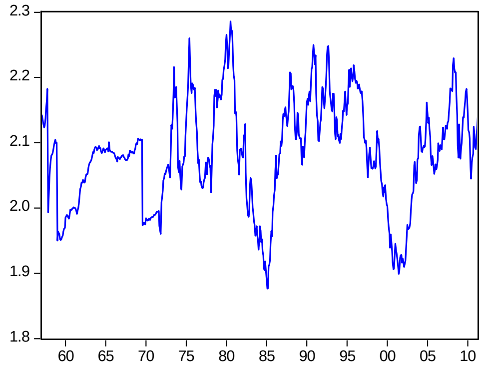

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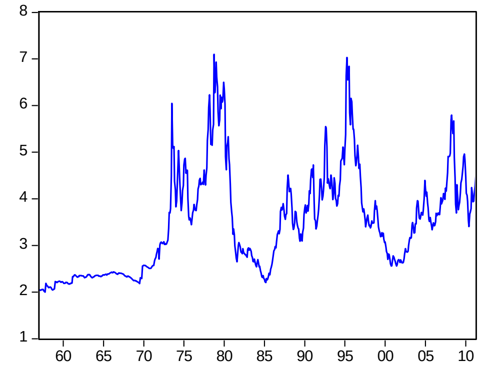

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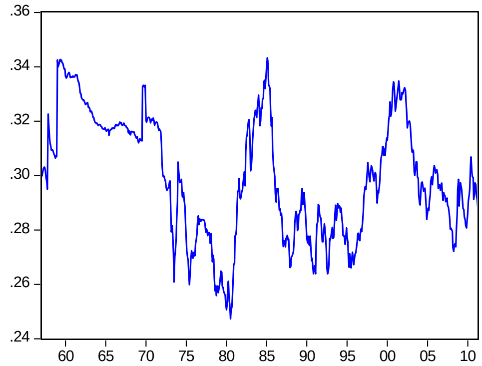

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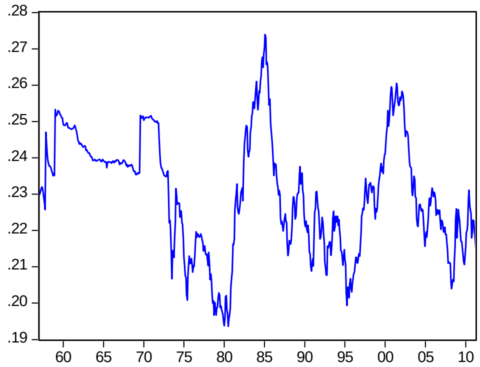

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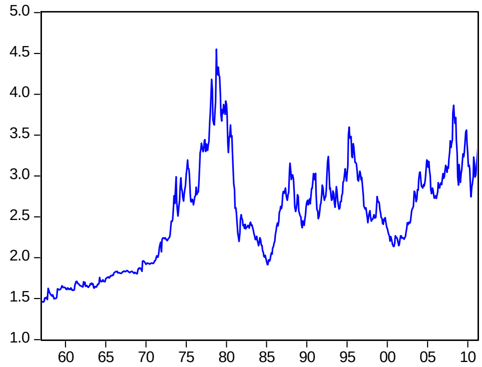

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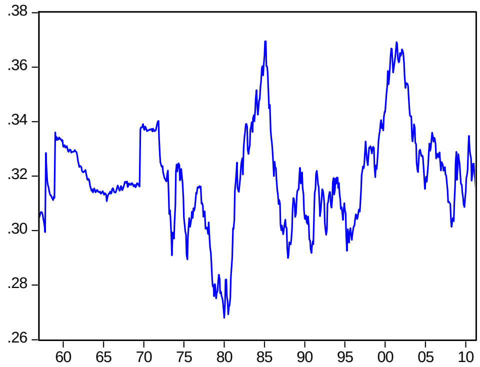

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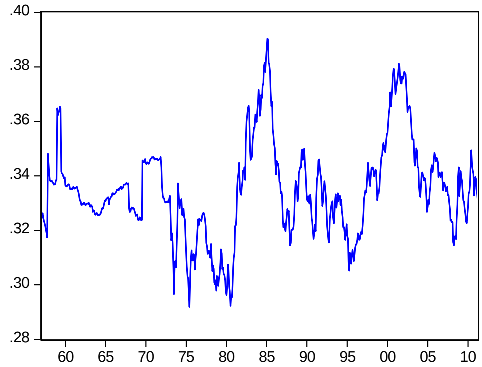

