Non-linear Panels in Economics and Finance

Souhaila Al Hesso

Department of Economics and Finance

College of Business, Arts and Social Sciences

Brunel University London, UK

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Abstract

This thesis firstly examines the Purchasing Power Parity (PPP). Secondly, it investigates the impact of military expenditure, healthcare expenditure, trade openness and political instability on economic growth. Finally, this thesis diagnoses the relationship between financial development and economic growth.

The second chapter examines Purchasing Power Parity (PPP) in a set of developed and developing countries. The chapter specifically examines whether PPP holds when applying linear and nonlinear methods in order to determine whether the nonlinearity of real exchange rate is the cause of exchange rates' inability to reject the null of unit root even when it is false. The results indicate that PPP holds in developed countries using linear methods. However, for developing countries, the results show that the behaviour of real exchange rates is nonlinear.

The third chapter examines the impact of the military expenditure, healthcare expenditure, trade openness and political instability on economic growth in NATO countries by applying System GMM and the dynamic panel threshold model, which allows for the non-linear threshold effect with endogenous regressors as well as threshold variables. The results from GMM indicate that there is a negative relationship between military expenditure and economic growth and a positive relationship between healthcare expenditure and economic growth as well as a positive relationship between trade openness and economic growth. Finally, there is no statistical relationship between political instability and economic growth. Furthermore, the nonlinear approach indicates that when healthcare spending and trade openness serve as threshold variables, the impact of military spending on economic growth is positive and significant.

The last chapter in this thesis examines the relationship between financial development and economic growth by applying the Panel-GARCH method. Two indicators for financial development are used as a proxy for financial development in investigating this relationship between financial development and economic growth. The results suggest that there is a positive and statistically significant relationship between financial development and economic growth uncertainty.

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List of Acronyms

CSD Cross-Section Dependence

EO Emirmahmutoglu and Omay's panel asymmetric nonlinear unit root test

GDP Gross Domestic Product

GMM Generalized method of moments

LDC Less-Developed Country

LOP Law of One Price

MENA Middle East and North African

NATO North Atlantic Treaty Organization

OECD Organization of Economic Co-operation and Development

OEE Omay, Corakci and Emirmahmutoglu's nonlinear panel test with breaks and cross-sectional dependence with the null hypothesis of a unit root

Panel-GARCH Panel Generalized Autoregressive Conditional Heteroskedastic

PCA Principal Component Analysis

PPP Purchasing Power Parity

SPAM Sequential Panel Selection Method

UO Ucar and Omay's nonlinear panel unit root test

WTO World Trade Organization

1 Introduction

This thesis consists of three chapters that investigate three different topics in economics and finance. Firstly, we examine the Purchasing Power Parity (PPP) puzzle applying linear and nonlinear methods. Secondly, this thesis examines defence-growth nexus using the System GMM and dynamic panel threshold model. Finally, this thesis investigates finance-growth nexus applying Panel-GARCH approach.

Chapter 2 focuses on the Purchasing Power Parity in developed and developing countries. The literature on the behaviour of real exchange rates has been a vital branch of international finance. The movements in real exchange rates are dynamic issues for the competitiveness, henceforth, the stability of trade flows. PPP is one of the earliest and simplest methods of exchange rate determination. However, it is difficult to find support for PPP. Therefore, it is one of the biggest puzzles in finance, known as Purchasing Power Parity Puzzle. We investigate PPP in 10 developed and 13 developing countries, where the developing countries are in the Middle East and North African (MEAN) region. We divided our developing countries into two samples depending on data availability. The data for developed countries starts from 1975:01 to 2016:12. The data for the first panel for developing countries starts from 1975:01 to 2016:07 and the second panel starts from 1991:01 to 2016:07. There are two motivations for investigating PPP in this chapter:

- Firstly, various economists claim that nonlinearity of the real exchange rate may be the cause of exchange rates' inability to reject the null of unit root when it is false. Thus, applying linear methods in examining PPP when the real exchange rate follows a nonlinear stationary process will be mis-specified. Furthermore, many researchers argue that nonlinear approaches are more efficient. For this reason, linear and nonlinear approaches with and without structural breaks are used to examine PPP in a set of developed and developing countries.
- Secondly, many studies argue that the validity of PPP depends on the degree of the development of the economies under the study, which makes PPP hold in developed countries, but it does not in developing ones.

In our analysis, we use a set of linear and nonlinear methods. Firstly, a linear approach contains panel unit root tests without structural breaks (LLC, IPS, Fisher and Hadri stationary test) and a panel unit root test with structural breaks. Secondly, we use four nonlinear panel unit root tests. We apply Ucar and Omay's (2009) nonlinear panel unit root test to examine the nonlinear hypothesis. We also apply Emirmahmutoglu and Omay's (2014) nonlinear panel unit root test that accounts for asymmetric nonlinear adjustment for real exchange rates and cross-sectional dependence bias encountered in panel data. Additionally, Omay *et al*.'s (2017) nonlinear panel unit root test with structural breaks and cross-sectional dependence utilised. Finally, Karavias and Tzavalis' (2014) panel unit root test that allows for a common break of known and unknown date in the deterministic component of the AR (1) model in addition to cross-correlation across the error terms is used for examining whether PPP holds.

The results for developed countries indicate that PPP holds when applying linear panel unit root without structural breaks approaches. However, for developing countries, the results from the linear panel unit root test suggest that PPP does not hold. Therefore, a linear panel test with breaks has been applied but the results indicate that PPP holds only in one series in sample 1 but it does not hold in sample 2. For this reason, nonlinear panel unit root tests are applied. The nonlinear methods for developing economies indicate that PPP holds in both samples. Our results are in the line with the literature in that the real exchange rates follow a nonlinear stationary process, see, for example, Sarno (2000), Holmes (2002), Leon and Najarian (2005), Liew *et al.* (2004) and Pay and Peel (2005), Bahmani-oskooee and Tanku (2007), He and Chang (2013) and Su *et al*. (2014).

We conclude that the degree of development matters when examining the validity of PPP in samples of developed and developing countries. Furthermore, we find that the behaviour of the exchange rate in developing countries is nonlinear, suggesting that nonlinear approaches are more efficient in investigating PPP validity.

Chapter 3 investigates issues related to the impact of the military expenditure, healthcare expenditure, trade openness and political instability on economic growth in 16 NATO countries using annual data. The impact of military expenditure on economic growth has received huge attention from researchers. However, there is no theory on the defence-growth nexus. On the one hand, many works consider military expenditure as a guarantee for peace and wellbeing. However, others argue that this expenditure is wasteful spending that affects the economy negatively as it decreases the spending on healthcare and social activities in the economy. There is another view which claims that there is no evidence of any relationship between military expenditure and economic growth. Therefore, the impact of defence expenditure on economic growth needs to be analysed more carefully.

Our purpose in this chapter is to examine whether the relationship between military expenditure and economic growth is nonlinear by using linear as well as nonlinear methods. We investigate the impact of the military expenditure, healthcare expenditure, trade openness and political instability on economic growth for NATO countries applying System GMM and dynamic panel threshold model. The results indicate that there is a negative relationship between military spending and economic growth when System GMM is applied. Secondly, there is a positive relationship between healthcare expenditure and economic growth. These results are in line with the literature, especially with Bhargava *et al*. (2001) and Atilgan (2016) among others who have found that there is a positive relationship between healthcare expenditure and economic growth. Furthermore, our results suggest that there is a positive relationship between trade openness and economic growth. This is in line with the literature, see, for example, Dollar (1992) and Warner (1995).

Finally, for political instability, we find that there is a significant correlation that causes multi-collinearity problems. Thus, Principle Component Analysis (PCA) has been used in order to drive three summary measurements. The results from System GMM for political instability indicate that there is no statistically significant relationship between the latter and economic growth in these countries. For this reason, political instability has been removed from our further analysis where nonlinear approaches are used.

Karavias and Tzavalis' (2014) nonlinear panel unit root test is applied to examine the nonlinearity of the series. The null hypothesis of a unit root is rejected in favour of its stationary alternative. For further assessment of the non-linear relationship between these variables and economic growth, a dynamic panel threshold model for Seo and Shin (2016) that allows for non-linear threshold effect with endogenous regressors besides threshold variables is used. This method is firstly applied using healthcare expenditure as a threshold variable. Secondly, we used this approach with trade openness as a threshold variable. The optimal threshold level for healthcare spending is 2.4492. Therefore, if healthcare spending is below the threshold, a 1% increase in the spending will enhance the economic growth by 0.3311%. However, when healthcare spending is above the threshold, a 1% increase in the spending will contribute to only 0.1169% of the economic growth.

Secondly, the results show that the optimal threshold level for trade openness is 0.3800. Accordingly, if the trade openness is below the threshold, a 1% increase in the trade openness will enhance the economic growth by 2.1090%. However, if the trade openness is above the threshold, a 1% increase in trade openness, will improve the economic growth by 0.6872% only.

Interestingly, when applying nonlinear GMM for Seo and Shin (2016), the results indicate that military expenditure has a positive effect on economic growth when healthcare expenditure and trade openness serve as threshold variables. This is in line with the literature, especially with Cuaresmanand and Reitschuler (2006), Aizenman and Glick (2006), Pieroni (2009), Alptekin and Levine (2012), who apply the nonlinear methods and argue that the effect of military expenditure on economic growth is positive and non-linear.

Chapter 4 focuses on the relationship between financial development and economic growth. This relationship has received massive consideration where the finance-growth nexus is one of the extremely argued matters in the literature of financial economics. Many researchers have tried to find whether financial deepening leads to economic growth. However, there is disagreement regarding the role that the financial system has in economic growth. Lucas (1988) suggests that the role of financial development in the economy is over-stressed. However, Levine (1997) claims that financial intermediaries develop economic efficiency so economic growth.

Many studies have applied panel approaches and only one study by Campos *et al*. (2012) utilised power ARCH (PARCH) to examine the relationship between financial development and economic growth. The purpose of this chapter is to apply the panel-GARCH method in investigating the relationship between financial development and economic development. To the best of our knowledge, none of the studies has attempted to investigate this relationship applying Panel-GARCH approach. This chapter contributes to the literature by analysing the relationship between financial development and economic growth in 17 countries applying the Panel-GARCH method. Two indicators of financial development as an independent variable are applied. The first indicator is the ratio of liquid liabilities (M3) to nominal GDP. The second indicator is private credit by deposit money banks to GDP. We also include the lagged values of economic growth as an independent variable in order to examine the effect of the lagged economic growth on the output growth uncertainty.

The ADF test indicates that all series have a unit root, so the first difference is applied to transfer them to stationary ones. Secondly, panel unit root tests show that these series are stationary. Finally, the results when applying panel-GARCH suggest that there is a positive and statistically significant relationship between financial development and economic growth uncertainty for the first and second financial development indicators. These results are in line with the literature that suggests that there is a positive relationship between economic growth and financial development. In particular, they lend support to studies conducted by Fry (1978), Herwartz & Walle (2014), Muhammad, Islam, & Marashdeh (2016) and Durusu-Ciftci, Ispir,

& Yetkiner (2017), who argue that financial development is definitely an essential determinant of economic growth.

Regarding the level effect for the first indicator, the results suggest that the first and second lagged values are also positive and significant. For the second indicator, the first lagged value for economic growth is positive and significant. This in line with Kormendi and Meguire (1985), Grier and Tullock (1989), Caporale and McKiernan (1996) and Fountas and Karanasos (2006), who find that increased volatility raises economic growth potential. However, the second lagged value of economic growth for the second financial development indicator is positive but is not significant which is similar to Grier and Perry (2000) results who find no evidence of any empirical relationship.

Finally, Chapter 5 summarises the main outcomes of this thesis and presents the main conclusions. Furthermore, it suggests some recommendations for future research that are beyond the scope of this thesis.

2 Purchasing Power Parity (PPP)

2.1 Introduction

Purchasing Power Parity (PPP) is a fundamental principle in international economics and finance, and it is one of the earliest and simplest models of exchange rate determination. PPP identifies national prices as determinants of the equilibrium exchange rate, which makes it essential to ensure PPP's validity. If PPP is rejected, this implies that exchange rates flow a random walk process and do not depend on relative prices.

However, empirically and beyond the developed economies, it is difficult to find support for PPP, which is one of the biggest puzzles in international finance and is well-known as the Purchasing Power Parity Puzzle. The results from empirical studies are valuable as they have policy implications in international finance and international trade. Munir and Kok (2015) argue that the results of PPP from empirical research can be used to predict the exchange rates in order to know whether a currency is undervalued or overvalued, which is essential for developing countries. Furthermore, comparing national income levels between economies is typically achieved by using PPP theory.

The existing literature on PPP theory has witnessed various ways to examine PPP empirically. One method of assessing PPP is by applying a univariate unit root test to the real exchange rate. Another approach for investigating PPP is the cointegration test by assessing the relationship between the nominal exchange rate and price index. The third method applied in testing PPP is the panel unit root method and panel cointegration approach since several of the existing works in PPP literature claim the low power of univariate unit root tests to support PPP. The final approach that has been applied to examine whether PPP holds is a nonlinear method. Several researchers argue that the nonlinearity of the real exchange rate may be the main cause of the inability of linear tests to reject the null of unit root when it is false.

In this work, PPP theory is re-examined in ten developed countries and thirteen developing countries, where all developing countries are in the Middle East and North African (MENA) region. The developed countries are Australia, Canada, Denmark, Japan, Mexico, Norway, Singapore, South Korea, Sweden and Switzerland. The developing countries are Kuwait, Morocco, Cyprus, Malta, Algeria, Egypt, Tunisia, Sudan, Saudi Arabia, Iran, Jordan, Pakistan and Turkey. The Middle East and North African countries provide interest for different reasons. Most of the nations in the MENA region have experienced an increase in trade and economic growth since more Middle Eastern and North African countries joined the

World Trade Organization (WTO). We divided the data for developing countries into two panels due to data availability. The data for the first panel for developing countries starts from 1975:01 to 2016:07 and the second panel starts from 1991:01 to 2016:07.

This thesis contributes to the literature by examining whether PPP holds for a panel of developed and developing countries. Data from developed and developing countries are used in order to examine whether the degree of development plays a role in the validity of PPP by using various linear and nonlinear methods. Secondly, we apply nonlinear approaches as many recent studies argue that the nonlinear behaviour of real exchange rates causes the rejection of PPP when linear methods are used. To the best of our knowledge, the empirical literature has not considered testing PPP in MENA countries using nonlinear panel unit root tests that allow for asymmetric and nonlinearity adjustment and nonlinear panel unit root tests that consider a structural break and cross-sectional dependence.

In terms of the linear approach, the ADF and KPSS unit root tests are applied in order to examine whether the real exchange rate is stationary or has a unit root. If the unit root null hypothesis is rejected in favour of the stationary alternative hypothesis, there is long-run mean reversion so long-run PPP holds. However, when the real exchange rates follow a random walk without reverting to the constant mean, the nominal exchange rates as well as the relative prices do not converge in the long run, so there is no evidence in favour of PPP. Secondly, in order to increase the power of the test, this research applies various linear panel unit root tests without breaks as well as linear panel unit root tests with breaks. Finally, this research uses nonlinear panel unit root tests in examining whether PPP holds. In terms of nonlinear tests, various nonlinear methods are used. Firstly, the UO nonlinear panel unit root is applied to examine the nonlinearity of the series. Secondly, we apply the EO nonlinear panel unit root test that accounts for asymmetric nonlinear adjustment for real exchange rates and CSD bias encountered in the panel data. Thirdly, we use the OEE nonlinear panel unit root test with structural breaks and cross-sectional dependence. Finally, we apply Karavias and Tzavalis' (2014) panel unit root test that allows for a common break of known and unknown dates in the deterministic component of the AR (1) model in addition to cross-correlation across the error terms.

On the one hand, the results from univariate unit root tests for developed countries show that PPP does not hold in these countries. However, when applying linear panel unit root tests without breaks, the results indicate that PPP holds in developed countries. On the other hand, the results from these tests show that there is no evidence in favour of PPP in our two considered panels for developing countries. Furthermore, the linear panel unit root test with breaks yields similar results where all the series in both panels have unit root except for one series in panel 1.

Nonlinear methods give better results where PPP holds in both panels for developing countries. Furthermore, the results indicate that the exchange rate of developing countries is stationary and has nonlinear behaviour.

This paper is organised as follows. Section 2 introduces the PPP theory and concept. Section 3 presents a review of the relevant literature. Section 4 provides the data. Section 5 describes the methodology. Section 6 provides an empirical analysis of the data and a report of the results, and Section 7 is the conclusion.

2.2 Purchasing Power Parity Concept

PPP stands on the law of one price (LOP), which states that identical goods should be sold for the same price in different countries when converted to a common currency. This means that the value of one currency being measured could be obtained through the price of goods in relevant countries.

However, in the real world, this condition is not very effective as we have transaction costs, taxes and other tariffs and nontariff barriers. The LOP can be written in algebraic form as follows:

$$P_{i,t} = S_t P^*_{i,t} \qquad I = 1, 2, 3, \ldots, N \qquad (2.1)$$

S_t is the nominal exchange rate, $P_{i,t}$ is the price of good *I* in the domestic currency at time *t* and $P^*_{i,t}$ is the price of good *I* in foreign currency at time *t*. Absolute PPP can be viewed as a generalisation form for the law of one price, and it assumes that given the same currency, a basket of the same goods will cost the same in any country. So, by equating the price of an aggregation of goods in one country to another, the absolute version for PPP can be as follows:

$$P_t = \Sigma_{n=1}^{N} W_n P_n$$

$$P^*_t = \Sigma_{n=1}^{N} W^*_n P^*_n$$

$$P_t = S_t P^*_t \qquad (2.2)$$

P_t and P^*_t are the prices of the same basket of goods in domestic and foreign countries which are proxy by a national price index such as CPI, producer price index such as PPI, or wholesale price index such as WPI. W_n and W^*_n are the consumption weights on individual goods across two countries. Relative PPP holds if the rate of depreciation in a currency relative to another is equal to the difference in price inflation between both currencies concerned. Taylor (2006) argues that according to relative PPP, when the increase in the domestic price is faster than the increase of foreign price, the exchange rate will depreciate proportionally.

In the academic literature, a popular form is to take log of the equation (2.2):

$$s_t = p_t - p_t^* \tag{2.3}$$

where lowercase denotes the log.

Taking the first difference of the equation (2.3) gives relative PPP in the log:

$$\Delta s_t = \Delta p_t - \Delta p_t^* \tag{2.4}$$

From equation (2.3) the real exchange rate defined in the level and logarithmic forms:

$$Q = \frac{sp^*}{p}$$

$$q = s - p + p^* \tag{2.5}$$

where q is the logarithm of the real exchange rate, s represents the logarithm of the nominal exchange rate, p refers to the logarithm of the price index in the domestic country, p^* represents the logarithm of the price index in the foreign country. When PPP holds, the real exchange rate is a constant, therefore, movements in the real exchange rate indicate deviations from PPP.

2.3 Literature Review

In this section, we present a review of the PPP literature depending on the type of the test applied.

2.3.1 Univariate Unit Root Tests

One of the earliest and simplest ways to examine whether PPP holds is the univariate unit root test. Most researches studies that have used this method have not obtained supportive results in favour of PPP. For example, Darby (1980), Adler and Lehmann (1983), Mishkin (1984), Hakkio (1984), Roll (1979), Meese and Rogoff (1988) and Akinboade and Makina (2006) found no evidence that supports PPP. However, some other studies have lent support to PPP. For instance, Abumustafa (2006) used monthly data from Jordan and applied the unit root test method and found that PPP holds.

The literature that applied unit root tests has been criticised due to the lowe power of these tests. The low power of the test fails to reject the null of the unit root when the series has a slow mean-reverting process. In order to overcome the low power of the unit root test, studies have applied different methods, which are explained in details in the next Sections of this chapter.

2.3.2 Univariate Cointegration Analysis

The cointegration test assesses whether there is a long-run relationship between the nominal exchange rate and the consumer price index. Two series may have a unit root, but the linear combination of both series may be stationary.

The cointegration equation applied to test the validity of PPP is:

$$s_t = \alpha + \beta \Delta p_t + e_t \qquad (2.6)$$

If the residual-based test indicates that e_t is stationary, s_t is said to be cointegrated with Δp_t and a long-run relationship exists between the nominal exchange rate and the price ratio.

On the one hand, studies have found evidence for PPP using the cointegration method. For instance, Bahmani-Oskooee (1993b), El-Sakka and McNabb (1994), Islam and Ahmed (1999), Zhou (1997) and Kargbo (2004, 2006) obtained supportive results for PPP. On the other hand, other researchers have not found any evidence in favour of PPP when using cointegration analysis. See, for example, Thacker (1995), Gan (1994), Bahrumshah and Ariff (1997) and Wang (2000), where PPP did not hold in their samples.

However, a recent empirical work done by Triki and Maktouf (2015) applied the fractional cointegration method to test whether PPP holds in 13 countries, and the results indicated that there was a long-run relationship between 9 out of 13 countries and PPP held but very weakly and the deviations from it did not follow a stationary process.

2.3.3 The Power Problem

Frankel (1986) argues that the univariate tests applied to investigate the stability of the real exchange rate may have low power in order to reject the null of unit root hypothesis even when it is false. He shows that if a single real exchange rate is mean reverting and performing very slowly, conventional testing will be unable to detect it and hence reject long-run PPP. Abuaf and Jorion (1990), Wu and Wu (2001) and Kalyoncu and Kalyoncu (2008) argue that rejection of PPP in previous studies reflects the poor power of the tests rather than being evidence against the PPP concept.

In order to deal with the low power of unit root tests, researchers have followed two strategies. Many have applied long-span datasets to deal with the low power of the tests. For instance, Frankel (1986) used data from 117 years and obtained evidence that supported PPP. However, the studies based on long-span data have been subjected to extensive criticism. Froot and Rogoff (1995) argue that long-span data is only available for industrialised countries. Additionally, the long-span data that have been used in testing PPP may generate structural changes in the long run equilibrium in the exchange rates due to the shocks that might exist. Due to these criticisms to long-span studies, researchers have followed another method to increase the power of the test which is based on expanding the number of cross-section dimensions and applying panel unit root tests, which we will explain in detail in the next section.