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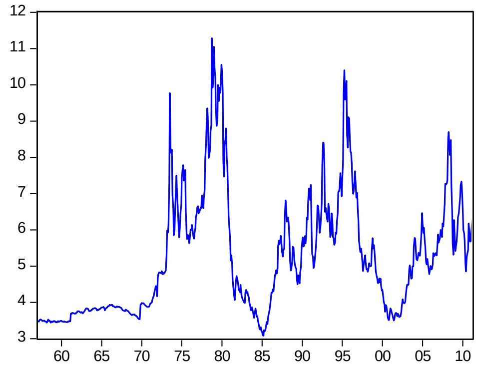

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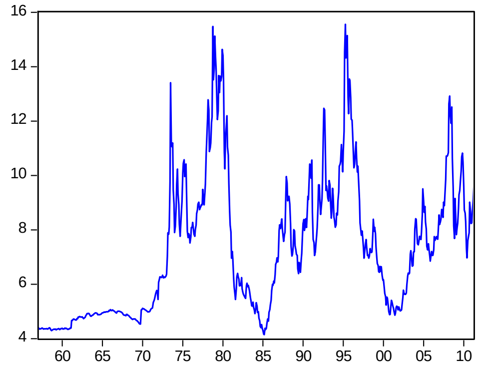

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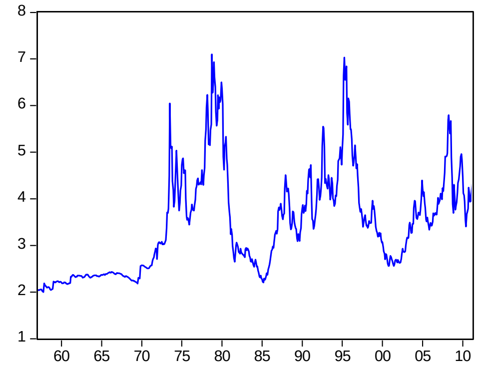

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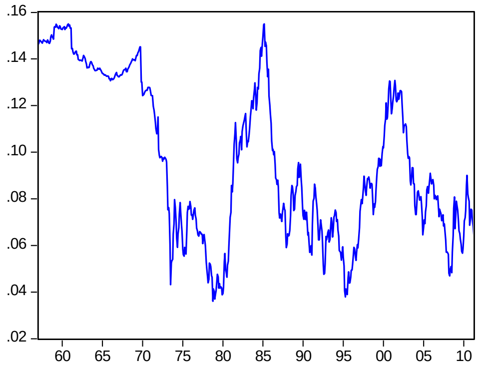

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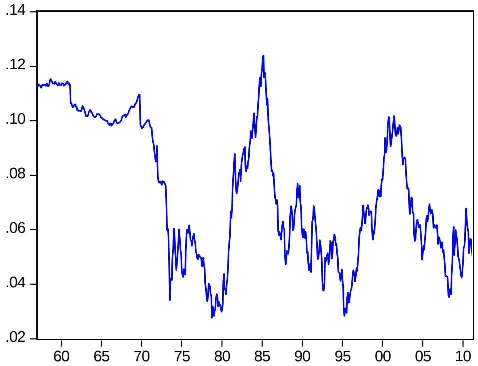

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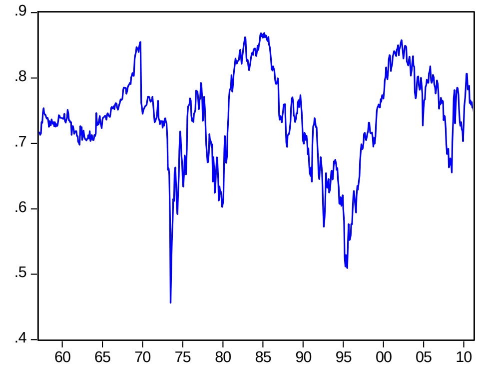