2.3.4 Panel Unit Root Tests

Most of the studies applied the panel unit root tests to gain statistical power by combining information across individual observations. The notable contributors in theoretical research on the panel tests include Maddala and Wu (1999), Levin, Lin and Chu (LLC, 2002), Im, Pesaran and Shin (IPS, 2003), Change (2004) and Hadri (2000) stationarity test.

An early work that applied the panel method was carried out by Abuaf and Jourion (1990), who tested PPP using the Seemingly Unrelated Regression (SUR) approach and they found evidence in favour of PPP. Frankel and Rose (1996) also obtained supportive results for PPP by examining PPP in 150 countries. Similar to the above studies, Luintel (2000) found evidence for PPP in eight Asian countries. Solakoglu (2006) and Chiu (2002) also generated supporting results in favour of PPP. On the other hand, other studies have rejected PPP when applying the panel unit root method. For instance, Baher and Mohsin (2004), Drine and Rault (2007), Holmes (2001) and Wu and Chen (1999) found no evidence for PPP. Wu and Chen (1999) applied panel unit root tests for eight countries and they found no evidence for PPP. Most recent work has been done by Bahmani-Oskooee *et al.* (2015), who have applied the panel unit root test, which accounts for sharp breaks and smooth shifts using data from 8 transition economies. They have found that PPP holds only in two countries.

2.3.4.1 Cross-Sectional Dependence (CSD)

Even though the panel data method is one way to increase the power of the test, it is subjected to cross-section dependence (CSD) criticism. O'Connell (1998) found that even the panel studies of PPP had given strong evidence of mean-reversion in real exchange rates; the panel approach failed to control cross-sectional dependence in the data. The researchers later developed different panel unit root tests to account for CSD, such as Phillips and Sul (2003), Bai and Ng (2004) and Pesaran (2007).

Chang and Song (2009) apply the panel unit root test that accounts for cross-sectional dependence to examine whether PPP holds in 37 countries for a period from 1973 to 1998 but they do not find evidence in favour of PPP. Snaith (2012) also does not get a supportive result for PPP by applying panel tests that account for cross-sectional dependence and structural breaks in 15 OECD countries. Westerlund and Narayanb (2015) also apply panel tests for 64 countries using monthly data but they find weak evidence for PPP. Furthermore, He *et al.* (2014) use monthly data from 15 Latin American countries from 1994 to 2010 and they find that PPP does not hold using the SURKSS panel unit root test, which is the Kapetanios *et al.* (2003, KSS) test based on the panel estimation approach of seemingly unrelated regressions (SUR). However, applying the SURKSS test with Fourier function, they get supportive results for PPP.

2.3.5 Panel Cointegration Tests

Some researchers have evaluated PPP applying panel cointegration methods such as Pedroni (1999, 2004) and Kao (1999). For example, Azali *et al*. (2001) used Pedroni's (1999) panel cointegration test for seven Asian countries and they found strong evidence for PPP. Nagayasu (2002) also found evidence for PPP, similar to Azali *et al*. (2001), by applying Pedroni's (2001) panel cointegration test in 17 African countries. However, applying Pedroni (1999) panel cointegration test for ten countries based in Asia, Basher and Mohsin (2004) did not find evidence for a cointegration relationship between nominal exchange rates and relative prices. Drine and Rault (2007) also applied a panel cointegration approach for 80 countries and they obtained similar results to Basher and Mohsin's (2004) in that PPP did not hold in the countries under consideration. Munir and Kok (2015) examine whether PPP holds in five ASEAN countries using panel unit root tests and the Lagrange multiplier (LM) cointegration test developed by Westerlund, which accommodates for CSD and multiple structural breaks.

They find that when applying panel unit root tests that do not control for CSD, PPP does not hold. Additionally, applying panel unit root approach that controls for CSD, the results indicate that there is no evidence for PPP for a period before the financial crisis but they find sufficient evidence to support PPP for a period after the crisis. Finally, when they apply the panel cointegration method, the result shows strong evidence for PPP but these outcomes have become apparent when the breaks and CSD are considered in their investigation through bootstrap approaches.

Dimtriou and Simos (2013) test the weak and strong forms of PPP hypothesis among the US and Japan. The authors apply the Gregory and Hansen (1996) and Hatemi (2008) cointegration methods. They find that the weak form of PPP hypothesis holds over the sample period from January 2000 to October 2012 where the strong PPP hypothesis is not rejected by using Dynamic Ordinary Least Squares, (DOLS) for the period after the US subprime crisis.

2.3.6 Nonlinear Methods

Even when advanced linear approaches, like the ones discussed before, have been applied in examining whether PPP holds, no strong evidence for PPP has been found. Many economists argue that nonlinearity of real exchange rate may be the cause of exchange rates inability to reject the null of unit root even when it is false. Chortareas *et al.* (2002) argue that applying linear methods in examining PPP when the real exchange rate follows a nonlinear stationary process will be mis-specified. Furthermore, several studies that have examined PPP have found evidence for the nonlinear adjustment of exchange rates when these exchange rates are applied to examine whether PPP holds. The nonlinearity of the exchange rates might be because of different reasons like trade barriers such as transport or transaction costs; see for example Dumas (1992) and Taylor (2004). Additionally, the nonlinearity of exchange rates may be due to official interventions (Taylor, 2004; Reitz and Taylor, 2008) or heterogeneity agents (Taylor and Allen, 1992; Kilian and Taylor, 2003). There are different methods to examine the nonlinearity of exchange rates such as Smooth Transition Regression (STR), Threshold Autoregressive (TAR), Logistic Smooth Transition Autoregressive (LSTAR) and Exponential Smooth Transition Autoregressive (ESTAR).

The literature review shows that most of the studies that apply nonlinear methods find support for PPP. For example, Sarno (2000) examines PPP in 11 Middle Eastern countries and he finds mean reversion of exchange rates when the nonlinear ESTAR test is applied. Holmes

(2002) also finds evidence for PPP in 13 Latin American countries when the STAR model is used. Liew *et al.* (2004) uses data from 11 Asian counties and found evidence for PPP when nonlinear KSS method is applied. Pay and Peel (2005) use the same method as in Sarno (2000) and find nonlinear support for PPP. Leon and Najarian (2005) use threshold autoregressions (TAR) and smooth transition regressions (STR) for the exchange rate in 26 countries and they do not find any evidence for PPP. Alba and Park (2005) also find evidence for nonlinear mean reversion for Turkey's exchange rate so PPP holds but they could not reject the unit root null when the ADF test is applied. Bahmani-oskooee and Tanku (2007) use Kapetanios, Shin and Snell's (2003, KSS) test for 24 countries and find that 11 out of 24 exchange rates are stationary, whereas when applying the ADF test the null is rejected only in 3 countries; therefore, the authors argue that nonlinear tests are more efficient in examining PPP. Change *et al*. (2010) use the nonlinear cointegration test and conclude that PPP holds in BRIC countries except China. Change *et al.* (2010) also find that PPP is valid in G7 countries when they apply the same nonlinear method in Change *et al*. (2010).

Change and Su (2010) also apply the nonlinear panel unit root test and find that PPP is valid in four countries in their sample. Furthermore, Cuestas and Regis's (2013) results indicate that PPP holds in OECD countries when the KSS nonlinear test is applied. He and Chang (2013) apply Ucar and Omay's (2009, UO) nonlinear panel unit root test and their results indicate that PPP holds in 14 countries considered in their sample. Liu *et al*. (2012) apply a nonlinear approach and the results suggest that PPP is valid in East Asian countries except Japan and the Philippines. Change *et al*. (2013) find that PPP does not hold in nine transition countries except Estonia and Hungry. Su *et al*. (2014) also find strong evidence for PPP in 61 countries applying the nonlinear unit root method. However, some studies could not get a strong supportive result when nonlinear methods were employed. For instance, Chang *et al.* (2006) apply data from 22 countries and find that PPP holds only in six cases out of 22 cases.

2.3.7 Cross-Sectional Aggregation in PPP Debate

Jean *et al.* (2005) argue that a dynamic aggregation bias should be accounted for when examining PPP puzzle. They show that the time series and panel methods substantially exaggerate the persistence of real exchange rates because of heterogeneity in the dynamics of disaggregated relative prices. When heterogeneity is taken into account, estimates of the real exchange rate half-life fall dramatically. Furthermore, the results show that corrected estimates are consistent with plausible nominal rigidities explaining the PPP puzzle.

2.4 Data

This chapter uses monthly real exchange rates for ten developed countries and thirteen developing countries in the Middle East and North African (MENA) region. The data from developed countries start from 1975:01 to 2016:12 and contains Australia, Canada, Denmark, Japan, Mexico, Norway, Singapore, South Korea, Sweden, and Switzerland. For developing countries, we divide our sample into two panels depending on data availability. The first panel starts from 1975:01 to 2016:07 and contains Turkey, Algeria, Cyprus, Kuwait, Malta, and Morocco. The second panel starts from 1991:01 to 2016:07 and includes Egypt, Sudan, Tunisia, Iran, Jordan, Saudi Arabia, and Pakistan.

We calculate the real exchange rates series using the nominal exchange rate and consumer price index (CPI) data from the International Monetary Fund database and DataStream. The real exchange rates are calculated as in equation (2.7):

$$q = s - p + p^{*} \qquad (2.7)$$

where q is the calculated real exchange rates in logarithm form, s is the logarithm of the nominal exchange rate, p is the price index in the domestic country in the logarithm form and p^{*} is the logarithm of price index in the foreign country.

2.5 Methodology

In our research, we apply various linear and nonlinear approaches. Firstly, we use unit root tests (ADF and KPSS) to check whether the exchange rates are stationary or not. Furthermore, we apply linear panel unit root tests with and without breaks in order to overcome the power problem of univariate unit root tests. In terms of linear panel unit root tests without breaks, we apply the following tests: Levin, Lin and Chu (LLC, 2002) with null of unit root and alternative no unit root, Hadri (2000) with null of stationarity, the Fisher-ADF test and Im, Pesaran and Shin (IPS, 2003) test under the assumption of CSD. Regarding the linear panel unit root test with breaks, Leybourne, Newbold and Vougas' (PLNV, 1998) panel unit root test is applied in order examine whether accounting for structural breaks changes the results and hence PPP holds. The motivation in applying univariate unit root in addition to panel unit root tests with and without breaks is to compare the results and investigate whether the power of the test and structural breaks play a role in determining whether PPP holds.

This research also applies nonlinear panel unit root tests as many researchers argue that nonlinearity of exchange rates is the cause of exchange rates' inability to reject the null of unit root even when it is false. In terms of nonlinear tests, we apply four nonlinear methods in examining whether PPP holds. Firstly, Ucar and Omay's (2009, UO) nonlinear panel unit root test has been applied. The null hypothesis for the test is that exchange rates are linear non-stationary and the alternative hypothesis is that they are nonlinear stationary:

H_0: Linear non-stationary

H_1: Nonlinear stationary

Secondly, Emirmahmutoglu and Omay's (2014, EO) panel asymmetric nonlinear unit root test is applied and reflected by F_{AE} and t_{AE} test statistics. If the null is rejected by F statistic (H_0: nonlinear unit root, H_1: stationary symmetric or asymmetric ESTAR nonlinearity), then we examine the null hypothesis of symmetric ESTAR nonlinearity in contrast to the alternative hypothesis of asymmetric ESTAR nonlinearity (H_0: symmetric ESTAR nonlinearity, H_1: asymmetric ESTAR nonlinearity).

The third nonlinear test is Omay, Corakci and Emirmahmutoglu's (2017, OEE) nonlinear panel test with breaks and cross-sectional dependence with the null hypothesis of a unit root.

Finally, we apply Karavias and Tzavalis' (2014) panel unit root test that allows for a common break of known and unknown date in the deterministic component of the AR (1) model in addition to cross-correlation across the error term.[1]

2.6 Empirical Results

Table 2.1 shows summary results for all linear and nonlinear methods that have been applied in the current chapter in order to examine whether PPP holds or does not hold for developed and developing countries.

[1] All nonlinear methods are explained in details in the Appendix

Table 2. 1 Summary off the results for developed and developing countries

Developed		*Developing*		
Univariate test				
			Panel 1	*Panel 2*
ADF	*PPP does not hold (for 8 out of 10)* *Corresponding Table 2.2*	***ADF***	*PPP does not hold (5 out of 6)* *Corresponding Table 2.4*	*PPP does not hold (5 out of 7)* *Corresponding Table 2.12*
KPSS	*PPP does not hold* *Corresponding Table 2.2*	***KPSS***	*PPP does not hold* *Corresponding Table 2.4*	*PPP does not hold* *Corresponding Table 2.12*
Linear Panel Unit Root tests				
			Panel 1	*Panel 2*
LLC	*PPP holds*	***LLC***	*PPP holds*	*PPP does not hold*
IPS	*PPP holds*	***IPS***	*PPP does not hold*	*PPP does not hold*
Fisher	*PPP holds*	***Fisher***	*PPP does not hold*	*PPP holds (AIC)*
Hadri	*PPP holds* *Corresponding Table 2.3*	***Hadri***	*PPP does not hold* *Corresponding Table 2.5*	*PPP does not hold* *Corresponding Table 2.13*
		Linear Panel Unit Root tests with Breaks		
			Panel 1	*Panel 2*
		PLNV	*Holds in Algeria* *Corresponding Table 2.6 and 2.7*	*PPP does not hold* *Corresponding Table 2.14*
		Nonlinear Panel Unit Root tests		
			Panel 1	*Panel 2*
		UO	*PPP does not hold* *Corresponding Table 2.8*	*PPP does not hold* *Corresponding Table 2.15*
		EO	*holds in Kuwait* *Corresponding Table 2.8 and 2.9*	*PPP does not hold* *Corresponding Table 2.15*
		EEO	*PPP does not hold* *Corresponding Table 2.10*	*PPP holds* *Corresponding Table 2.16*
		KT(2014)	*PPP holds* *Corresponding Table 2.11*	

2.6.1 Empirical Results for Developed Countries

2.6.1.1 Unit Root Tests

Computing the ADF and KPSS tests on a country-by-country basis using the real exchange rates from developed countries and the US as a numeraire, mixed results are obtained. Table (2.2) shows that eight series do not reject the null of a unit root according to both AIC and SIC. Applying the KPSS test, the obtained results confirm that these eight series have unit root as the null of stationarity is rejected. However, two series, Mexico and Singapore, show conflicting results when both ADF and KPSS tests are applied.

Table 2. 2 ADF and KPSS for real exchange rates for developed countries

Country	ADF (AIC)	ADF(SIC)	KPSS
Australia	-2.654359(5)	-2.654359(5)	2.670933***
Canada	-2.222930(13)	-1.910524(0)	0.377774***
Denmark	-2.146945(0)	-2.146945(0)	0.308196***
Japan	-2.301782(2)	-2.021787(0)	0.474384***
Mexico	-3.411455(10)**	-3.386825(0)**	0.238803***
Norway	-2.587675(2)	-2.329512(0)	0.109230***
Singapore	-3.029516(0)**	-3.029516(0)**	2.722978***
South Korea	-2.541019(1)	-2.386838(0)	0.548003***
Sweden	-1.655859(0)	-1.655859(0)	1.054795***
Switzerland	-2.411297(0)	-2.411297(0)	0.757114***

Column 2 and 3 present ADF test according to AIC and SIC with lag length shown in the brackets. Column 4 presents KPSS test and *, **, *** indicate rejection of the null at 10%, 5% and 1% respectively.

2.6.1.2 Linear Panel Unit Root Tests

2.6.1.2.1 Panel Unit Root Test without Structural Breaks

When applying panel unit root tests to developed countries, the results show that PPP holds in these countries as the null of unit root test is rejected, as shown in Table (2.3).

Table 2. 3 t-statistic for panel unit root tests for the real exchange rate for developed countries

Panel test	t-statistic using AIC	t-statistic using SIC
LLC test	-4.38913**	-4.27141**

IPS test	-2.74998**	-2.40213**
Fisher ADF	33.6604**	30.6442**
Hadri test		
	Hadri Z-stat	45.0467
	Heteroscedastic Consistent Z-stat	20.5178

*, **, *** indicate rejection of the null of the unit root for LLC, IPS and Fisher ADF test and the null of stationarity for Hadri test at 10%, 5% and 1% respectively.

2.6.2 Empirical Results for Developing Countries

2.6.2.1 Developing Countries in Panel 1

2.6.2.1.1 Unit Root Tests

Upon applying the ADF and KPSS tests for developing countries, the results do not confirm whether PPP holds or not. Table (2.4) shows the results from the ADF and the KPSS tests for panel 1. They indicate that all the real exchange rates except Maltese real exchange rates are not stationary. However, the results for Maltese real exchange rates are mixed as the ADF test shows that the real exchange rate is stationary whereas the KPSS test shows that it has unit root, so we carry panel unit root tests for Maltese real exchange rates as well as the other exchange rates in the panel 1 as no strong evidence has been obtained in favour of PPP.

Table 2. 4 ADF and KPSS for real exchange rate for panel 1

Country	(ADF)AIC	(ADF)SIC	KPSS
Algeria	-0.872572(13)	-0.708189(0)	2.471036***
Cyprus	-2.100990(0)	-2.100990(0)	0.774372***
Kuwait	-2.186515(13)	-2.186515(13)	2.659234***
Malta	-2.798574(4) *	-3.196138(2) **	0.478196***
Morocco	-1.951917(0)	-1.951917(0)	1.038543***
Turkey	-1.792600(8)	-2.185169(0)	0.639954***

Note: column 2 and 3 present ADF test according to AIC and SIC with lag length shown in the brackets. Column 4 presents KPSS test and *, **, *** indicate rejection of the null at 10%, 5% and 1% respectively.

2.6.2.1.2 Linear Panel Unit Root Tests

Panel Unit Root Test without Structural Breaks

For panel 1, the null of the unit root has not been rejected when applying the LLC test but has been rejected when IPS and Fisher-ADF test methods are used. However, the null of stationarity for Hadri approach has also been rejected so we could not get strong evidence whether PPP holds when the results from LLC, IPS and Hadri tests are compared since they show conflicting results as shown in the Table (2.5).

Table 2. 5 T-statistic for panel unit root tests for the real exchange rate for the panel (1)

Panel test	t-statistic using AIC	t-statistic using SIC
LLC test	-0.25018	-0.56828
IPS test	-1.81868**	-2.36152***
Fisher ADF	21.0389**	28.2445**
Hadri test		
	Hadri Z-stat	26.6686***
	Heteroscedastic Consistent Z-stat	12.0594***

*, **, *** indicate rejection of the null of the unit root for LLC, IPS and Fisher ADF test and the null of stationarity for Hadri test at 10%, 5% and 1% respectively.

Panel Unit Root Test with Structural Breaks

For panel 1, when potential breaks in the real exchange rates are considered and the PLNV linear panel unit root test with structural breaks is applied, the results show that PPP holds in the countries in panel 1 with *p*-value 0.0096 and 0.0097 using SIC and AIC respectively as shown in Table (2.6).

Table 2. 6 PLNV nonlinear Panel unit root test with structural breaks for panel 1

$\bar{t}_{LNV}$	
SIC	**AIC**
-3.2323	-3.232
(0.0096) **	(0.0097) **

The numbers in parentheses denote the bootstrap P-value. *, **, and *** denote rejection of the unit root null hypothesis at 10%, 5% and 1% significance levels respectively. The $\bar{t}_{LNV}$ is for PLNV panel unit root test with structural breaks.

However, Taylor and Sarno (1998) argue that panel unit root tests are joint tests and are unable to determine the mix of stationary and non-stationary series in the panel. Therefore, it is essential to classify the non-stationary and stationary series when the unit root null hypothesis is rejected. In doing so, a sequential panel selection method (SPSM) is used. There are three steps of the SPSM procedure as follow:

1. Estimate the test’s equation for all series in the panel. Once the null hypothesis is rejected, the non-stationary alternative hypothesis is not rejected, the procedure stops and all the series are non-stationary. However, if the null hypothesis is rejected, the procedure should continue to step 2.
2. Take out the series with the minimum *t*-statistic and continue to step 3.
3. Repeat stage 1 for the remaining series in the panel or stop the procedure if all the series drop from the sample.

So, applying the SPSM method as in Table (2.7), we find that only Algeria is stationary with the value of -3.2323 and *p*-value of 0.0096.

Table 2. 7 PLNV Panel unit root test with structural breaks results based on the SPSM approach for the panel (1)

Sequence	Series	$\bar{t}_{LNV}$	Min. LNV
1	Algeria	-3.2323(0.0096) **	-4.3265
2	Kuwait	-3.198(0.200)	-4.1350
3	Malta	-2.964(0.443)	-3.4219
4	Morocco	-2.812(0.524)	-3.1851
5	Turkey	-2.625(0.620)	-2.7439
6	Cyprus	-2.507(0.678)	-2.507

*, **, and *** indicate rejection of the null hypothesis at 10%, 5% and 1% significance levels respectively. The series presented in the second column are organized in descending order depending on the univariate counterparts of each panel unit root test used on the real exchange rates in the study. Min. LNV represents the individual minimum LNV statistics applied in order to remove the individual series for the SPSM and PLNV test.

Nonlinear Panel Unit Root Tests

Firstly, the UO nonlinear panel unit root test is applied to examine the null hypothesis of a unit root. The results from the nonlinear UO panel unit root test as shown in Table (2.8) indicate that PPP fails to hold in panel 1.

Table 2. 8 Nonlinear panel asymmetric unit root tests for panel 1

$\bar{t}_{UO}$		$\bar{F}_{AE}$		$\bar{t}_{AE}^{as}$	
SIC	**AIC**	**SIC**	**AIC**	**SIC**	**AIC**
-0.7554	0.768	3.1951	2.9807	2.0035	1.891
(0.552)	(0.526)	(0.069) ***	(0.091) ***	(0.016) **	(0.025) **

The numbers in parentheses denote the bootstrap *P*-value. *, **, and *** indicate rejection of the null hypothesis of unit root at 10%, 5% and 1% significance levels respectively.