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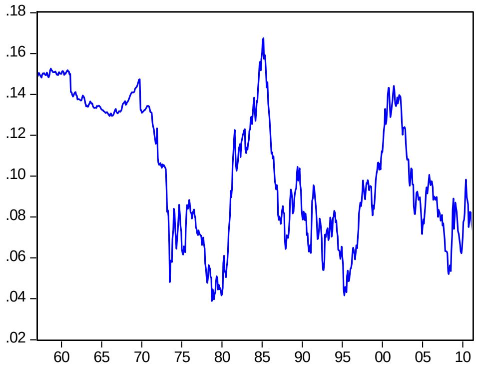

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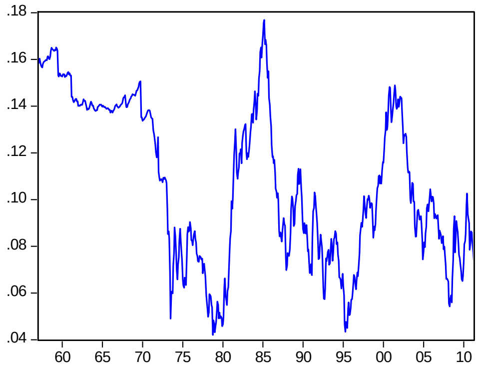

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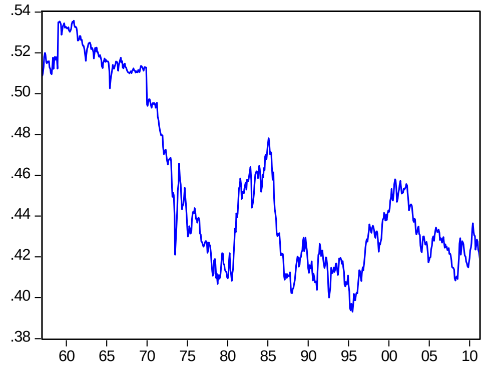

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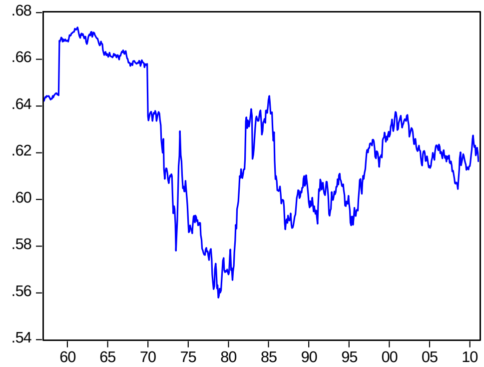
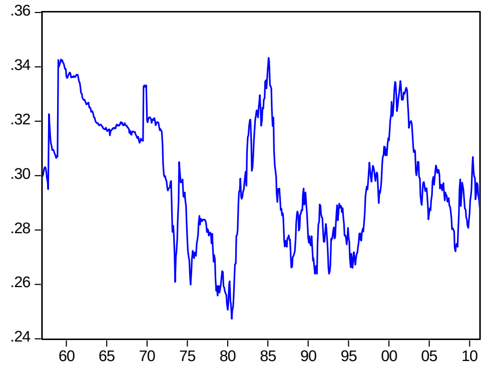
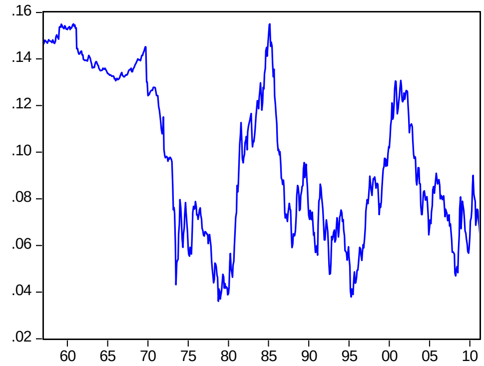


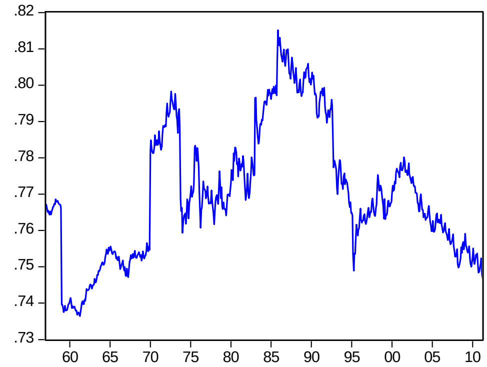
France_Greece



Germany_Greece



Greece_Italy



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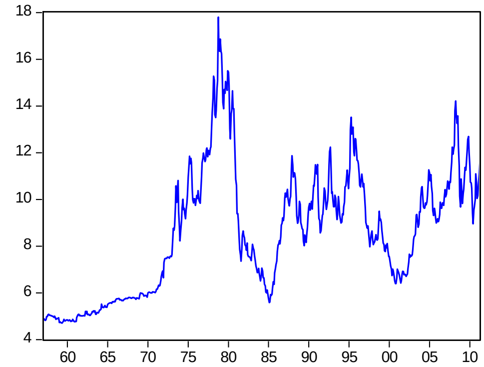

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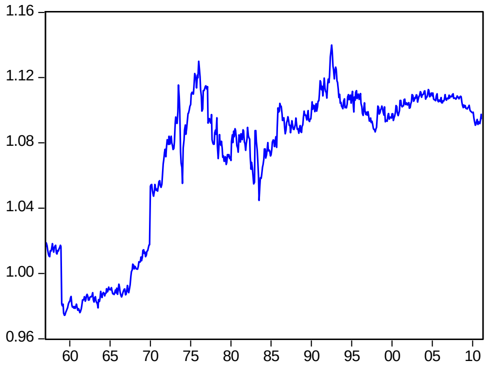
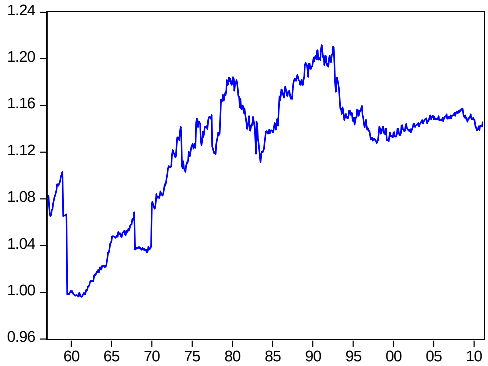
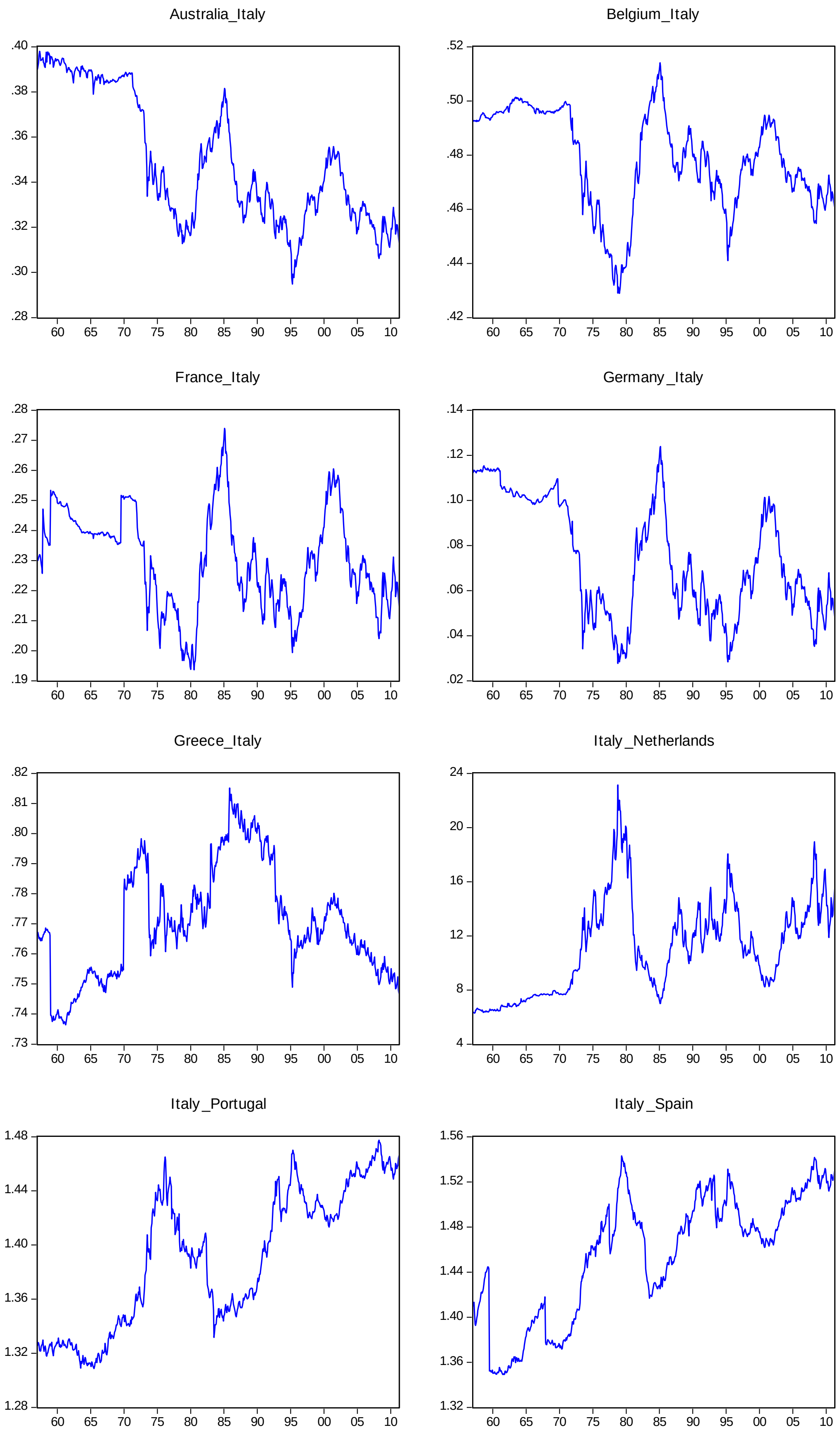