We check whether the outcome of the test changes when we shift to the EO panel asymmetric nonlinear unit root test. The results from the EO panel asymmetric nonlinear unit root test are presented in Table (2.8) and reflected by $\bar{F}_{AE}$ and $\bar{t}_{AE}^{as}$ test statistics. It can be seen that $\bar{F}_{AE}$ test rejects the null hypothesis of the nonlinear unit root against the alternative of globally stationary symmetric or asymmetric nonlinearity. Furthermore, the result from $\bar{t}_{AE}^{as}$ test shows evidence that supports the nonlinear and asymmetric behaviour of the real exchange rates where the null hypothesis is symmetric ESTAR nonlinearity and the alternative is asymmetric ESTAR nonlinearity.

Table 2. 9 Panel asymmetric nonlinear unit root test results based on the SPSM approach for panel 1

Sequence	$\bar{F}_{AE}$	$\bar{t}_{AE}^{as}$	Max. $\bar{F}_{i,AE}$	series
1	3.1951 (0.01699) ***	2.0035(0.0160) **	6.8570	Kuwait
2	2.4627(0.1598)	n.a.	3.8891	Morocco
3	2.106(0.276)	n.a.	3.7900	Cyprus
5	1.422(0.512)	n.a.	1.5315	Turkey
6	1.313(0.4326)	n.a	1.3127	Malta

The numbers in parentheses denote the bootstrap *P*-value. *, **, and *** represent a rejection of the null hypothesis of unit root at 10%, 5% and 1 % significance levels respectively.

The results from the SPSM technique once the nonlinear panel asymmetric test is used are reported in Table (2.9). The null hypothesis of the unit root test is rejected when the test is first used to the whole panel with a value of 3.1951 and *p*-value of 0.01699. Additionally, the symmetric nonlinearity null hypothesis is also rejected with a value of 2.0035. After employing the SPSM technique, the result indicates that Kuwait is stationary. Then, Kuwait is removed and the test is applied to the remaining series. However, the test cannot reject the null hypothesis with a value of 2.4627 and bootstrap *p*-value of 0.1598. So, the SPSM procedure shows evidence of nonlinear stationary asymmetric reversion for Kuwait only out of 6 countries in panel 1. Finally, the OEE nonlinear panel unit root test with structural breaks is applied for the rest of the countries in panel 1. The null of unit root has not been rejected as presented in Table (2.10) for the entire panel so we conclude that the exchange rates in panel 1 are not stationary and they have a unit root, which means that PPP does not hold.

Table 2. 10 Nonlinear OEE nonlinear panel unit root test with structural breaks for panel 1

***F*-OEE**	
SIC	**AIC**
5.081(0.376)	5.232(0.217)

*, **, and *** represent a rejection of the null hypothesis of unit root at 10%, 5% and 1 % significance levels respectively.

Karavias and Tzavalis (2014) Nonlinear Panel Unit Root Test

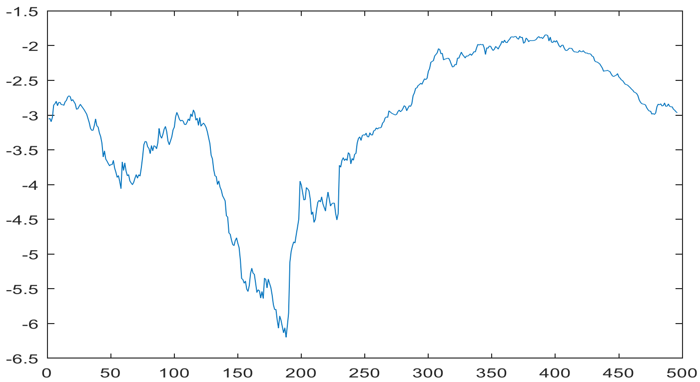
As we could not find a supportive result for PPP applying the previously mentioned nonlinear tests, we use Karavias and Tzavalis' (2014) nonlinear panel unit root test that allows for a common break of known and unknown date in the deterministic component of the AR (1) model in addition to cross-correlation across the error terms. The results from Fig.1 indicate that the null hypothesis of a unit root is rejected. The estimate of statistic z is (-6.1965) for panel 1, which is smaller than the critical value of this statistic at 5%. Therefore, this result indicates that PPP holds in panel 1.

Table 2. 11 Karavias and Tzavalis panel unit root test with a break for panel 1

Statistic *z* for panel 1
-6.1965**

*, **, and *** represent a rejection of the null hypothesis of unit root at 10%, 5% and 1 % significance levels respectively.

Figure 2. 1 Estimated of Z(λ) over all possible break points for panel 1



2.6.2.2 Developing Countries in Panel 2

2.6.2.2.1 Unit Root Tests

The results from panel 2 are in Table (2.12). Both the ADF and the KPSS tests confirm that five series are not stationary: Egypt, Jordan, Tunisia, Pakistan and Saudi Arabia. However, for the rest of two series, we get conflicting results as we reject the null for both tests in the case of Iran and Sudan. Therefore, we carry out panel tests for these two series as well as the other five series where we get strong results in that they have unit root.

Table 2. 12 ADF and for KPSS for real exchange rate for panel 2

Country	AIC	SIC	LM-Stat
Egypt	-1.429755(3)	-1.257232(0)	1.892553***
Iran	-3.096114(0) **	-3.096114(0) **	0.866096***
Jordan	-0.242329(1)	-0.5885(1)	1.177528***
Pakistan	-1.556127 (0)	-1.556127 (0)	1.356044***
Saudi Arabia	-1.889147(13)	-1.237222(1)	1.969855***
Sudan	-3.703607(3) **	-3.407691(1) **	1.736162***
Tunisia	-1.513517(0)	-1.513517(0)	1.752581***

Column 2 and 3 present ADF test according to AIC and SIC with lag length shown in the brackets. Column 4 presents KPSS test and *, **, *** indicate rejection of the null at 10%, 5% and 1% respectively.

To sum up, no evidence is found to support PPP using ADF and KPSS methods in panel 2. Our results are in line with the previous literature in that univariate unit root tests fail to find supportive results in favour of PPP. See, for example, Meese and Rogoff (1988), Froot and

Rogoff (1995), Sarno and Taylor (2002), Christidou and Panagiotidios (2010), Carvalho and Julio (2012) and Hoque and Banerjee (2012).

2.6.2.2.2 Linear Panel Unit Root Tests

Linear Panel Unit Root Test without Breaks

The results from panel 2 are presented in Table (2.13). The null of unit root has not been rejected through LLC and IPS tests. The null hypothesis of unit root also cannot be rejected applying Fisher-ADF test through AIC but it has been rejected through SIC. Furthermore, the null of stationarity of Hadri test is rejected for panel 2. To sum up, we could not conclude whether PPP holds in panel 2 applying LLC, IPS and the Fisher-ADF panel unit root tests and stationarity panel test for Hadri.

Table 2. 13 t-statistic for panel unit root tests for the real exchange rate for panel 2

Panel test	t-statistic using AIC	t-statistic using SIC
LLC test	-1.10778	-0.67060
IPS test	-1.23953	-0.85213
Fisher ADF	24.0767**	20.7333
Hadri test		
	Hadri Z-stat	7.67926***
	Heteroscedastic Consistent Z-stat	12.0492***

*, **, *** indicate rejection of the null of unit root for LLC, IPS and Fisher ADF test and the null of stationarity for Hadri test at 10%, 5% and 1% respectively.

Linear Panel Unit Root Test with Breaks

Table 2. 14 PLNV nonlinear Panel unit root test with structural breaks for panel 2

$\bar{t}_{LNV}$	
SIB	**AIC**
-3.0425 (0.206)	-2.103(0.259)

The numbers in parentheses denote the bootstrap *P*-value. *, **, and *** denote rejection of the unit root null hypothesis at 10%, 5% and 1 % significance levels respectively.

For panel 2, the results from PLNV confirm that PPP does not hold in the countries in panel 2 as in Table (2.14).

Nonlinear Panel Unit Root Test

The results from Table (2.15) indicate that by applying nonlinear UO panel unit root test; the PPP fails to hold in panel 2. We check whether the outcome of the test changes when the EO panel asymmetric nonlinear unit root test is applied and the result is presented in Table (2.15) and reflected by $\bar{F}_{AE}$ and $\bar{t}_{AE}^{as}$ test statistic. However, the results indicate that the adjustment processes for the real exchange rates for the countries in panel 2 are not nonlinear and asymmetric since the null hypothesis cannot be rejected.

Table 2. 15 Nonlinear panel asymmetric unit root tests for panel 2

$\bar{t}_{UO}$		$\bar{F}_{AE}$		$\bar{t}_{AE}^{as}$	
SIC	**AIC**	**SIC**	**AIC**	**SIC**	**AIC**
-0.1711	-0.255	1.0535	1.411	*NA*	*NA*
(0.912)	(0.891)	(0.946)	(0.822)		

The numbers in parentheses denote the bootstrap *P*-value. *, **, and *** represent a rejection of the null hypothesis of unit root at 10%, 5% and 1 % significance levels respectively.

Since no supportive result has been reported in panel 2 when the above tests are applied, OEE nonlinear panel unit root tests with structural breaks have been used. The null of a unit root is rejected as presented in Table (2.16) for the entire panel. However, as noted earlier, panel-based unit root methods are joined tests of the null of unit root for all the units in the panel and thus these panel-based approaches are incapable to define the mix of stationary and non-stationary series in the panel. For this reason, we continue by applying the SPSM test that is introduced by Chortareas and Kapetanios (2009) in order to examine the time series possessions of the real exchange rates of the countries in panel 2. The SPSM test groups the entire panel into a set of stationary and non-stationary series.

Table (2.16) presents the results from the SPSM method when the OEE nonlinear panel unit root test with structural breaks has been applied. The unit root null hypothesis is rejected after the test is applied first for the entire panel with bootstrap *p*-value of 0.024. After employing the SPSM method, the results show that Saudi Arabia's real exchange rate is stationary with the *F*-value of 7.380. Then, when Saudi Arabia’s real exchange rate is uninvolved from the panel and the OEE test is applied for the remaining set of units, the test rejects the null hypothesis with a value of 8.0227 and *p*-value of 0.015 and Pakistan is found to be stationary. The results from the OEE test based on SPSM show that the null of a unit root is rejected again with a p-value of 0.012 and Egypt is stationary. After Egypt is removed from the panel, the results from SPSM indicate that the null is rejected with *a p*-value of 0.009 and Tunisia is found to be stationary. We run the test again and the results show that PPP still holds in the remaining set of series and Iran is stationary with *F* value 14.402 and *p*-value 0.009. After removing Iran, the results from OEE based on SPSM reject the null and Jordan is found to be stationary with *a p*-value of 0.001. Finally, when Jordan is removed and the OEE test is run again based on the SPSM method, we find that PPP holds and Sudan is stationary with a *p*-value of 0.002.

Table 2. 16 OEE nonlinear panel unit root tests based on SPSM method for panel 2

Sequence	Series	$\boldsymbol{\bar{F}_{1p,a}}$	Min.$\boldsymbol{\bar{F}_{1p,a}}$
1	Saudi	7.380 (0.024) **	0.6429
2	Pakistan	8.0227 (0.015) **	0.8617
3	Egypt	10.031 (0.012) **	2.5067
4	Tunisia	11.912 (0.009) *	4.4420
5	Iran	14.402 (0.009) *	7.0604
6	Jordan	18.072 (0.001) *	10.7801
7	Sudan	25.364 (0.002) *	25.364

*, **, and *** represent the rejection of the null hypothesis of unit root at 10%, 5% and 1 % significance levels respectively. In each panel, the series specified in the second column are organised in descending order using the univariate counterparts of each panel unit root method used on the real exchange rates in the study. Min. $\bar{F}_{1p,a}$ denotes Sollis's (2004) individual minimum *F* that is used to remove of the individual series for the SPSM and the OEE-*F* test.

Our results for developing countries are in line with the literature in that the real exchange rates follow a nonlinear stationary process. See, for example, Sarno (2000), Holmes (2002), Leon and Najarian (2005), Liew *et al*. (2004) and Pay and Peel (2005), who find evidence for PPP when nonlinear methods are applied. Bahmani-oskooee and Tanku (2007) also find that 11 out of 24 exchange rates are stationary, the null is rejected only in 3 countries when applying ADF test; so, the authors argue that nonlinear tests are more efficient in examining PPP. In line with this, Cuestas and Regis (2013) also obtain supportive results for PPP in OECD countries when the KSS nonlinear test is applied. Similarly, He and Chang (2013) find evidence for PPP using nonlinear tests for 14 countries. Su *et al.*'s (2014) results indicate that PPP holds when nonlinear methods are considered. Furthermore, our conclusion is also consistent with He *et al*. (2014), where they find evidence in favour of PPP and they conclude with highlighting the importance of considering the nonlinearity and structural breaks in examining the PPP. For future research, panel AR models can be estimated for the real exchange rate.

2.7 Conclusion

Purchasing power parity (PPP) is an extensively examined theory in the literature. PPP is an essential concept as knowing the degree of persistence in the real exchange rates is a vital issue. Furthermore, when the real income of the economies is compared, PPP exchange rates are applied and if PPP is not valid, then this comparison is meaningless. Consequently, it is significant to test the PPP theory accurately.

The current PPP literature has used many methods to test whether PPP holds applying the time series methods and panel data methods. However, several researchers argue that there are many shortcomings which linear methods cannot handle when examining PPP, especially if the real exchanges rates have nonlinear behaviour for different reasons.

The aim of this chapter is to empirically test whether PPP holds in ten developed countries and thirteen developing countries in the Middle East and North African (MENA) applying linear and nonlinear approaches. We divided our sample for developing countries into two panels due to data availability. This chapter uses a bundle of univariate unit root tests (ADF and KPSS tests), linear panel unit root tests without structural breaks (LLC, IPS, the Fisher-ADF test and Hadri stationary test) and linear panel unit root test with structural breaks (PLNV). Finally, this paper applies four nonlinear panel unit root tests in examining PPP (UO, EO, OEE and Karavias and Tzavalis (2014) nonlinear panel unit root tests).

The motivation for applying nonlinear methods is that several researchers argue that using linear methods to investigate PPP validity when the real exchange rate follows a nonlinear stationary process will be mis-specified. Therefore, we applied nonlinear approaches in our investigation for PPP validity as well as linear methods. Furthermore, the motivation for utilising data from developed and developing countries is to investigate whether the degree of the development of the countries matters when examining PPP, which makes PPP hold in developed countries but does not hold in developing economies.

Several results have been obtained by applying these tests. Firstly, utilising ADF and KPSS tests, no evidence has been found in favour of PPP in developed and developing countries. However, upon using linear panel unit root tests without structural breaks for developed countries, the results indicate that PPP holds in these countries.

On the other hand, when these linear panel unit root tests are applied for developing countries, the results indicate that PPP does not hold in both panels. However, applying the linear panel unit root test that accounts for structural breaks, there is supportive evidence for PPP in panel 1 but not for panel 2. Since panel unit root tests are joint tests so we are unable to determine the mix of stationary and non-stationary series in the panel. Consequently, it is important to identify the non-stationary and stationary series when the unit root null hypothesis is rejected by applying SPSM. When SPSM is implemented in order to identify the exchange rate that is stationary in panel 1, only Algeria is found to be stationary.

Finally, nonlinear panel unit root tests give better results. The results from UO, EO and OEE nonlinear panel unit root method do not support PPP in panel 1. However, when applying Karavias and Tzavalis' (2014) panel unit root test, which accounts for structural breaks and correlation of the error terms for panel 1, the results show that PPP holds for this panel.

The results from EO and OEE nonlinear panel unit root tests for panel 2 are different, as more supporting evidence has been found in favour of PPP. The results show that all the exchange rates in panel 2 are stationary as the null hypothesis is rejected for the entire panel and for each exchange rate in panel 2 by applying SPSM. Therefore, we conclude that PPP holds in all the countries in this panel.

To conclude, the results show that PPP holds in all developed countries using linear panel unit root tests. However, the results indicate that PPP does not hold in developing countries when linear approaches are applied. The results also reveal that the exchange rates of developing countries where PPP holds are stationary and have nonlinear behaviour. The results of this research are in line with the previous literature in that when examining PPP, the nonlinearity of real exchange behaviour and the structural breaks should be taken into account as ignoring them might yield misleading results. Additionally, the nonlinear approach is more efficient in examining PPP. Furthermore, the degree of development of the countries matters when examining the validity of PPP as it makes PPP hold in developed economies but it is not valid in developing ones.

3 Military Expenditure and Economic Growth

3.1 Introduction

Military expenditure is spending by governments to protect the country from internal and external threats and it is an important issue for the countries' economy. Over the past few decades, the relationship between military expenditure and economic growth has received considerable attention from researchers. Many economists believe that defence spending has a negative impact on economic growth, which is in contrast with Benoit's (1978) view. Benoit (1978) found that military expenditure had an unexpected positive effect on the economic growth of 44 less developed countries (LDCs).

However, there is neither a theory on the defense-growth nexus nor empirical evidence on the impact of military expenditure on economic growth. For example, Smith (1980) claims that military spending protects nations from external threats as well as increases foreign investment. By contrast, Deger and Smith (1983) and Deger (1986) suggest that military expenditure transfers resources from the civilian to the defence sector and reduces private savings; hence it has a negative impact on the economic growth. On the other hand, Yildirim *et al.* (2005), among other studies, find no evidence of any relationship between military expenditure and economic growth.

By the end of the Cold War, the countries have decreased their military expenditure. However, many countries still spend a significant amount of scarce resources on defence expenditure. Many researchers argue that this expenditure might reduce the spending in social activities, which will consequently affect economic growth. For this reason, the impact of military expenditure on economic growth needs to be analysed more carefully.

In his chapter, we address the effect of military expenditures, healthcare expenditures as well as the effect of trade openness and political instability on economic growth for NATO countries applying the Generalized Method of Moments (GMM) and Seo and Shin's (2016) non-linear panel GMM approach which allows for non-linear threshold effect with endogenous regressors and threshold variable.

There are different studies that have examined the effect of military expenditures, healthcare expenditures, trade openness and political instability on economic growth, but to the best of our knowledge, there is no study in this area that has applied the nonlinear panel GMM method for Seo and Shin (2016). Therefore, by applying nonlinear panel GMM, we examine if the relationship between military spending and economic growth is nonlinear.

The results of applying the System GMM show that military expenditure has a negative impact on economic growth. However, healthcare expenditure and trade openness have a positive effect on the economic growth of NATO countries. However, there is no statistically significant effect of political instability on economic growth. Therefore, political instability has been removed from our sample in the further investigation using a nonlinear approach.

Next, we apply Karavias and Tzavalis' (2014) panel unit root test that accounts for structural breaks and correlation of the error terms to study the nonlinearity of the series. The null hypothesis of a unit root is rejected in favour of its stationary alternative. As Karavias and Tzavalis' (2014) test shows that these series are stationary and nonlinear, we next examine the non-linear relationship between these variables and economic growth using a dynamic panel threshold model for Seo and Shin (2016). We applied two models. In the first model, healthcare spending is the threshold variable whereas in the second model, trade openness serves as the threshold variable. The results indicate that the optimal threshold level for healthcare spending is 2.4492. Thus, if healthcare spending is below the threshold, a 1% increase in the spending will enhance the economic growth by 0.3311%. On the other hand, when healthcare spending is above the threshold, a 1% increase in the spending increases the economic growth by 0.1169% only. Furthermore, we assess the non-linear relationship between trade openness and economic growth and find that the optimal threshold level for trade openness is 0.3800. Consequently, if the trade openness is below the threshold, a 1% increase in the trade openness will enhance the economic growth by 2.1090%. However, if the trade openness is above the threshold, a 1% increase in trade openness will improve the economic growth by 0.6872% only.

Since military expenditure has a negative impact on economic growth, we did not use it as a threshold variable when Seo and Shin (2016) method applied. Additionally, as there is no statistically significant effect of political instability on economic growth, we did not use political instability as a threshold variable when Seo and Shin (2016) approach.

Our results for military expenditure using a dynamic threshold model are different when compared with the results obtained by applying the system GMM. When healthcare expenditure and trade openness are served as threshold variables, the coefficient of military spending is positive and statistically significant. Therefore, we conclude that the relationship between military expenditure and economic growth is positive and nonlinear, which is in line with the literature; see, for example, Cuaresmanand and Reitschuler (2006), Pieroni (2009) and Alptekin and Levine (2012) among others, who argue that the impact of military spending on economic growth is positive and nonlinear.

The chapter is organised as follows: Section 2 is the literature review, Section 3 describes the dataset, Section 4 presents the methodology, Section 5 discusses the empirical results and Section 6 is the conclusion.

3.2 Literature Review

3.2.1 Military Spending and Economic Growth

Military spending is expenditure by governments to deal with internal and external threats and it is a vital matter for any country's economy. This expenditure drains the reserves of foreign exchange especially in developing countries as they import the arms. The long-standing and growing literature regarding the effects of military spending on economic growth is complex and difficult to summarise. This is because the studies in the literature are different in the empirical methods they applied, the periods they employed and the theoretical approaches they followed. However, much of economic theory does not have a clear role for military spending as a unique economy activity. The dominant neoclassical method argues that the state is a rational body that balances the costs and benefits of military spending. Therefore, this approach sees the arms spending as a public good. The Keynesian and institutionalist approach sees that increased military spending will increase the capacity utilisation and profit so it will increase investment and growth. The Marxist method argues that military expenditure is vital due to its role in capitalist development.

Dunne (1996) reviews 54 studies and demonstrates that military spending has no significant effect on growth. Furthermore, Dunne and Uye (2010) review 103 studies about the relationship between defence expenditure and economic growth. They find that 39% of the cross-country studies and 35% of the case studies provide evidence that military spending has a negative effect on growth and only 20% of both types of studies show a positive effect. Dunne and Tian (2013) update and extend their survey in 2010 with 103 studies to cover 168 studies and cover non-developing countries. 44% of the cross-country studies and 31% of the case studies provide evidence that defence expenditure has a negative effect on economic growth and only around 20% -25% of cross-country and case studies show a positive effect. They also divide the studies into two panels. Panel A contains studies published between 1973 and 2006 and panel B has studies published since 2006. Panel A shows that 39% of the cross-country studies being negative and 40% of the case studies provide unclear evidence. Case studies show ambiguous results for 41% of the work. Panel B shows that 55% of the cross-country studies being negative and 17% of the reviews show a positive relationship and 28% unclear results. For case studies, 18% of the cross-country studies are found to have a negative relationship and 41% of the studies show a positive relationship and 41% unclear results. They conclude that cross-country studies give negative effect and case studies tend to show a positive impact.