Greece_Spain

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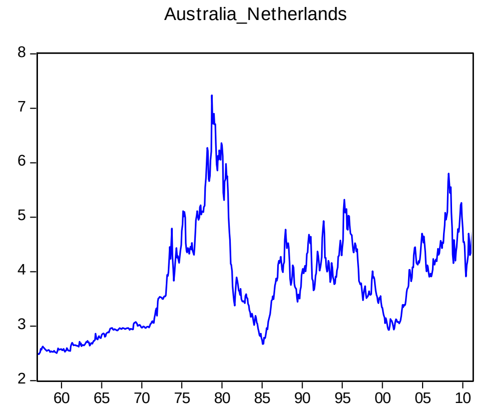
Belgium_Italy
France_Italy
Germany_Italy
Greece_Italy
Italy_Netherlands
Italy_Portugal
Italy_Spain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4
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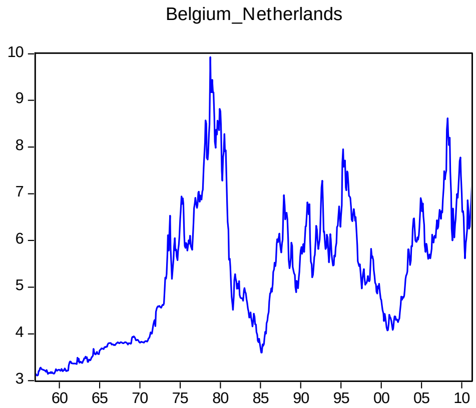
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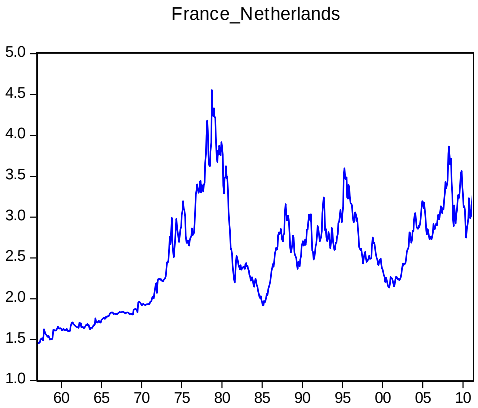
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1.5
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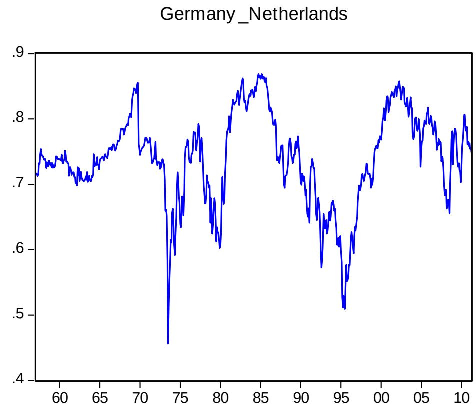