However, Dakurah *et al.* (2001), using data from 62 developing countries find that there is a unidirectional causality in the opposite direction in ten economies, a unidirectional causality from defence expenditure to growth in thirteen economies, bidirectional causality in seven countries but no evidence of a causal relationship between economic growth and defence spending in the remaining eighteen economies. Therefore, they conclude that a causal relationship between economic growth and military spending cannot be inferred in the countries under the study. Change *et al*. (2014) also examine the causal relationships between military spending and economic growth for the period 1988–2010 in China and G7 economies (France, Germany, Italy, Canada, Japan, USA, and the UK). They apply panel causality method, which considers CSD as well as heterogeneity through economies under the study. the neutrality theory is supported in three economies France, Germany, and Italy. However, the outcomes for Canada and the UK support the growth detriment theory. They claim that the linkage between military expenditure and economic growth cannot be generalised over the economies.

Lai *et al.* (2005) and Dunne and Tian (2015) follow nonlinear methods in examining the relationship between military expenditure and economic growth. Applying linear and non-linear methods for the period from 1953 to 2000, Lai *et al*. (2005) demonstrate the existence of unidirectional causality from military expenditure to economic growth. Dunne and Tian (2015) consider the possibility of group heterogeneity in examining the impact of military expenditure on economic growth for a panel of 106 countries over the period 1988–2010. They apply an exogenous growth model and dynamic panel data methods. The whole panel is broken down into different groupings depending on a range of relevant factors (openness and aid, conflict experience, natural resources abundance) in addition to the robustness of the results. Their results indicate that military spending has a negative effect on economic growth in the short and long run. On the other hand, using the nonlinear method, Alptekin and Levine (2012) find that military expenditure does not reduce economic growth and the effect of military spending on economic growth is positive. Furthermore, they find that the effect of military expenditure on economic growth is non-linear.

Cuaresmanand and Reitschuler (2006) argue that the use of linear models can lead to misleading results on the impact of defence spending on growth. Hence, nonlinear models are found to generate better results regarding the relationship between defence spending and economic growth. Pieroni (2009) also highlights that the relationship between military expenditure and growth is nonlinear. Thus, the nonparametric methods are a useful tool to avoid functional misspecifications in the growth equation. In line with this, Aizenman and Glick (2006) examine the non-linearities in an extended version of Barro and Sala-i-Martin (1995) and find that military spending in the existence of threats raises economic growth.

Atesoglu and Mueller's (1990) results reveal that there is a significant and positive relationship between defence expenditure and economic growth. Atesoglu (2009)'s findings also suggest that defence expenditure has a positive effect on economic growth.

Ramey (2011) uses the VAR approach and the Ramey–Shapiro narrative approach to estimating the effects of government spending. The results provide explanations for the different outcomes between standard VAR approaches and the narrative method for detecting shocks to government spending. The main difference is that the narrative approach shocks capture the timing of the news about future rises in government spending much better. As the VAR approach captures the shocks too late, it misses the initial drop in consumption and real wages that happens as soon as the news is learned. The results also show that the shocks imply that temporary rises in government spending generally cause declines in output, hours, consumption and investment. So none of the results indicates that government spending has multiplier effects beyond its direct effect.

Yildirim and Öcal (2016) as well investigate the relationship between economic growth and military expenditure for the period from 2000 to 2010 by considering the spatial dimension. Data from 128 countries are used and the augmented Solow model is applied. They find that the spatial Durbin model is the best applicable model; thus the typical least-squares model is mis-specified. The results show that military expenditure has a positive effect on economic growth. Niloy *et al*.'s (2007) analysis also indicate a positive and significant link between defence spending and growth for a panel of 30 emerging economies over the 1970s and 1980s. This is in line with Benoit's (1978) and Fredriksen and Looney's (1982) works.

Khalid and Noor's (2015) results are in line with Yildirim and Öcal's (2016) and Niloy *et al*.'s (2007), who find a positive relationship between these two variables. Khalid and Noor (2015) integrate the impact of defence spending on economic growth applying the system GMM estimators for the period between 2002 and 2010 for 67 emerging countries. Their results indicate that military spending has a positive and significant effect on economic growth.

More recently, Augier et al. (2017) examine whether military spending contributes to the economic growth in China applying the Feder-Ram model and augmented Solow models for the period from 1952 to 2012. The Feder-Ram method gives an inadequate explanation of China's economic growth. However, the augmented Solow model shows that a 1% increase in military expenditure causes a 0.15-0.19% increase in economic growth.

Oliver and Paul (2017) argue that the arms imports have no positive impact on military expenditures if the country receives it as military aid, are bought on credit, are kept of the books for domestic or international political aims, involve a barter deal, and are offset by spending cuts in other parts of the military budget. The impact of imports on defence spending varies for different country groups and for different time periods. There are positive as well as negative relations between arms exports and military expenditures which depend on the security externalities of exports, the regime type, the economic situation, and political lobbying efforts. Regarding the exports, there is evidence that the relationship between military expenditures and arms exports in democratic states: increases in arms exports caused a reduction in military expenditures. On the other hand, in non-democratic countries, arms exports do not tend to be linked to lower military spending.

Ramey (2018) investigated whether government spending multipliers vary depending on the state of the economy using historical quarterly data spanning more than 120 years in the U.S. the results show that the WWII government spending did help lift the economy out of the Great Depression, not because multipliers were so large, but because the amount of government spending was so great. Although multipliers may be modest in magnitude, they are positive.

3.2.2 Health Care Expenditure and Economic Growth

The relationship between health care expenditure and economic development is known as the health-led growth hypothesis (HLGH) and has been discussed in the literature. Theoretically, the claim is that health care spending stimulates economic growth since the investment into health care can rise human as well as physical capital accumulation resulting in economic development. People tend to place larger value on the quality of their life when the economy of their country develops. Therefore, there will be a higher demand for medical services especially in advanced economies with higher income.

According to the health-led growth hypothesis, a healthier population infers a growth in the total factor productivity. Fogel (1997) argues that economic growth leads to a rise in per-capita income, which results in the consumption of a higher quantity of nutritious food. Consequently, health improves with an increase in income. According to Lucas (1998), an improvement in the individual human capital enhances an individual's own efficiency as well as increases the productivity of entire production factors. This implies that healthy individuals are motivated to improve their educational achievement and skills because of their exception to benefit from health investment over a longer period. Moreover, Schultz (1999) shows that a healthier population can work harder, longer and more productively, think more clearly and have higher learning abilities, which improves the efficiency of the economy's human capital. Morand (2005) finds that any improvement in medical services, as it is part of technological progress, could feed and enhance the economic growth of any country. Murthy (2009) highlights that rising national healthcare expenditure could raise the quality of life, general safety and general welfare and reduce morbidity and infant mortality rates as a health outcome.

The existing literature, e.g. Gerdtham (2000), Baltagi (2010) and Kumar (2013), uses the panel data method to examine the validity of the HLGH for OECD economies. However, the alternative group of the literature applies country-specific time series data, e.g. Samudram (2009) and Tang (2011). The time series approaches could be more appropriate to test the HLGH as panel data approaches work as if all countries are homogenous and do not account for the dynamism of country-specific properties.

Bhargava *et al*. (2001) and Bloom *et al.* (2001) examine the effects of health care spending on economic growth rates applying panel data approach. Their results indicate that there is a positive relationship between health and economic growth. Erdil and Yetkiner (2009) also apply the panel method using the Granger causality method to investigate the relationship between health expenditures and GDP per capita. They find that the dominant type of causality is bidirectional. Wang (2011) also examines this relationship in 31 countries from 1986 to 2007 applying panel regression as well as quantile regression analysis. His results reveal that health expenditure growth will encourage economic development but economic development will decrease health spending growth. Moreover, in economies with a low level of growth, health expenditure growth will decrease economic growth.

Clemente *et al.* (2004) also investigate the effect of healthcare expenditure on economic growth in many OECD countries applying the cointegration method. They find a long-run relationship between the health care expenditure and GDP only when they admit the presence of changes in elasticities of the applied model. Recently, Odubunmi *et al*. (2012) have applied the multivariate co-integration technique in Nigeria and found that there is at least one co-integrating vector describing a long-run relationship between them. More recently, Atilgan *et* *al.* (2016) have investigated the health-led growth hypothesis for Turkey applying autoregressive-distributed lag approach (ARDL). Their results indicate that a 1 per cent increase in per-capita health expenditure will result in a 0.434 per cent increase in per-capita GDP, which makes them conclude that the health-led growth theory is held in Turkey. Khan *et al*. (2016) investigate the relationship between health care expenditure and economic growth for SAARC countries applying the panel cointegration and panel causality analysis. They find that there is evidence of unidirectional causality running from per-capita GDP to health care expenditure in these countries in the short run. Furthermore, their results indicate that income elasticity with respect to health care expenditure is less than unity, so their study shows that it is health care expenditure that is necessary rather than luxury goods.

3.2.3 Trade Openness and Economic Growth

The relationship between trade openness and economic growth has long been a matter of disagreement between economists. Different econometric tools have been applied to ascertain a robust relationship between economic growth and trade openness. Various aspects can explain why the literature has not been able to provide a clear answer to whether trade openness matters for reaching better growth in any country. Firstly, the methodologies applied to estimate models that examine this relationship are still open to doubt. Greenaway *et al.* (2002) argue that the inconsistent evidence regarding the relationship between growth and trade openness may be due to the use of diverse indices of liberalisation in addition to the problem of miss-specification. Secondly, the poor quality of data especially in low-income developing economies, the existence of non-linearity in the trade-growth relationship and the sample heterogeneity can explain up to some degree the disagreement over the relationship between the trade openness and economic growth among the researchers.

Evidence of a positive relationship between trade openness and economic growth has been demonstrated by early studies in the literature. For example, Dollar (1992) and Warner (1995) provide such evidence. They argue that open economies grow faster than closed ones. Moreover, Warner (1995) shows that open developed economies have grown at 2.29 per cent per year where developing economies have grown at 4.49 per cent per year at the same time. However, closed developing economies have grown at 0.69 and developed countries have grown at 0.74 per cent per year. Edward (1998) demonstrated that open economies have higher total factor productivity comparing with closed ones.

However, these studies by Dollar (1992), Warner (1995) and Edwards (1998) have been criticised by Rodrink and Rodriguez (2000) who argue that the positive relationship between trade openness and economic growth is due to inappropriate econometric techniques used or due to the measures of openness applied in these studies. Warner (2003) analysed the criticism of Rodrink and Rodriguez (2000) and he argued that they ignored the fact that there was a negative relationship between trade restrictions and economic growth. Furthermore, Wacziarg and Welch (2003) demonstrate that the economies with liberalised trade policies over the period 1950-1998 have annual growth rates at 1.5 percentage points better. Krueger and Berg (2003) review the trade growth relationship literature with a focus on cross-country and panel regressions. They find that trade influences economic growth. Furthermore, Gries and Redlin (2012) examine the causal dynamics among trade openness and economic development using data from 158 economies over the period from 1970 to 2009. By applying panel error correction models with GMM estimation, their results show that there is a positive and significant bidirectional causality relationship between trade openness and economic growth. Therefore, they conclude that trade liberalisation plays an important role in growth in the long-run. Bruckner and Lederman (2012) also find a positive relationship and demonstrate that a one per cent increase in openness affects the short-run economic growth by 0.5 per cent per year and the long-run economic growth by 0.8 per cent per year.

On the other hand, some studies have found that there are bidirectional causalities between the two variables. For example, Habibi (2015) finds that according to panel error correction models, there are bidirectional causalities between economic growth and trade openness in whole panels with an exception for low-income countries. Habibi employs data from 120 countries using four subpanels according to the income. Furthermore, unidirectional causation from trade openness to economic growth is found in low-income countries. More recently, Nikolaos and Pavlos (2016) have investigated the relationship between trade openness and economic growth for 13 European Union countries. They apply panel cointegration and causality methods to test the long run as well as the causal relationship. They find that there is a cointegrating vector between trade openness and economic growth. Furthermore, panel Granger causality confirms that there is a unidirectional causal relationship from trade openness to economic growth both in the short and in the long-run.

3.2.4 Political Instability and Economic Growth

Political stability has an important role in the economic growth of a country as an unstable political system could seriously harm an economy. According to the Economist (2009), Political instability is a type of events that threaten a government or current political order and it is the propensity of a government to collapse. Political instability leads to uncertainty, which, as a result, reduces private investment and affects economic growth. Asteriou and Price (2001) argue that political uncertainty has a direct effect on economic growth rather than on investment and causes uncertainty of policies and decision making. Alesina and Perotti (1996) and Barro (1991) show that for risk-averse agents, the possibility of a change of governments threatens future policies and makes agents prefer to invest in a safer environment rather than in a risky place.

There are many channels in which political instability can impact the economic development of a country. Aisen and Veiga (2013) argue that the total factor productivity is the central channel in which political instability influences economic growth negatively. Additionally, in developing countries, government expenditure, consumption and trade tend to decay through political instability. Moreover, political instability affects growth as well through physical and human capital accumulation. Cooray *et al*. (2017) have recently used data from African countries to examine the effect of political institutions, civil liberties, political rights as well as democracy on trade openness in addition to labour force participation rate (LFPR). The outcomes show that developed political institutions improve LFPR and increase a country's economic development. They conclude that political stability forms a favourable atmosphere for business to attract domestic as well as foreign investment opportunities and generate employment chances and movement into the cities, which consequently stimulate economic growth.

A few studies, such as Goldsmith (1987) and Londregan and Poole (1989), found that there is no relationship between political instability and economic growth. Moreover, Londregan and Poole (1989) found that low economic growth rises the possibility of political instability.

However, various researches have concluded that there is a relationship between political instability and economic growth. For example, Alesina (1996) investigates the relationship between these two variables in a sample of 113 countries and they find that countries with higher political instability have lower economic growth. He concludes that economies with an unsteady political atmosphere may decrease investment activities and that weak economic activity may result in government failure. On the other hand, he finds that low economic growth does not impact political instability. Radu (2015) analyses the influence of political stability on economic growth in Romania, applying multivariate regression. The results indicate that political stability plays a vital role in the growth of the economy since a stable political environment leads to building a coherent and continuous way for sustainable development.

Applying advanced econometric method with system GMM, Aisen and Vegia (2013) also find that political instability decreases GDP growth rates in 169 countries. Similarly, Uddin *et al*. (2017) use GMM approach. They apply dynamic two-step system-GMM and quantile regression to investigate the effect of political stability on economic growth for an unbalanced panel of 120 developing countries for the period starting from 1996 to 2014. Their results show that political stability is pivotal for economic growth. Furthermore, political instability is likely to impact economic development through the channels of investment as well as human capital accumulation in emerging economies. Therefore, they suggest that emerging economies need to improve the political and economic institutions besides human capital growth.

3.3 Data

Annual data on GDP growth, military expenditure, trade openness, healthcare spending and political instability variables over the period from 1996 to 2010 were gathered for 16 NATO economies as follows: Canada, Czech Republic, Denmark, France, Germany, Greece, Hungary, Italy, Luxembourg, Netherlands, Norway, Poland, Portugal, Turkey, United Kingdom and United States. The data was obtained from OECD and World Bankdata base.

The dependent variables is:

- GDP growth for NATO countires.

The explanatory variables are:

- Military expenditure (MIL): Military Expenditures for NATO Countries as %GDP.
- Trade openness (TO): the standard ratio of exports plus imports as a share of GDP.
- Healthcare expenditure (HE): Health Expenditures as %GDP.

- Political instability (PI): consists of the number of assassinations (as), number of general strikes (str), number of guerrilla warfare (gw), number of government crises (gc), number of purges (pur), number of riots (rit), number of revolutions (rev) and number of Anti-Government Demonstrations (agd).

Table 3. 1 Descriptive Statistics of Variables

Variable	Obs	Mean	Std.Dev.	Min	Max
GDP growth	288	0.0640636	0.1231189	-.2999667	1.06269
MIL	288	0.0209201	0.0085477	0.005	0.0480693
HE	288	2.118098	0.286434	0.9202828	2.83615
TO	288	0.5849253	0.2826866	0.1597659	1.413223

Political instability

For political instability indicators, there is a strong significant correlation amongst these indicators (see Table 2), which leads to multi-collinearity problems. Hence, the Principal Component Analysis (PCA) has been applied to counteract the correlation and to drive one or more summary measures from the indicators highlighted in aforementioned Table.

Table 3. 2 Cross-correlation between variables

	as	str	Gw	gc	pur	rit	rev	agd
As	1.0000							
Str	0.1039	1.0000						
Gw	0.4337	0.2275	1.0000					
Gc	0.0720	0.1304	0.0834	1.0000				
Pur	0.0637	0.1587	0.0541	0.1979	1.0000			
Rit	-0.0121	0.0976	0.0118	0.2375	0.2607	1.0000		
Rev	0.4645	0.0904	0.5281	0.1193	0.1406	-0.0070	1.0000	
Agd	0.0266	0.3542	0.0991	0.0594	0.3025	0.1576	0.0376	1.0000

We can see from Table (3.3) that the Eigenvalue of Components 1, 2 and 3 is higher than 1. So these three components should be kept as a proxy of political instability.

Table 3. 3 Component Eigenvalues

Component	Eigenvalue	Difference	Proportion	Cumulative
Comp1	2.18242	0.579446	0.2728	0.2728
Comp2	1.60297	0.520612	0.2004	0.4732
Comp3	1.08236	0.251976	0.1353	0.6085
Comp4	0.830385	0.109531	0.1038	0.7123
Comp5	0.720854	0.144284	0.0901	0.8024
Comp6	0.57657	0.00734546	0.0721	0.8744
Comp7	0.569225	0.13401	0.0712	0.9456
Comp8	0.435214	.	0.0544	1.0000

The advice indicated by the scree plot below would also be to pick Components 1, 2 and 3 because the elbow in the curve happens at Component 4. Thus, these three components account for a disproportionately large amount of the combined variance and capture as much as possible the original variance in these indicators.

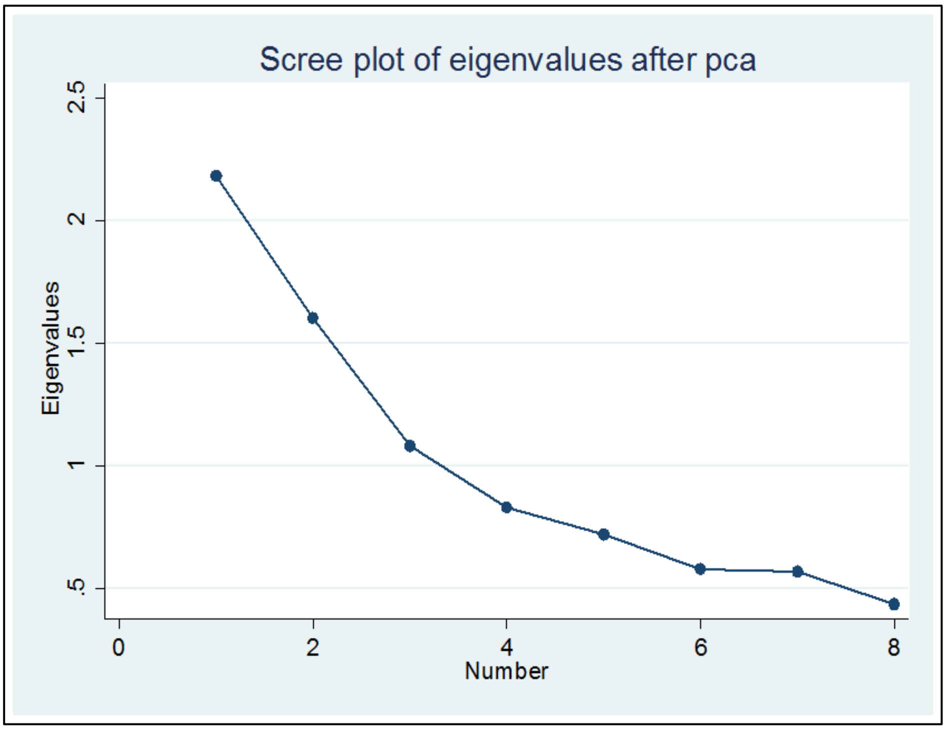


Figure 3. 1 Eigenvalues

Table 3. 1 The results for the unit root tests for each series under this study

		Military	Trade openness	GDP growth	Healthcare
United States	Levels	-2.366759(1)	-2.305392	-3.389174**	-0.184967(1)
	1st dif	-4.814213(0)***	-5.961203**	-5.441848**	-4.391856 (0)**
Canada	Levels	-1.042281(0)	-0.797635	-3.489241**	-0.356340(0)
	1st dif	4.157966(0)***	-3.287415**	-4.923700**	-5.430334(0)***
Czech Republic	Levels	-0.770989(0)	-3.087730	-7.487765***	-2.405825(0)
	1st dif	-4.081580(0)***	-4.039867**	-8.591267***	-4.364745(0)**
Denmark	Levels	-1.057588(0)	-1.988905	-3.413297**	-0.335310(0)
	1st dif	-6.187290(0)***	-4.311840**	-5.800558**	-6.728655(0)***
France	Levels	-0.825072(0)	-2.155608	-3.259072**	-1.807904(0)
	1st dif	-6.970597(0)***	-5.176343**	-5.556426**	-4.642900(0)**
United Kingdom	Levels	-0.564685(0)	-1.590728	-3.334257**	0.610568(0)
	1st dif	-4.892136(0)***	-4.473076**		-6.314877(0)***
Germany	Levels	-1.147792(0)	-0.770691	-3.527483**	-2.002481(0)
	1st dif	-12.44159(0)***	-4.695887**		-4.058102(4)**
Greece	Levels	-1.591597(0)	-2.60505	-3.550652**	-1.478679(0)
	1st dif	-7.891699(0)***	-3.835252**		-5.715438(0)**
Hungary	Levels	-4.613412(0)***	-1.431438	-2.646457	-2.169738(0)
	1st dif	-5.321181(0)***	-4.427762**	-4.359968**	-4.493716(0)**
Italy	Levels	-2.446440(0)	-2.442078	-3.442344**	-4.493716(0)**
	1st dif	-9.710778(0)***	-4.627163**		-0.426294(0)
Luxembourg	Levels	-1.561285(0)	-1.831006	-3.631156**	-1.636421(0)
	1st dif	-6.334185(0)***	-4.875449**		-7.403117(0)***
Netherlands	Levels	1.600359(9)	-1.601578	-3.744972**	1.570967(0)
	1st dif	-2.683747(8)**	-4.457475**		-4.843101(0)**
Norway	Levels	-0.957199(0)	-3.221337**	-3.534234**	-1.521904(0)
	1st dif	-5.661387(0)**			-7.218000(0)***
Poland	Levels	-3.663937(0)	-0.713786	-4.201926**	-2.331196(0)
	1st dif	-7.349528(1)***	-4.570572**		-5.612028(0)**
Portugal	Levels	-0.979688(0)	-3.630124**	-3.625473**	-1.107182(0)
	1st dif	-7.633658(0)***			-5.797803(1)***
Turkey	Levels	-2.991680(1)**	-3.608634**	-4.476722**	-0.328242(0)
	1st dif	-8.970484(0)***			-4.922679(0)**

*, **, *** indicate rejection of the null of unit root for ADF test at 10%, 5% and 1% respectively.