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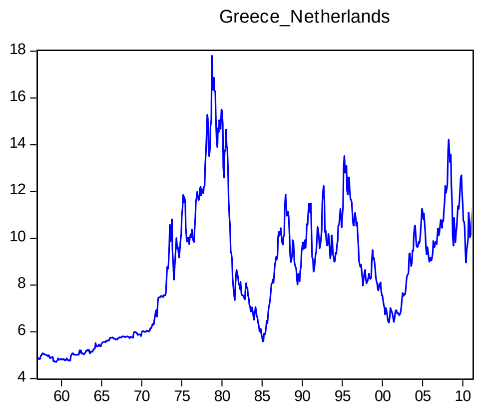
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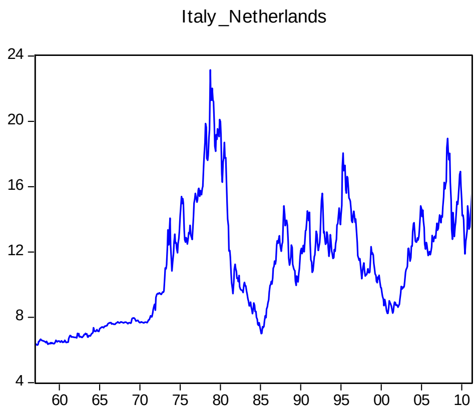
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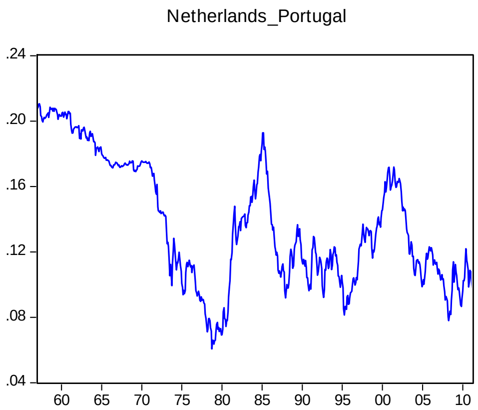
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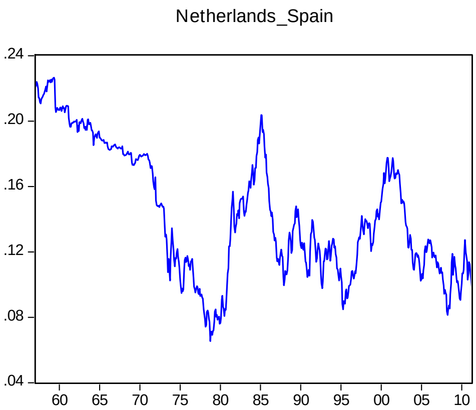
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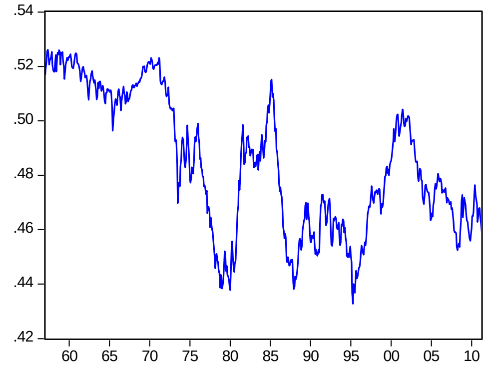
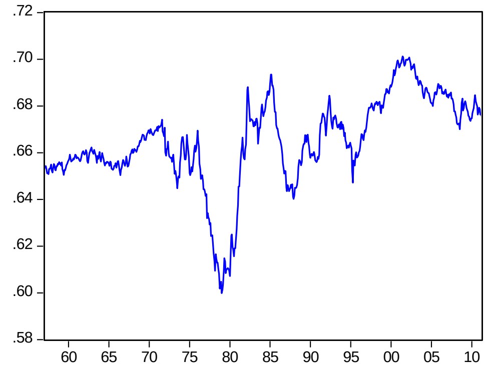
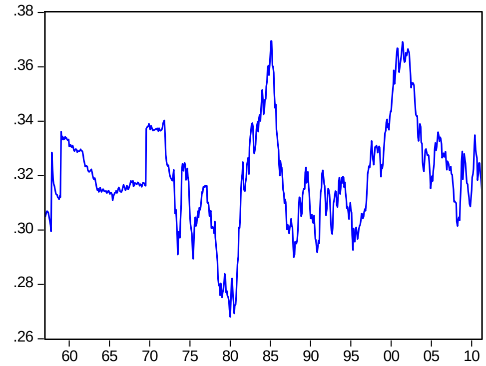
Australia_Portugal