Applying the ADF test, the results indicate that the military expenditure, healthcare spending, trade openness are stationary as shown in Table (3.4).

Table 3. 2 The results for the panel unit root tests

	SIC			AIC		
Panel tests	LLC	IPS	ADF	LLC	IPS	ADF
GDP	-13.12***	-10.014***	154.4***	-11.42***	-8.309***	132.04***
MIL	-4.9738*	-2.2841**	50.36**	-4.6591**	-2.231**	49.30**
TO	-3.8584**	-4.286***	113.007***	-3.0493**	-3.8208**	106.51**
HE	-12.554**	-10.103**	148.35***	-8.9218**	-8.237***	126.41***

*, **, *** indicate rejection of the null of unit root at 10%, 5% and 1% respectively.

Applying LLC, IPS and ADF panel unit root tests, the results show that all the series are stationary as presented in Table (3.5).

3.4 Methodology

3.4.1 Arellano Bond Dynamic Panel GMM Estimator

The GMM was introduced by Arellano and Bond (1991), Arellano and Bover (1995) and Blundell and Bond (1998/2000). The GMM can be illustrated as follows:

$$y_{it}= \beta_1 y_{it-1} + \beta x_{it} + \eta_i + \varepsilon_{it} \quad (3.1)$$

where y_{it} is the GDP growth, x_{it} contains MIL, HE, TO and PI which represent military expenditure, healthcare expenditure, trade openness and political instability respectively. η_i represents individual effects and ε_{it} is the error term.

There are two types of GMM. The first one is introduced by Balestra-Nerlove (1996) in which the instruments for the lagged dependent variables are the lagged values of the exogenous variables. The other type is introduced by Arellano and Bond (1991) where the instruments are the dependent variables lagged by two or three periods.

Arellano and Bond (1991) suggested the first difference transformation for Eq. (3.1) to eliminate the individual effects:

$$\Delta y_{it} = \beta_1 \Delta y_{it-1} + \beta \Delta x_{it} + \Delta\varepsilon_{it} \quad (3.2)$$

where Δ is the operator for the first difference. Although differencing removes the country-specific effect, it presents a new bias; that comes from the high correlation of $\Delta\varepsilon_{it}$ with the lagged dependent variable $\Delta y_{i,t-1}$. Another bias is the possible existence of endogeneity in other explanatory variables.

Following the literature, we apply a vector of errors Δv_i for countries *i* in the first difference model:

$$\Delta v_{i=} \begin{bmatrix} v_{i3} - v_{i2} \\ v_{i4} - v_{i3} \\ \vdots \\ v_{iT} - v_{iT} \end{bmatrix} = \begin{bmatrix} \Delta y_{i3} - a\Delta y_{i2} \\ \Delta y_{i4} - a\Delta y_{i3} \\ \vdots \\ \Delta y_{iT} - a\Delta y_{iT} \end{bmatrix} \tag{3.3}$$

Consider A_i as a matrix of instruments for variables i.

$$A_i = \begin{bmatrix} y_{i1} & 0 & & 0 & & & 0 \\ 0 & y_{i1} & y_{i2} & 0 & & & 0 \\ & & & \ddots & & & \\ 0 & \dots & & 0 & y_{i1} & y_{i2} & \cdots & y_{iT-2} \end{bmatrix} \tag{3.4}$$

The rows in equation 3.4 are corresponding with equation 3.2.

Under the assumptions that (a) the error term in equation (3.2), ε, is not serially correlated, and (b) the explanatory variables, x, are weakly exogenous, Arellano and Bond introduced the following moment conditions:

$E\left[Y_{i,t-s}\Delta v_i\right] = 0$ for $s \geq 2$ $and\ t = 3, \dots, T,$

$E\left[X_{i,t-s}\Delta v_i)\right] = 0$ for all s and $t = 3, \dots, T,$

There are various shortcomings with this difference GMM estimator, Alonso-Borrego and Arellano (1999) and Blundell and Bond (1998) highlight that in the case of persistent explanatory variables, lagged levels of explanatory variables are weak instruments for the regression equation in differences. This affects the asymptotic and small sample performance of the difference estimator. Hence, the variance of the coefficients rises asymptotically.

To deal with the potential bias related to GMM estimator, the System GMM of Arellano and Bover (1995) and Blundell and Bond (1998) is applied. The essential concept for the system's GMM estimator is to simultaneously evaluate a structure of two equations: one equation in levels and the other equation in first-differences.

When the instrument matrix is created, the two-step estimator is estimated. The two-step GMM estimator is asymptotically more effective compared to the one-step GMM estimator. To ensure the validity of the system GMM, we need to check two conditions. First, the first-differenced residuals show negative as well as significant first-order autocorrelation since the model will typically be over-differenced. However, there should be no second-order autocorrelation. Second, the instruments and the error term should be uncorrelated. Hansen's (1982) J-test of over-identifying restrictions can be applied to check this condition. This test statistic is robust to issues of heteroskedasticity and autocorrelation comparing with the test used to determine instrument validity by Sargan (1964).

The specific linear dynamic model used for our estimation can be defined as follows:

$$GDP_{it} = \alpha + \beta GDP_{i,t-1} + \beta_1 MIL_{i,t} + \beta_2 HE_{i,t} + \beta_3 TO_{i,t} + \beta_4 PI_{i,t} \ \eta_i + \varepsilon_{i,t} \quad (3.5)$$

where $i = 1, \dots, n$ and $t = 1, \dots, T$. GDP is GDP growth. MIL, HE, TO and PI represent military expenditure, healthcare expenditure, trade openness and political instability respectively. η_i represents individual effects and $\varepsilon_{i,t}$ is the error term.

3.4.2 Nonlinear Panel Unit Root Test allowing for a Structural Break

We applied Karavias and Tzavalis' (2014) panel unit root test that has been highlighted in the previous chapter.

3.4.3 Dynamic Panels with Threshold Effect and Endogeneity

The estimated model is for Asimakopoulos and Karavias (2016) which is a special case of Seo and Shin (2016) model.

$$y_{it} = (1, X'_{it})\phi_1 1\{q_{it} \leq \gamma\} + (1, X'_{it})\phi_2 1\{q_{it} > \gamma\} + \varepsilon_{it} \quad , \qquad i=1,\dots, \quad n; \quad t=1,\dots,T$$
(3.6)

where y_{it} is economic growth, X_{it} contains military expenditure, trade openness and lagged value of economic growth. We have two models: in the first one, q_{it} is healthcare expenditure and serves as the threshold variable. In the second model, q_{it} is trade openness and serves as the threshold variable. $\boldsymbol{1}\{.\}$ is an indicator function. γ is the threshold parameter, ϕ_1 and ϕ_2 are the slope parameters associated with various regimes. The error term contains the error components:

$$\varepsilon_{it} = \alpha_i + v_{it}, \tag{3.7}$$

where α_i is an unobserved individual fixed effect and v_{it} is a zero-mean random disturbance.

Seo and Shin (2016) follow Arellano and Bond's (1991) method to deal with the correlation of regressors with individual effects in (3.6) and (3.7) so the first difference has been considered as follows:

$$\Delta y_{it} = \beta' \Delta x_{it} + \delta' X_{it}' \mathbf{1}_{it}(\gamma) + \Delta\varepsilon_{i,t}, \tag{3.8}$$

where Δ represents the first difference, $\underset{k_1 \times 1}{\beta} = (\phi_{12}, \dots, \phi_{1,k_1+1})'$,

$$\underset{(k_1+1)\times 1}{\delta} = \phi_2 - \phi_1,$$

$$\underset{2\times(1+k_1)}{X_{it}} = \begin{pmatrix} (1, x_{it}') \\ (1, x_{i,t-1}') \end{pmatrix} \text{ and } \underset{2\times 1}{\mathbf{1}_{it}(\gamma)} = \begin{pmatrix} 1\{q_{it} > \gamma\} \\ -1\{q_{it-1} > \gamma\} \end{pmatrix}.$$

Let $\theta = (\beta', \delta', \gamma)'$ and assume that θ belongs to a compact set, $\Theta = \Phi * \mathrm{r} \subset \mathbb{R}^k$, and $k = 2k_1 + 2$. Let $\mathrm{r} = [\underline{\gamma}, \overline{\gamma}]$, where $\underline{\gamma}$ and $\overline{\gamma}$ are two percentiles of the threshold variable. Allowing for fixed threshold impact and lessening or small threshold effect for statistical inference for the threshold parameter, γ, by defining:

$$\delta = \delta_n = \delta_0 n^{-\alpha} \text{ for } 0 \leq \alpha < 1/2. \tag{3.9}$$

The OLS estimator from (3.9) is biased as the transformed regressors are correlated with $\Delta\varepsilon_{it}$. To deal with this problem, an $l * 1$ vector of instrument variables are needed to be found, $(z_{it_0}', \dots, z_{iT}')'$ for $2 < t_0 \leq T$ with $l \geq k$ so that either

$$E(z_{it_0}' \Delta\varepsilon_{it_0}, \dots, z_{iT}' \Delta\varepsilon_{iT})' = 0, \tag{3.10}$$

Or

$$E(\Delta\varepsilon_{iT} | z_{it}) = 0, \text{ for each } t = t_0, \dots, T. \tag{3.11}$$

z_{it} may contain lagged values of $(q_{it}, x_{it})$and lagged dependant variables. The number of instruments may be different for each time *t*.

FD-GMM estimation

Allowing the threshold variable q_{it} to be endogenous: $E(q_{it}\Delta\varepsilon_{it}) \neq 0$ so q_{it} does not belong to the instrumental variables$\{ z_{it}\}_{t=t_0}^{T}$. The *l*-dimensional column vector of the sample moment conditions:

$\overline{g}_n(\theta) = 1/n\sum_{i=1}^{n} g_i(\theta)$,

where

$$\underset{1*1}{g_{i(\theta)}} = \begin{pmatrix} (z_{it_0}(\Delta y_{it_0} - \beta'\Delta x_{it_0} - \delta' X'_{it_0}\mathbf{1}_{it_0}(\gamma)) \\ \vdots \\ z_{iT}(\Delta y_{iT} - \beta'\Delta x_{iT} - \delta' X'_{iT}\mathbf{1}_{iT}(\gamma)) \end{pmatrix}. \tag{3.11}$$

E$g_i(\theta)$=0 if and only if $\theta = \theta_0$ and let $g_i = g_i(\theta_0) = (z'_{it_0}\,\Delta\varepsilon_{it_0}, \dots, z'_{iT}\Delta\varepsilon_{iT})'$ and $\Omega = E(g_i g_i{'})$, Ω is positive definite. For positive definite matrix, w_n so that $w_n \overset{p}{\to} \Omega^{-1}$, let

$$\bar{J}_n(\theta) = \overline{g}_n(\theta)' w_n \overline{g}_n(\theta). \tag{3.12}$$

Then the GMM of θ is given as:

$$\hat{\theta} = \arg\min_{\theta\in\Theta} \bar{J}_n(\theta). \tag{3.13}$$

The model is linear in ϕ and the objective function $\bar{J}_n(\theta)$ is not continuous in γ with θ=$(\emptyset', \gamma)'$, the grid search algorithm is practical. Let for a fixed γ, $\overline{g}_{1n}$ be:

$\overline{g}_{1n} = 1/n\sum_{i=1}^{n} g_{1i}$, and $\overline{g}_{2n}(\gamma) = 1/n\sum_{i=1}^{n} g_{2i}(\gamma)$,

where

$$\underset{l\times 1}{g_{1i}} = \begin{pmatrix} z_{it_0}\Delta y_{it_0} \\ \vdots \\ z_{iT}\Delta y_{iT} \end{pmatrix}, \quad \underset{1\times(k-1)}{g_{2i}(\gamma)} = \begin{pmatrix} z_{it_0}(\Delta x_{it_0}, \mathbf{1}_{it_0}(\gamma)' X_{it_0}) \\ \vdots \\ z_{iT}(\Delta x_{iT}, \mathbf{1}_{it}(\gamma)' X_{iT}) \end{pmatrix}.$$

Then GMM estimator of β and δ is given by

$$\left(\hat{\beta}(\gamma)', \hat{\delta}(\gamma)'\right)' = \left(\overline{g}_{2n}(\gamma)' w_n \overline{g}_{2n}(\gamma)\right)^{-1} \overline{g}_{2n}(\gamma)' w_n \overline{g}_{1n}.$$

If we denote the objective function evaluated at $\hat{\beta}(\gamma)$ and $\hat{\delta}(\gamma)$ by $\widehat{J_n}(\gamma)$, we get the GMM estimator of θ by

$\hat{\gamma}$=$\underset{\gamma\in\Gamma}{\text{argmin}}\,\widehat{J_n}(\gamma)$, and $(\hat{\beta}', \widehat{\delta'})'$=$(\hat{\beta}(\hat{\gamma})', \hat{\delta}(\hat{\gamma})')'$.

The two-step optimal GMM estimator is generated as follows:

1. Estimate the model by minimising $\bar{J}_n(\theta)$ with either $w_n = I_l$ or with the following equation and collect the residuals.

$$W_n = \begin{pmatrix} \frac{2}{n}\sum_{i=1}^{n} z_{it_0}z'_{it_0} & \frac{-1}{n}\sum_{i=1}^{n} z_{it_0}z'_{it_{0+1}} & 0 & \cdots \\ \frac{-1}{n}\sum_{i=1}^{n} z_{it_{0+1}}z'_{it_0} & \frac{2}{n}\sum_{i=1}^{n} z_{it_{0+1}}z'_{it+1} & \ddots & \ddots \\ 0 & \ddots & \ddots & \frac{-1}{n}\sum_{i=1}^{n} z_{iT-1}z'_{iT} \\ \vdots & \ddots & \frac{-1}{n}\sum_{i=1}^{n} z_{i\mathrm{T}}z'_{iT-1} & \frac{2}{n}\sum_{i=1}^{n} z_{iT}z'_{iT} \end{pmatrix}$$

2. Estimate the parameter θ by minimising $\bar{J}_n(\theta)$ with

$$w_n = \left(\frac{1}{n}\sum_{i=1}^{n} \hat{g}_i\hat{g}'_i - \frac{1}{n^2}\sum_{i=1}^{n} \hat{g}_i \sum_{i=1}^{n} \hat{g}'_i\right)^{-1}, \tag{3.14}$$

where $\hat{g}_i = (\widehat{\Delta\varepsilon}_{it_0}z'_{it_0}, \dots, \widehat{\Delta\varepsilon}_{iT}z'_{iT})'$.

3.5 Empirical Results

3.5.1 Empirical Results from Panel Estimator System GMM

We examined the effect of military expenditure, healthcare expenditure, trade openness and political instability on economic growth applying dynamic panel data estimator system GMM. Table (3.6) presents the results of the estimation. The model passed the AR(2) test as indicated by the p-value which shows that the serial correlation in the error terms is not second order. The validity of the instruments applied as a necessity for the system GMM is confirmed by the Hansen test of the over-identifying restrictions. Therefore, we can conclude after considering all these test statistics that the GMM model is adequately specified.

Furthermore, the results show that military expenditure has a negative effect on economic growth. The estimated GMM value of healthcare expenditure is positive and significant. The variable of trade openness is a significant determinant of economic growth as well. The effect of political instability represented by PCA1, PCA2 and PCA3 is not a significant determinant of economic growth.

We conclude that if the country increases the healthcare expenditure, this will lead to a healthier population that can work harder and longer improving economic growth. Furthermore, trade liberalisation plays a vital role in the growth of any economy. Our results are in line with the literature where Bhargava *et al*. (2001), Bloom *et al.* (2001), Atilgan (2016) and Khan (2016) among other find that there is a positive relationship between healthcare expenditure and economic growth. Moreover, Gries and Redlind (2012) and Lederman (2012) among others argue that there is a positive relationship between trade openness and economic growth. With regards to military expenditure, our results are also in line with Dunne and Tian (2016) and Dunne and Uye (2013) where they find in their survey that around 55% of the literature shows a negative relationship between military expenditure and economic growth.

Table 3. 3 The results for dynamic panel data estimator (SYS-GMM)

Variables	SYS-GMM
l.GDP growth	0.3225**
	(0.102)
lnMIL	-1.180***
	(0.1707)
lnHE	0.252**
	(0.1099)
lnTO	0.213**
	(0.0622)
PCA1	-0.0099
	(0.0285)
PCA2	-0.0145
	(0.0187)
PCA3	0.01467
	(1.14)
Constant	0.4814
	(0.447)
Hansen test	14.00
	(0.981)
AR(1) test, p.value	-2.33**
AR(2) test, p.value	-1.15

All regressions are calculated applying a dynamic system GMM estimator introduced by Blundell and Bond (1998). Robust standard errors in parentheses. ***, **, and * coefficients are statistically significant at 1%, 5%, and 10%, respectively. The Hansen (1982) test statistic with p-values is for over-identifying restrictions. AR(1) and AR(2) are tests for 1st and 2nd order serial correlation.

3.5.2 Karavias and Tzavalis (2014) Nonlinear Panel Unit Root Test

Karavias and Tzavalis (2014) panel unit root test that accounts for structural breaks and correlation of the error terms has been applied to examine the nonlinearity of the series. The results from Table (3.7) clearly indicate that the null hypothesis of a unit root is rejected in favour of its stationary alternative. The estimate of statistic z are smaller than the critical value of this statistic at 5%.

Table 3. 4 Karavias and Tzavalis panel unit root test with a break

Variables	Statistic *z*
GDP	-15.7001**
MIL	-1.8103**
HE	-1.2592**
TO	-3.5031**
PI	-19.4722**

*, **, and *** denote rejection of the unit root null hypothesis at 10%, 5% and 1 % significance levels respectively.

3.5.3 Dynamic Panel with Threshold effect and Endogeneity

Table 3. 5 Results of non-linear dynamic threshold estimations where healthcare expenditure is the threshold variable

	Coefficient	Standard Error	T-statistic
Economic Growth (y_{t-1})	0.1452	0.0361	4.0242***
Military expenditure	0.7161	0.2067	3.4640***
Trade openness	0.2360	0.1101	2.1435**
Healthcare spending (in low Regime)	0.3365	0.1630	2.0645**
Healthcare spending (in high Regime)	0.1169	0.0393	2.9773***
Threshold	2.4492	1.3062	1.8750**

*, **, and *** denote significant at 10%, 5% and 1 % significance levels respectively.

Since Karavias and Tzavalis' test shows nonlinearity of the series, we have also evaluated the non-linear relationship between these variables and economic growth using a dynamic panel threshold model that allows for non-linear threshold effect with endogenous regressors and threshold variables. In the first model when healthcare spending is the threshold variable, we find that the optimal threshold level for healthcare spending is 2.4492. When healthcare spending is below the threshold, a 1per cent increase in the spending will enhance the economic growth by 0.3365 per cent. However, if healthcare spending is above the threshold, a 1 per cent increase in the spending will improve the economic growth by 0.1169 per cent only.

Test for linearity and exogeneity

Seo and Shin (2016) developed the Hausman type testing procedure for the validity of the unll hypothesis that the threshold variable is exogenous by combining FD-GMM and FD-2SLS estimators and their asymptotic results. They also developed linearity test following Hansen et al .(1996) and bootstrap or simulate the asymptotic critical values.

Table 3. 6 Results of non-linear dynamic threshold estimations where trade openness is the threshold variable

	Coefficient	Standard Error	T-statistic
Economic Growth (y_{t-1})	0.1078	0.0401	2.6855***
Military expenditure	19.8112	8.8671	2.2343**
Healthcare spending	0.1171	0.0644	1.8191**
Trade openness (in low Regime)	2.1090	0.2605	8.0972***
Trade openness (in high Regime)	0.6872	0.0569	12.0784***
Threshold	0.3800	0.1209	3.1430***

*, **, and *** denote rejection at 10%, 5% and 1 % significance levels respectively.

In the second model when trade openness is the threshold variable, we find that the optimal threshold level for trade openness is 0.3800. Thus, when trade openness is below the threshold, a 1% increase in the trade openness will improve the economic growth by 2.1090%. However, if the trade openness is above the threshold, a 1% increase in the trade openness will increase the economic growth by 0.6872% only.

Nonlinear GMM shows that military expenditure has a positive impact on economic growth in both cases. Firstly, when the healthcare expenditure is the threshold variable, the military expenditure coefficient is 0.7161. Thus, there is a positive and statistically significant effect of military spending on economic growth. Secondly, when the trade openness is the threshold variable, the military expenditure coefficient is 19.8112 as in Table (3.9). Therefore, the impact of military expenditure on economic growth is positive, significant and nonlinear. This is in line with the literature, especially with Benoit (1978), Fredriksen and Looney (1982), Atesoglu and Mueller (1990), Atesoglu (2009), Niloy *et al*. (2007), Yildirim and Öcal (2016) and Augier et al. (2017) among others.

The most interesting result is that the results form nonlinear GMM regarding military expenditure is in contrast with the results we obtained from GMM. This is in line with Cuaresmanand and Reitschuler (2006), Pieroni (2009), Aizenman and Glick (2006) and Alptekin and Levine (2012) who find that the effect of military expenditure on economic growth is non-linear and positive.

3.6 Conclusion

The growing literature regarding the impact of military expenditure on economic growth is complex and difficult to conclude. Many researchers argue that as defence spending requires importing the arms, it results in draining the reserves of foreign exchange. Furthermore, this expenditure will affect the spending in education, health sectors and other social sectors in a country, which will influence economic growth. However, various studies show that military expenditure protects the countries from external threats and raises the foreign investment.

As there is no clear conclusion on the impact of military expenditure on economic growth, we investigate the impact of the military expenditure, healthcare expenditure, trade openness and political instability on economic growth for NATO countries. We apply a set of linear and nonlinear approaches. The results from the ADF test indicate that military spending, healthcare spending, trade openness series are stationary. Panel unit root tests are used as well, and the empirical results show that these series are stationary. For further investigation of the impact of these variables on economic growth for NATO countries, system GMM has been applied. The results indicate that, firstly, there is a negative relationship between military spending and economic growth. Secondly, there is a positive relationship between healthcare expenditure and trade openness and economic growth. Finally, we find that there is no statistical relationship between political instability and economic growth in these countries when applying system GMM. As there is no statistical relationship between political instability and economic growth, we removed it from our sample in our further analysis upon applying nonlinear methods.

Karavias and Tzavalis' (2014) panel unit root test that accounts for structural breaks and correlation of the error terms was applied to examine the nonlinearity of the series. The null hypothesis of a unit root was rejected in favour of its stationary.

Since Karavias and Tzavalis (2014) test indicates that these series are stationary and nonlinear, we further assessed the non-linear relationship between these variables and economic growth applying a dynamic panel threshold model for Seo and Shin (2016) that allows for non-linear threshold effect with endogenous regressors and threshold variables. We used two models. In the first model, healthcare expenditure serves as a threshold variable and in the second model trade openness is the threshold variable.

When healthcare spending is the threshold variable, the empirical results show that the optimal threshold level is 2.4492. Thus, if healthcare spending is below the threshold, a 1% increase in the spending will enhance the economic growth by 0.3311%. However, when healthcare spending is above the threshold, a 1% increase in the spending increases the economic growth by 0.1169% only.

Furthermore, we assessed the non-linear relationship between trade openness and economic growth. The results show that the optimal threshold level for trade openness is 0.3800. When the trade openness is below the threshold, a 1% increase in the trade openness will boost the economic growth by 2.1090%. On the other hand, if the trade openness is above the threshold, a 1% increase in the trade openness improves the economic growth by 0.6872% only.

The interesting result in our analysis is that nonlinear GMM shows that military expenditure has a positive effect on economic growth, which is in contrast with the results we obtained from GMM. This in line with the literature in that the effect of military expenditure on economic growth is non-linear. Cuaresmanand and Reitschuler (2006), Aizenman and Glick (2006), Pieroni (2009), Alptekin and Levine (2012) among others who applied the nonlinear technique and show that the effect of military expenditure on economic growth is non-linear.

We conclude that there is a positive and statistically significant impact of military spending, healthcare expenditure and trade openness on the economic growth of NATO countries. However, there is no statistically significant impact of political instability on the economic growth of these countries.

Future research could also expand the analysis by using a group of developed and developing countries. The works in the literature suggest that there is a difference in the growth of developed and developing countries. Therefore, further research can be carried out applying nonlinear GMM to examine whether the optimal threshold level varies between these two groups of developed and developing economies. Furthermore, for future research, a larger panel could be applied.

4 Financial Development and Economic Growth

4.1 Introduction

World Economic Forum defines financial development as 'the factors, policies, and institutions that lead to effective financial intermediation and markets, as well as deep and broad access to capital and financial services' (WEF, 2011, p. 13).

The impact of financial development on economic growth has received enormous attention. Different studies have dealt with several aspects of the linkage between financial development and economic growth at the theoretical and empirical levels. The finance-growth nexus is one of the extremely questioned matters in financial development and growth literature. Various researches have tried to find whether financial deepening leads to developed growth performance. On the other hand, several studies have attempted to detect the channels of transmission from financial development to economic growth.

However, there are conflicting views regarding the role that financial development has in economic growth. On one hand, many researchers argue that financial development encourages economic growth since it supports the mobilization of reserves and assists the investment. On the other hand, different studies claim that economists exaggerate the role of the financial system in economic growth. Andersen and Tarp (2003), Ayadi *et al.* (2015), and Ductor and Grechyna (2015) have a similar view and provide evidence that shows an inverse relationship between the financial system and economic growth. Moreover, other studies results show no evidence that neither the financial nor the banking sector develop growth.

There is a lot of literature on the relationship between financial development and economic growth. However, no consensus has been reached on the nature of this relationship or the direction of causality. Four different views have been proposed on the relationship between financial development and economic growth. The first view is that financial development is a supply-leading hypothesis in which financial development encourages economic growth as it is a productive input. Schumpeter (1911) is one of the earliest studies to show that financial development fosters economic growth. Fry (1978), Greenwood and Jovanovic (1990) and Hicks (1969) highlight that the liberalisation of the financial system helps financial deepening and improves the competition in the financial system, which supports economic growth. They argue that financial development is an essential element of economic growth. Applying panel cointegration techniques, Chistopoulos and Tsionas (2004) find that that financial development is certainly the main factor of economic growth. Atje and Jovanovic

(1993), Levine and Zervos (1998), Levine *et al.* (2000), Zhang *et al.* (2012), Uddin *et al.* (2013), Herwartz and Walle (2014), Samargandi *et al*. (2014), Muhammad *et al.* (2016), and Durusu-Ciftci *et al.* (2017) also support this hypothesis.

The second hypothesis is a demand-following hypothesis. According to this view financial development follows economic growth. Kuznets (1955), Al-Yousif (2002) and Ang and McKibbin (2007) argue that when the real side of the economy reaches the intermediate level of growth, the demand for financial services starts to rise. So, financial development relies on economic development.

The third hypothesis is the bidirectional causalities hypothesis. There is a two-way causal relationship between financial development and economic growth. Patrick (1966) was the first to introduce this view. Patrick (1966) shows that the development of the financial sector is a consequence of economic growth, which feeds back as an element of growth. Demetriades and Hussein (1996) and Greenwood and Bruce (1997) also support this view among other studies.

The last hypothesis has already been mentioned above and it is introduced by Lucas (1988) who argues that financial development and economic growth are not causally linked. According to this opinion, financial development does not lead to economic growth or vice versa.

Early works on financial development and economic development were grounded on cross-country investigation. For example, Goldsmith (1969) and Levine and Zervos (1998) apply a cross-country method to examine the relationship between financial development and economic growth. These studies argue that financial development helps to predict growth but they do not deal with the issue of causality. Khan and Senhadji (2000) claim that cross-country studies are not reliable analysis since they are sensitive to the sample countries under the study, data frequency, proxy measures, and estimation methods.

Studies later used the panel time-series method that exploits time series and cross-sectional variations in data. Furthermore, Levine (2005) argues that the panel time series method avoids biases related to cross-sectional regressions by accounting for the country-specific fixed effect. Many studies applied panel framework in examining the finance-growth nexus; for example, see Chistopoulos and Tsionas (2004), Rachdi and Mbarek (2011), Bangake and Eggoh (2011) among others.

This thesis contributes to the literature by examining the relationship between financial development and economic growth in 17 countries applying the Panel-GARCH method. To the best of our knowledge, no study has been conducted to investigate the relationship between financial development and economic growth utilising Panel-GARCH approach; there is only one piece of research carried out by Campos *et al*. (2012), who apply power ARCH (PARCH) to examine the relationship between financial development and economic growth in Argentina. We use two indicators as financial development proxies in examining the relationship between financial development and economic growth. The first one is M3/GDP and the second indicator is the private credit by money banks to GDP.

Our results when applying the ADF test indicate that all series under our study have a unit root, so the first difference is utilised to transfer them to stationary ones. Secondly, panel unit root tests show that these series are stationary. Finally, applying panel-GARCH, the results indicate that there is a positive and statistically significant relationship between financial development and economic growth regardless of the financial development indicators used.

In order to investigate the effect of the lagged economic growth on the economic growth uncertainty, the lagged values of economic growth are used. For the first financial development indicator, both lagged values for economic growth are positive and significant. For the second indicator, the first lagged value for economic growth is positive and significant. This in line with Caporale and McKiernan (1996) and Fountas and Karanasos (2006) among others, who find that increased volatility rises the growth potential of the economy. On the other hand, the second lagged value for economic growth for the second indicator is positive but is not significant which is similar to Grier and Perry’s (2000) results.

This paper is organised as follows. Section 2 introduces the literature review. Section 3 presents the data. Section 4 provides a description of the methodology. Section 5 provides the empirical analysis and the results, and Section 6 is the conclusion.

4.2 Literature Review

4.2.1 Theoretical Framework

The theoretical links between financial development and economic growth have been growing since the 1980s. The views on the importance of financial development in economic growth can be categorised into two groups. The first one is traced back to the work of Schumpeter (1911). Schumpeter (1911) argues that financial development is vital for economic growth as financial development contributes to economic growth through technological innovations. Additionally, Schumpeter (1911) highlights that financial development influences the growth by providing an adequate fund to the sectors that have the best productive use. Goldsmith (1969) supports Schumpeter's (1911) view. Goldsmith (1969) argues that developed financial markets help economic growth by mobilising reserves to fund the most productive investments. The second group is rooted in the work of Robinson (1952) who claims that financial development is an unimportant factor in economic growth.

Patrick (1966) also contributed to this literature by classifying two important hypotheses on the relationship between finance and growth. These aspects of financial development are 'supply leading' and 'demand following' theories. The financial institutions have a supply leading role to transfer resources from traditional to modern sectors. The other role for financial development, as Patrick (1966) argues, is the demand following role where the real side of the economy drives the growth, which in turn generates the demand for financial services. This debate on finance-growth nexus is also supported by Levine (1997), who argues that financial development is the most important element for economic growth.

The appearance of endogenous growth theory in the 1980s attracted consideration to the relationship between financial development and economic development. Thus, many studies were done to clarify how the operation of the financial system may impact the rate of economic growth in the endogenous framework; see, for example, King and Levine (1993a) and Deidda (2006) among others. These studies highlight that financial intermediaries are modelled in which financial development is mostly growth-promoting.

There are different indicators in the literature to measure the financial development of any economy. These proxies are financial depth, the bank ratio, and financial activity. For financial depth, the ratio of liquid liabilities to GDP is applied to measure financial development. However, Levine (1997) argues that financial depth indicators may contain deposits from other financial intermediaries in the banks that cause the problem of double counting. The second measurement of financial development is the bank ratio, which is the ratio of bank credit to the sum of bank credit and domestic assets of the central bank. However, Levine (1997) shows that the bank ratio does not replicate how good commercial banks organise in allocating resources as well as exercising corporate control. Furthermore, the third proxy is applied in the literature to measure financial development is financial activity. This proxy is reflected, firstly, by the ratio of private domestic credit is provided by deposit money banks to GDP. Secondly, the ratio of private domestic credit provided by deposit money banks and other financial institutions to GDP. Finally, the ratio of credit is allocated to private enterprises to total domestic credit. Some research has examined the effect of stock markets as a proxy for financial development. The typically used measurements of stock market development are: the market capitalisation ratio, which is the total value of listed shares relative to GDP, the stock market activity, which equals the total value of traded shares relative to GDP, the turnover ratio, which is the total value of traded shares relative to the total value of listed shares.

The literature on the relationship between financial development and economic growth is divided into three groups, cross-sectional, panel studies and finally time series studies. Most of the literature on cross-sectional and panel data indicates a positive relationship between these two variables. For the first time applying data from 35 economies over the period from 1860 to 1963, Goldsmith (1969)'s results indicated a positive correlation between financial development and economic growth. Using bank-based financial development indicators, King and Levine (1993a) investigate the impact of financial development on economic growth. Using cross-country data from 80 countries over the 1960–1989 period, the results showed evidence consistent with Schumpeter's view in that the financial system can stimulate economic growth.

The literature review is divided into sections depending on the methods applied or the area in which the relationship between financial development and economic growth is examined. These divisions are highlighted in details in the next sections.

4.2.2 Empirical Framework

The studies highlighted in the sections applied the panel approached and GARCH method.

4.2.2.1 Panel Methods

4.2.2.1.1 Generalized Method of Moments (GMM)

A pioneer work that applies a panel approach to investigate the relationship between financial development and economic growth is done by Beck *et al.* (2000). Beck *et al.* (2000) find that there is a statistically significant relationship between financial development and GDP growth as well as productivity growth. Beck *et al.* (2000) apply the GMM method to account for the endogeneity of the regressors. The results show that better-running financial intermediaries expand resource allocation with positive effects on long-run economic growth. Applying the same method as in Beck *et al.* (2000), Levine *et al.* (2000) empirically examine whether financial development leads to economic growth using data from 71 countries for the period 1960-1995. They apply three ratios as a proxy for financial development. They conclude that the exogenous component of financial intermediary development is positively related to economic growth. Likewise, Yay and Oktayer (2009) also use the GMM method for data from 21 developing and 16 developed economies for the period 1975-2006 and turnover ratio as an indicator of financial development. Their results show that there is a positive effect of financial development on economic growth, particularly in developing countries. In line with this, Anwar and Cooray (2012), using the ratio of M2 to GDP and applying system GMM, find that financial development improves the economic growth in South Asia as well as enhances the benefits of foreign direct investment.

Similarly, Mhadhbi (2014) re-examines the empirical relationship between financial development and economic growth in developing and developed countries for the period from 1973 to 2012 using a dynamic panel GMM estimation method. The estimation results indicate that financial development, which measures credits by the financial system to the private sector, has a significant and negative influence on growth. Furthermore, the measure that reflects the financial deepening of the economy affects positively on economic growth in developed economies but negatively in the developing economies. Andersen and Tarp (2003) also use GMM and apply data from least developed countries (LDCs) to examine the relationship between financial development and economic growth. They find that a well-functioning financial sector has an essential role in the course of economic growth. Furthermore, they argue that government involvement in the financial system has a harmful impact on financial development.

However, Christopoulos and Tsionas (2004) challenged the conclusions of these studies by raising the issue on the GMM technique used, as the integration and cointegration properties of the data are not considered when GMM is applied. Therefore, it is not clear whether the estimated panel models represent a long-run structural relationship or a spurious one.

Another category of studies has concluded either with a negative or no relationship between financial development and economic growth. Narayan and Narayan (2013), using GMM in 65 developing countries, obtain results which indicate that neither the financial sector nor the banking sector contributes to growth in the Middle Eastern economies. The role of financial development on economic growth is relatively weak in these countries except for Asia. Furthermore, there is evidence that the bank credit has a statistically significant and negative effect on economic growth with an exception of the Middle Eastern countries.

4.2.2.1.2 Panel Cointegration Approaches

In the existent literature, there are studies that consider the panel cointegration approaches when examining the relationship between financial development and economic growth.

Chistopoulos and Tsionas (2004) investigate the relationship between financial development and economic growth in ten developing countries using the ratio of total bank deposit liabilities to nominal GDP and the ratio of investment to GDP. They find evidence for long-run causality runnings from financial development to growth when they apply panel unit-root tests and panel co-integration tests as well as considering threshold effects. The results also indicate a unidirectional long-run causality among financial system and economic development, which runs from finance to growth. Conversely, the problem is that cross-sectional dependency is not considered in their analysis. Similarly, Ghirmay (2004) also analyses the causal link among financial development and economic growth in 13 economies applying Johannsen's cointegration method. The results indicate that there is a cointegrating relationship between financial development and economic growth. Furthermore, these results are sensitive to the individual country. In line with this, Loayza and Ranciere (2006) distinguish between the short and long-run impacts of finance on growth for 75 countries using a panel error-correction model and pooled mean group estimator. They find a positive and significant long-run relationship but significant and negative short-run impact between financial development and economic growth. They argue that this negative effect may be because of the higher volatility of business cycles and cross-country heterogeneity. A similar study by Ahmed and Wahid (2011), who use the panel data co-integration test and the dynamic time series modelling method, find that higher levels of banking system development results in faster rates of economic growth in seven African economies. Additionally, the results reveal that a unidirectional causality is running from financial systems to economic growth. The panel cointegration method is also applied by Rachdi and Mbarek (2011) using panel data cointegration analysis and they find a long-term relationship between financial development and economic growth for the OECD and the MENA countries. Similarly, Neusser and Kugler (1998) examined the impact of financial development on economic growth in 13 OECD countries for the period 1970-91. Applying panel cointegration, their study shows a positive correlation between financial development and growth.

4.2.2.1.3 Nonlinear Panel Method

The existent panel literature on the relationship between financial development and economic growth shows that some studies have raised non-linearity concern. This part of the literature claims that financial development is useful for economic development up to a certain level. When financial development approaches this threshold, further financial development causes declining of economic growth. Deidda and Fattouh (2002) used data from 119 developed and emerging economies using threshold regressions to low income as well as high-income economies and find that finance is an important factor of economic development for high-income economies and an insignificant element for low-income countries. Applying similar approach, Rioja and Valev (2004a, 2004b), who consider panel data for 74 developed and developing countries, find a positive and significant effect in countries with high- and intermediate-income countries but an insignificant effect in low-income economies. Huang and Lin (2009) also use a nonlinear method in investigating the relationship between financial development and economic growth. They consider a sample of 71 high-income countries and low-income countries in a cross-section IV threshold method from 1960 to 1995. Their results show that the relationship between finance and growth is nonlinear and positive.

In line with this, Law and Singh (2014) examine whether finance development affects economic growth after exceeding a certain threshold level. They apply dynamic panel threshold methods for 87 developed and developing countries. They highlight that a threshold beyond which private sector credit is not beneficial. The threshold value is 88% of GDP, which is close to Cecchetti and Kharroubi's (2012) threshold value of 90%. In line with this, Arcand *et al.* (2015) highlight that in the economies which have large financial sectors, there is no positive correlation among financial development and economic development. Furthermore, there is a positive and robust correlation among financial development and economic development in economies with small and intermediate financial sectors. However, a threshold is around 80–120% of GDP, above which financial development has a negative effect on economic growth.

A similar study by Samargandi *et al*. (2015) examines the relationship between financial development and economic growth in 52 middle-income countries over the 1980–2008 period. They apply a dynamic heterogeneous panel setting and find that in the long run there is an inverted U-shaped relationship among financial development and economic development. However, this relationship is insignificant in the short run. This indicates that too much financial development can lead to a negative impact on economic growth in middle-income economies. Furthermore, the results suggest that relationship between financial development and economic development is not linear, similar to the findings of Arcand *et al.* (2015). Similarly, Ductor and Grechyna (2015) apply the threshold method and find that the positive influence of financial development on economic development is maximum under balanced growth of financial and real sectors. These results are robust to various measures of financial development. The results also indicate that the effect of financial development on economic growth is reduced by unbalanced economic growth between financial development and real output. A threshold level after which financial development has a harmful influence on economic growth is estimated between 1.72% and 4.97%. Therefore, they argue that acceleration of financial development that is not accompanied by growth in the real sector decreases the positive impact of financial development on economic growth and the influence of financial development might become negative in case that the financial development grows significantly faster than real output.

Recently, Demetriades and Rousseau (2016) conclude that the financial depth is not a significant element of long-run growth and they argue that bank regulation and supervision affect finance growth-nexus.

4.2.2.1.4 Panel Causality Approaches

A large number of panel studies in the literature that investigate the relationship between financial development and economic growth apply causality approaches. Shan and Morris (2002) examine the relationship between financial development and economic development for 19 OECD economies and China applying the Toda and Yamamoto (1995) causality method procedure and they find supporting evidence of the supply leading hypothesis for one country. In line with this, Odhiambo (2004) investigates the relationship between financial development and economic growth in South Africa applying three ratios: the ratio of M2 to GDP, and the ratio of bank claims on the private sector to nominal GDP and the currency ratio. Their empirical results indicate the rejection of the supply leading hypothesis and show that economic growth drives the development of the banking sector. Similarly, Ang and McKibbin (2007) also apply causality tests and their results support the demand-following hypothesis in the long-run. Likewise, Zang and Kim (2007) use a causality test and apply the ratio of liquid liabilities to GDP, the ratio of deposit money bank domestic assets to deposit money bank domestic assets plus central bank-domestic assets and credit issued to private enterprises as a share of GDP from 74 countries over the period 1961-95. They do not find evidence of any positive unidirectional causal link from financial development indicators to economic growth. On the contrary, economic growth leads the subsequent financial development. In line with this, Akinlo and Egbetunde (2010) use the ratio of M2 to GDP to investigate the relationship between financial development and economic growth in ten countries in SSA. Their results indicate a long-run relationship between financial development and economic growth in these countries when they apply a multivariate Granger causality test within the context of the VECM method.

Odhiambo (2011) also applies a trivariate Granger causality model for South Africa during the period 1980:1-2007:3. The results show that there is a bidirectional causal relationship between financial development and economic growth.

The market capitalisation ratio as a proxy for financial development is applied by Yu *et al.* (2012). They find a positive relationship between financial development and economic growth in long-run over 20 years, but Granger causality investigations show a short-run relationship between finance and growth. Consequently, they conclude that under-developing economies experience slower economic growth regardless of financial and stock market development in the short run. Bangake and Eggoh (2011) also apply a causality test with a different indicator of financial development. They use financial allocation efficiency, which is the ratio of bank credit to bank deposits, as financial development proxy. They also use government expenditure to GDP and trade openness as control variables. Data from 71 developed and developing countries over the period 1960–2004 reveal a bidirectional causality relationship between financial development and economic growth. Moreover, they find that there is no evidence of short-run causality between financial development and economic growth in low- income economies and middle-income economies. However, in high-income countries, economic development impacts financial development significantly.