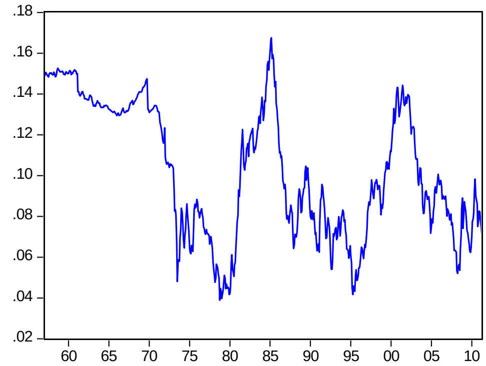
Belgium_Portugal



France_Portugal



Germany_Portugal



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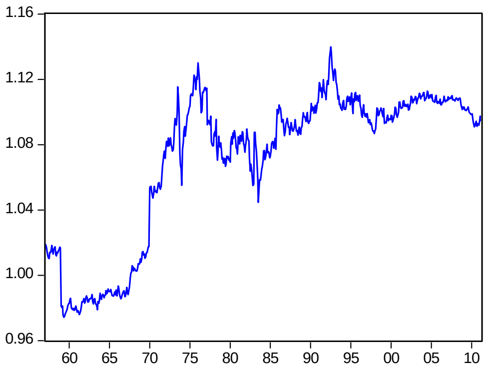