Hassan *et al.* (2011) also examine the relationship in economies with different degree of development. They use data from countries with a different degree of development. These counties are from low, middle, and high-income countries. They find a positive relationship among financial development and economic growth in emerging economies. They apply M3 to GDP as a proxy for financial depth as well as other indicators of financial development such as the ratio of gross domestic savings to GDP, domestic credit to the private sector as a percentage of GDP and finally domestic credit provided by the banking sector as a percentage of GDP. Additionally, variables like trade openness and government expenditure have a vital role in economic growth so they conclude that a well-functioning financial system is essential but not sufficient for economic growth in emerging economies. The results also indicate a two-way causality link among financial development and economic growth for most of the areas and one-way causality from economic growth to finance for the poorest countries.

However, Menyah *et al*. (2014) examine the relationship using data from 21 African countries and apply panel causality but they do not find strong evidence for finance-led growth.

4.2.2.2 ARCH Method

Power ARCH (PARCH)

Campos *et al*. (2012) investigate the short- and long-run effects of finance on economic growth similar to Kaminsky and schmukler's (2003) and Loayza and Ranciere's (2006) works. They use data from Argentina for the period from 1896 to 2000 and apply power ARCH (PARCH) framework. Campos *et al*. (2012) apply three indicators for financial development. The first indicator is the ratio of M3 to GDP. The other two indicators capture the efficiency of the financial sector and include the bank deposits by the private sector as a share of GDP as well as the total deposits in savings banks as a share of GDP. Their results indicate that the long-run effect of financial liberalisation on economic growth is positive but the short-run effect is negative.

4.3 Theory and Evidence on the Relationship between Economic Growth and Economic Growth Uncertainty

Macroeconomic theory introduces three possible effects for economic volatility on economic development. First, there is the probability of a positive effect of output unpredictability on the growth. Black (1987) shows that investments in riskier machineries will require the return on these investments to be high enough to accept the extra risk. Additionally, Blackburn (1999) demonstrates that business cycle volatility increases long-run economic growth.

A second prospect is for output variability and growth to be independent of each other. For example, output variations around their usual level are the result of price misperceptions principle proposed by Friedman (1968) and Lucas (1972), although variations in the growth rate yield from real factors. Lastly, economic growth volatility may have a negative effect on growth. Greater volatility in output growth may cause unpredicted deviations in output growth and generates the demand for a firm's product in the future more unclear. Henceforth, firms are less probable to invest in plant and equipment as they face growing risk. Thus, the demand for investment decreases and output growth decrease as Bernanke (1983) and Ramey and Ramey (1991) claim.

The third possibility of the literature applies small equilibrium models built on the AK growth models to examine the link among economic growth volatility as well as growth rate. The claim here is that the impact of volatility on savings and growth relies on the size of the elasticity of intertemporal substitution. So, when clients do not like to substitute consumption, a rise in the volatility of income causes growth in savings hence the economic growth. However, when consumers prefer to substitute consumption over time, rise in the volatility of income causes a reduction in savings as well as growth.

The empirical literature presents two methods. Kormendi and Meguire (1985) and Grier and Tullock (1989) find a positive relationship between growth and growth volatility using cross-country data; on the other hand, Ramey and Ramey (1995), Martin and Rogers (2000), and Kneller and Young (2001) find a negative relationship. Rafferty (2005) highlights that unpredicted volatility decreases the growth and anticipated volatility increases it, whereas the combined influence of anticipated and unpredicted volatility decreases growth.

Applying GARCH-M models, Caporale and McKiernan (1996, 1998) claim that there is a positive relationship among output volatility and growth for the United Kingdom and the United States, whereas Fountas and Karanasos (2006) find a positive relationship for Germany and Japan only. Other studies find no relationship in the United Kingdom and the United States, see, for instance, Grier and Perry (2000) and Fountas and Karanasos (2006). On the other hand, Macri and Sinha (2000) and Henry and Olekalns (2002) find a negative link between volatility and growth for Australia and the United States.

Uncertainty appears to increase after major economic and political shocks like the Cuban missile crisis, the assassination of JFK and the 9/11 terrorist attacks. Bloom (2009) shows that due to the effect of uncertainty, the firms pause their investment and the increased volatility from the uncertainty shock generates a volatility overshoot in the medium term. Bloom (2009) builds a model with a time-varying second moment that estimated using firm-level data. The results show that the temporary impact of a second-moment shock is different from impact of a first-moment shock. While the second-moment impact has its biggest fall by month 3 and has rebounded by about month 6, persistent first-moment shocks generate drops in an activity that last many quarters.

The uncertainty shock induces a strong insensitivity to other economic stimuli. At high levels of uncertainty the real option value of inaction is very large so the effects of empirically realistic general equilibrium type interest rate, wage, and price falls have a very limited short-run effect on reducing the drop and rebound in activity. To sum up, it appears that second-moment shocks can generate short sharp drops and rebounds in output, employment, investment, and productivity growth without the need for a first-moment productivity shock. Thus, recessions could potentially be driven by increases in uncertainty.

4.4 Data

Annual data was collected from the World Development Indicators (WDI) dataset for 17 countries from 1960 to 2015. The data set contained lower middle-income countries in addition to upper middle-income countries as follows: Argentina, Belgium, Bolivia, Brazil, Chad, Costa Rica, Ecuador, Egypt, Finland, Greece, Guyana, Honduras, Malaysia, Mexico, Panama, Paraguay, and Peru.

Economic growth as a dependent variable in addition to two indicators of financial development as an independent variable were applied to investigate the relationship between economic growth and financial development. The first indicator was the ratio of liquid liabilities (M3) to nominal GDP. The second indicator was private credit by deposit money banks to GDP.

Primarily univariate and panel tests for the first indicator

The empirical work started with a data specification. Table (4.1) presents the unit root test results for financial development and economic growth. The results from augmented Dickey-Fuller (1981) in light of the Akaike Information Criterion (AIC) show that all data series in levels have a unit root when they are expressed in levels. When the first difference is applied to the data, the unit root null hypothesis is rejected for all series.

Table 4. 1 ADF test for economic growth and first financial development indicator, M3 to GDP

Country	Economic growth	M3/GDP	First difference
Argentina	-6.364008***	-2.981960	-6.986349***
Belgium	-5.405025***	0.393501	-7.374892***
Bolivia	-5.109418***	-0.770191	-5.446830***
Brazil	-3.947491**	-0.061402	-5.948959***
Chad	-5.814606***	-2.866056	-10.27782***
Costa Rica	-5.292169***	-1.773572	-4.950696***
Ecuador	-4.680533***	-1.247646	-6.319048***
Egypt	-3.983624***	-1.560289	-5.010252***
Finland	-4.712078***	-0.456725	-4.909846***
Greece	-3.940254***	-1.199997	-6.091423***
Guyana	-5.102583**	-2.031267	-7.579132***
Honduras	-5.752189***	-0.938062	-6.481992***
Malaysia	-6.286878***	-1.486579	-6.017493***
Mexico	-4.937669***	-3.317241**	-6.017493***
Panama	-4.546636***	-1.930865	-5.057944***
Paraguay	-5.420075***	-1.034513	-4.264636***
Peru	-4.659876***	-1.502569	-8.158796***

Note: *, **, *** indicate rejection of the null at 10%, 5% and 1% respectively.

In addition to the univariate test results, Table (4.2) shows the results from panel unit root tests. IPS, LLC and ADF-Fisher panel test statistics strongly reject the unit-root null in the case of the first-differenced data but not in the level.

Table 4. 2 t-statistic for panel unit root tests for GDP growth and first financial development indicator, M3to GDP

	levels		First Differences
	Economic growth	Financial development	Financial development
LLC	-18.117***	-0.97470	-19.5763***
IPS	-17.194***	0.38894	-20.6933***
ADF-Fisher	332.748***	35.0247	384.120***

*, **, *** indicate rejection of the null at 10%, 5% and 1% respectively.

In the case of heteroscedasticity, simple panel estimation is applied where the null hypothesis (H_0: the residuals are homoscedastic) is rejected at the 1% level, which supports the application of a GARCH-type model as shown in Table (4.3).

Table 4. 3 Panel heteroscedasticity LR test

Likelihood ratio	Values	P-value
Cross-section test	240.8638***	0.0000
Period test	196.8008***	0.0000

*, **, *** indicate rejection of the null at 10%, 5% and 1% respectively.

primarliy univariate and panel tests for the second indicator

Table (4.4) shows the unit root test results for financial development and economic growth. the results from augmented Dickey-Fuller (1981) in light of the Akaike Information Criterion (AIC) show that all data series in levels have a unit root when they are expressed in level except Greece, Honduras and Ecuador. When the first difference is applied to the data, the null hypothesis of a unit root is rejected for all series that have a unit root.

Table 4. 4 ADF test for economic growth and second financial development indicator, Private credit by deposit money banks to GDP

Country	Private Loan	First difference
Argentina	-2.241990	-6.130562***
Belgium	-1.494058	-6.778042***
Bolivia	-2.291838	-4.327882**
Brazil	-1.236084	-4.396610**
Chad	-1.527868	-7.855890***
Costa Rica	-0.693035	-4.405323**
Ecuador	-2.995981**	
Egypt	-1.452361	-3.630296**
Finland	-1.536915	-3.247557**
Greece	-0.536589**	
Guyana	-1.184570	-3.532694**
Honduras	-2.301652**	

Malaysia	-2.917818	-5.235023**
Mexico	-2.406036	-4.165484**
Panama	-2.940055	-3.343253**
Paraguay	-2.651437	-3.771096**
Peru	-1.789203	-3.100655***

*, **, *** indicate rejection of the null at 10%, 5% and 1% respectively.

Table (4.5) shows the results from panel unit root tests for the second financial development indicator. Only LLC panel test statistics strongly reject the unit-root null in the case of level but all three tests reject the null of a unit root in case of first difference.

Table 4. 5 Economic growth and the second financial development indicator, Private credit by deposit money banks to GDP

	Private loan	Private loan (first difference)
LLC	-3.72752**	-14.5594**
IPS	-1.57050	-14.9496***
ADF-Fisher	47.3027	281.671***

*, **, *** indicate rejection of the null at 10%, 5% and 1% respectively.

In the case of heteroscedasticity, the null hypothesis, i.e. the residuals are homoscedastic, is rejected at the 1% level, which supports the application of a GARCH-type model as shown in Table (4.6).

Table 4. 6 Panel heteroscedasticity LR test

Likelihood ratio	Values	P-value
Cross-section test	164.1010***	0.0000
Period test	114.9785***	0.0000

*, **, *** indicate rejection of the null at 10%, 5% and 1% respectively.

4.5 Methodology

Panel GARCH Model

We applied the following panel GARCH model:

$$y_{it} = \mu_i + \sum_{p=1}^{K} \phi_k y_{i,t-k} + \delta x_{it} + \varepsilon_{it}, \qquad i = 1, \ldots, N; t = 1, \ldots, T, \tag{4.1}$$

where μ_i captures possible country-specific effects. x_{it} denotes financial development. ε_{it} is an error term with the following conditional moments:

$$E[\varepsilon_{it}\varepsilon_{js}] = 0 \quad \text{for } t \neq s, \tag{4.2}$$

$$E[\varepsilon_{it}\varepsilon_{js}] = \sigma_{ij,t}^2 \quad \text{for } t = s, \tag{4.3}$$

The first moment assumes zero correlation and no non-contemporaneous correlation either cross or own and the second moments assumes conditional contemporaneous variance and covariance, whereas the third and fourth define the general conditions of the conditional variance-covariance process. The conditional variance-covariance processes of the output are assumed to follow a GARCH (1, 1) because of its popularity:

$$\sigma_{it}^2 = \omega_i + \alpha\sigma_{i,t-1}^2 + \beta\varepsilon_{i,t-1}^2 + \gamma\hat{x}_{it} + \varphi_1 y_{i,t-k_1} + \varphi_2 y_{i,t-k_2}, \quad i = 1, \ldots, N, \tag{4.4}$$

$$\sigma_{ij,t}^2 = \omega_{ij} + \lambda\sigma_{ij,t-1}^2 + \rho\varepsilon_{i,t-1}\varepsilon_{j,t-1}, \qquad i \neq j. \tag{4.5}$$

The Eq. (4.1) can be written as follow:

$$y_t = \mu + Z_t\theta + \varepsilon_t, \qquad t = 1, \ldots, T,$$

where y_t and ε_t are *N*1* vectors,

$Z_t = [y_{t-1} \ldots y_{t-k}\ x_t]$ is a matrix with their corresponding coefficient in $\theta = [\phi \vdots \delta]'$, ϕ =$(\phi_1, \ldots, \phi_2)'$The disturbance term ε_t has a normal distribution $N(0, \Omega_t)$, Ω_t is a variance-covariance matrix, $\Omega_t = [\sigma_{ij,t}^2]$ $i,j=1,\ldots,N$. As the ε_t is conditional heteroskedastic and cross-sectionally correlated, the least squares estimator is no longer efficient, so Cermeno and Grier's (2006) conditional maximum likelihood is applied in Eq. (4.6).

The log-likelihood function of the complete fixed-effects panel model with the time-varying conditional covariance can be written as:

$$L = -\frac{1}{2}NT \ln(2\pi) - \frac{1}{2}\sum_{t=1}^{T} \ln|\Omega_t| - 1/2\sum_{t=1}^{T}[(y_t - \mu - Z_t\theta)' * \Omega_t^{-1}(y_t - \mu - Z_t\theta)]$$

(4.6)

4.6 Empirical Results

We evaluated some diagnostics for testing serial correlation in the residuals and squared residuals. The LM test with *t*-statistic equal to (-0.67) and (-0.38) for first and second financial development indicator respectively suggests that there is no evidence of serial correlation in the residuals, meaning that the conditions in Eq. (4.3) are satisfied.

4.6.1 Empirical Results for the First Financial Development Indicator

Empirical Results from the Panel- GARCH

Table 4. 7 panel-GARCH estimation results for first financial development indicator, M3/GDP

	Coefficient	t-statistic
Mean equation		
Intercept	0.2849	2.19068**
Financial development	0.4541	10.8211***
y_{t-1} (economic growth, first lag)	0.6409	16.4586***
y_{t-2} (economic growth, second lag)	0.3381	10.0862***
Variance equation		
Intercept	0.3047	2.0071**
Financial Development	0.4335	7.5837***
y_{t-1} (economic growth, first lag)	0.6235	9.5412***
y_{t-2} (economic growth, second lag)	0.3120	4.6429***
α	0.1008	24.3031***
β	0.8010	284.0980***
Covariance equation		
ρ	0.0879	19.2672***
λ	0.8002	272.0909***

*, **, *** indicate rejection of the null at 10%, 5% and 1% respectively.

The estimated coefficient for financial development 0.4541(10.8211***) in the conditional mean equation is positive and significant as reported in Table (4.7). The results from variance equation with coefficient 0.4335(7.5837***) for financial development indicate that there is a positive relationship between financial development and economic growth uncertainty. The estimated first and second lagged value of economic growth 0.6235(9.5412***) and 0.3120(4.6429***) respectively are also positive and significant. The coefficients in the covariance equation are also positive and significant as presented in Table (4.4).

The purpose of using lagged values of economic growth is to concurrently check the effect of the lagged values of economic growth on the economic growth uncertainty.

The estimated first and second lagged values for economic growth are also positive and significant. This in line with previous literature especially with Kormendi and Meguire (1985), Grier and Tullock (1989) and Caporale and McKiernan (1996), who find that increased volatility raises the growth potential of the economy. Additionally, Fountas and Karanasos (2006) obtain results that show that there is a positive relationship for Germany and Japan.

4.6.2 Empirical Results for the Second Financial Development Indicator

Empirical Results from Panel- GARCH

The estimated coefficient for financial development in the conditional mean equation is positive and statistically significant 3.0901(4.0865***), as presented in Table (4.8). The results from the variance equation with a coefficient for financial development 2.9947 (3.9103***), shows that there is a positive and statistically significant relationship among financial development and economic growth uncertainty.

We also include the lagged values of economic growth in the conditional variance equation, the level effect. Therefore, we examine the effect of lagged values of economic growth on the output growth uncertainty. The first lagged value for economic growth is positive and significant. This is in line with Caporale and McKiernan (1996) and Fountas and Karanasos (2006), who find that increased volatility raises the growth potential of the economy. However, the second lagged value is positive but is not significant which is similar to Grier and Perry's (2000) results where there was no evidence of any empirical relationship. The parameters in the covariance equation were also positive and significant.

Table 4. 4 economic growth and second financial development indicator, Private credit by deposit money banks to GDP

	Coefficient	t-statistic
Mean equation		
Intercept	-0.1280	-0.5525
Financial Development	3.0901	4.0865***
y_{t-1}	0.2327	5.2502***
y_{t-2}	0.0926	2.2388**
Variance equation		
Intercept	-0.1339	-0.6923
Financial Development	2.9947	3.9103***
y_{t-1}	0.2415	4.1207***
y_{t-2}	0.0937	1.1737
α	0.0913	12.3647***
β	0.7987	90.2272***
Covariance equation		
ρ	0.0311	5.0647***
λ	0.8056	82.9370***

*, **, *** indicate rejection of the null at 10%, 5% and 1% respectively.

4.7 Conclusion

The relationship between financial development and economic growth has been extensively studied, as financial development is vital for economic growth. Many researchers are looking for empirical evidence on the relationship among economic and financial development. Conversely, most studies examine the relations between financial development and economic development. Economic theory expects a positive relationship between these two variables however the empirical studies on the relationship between financial development and economic growth yield mixed outcomes. Hence, there is no general agreement between economists that financial development is conducive to economic growth.

This study was conducted to analyse the relationship between financial development and economic growth using a dataset from 17 countries for a period from 1960 to 2015. Many studies applied panel framework in examining the finance-growth nexus. Furthermore, there is only one study by Campos *et al*. (2012) that has used power ARCH (PARCH). To the best of our knowledge, there is no work that has investigated the relationship between financial development and economic growth applying Panel-GARCH. Thus, we applied this method using two financial development indicators to investigate the relationship between economic growth and financial development. The first indicator was the ratio of liquid liabilities (M3) to nominal GDP. The second indicator was private credit by deposit money banks to GDP.

The results of applying the ADF test suggest that all series under our study had a unit root, so the first difference was applied to transfer these series to stationary ones. Additionally, Panel unit root tests show that these series are stationary. Finally, applying Panel-GARCH, the results show that there is a positive relationship between financial development and economic growth uncertainty using both indicators, M3/GDP indicator and the private credit by money banks to GDP financial development indicator.

The results of this study are in line with previous studies that show that there is a positive relationship between financial development and economic growth, in particular studies done by Schumpeter (1934), Fry (1978), Hicks (1969), Atje and Jovanovic (1993), Levine and Zervos (1998), Zhang, Wang, & Wang, 2012, Herwartz & Walle (2014), Muhammad, Islam, & Marashdeh (2016) and Durusu-Ciftci, Ispir, & Yetkiner (2017) where they argue that financial development is definitely an essential determinant of economic growth.

We also included the lagged value of economic growth to examine the effect of the lagged values of economic growth on the economic growth uncertainty. The first and second lagged values are positive and significant for the first financial development indicator. For the second indicator, the first lagged value for economic growth is positive and significant. This in line with previous with Kormendi and Meguire (1985), Grier and Tullock (1989), Caporale and McKiernan (1996) and Fountas and Karanasos (2006) who find that increased volatility rises the growth potential of the economy. This results support Blackburn (1999) work where he argues that business cycle volatility raises an economy's growth rate in long run.

However, the second lagged value for economic growth for the second financial development indicator is positive but is not significant which is similar to Grier and Perry's (2000) results where there is no evidence of any empirical relationship.

Finally, the results of this research raise a number of questions that may be useful in motivating future research. One suggestion is investigating this relationship between financial development and economic growth by applying Panel GARCH-in-mean. Another suggestion is to use more independent variables and lags of financial development besides financial development to examine their impact on economic growth uncertainty.

5 Conclusion

This thesis firstly contributed to the issue in the field of Purchasing Power Parity (PPP) in developed and developing countries. Secondly, it investigated the impact of military expenditure, healthcare expenditure, trade openness and political instability on economic growth. Finally, this thesis contributed to the discussion related to the relationship between financial development and economic growth.

Chapter 2 examined PPP as it remains an interesting topic in international macroeconomics. PPP is critical for both empirical researchers and policymakers. Furthermore, PPP is a central building block of the models of the exchange rates determination. A large number of researches for PPP have not found supportive results for PPP. These results reflect the poor power of the methods applied rather than evidence against PPP. A number of works increase the power of the tests employed by applying long-span data or increase the power of the test by using panel unit root tests. However, many studies that applied panel unit root tests and long-span data methods did not get evidence for PPP. Therefore, in order to solve PPP puzzles, nonlinear methods should be applied.

This chapter had two main purposes. Firstly, many researchers claim that linear models limit the degree of adjustment of real exchange rates to their PPP levels to be the same at all points of time. The basic concept suggests that transaction costs can determine when the law of one price leads the real exchange rates towards PPP and when it does not. Henceforth, nonlinear approaches that allow for regime switching behaviour may be more applicable when studying PPP. Taylor and Sarno (2003) highlight that nonlinear methods are more appropriate to examine PPP. Additionally, studies claim that nonlinear methods are more efficient in examining the validity of PPP. Moreover, the behaviour of the exchange rate is nonlinear therefore applying linear approaches generates misleading results. Therefore, linear and nonlinear methods with and without structural breaks were applied in this study to check the validity of PPP. Secondly, we aimed to examine the hypothesis that the degree of development of the countries under the study matters when examining the validity of PPP. Therefore, data from developed and developing countries were used in our analysis, developing countries were divided into two samples depending on data availability.

Firstly, a set of panel linear methods with and without structural breaks were applied. These tests were LLC, IPS, Fisher and Hadri stationarity test in addition to PLNV linear panel unit root test with a structural break.

Moreover, we used four nonlinear panel unit root tests in our analysis. Firstly, Ucar and Omay's (2009) nonlinear panel unit root test was applied to examine the nonlinear hypothesis. Secondly, Emirmahmutoglu and Omay's (2014) nonlinear panel unit root test was used, which accounts for asymmetric nonlinear adjustment for real exchange rates and cross-sectional dependence bias encountered in panel data. Additionally, Omay *et al.*'s (2017) nonlinear panel unit root test with structural breaks and cross-sectional dependence was used. Finally, Karavias and Tzavalis' (2014) panel unit root test that allows for a common break of known and unknown date in the deterministic component of the AR (1) model in addition to cross-correlation across the error terms was implemented for examining whether PPP holds.