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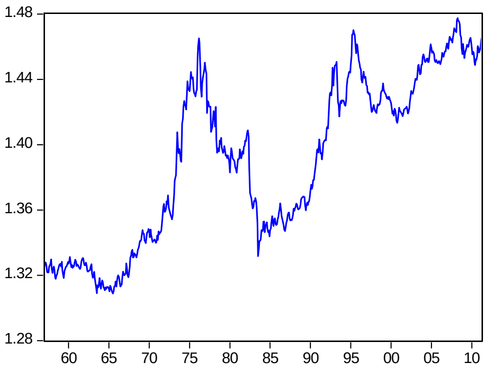
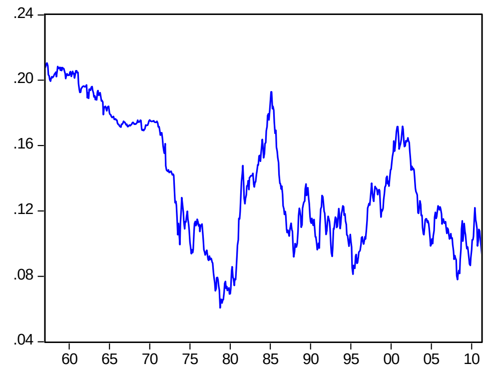
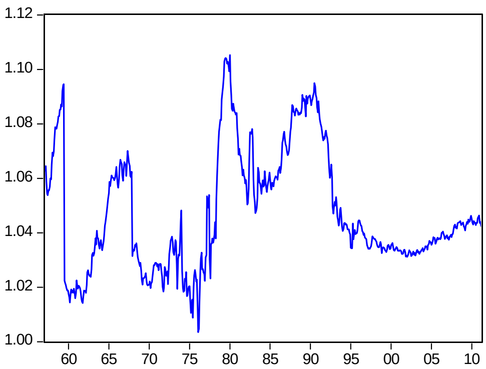
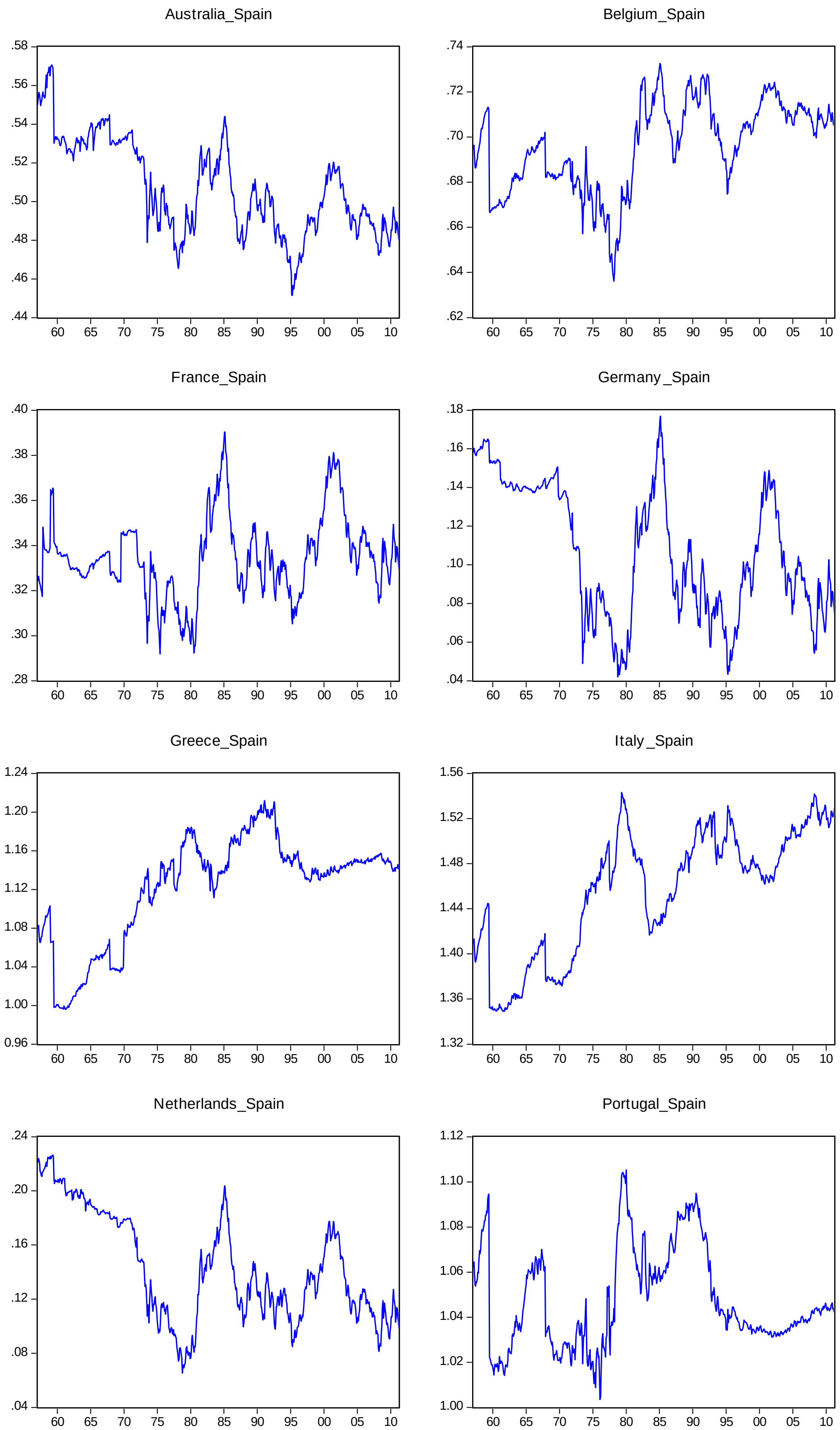


Netherlands_Portugal



Portugal_Spain




Australia_Spain
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Belgium_Spain
.74 .72 .70 .68 .66 .64 .62
France_Spain
.40 .38 .36 .34 .32 .30 .28
Germany_Spain
.18 .16 .14 .12 .10 .08 .06 .04
Greece_Spain
1.24 1.20 1.16 1.12 1.08 1.04 1.00 0.96
Italy_Spain
1.56 1.52 1.48 1.44 1.40 1.36 1.32
Netherlands_Spain
.24 .20 .16 .12 .08 .04
Portugal_Spain
1.12 1.10 1.08 1.06 1.04 1.02 1.00
60 65 70 75 80 85 90 95 00 05 10

Appendix 2

Asymptotic critical values of t_{NL} statistic

Fractile (%)	Raw data	De-meaned data	De-trended data
1	-2.82	-3.48	-3.93
5	-2.22	-2.93	-3.40
10	-1.92	--2.66	-3.13