Our results showed that PPP holds in developed countries when the linear method without structural breaks is used. However, the results for developing countries are different as applying linear methods without breaks shows that PPP does not hold in both of the samples. Therefore, a linear panel unit root test with structural breaks was applied and the results indicated that PPP holds only in one series in sample 1 but it does not hold in any of the series in sample 2. This conclusion confirms that the degree of development matters when we examine whether PPP is valid using samples from developed and developing countries.

As there is no supportive evidence for PPP in developing countries, we moved to apply nonlinear panel unit root tests. The results from nonlinear methods for developing economies indicated that PPP holds in developing countries. These results were in line with the literature in that the real exchange rates follow a nonlinear stationary process. Moreover, the results show that the behaviour of the exchange rate in developing countries is nonlinear, so nonlinear approaches are more efficient to be used when examining PPP validity.

Chapter 3 investigated the relationship between military expenditure and economic growth since it attracts great attention among economists as well as policy makers. There is no theory on the defence-growth nexus or empirical proof on the impact of military expenditure on economic growth. Although several researchers claim that military expenditure protects the nations from external threats and raises foreign investment, a number of works suggest that military expenditure transfers resources from the civilian to the defence sector, which leads to a negative outcome on economic growth.

We investigated the impact of the military expenditure, healthcare expenditure, trade openness and political instability on economic for NATO countries applying System GMM and dynamic panel threshold model. The motivation to apply nonlinear approach is to investigate whether the relationship between economic growth and military expenditure is nonlinear. There is no study has been done to examine the relationship between economic growth and military expenditure by applying a dynamic panel threshold model in these countries.

The results show that there is a negative relationship between military expenditure and economic growth in NATO countries applying System GMM. Additionally, there is a positive relationship between healthcare expenditure and trade openness and economic growth.

Finally, for political instability, the results indicate that there is a significant correlation that causes multi-collinearity problems. Hence, Principle Component Analysis (PCA) was applied to obtain three summary measurements. The results from system GMM for political instability show that there is no statistical relationship between political instability and economic growth. Therefore, political instability was removed, and it was not included in the sample when nonlinear approaches were applied.

Next, we applied Karavias and Tzavalis' (2014) panel unit root test, which accounts for structural breaks and correlation of the error terms to study the nonlinearity of the series. The null hypothesis of a unit root was rejected in favour of its stationary so we further analysed the non-linear relationship between these variables and economic growth applying the nonlinear model. The nonlinear model we used was a dynamic panel threshold model for Seo and Shin (2016) that allows for non-linear threshold effect with endogenous regressors and threshold variables. We used healthcare spending and trade openness as threshold variables in two separate models. The empirical results when healthcare spending is the threshold variable show that the optimal threshold level is 2.4492. Therefore, when healthcare spending is below the threshold, a 1% increase in the spending will increase the economic growth by 0.3311%. Conversely, when healthcare spending is above the threshold, a 1% increase in spending improves the economic growth by 0.1169%.

In the second model when trade openness serves as a threshold variable, the optimal threshold level for trade openness is 0.3800. Therefore, if the trade openness is below the threshold, a 1% increase in the trade openness will increase the economic growth by 2.1090%. However, if the trade openness is above the threshold, a 1% increase in the trade openness improves the growth by 0.6872%.

The interesting result in our analysis is that when nonlinear GMM is applied, military expenditure has a positive effect on economic growth. The coefficient of military spending is positive and significant in both models when healthcare spending and trade openness serve as threshold variables. This is in line with the previous studies in that the effect of military expenditure on economic growth is non-linear. Cuaresmanand and Reitschuler (2006), Aizenman and Glick (2006), Pieroni (2009), Alptekin and Levine (2012) among others claim that nonlinear techniques are better to be used when we examine the effect of military expenditure on economic growth. They show that the relationship between these two variables is positive and non-linear.

Chapter 4 investigated the relationship between financial development and economic growth. There are conflicting views regarding the role of the financial system in economic growth. Although many researchers argue that developed financial system enhances economic efficiency and economic growth, others argue that economists amplify the role of the financial system in economic growth. Furthermore, other researchers find no evidence that neither the financial system nor the banking sector improves growth. Subsequently, there is no general view among researchers on whether financial development is beneficial to economic growth or not.

This thesis investigated this relationship using a dataset from 17 economies for a period from 1960 to 2015. There have been various work that has applied panel methods in investigating the finance-growth nexus. However, there is only one study by Campos *et al*. (2012) that has applied power ARCH (PARCH). Therefore, research that has investigated the relationship between financial development and economic growth applying Panel-GARCH is thin on the ground. This thesis applied the Panel-GARCH method using two financial development indicators. The first indicator was the ratio of liquid liabilities (M3) to nominal GDP. The second indicator was private credit by deposit money banks to GDP.

The results show that there is a positive relationship between economic growth and financial development applying both financial development indicators. The results of this study are in line with previous studies especially with Campos *et al*. (2012) which show that there is a positive relationship between financial development and economic growth uncertainty.

In order to test for level effect, we included the lagged value of economic growth as an independent variable. We applied first and second lagged values for both first and second financial development indicators. By including these lagged values, we tested for the effect of the lagged economic growth on the economic growth uncertainty in the conditional variance equation. Our results indicate that the effect of economic growth is positive and significant for both lagged values for the first indicator. Moreover, the results suggest that the level effect of lagged value for the second indicator is positive and significant only at first lagged value. These results are in line with the literature, especially with Kormendi and Meguire (1985), Caporale and McKiernan (1996) and Fountas and Karanasos (2006). On the other hand, the results show that the level effect of lagged value for the second financial development indicator is positive but it is not significant at the second lagged value of economic growth.

Finally, the results of this thesis raise various motivations for future research. One suggestion is to examine the relationship between military expenditure and economic growth applying the nonlinear method for a set of developed and developing countries. Another recommendation is investigating this relationship between financial development and economic growth by applying Panel GARCH-in-mean. Furthermore, we suggest for further investigation is to use more independent variables in addition to financial development and lagged value of economic growth.

Appendix

Panel unit root tests

1.1. Linear panel unit root tests

1.1.1. Levin, Lin and Chu (LLC) test

The null hypothesis for Levin, Lin and Chu (LLC) test is that each individual series has a unit root. The null hypothesis as is mentioned in Levin *et al*. (2002) is:

$$\Delta y_{it} = \delta y_{it-1} + \sum_{L=1}^{P_i} \theta_{iL}\, \Delta y_{it-L} + \alpha_{mi} d_{mt} + \varepsilon_{it} \qquad m= 1,2,3.$$

where α_{mi} indicates the corresponding vector of coefficient for a specific model m=1,2,3. d_{mt} presents the vector of deterministic variables. Since P_i is unknown, three steps procedure has been suggested by LLC to implement their test. Firstly, we apply separate ADF regressions for each individual and produce two orthogonalized residuals. For the second step, the ratio of long to short innovation standard deviation for each series should be calculated. Finally, the pooled t-statistics are computed.

Step 1: apply separate ADF regressions for each series:

$$\Delta y_{it} = \delta_i y_{it-1} + \sum_{L=1}^{P_i} \theta_{iL} \Delta y_{it-L} + \alpha_{mi} d_{mt} + \varepsilon_{it} \qquad m=1,2,3. \qquad \text{(A.1)}$$

p_i is the lag order and it is permitted to differ across series. For T, select a maximum lag order p_{max} and use the t-statistics of $\hat{\theta}_{iL}$ to determine if a smaller lag order is preferred. $\varepsilon_{it} \sim IID(0, \sigma^2)$.

When p_i is determined, run two auxiliary regressions to obtain the orthogonalzed residuals:

Run Δy_{it} on Δy_{it-L} (L=1,…., p_i) and d_{mt} to obtain the residual $\hat{e}_{it}$

Run y_{it-1} on Δy_{it-L} (L =1,…., p_i) and d_{mt} to obtain the residual $\hat{v}_{it-1}$

where $$\hat{e}_{it} = \Delta y_{it} - \sum_{L=1}^{P_i} \hat{\pi}_{iL} \Delta y_{it-L} - \hat{\alpha}_{mi} d_{mt} \qquad \text{(A.2)}$$

$$\hat{v}_{it-1} = y_{it-1} - \sum_{L=1}^{P_i} \hat{\pi}_{iL} \Delta y_{it-L} - \hat{\alpha}_{mi} d_{mt} \qquad \text{(A.3)}$$

standardize these residuals in order to control for various variances across *i*:

$\tilde{e}_{it} = \hat{e}_{it} / \hat{\sigma}_{\varepsilon i}$,

$\tilde{v}_{it-1} = \hat{v}_{i,t-1} / \hat{\sigma}_{\varepsilon i}$

where $\hat{\sigma}_{\varepsilon i}$ is the standard error from regression (A.1) and it can be obtained from the regression of $\hat{e}_{it}$ against $\hat{v}_{i,t-1}$

$$\hat{\sigma}_{\varepsilon i}^2 = \frac{1}{T - P_i - 1} \sum_{t=p_i+2}^{T} (\hat{e}_{it} - \hat{\delta}_i \hat{v}_{it-1})^2. \qquad \text{(A.4)}$$

Step 2: Calculate the ratio of the long run to short-run standard deviations. It can be done as follows:

$$\hat{\sigma}_{yi}^{2} = \frac{1}{T-1}\sum_{t=2}^{T} \Delta y^{2}{}_{it} + 2\sum_{L=1}^{\bar{K}} w_{\bar{K}L} \left[\frac{1}{T-1}\sum_{t=2+L}^{T} \Delta y_{it}\Delta y_{it-L}\right], \quad \text{(A.5)}$$

where $\bar{K}$ is the lag which is data dependent. $\bar{K}$ must be got in a manner that ensures the consistency of $\hat{\sigma}_{yi}^{2}$. If the Bartlett Kernel is used:

$$w_{\bar{K}L} = 1 - \frac{L}{\bar{K}+1}$$

The ratio of the long-run standard deviation to the innovation standard deviation is assessed by

$$\hat{s}_i = \frac{\hat{\sigma}_{yi}}{\hat{\sigma}_{\varepsilon i}}$$

and the mean standard deviation ratio is

$$\hat{s}_N = \frac{1}{N}\sum_{i=1}^{N} \hat{s}_i$$

Step 3: Calculate the panel test statistics by running the pooled regression

$$\tilde{e}_{it} = \delta\tilde{v}_{it-1} + \tilde{\varepsilon}_{it} \quad \text{(A.6)}$$

based on $N\tilde{T}$ observations, where $\tilde{T} = T - \bar{p} - 1$ is the mean number of observations per series with $\bar{p} \equiv 1/N \sum_{i=1}^{N} p_i$.

The *t*-statistic for testing the null hypothesis H_0: δ =0 is

$$t_{\delta} = \frac{\hat{\delta}}{STD(\hat{\delta})}, \quad \text{(A.7)}$$

where $\hat{\delta} = \frac{\sum_{i=1}^{N}\sum_{t=2+p_i}^{T} \tilde{v}_{it-1}\tilde{e}_{it}}{\sum_{i=1}^{N}\sum_{t=2+p_i}^{T} \widetilde{v^2}_{it-1}}$,

and $STD(\hat{\delta}) = \hat{\sigma}_{\tilde{\varepsilon}} \left[\sum_{i=1}^{N}\sum_{t=2+p_i}^{T} \tilde{v}^{2}{}_{it-1}\right]^{-1/2}$,

with $\hat{\sigma}_{\tilde{\varepsilon}}^{2} = \left[\frac{1}{N\tilde{T}}\sum_{i=1}^{N}\sum_{t=2+p_i}^{T}(\tilde{e}_{it} - \hat{\delta}\,\tilde{v}_{it-1})^{2}\right]$

is the estimated variance of $\hat{\varepsilon}_{it}$. To calculate the adjusted t-statistic the following expression should be used:

$$t_{\delta}^{*} = \frac{t_{\delta} - N\tilde{T}\hat{S}_N\hat{\sigma}_{\tilde{\varepsilon}}^{-2}STD(\hat{\delta})\mu_{m\tilde{T}}^{*}}{\sigma_{m\tilde{T}}^{*}} \quad \text{(A.8)}$$

Where $\mu_{m\tilde{T}}^{*}$ and $\sigma_{m\tilde{T}}^{*}$ are the mean and standard deviation adjustments.

The LLC (2002) test has significant size distortion in the presence of correlation among contemporaneous cross-section error terms as O'Connell (1998) reports. Additionally, Baltagi (2008) argues that LLC method assumes independence of a cross-section, and therefore is not applicable when the cross-sectional correlation is existing. Additionally, the assumption that all individuals have or do not have a unit root is restrictive.

1.1.2. Im, Pesaran and Shin (IPS) test

The LLC test is restrictive in that it requires the correlation across N to be homogenous. However, Im *et al*. (2003)'s test allows for a heterogeneous coefficient of y_{it-1}. Additionally, the IPS test procedure is based on averaging all individual test statistics.

The null hypothesis for the IPS test is that all series are stationary with identical first order auto-regression coefficient as in the LLC test but the alternative hypothesis allows for some (but not all) of the individual series to have a unit root.

The IPS t-bar is the average of the individual ADF statistics as:

$$\bar{t} = \frac{1}{N}\sum_{i=1}^{N} t_{\rho i} \ , \quad \text{(A.9)}$$

where $t_{\rho i}$ is the individual *t*-statistic. Im *et al*. (2003) provided critical values for $\bar{t}$ for a various number of series N, series length T and ADF regressions that contain intercept or intercept and linear trend.

1.1.3. The Fisher-ADF test

Maddala and Wu (1999) introduce a method to test for unit root by using a test due to Fisher (1932). The null and alternative hypothesis is similar to the IPS approach. The idea for the Fisher-ADF test depends on combining the *p*-values of the t-statistic for a unit root in each cross-sectional unit. Summing up the *p* values for many cross-section units yield following:

$$P_{\lambda}=-2\sum_{i=1}^{N} log P_i$$

Which is chi-square with 2*N* degrees of freedom.

1.1.4. Hadri stationarity (H) test

The Hadri (2000) panel unit root test has null hypothesis of stationarity similar to the KPSS test. Hadri introduces a residual based LM test for the null hypothesis that each series is stationary around a deterministic level or around a deterministic trend. There are two models in Hadri test as follow:

$$y_{i,t} = r_{i,t} + \varepsilon_{i,t} \ , \quad \text{(A.10)}$$

and

$$y_{i,t} = r_{i,t} + \beta_{i,t}\ \varepsilon_{i,t} \quad \text{(A.11)}$$

where $r_{i,t}$ is a random walk. $r_{i,t} = r_{i,t-1} + u_{i,t}$, $u_{i,t}$ is *i.i.d.* (0, σ_u^2). Since $\varepsilon_{i,t}$ are assumed to be *i.i.d.* so $y_{i,t}$ is stationary around a deterministic level in model (A.10) and around a deterministic trend in model (A.11).

Model 17 and 18 can be rewritten as:

$$y_{i,t} = r_{i,0} + e_{i,t} \tag{A.12}$$

and model 18:

$$y_{i,t} = r_{i,0} + \beta_{i,t}\, e_{i,t} \tag{A.13}$$

$e_{i,t} = \sum_{j=1}^{t} u_{i,j} + \varepsilon_{i,t}$, $r_{i,0}$ is initial values which have the role of heterogeneous intercepts.

Let $\hat{e}_{i,t}$ be the estimated residuals from equation (A.12) and (A.13) then the LM statistic will be as follow:

$$\text{LM}= \frac{1}{\hat{\sigma}_\varepsilon^2} \frac{1}{NT^2} \left(\sum_{i=1}^{N} \sum_{t=1}^{T} S_{i,t}^2 \right) , \tag{A.14}$$

where $S_{i,t}$ is the partial sum of the residuals, $S_{i,t} = \sum_{j=1}^{t} \hat{e}_{i,j}$ and $\hat{\sigma}_\varepsilon^2$ is a consistent estimator of σ_ε^2.

1.2. Nonlinear panel unit root tests

1.2.1. Nonlinearity test in heterogeneous panels (UO)

Ucar and Omay (2009) use nonlinear time series framework of Kapetanios *et al*. (2003) along with Im *et al*. (2003) panel unit root test to propose unit root tests for nonlinear heterogeneous panels.

Let $y_{i,t}$ follows panel exponential smooth transition autoregressive process of order one (PESTAR (1)) on the time *t*=1, 2… T for the cross-section units *i*=1, 2… N. Let $y_{i,t}$ follows the data generating process with fixed effect parameter α_i

$$\Delta y_{i,t} = \alpha_i + \o_i y_{i,t-1} + \gamma_i y_{i,t-1}\left[1 - exp\left(-\theta_i y_{i,t-d}^2\right)\right] + \varepsilon_{i,t}$$

where d ≥ 1 is the delay parameter and θ_i is the mean speed reversion for all *i*. Let set $\o_i$ =0 for all *i* and d=1 which generates the specific PESTAR (1) model as follow:

$$\Delta y_{i,t} = \alpha_i + \gamma_i y_{i,t-1}\left[1 - exp\left(-\theta_i y_{i,t}^2\right)\right] + \varepsilon_{i,t} \; . \tag{A.15}$$

Based on the regression (22), the nonlinear panel unit root test examines the null hypothesis θ_i=1 for all *i* against θ_i> 0 for some *i* under the alternative.

The first-order Taylor series approximation has been applied to the PESTAR (1) model around θ_i=0 for all *i* so the following regression has been generated:

$$\Delta y_{i,t} = \alpha_i + \delta_i y_{i,t-1}^3 + \varepsilon_{i,t} \tag{A.16}$$

Where $\delta_i = \theta_i \gamma_i$. Based on regression (23) the testing hypotheses are as follows:

H_0: δ_i=0, for all *i*, so the null is*:* linear non-stationarity

H_1: δ_i<0, for some *i*, the alternative is: nonlinear stationarity)

The authors propose panel unit root test by averaging of the individual KSS statistics, which is simply the *t*-ratio of δ_i in regression (A.16) and it is defined as:

$$t_{i,NL} = \frac{\Delta y_i M_T y_{i,-1}^3}{\hat{\sigma}_{i,NL}(y'_{i-1} M_T Y_{i,-1})3/2} , \tag{A.17}$$

where $\hat{\sigma}_{i,NL}$is the consistent estimator and $\hat{\sigma}_{i,NL} = \Delta y'_i M_\tau \Delta y_i/(T-1)$, $M_\tau = I_T - \tau_T(\tau'_T\tau_T)^{-1}\,\tau'_T$. $\Delta y_i = (\Delta y_{i,1}, \Delta y_{i,2}, \ldots., \Delta y_{i,T})$, $y_{i,-1}^3 = (y_{i,0}^3, y_{i,1}^3, \ldots., y_{i,T-1}^3)$ and $\tau_T = (1,1, \ldots 1)'$.

For fixed T: $$\bar{t}_{NL} = \frac{1}{N}\sum_{i=1}^{N} t_{i,NL} , \tag{A.18}$$

which is the invariant average statistic. The individual statistics $t_{i,NL}$ are *i.i.d* random variables with finite means and variances so the average statistics $\bar{t}_{NL}$ have the limiting standard normal distribution as *N*→∞ such that

$$\bar{Z}_{NL} = \frac{\sqrt{N}(\bar{t}_{NL} - E(\bar{t}_{I,NL}))}{\sqrt{\sqrt{Var(}\bar{t}_{i,NL)}}} \xrightarrow{d} N\,(0, 1). \tag{A.19}$$

1.2.2. Nonlinear asymmetric heterogeneous panels (EO)

Emirmahmutoglu and Omay (2014) extend Sollis (2009) test to nonlinear asymmetric heterogeneous panel unit root test as follows:

$$\Delta y_{it} = G_{it}(\gamma_{1i}, y_{i,t-1}) * \left[\left(S_{it}(\gamma_{2i}, y_{i,t-1})\rho_{1i} + (1 - S_{it}(\gamma_{2i}, y_{i,t-1})\right)\rho_{2i}\right] y_{i,t-1} + \varepsilon_{it} \tag{A.20}$$

$G_{it}(\gamma_{1i}, y_{i,t-1})$ =1- $exp(-\gamma_{1i} y_{i,t-1}^2)$ γ_{1i}≥0 for all *i*,

$S_{it}(\gamma_{2i}, y_{i,t-1})$ = $\left[1 + exp(-\gamma_{2i} y_{i,t-1}^2)\right]^{-1}$ γ_{2i}≥ 0 for all *i*,

where ε_{it} ~ *iid* (0,σ_i^2).

When the errors in equation (A.20) are serially correlated, the equation can be extended to allow for higher order dynamics:

$$\Delta y_{it} = G_{it}(\gamma_{1i}, y_{i,t-1}) * \left[\left(S_{it}(\gamma_{2i}, y_{i,t-1})\rho_{1i} + (1 - S_{it}(\gamma_{2i}, y_{i,t-1})\right)\rho_{2i}\right] y_{i,t-1} + \sum_{j=1}^{p_i} \delta_{ij} \Delta y_{i,t-j} + \varepsilon_{it} \tag{A.21}$$

The model is simplified by using Taylor approximation as follows:

Δy_{it}=a$(\rho_{2i}^{*} - \rho_{1i}^{*})\gamma_{1i}\gamma_{2i}y_{i,t-1}^{4}$+$\rho_{2i}^{*}\gamma_{1i}y_{i,t-1}^{3}$+$\varepsilon_{it}$, (A.22)

where a=1/4. The equation can be written as:

Δy_{it}=$\varnothing_{1i}y_{i,t-1}^{3}$+$\varnothing_{2i}y_{i,t-1}^{4}$+$\varepsilon_{it}$. (A.23)

An augmented version for equation (A.23) is:

Δy_{it}=$\varnothing_{1i}y_{i,t-1}^{3}$+$\varnothing_{2i}y_{i,t-1}^{4}$+$\sum_{j=1}^{p_i}\delta_{ij}\Delta y_{i,t-j}$+$\varepsilon_{it}$ (A.24)

The null hypothesis is

H_0: $\varnothing_{1i}$ = $\varnothing_{2i}$ =0 for all *i*.

If the unit root hypothesis (H_0: $\varnothing_{1i}$ = $\varnothing_{2i}$ =0 for all *i*) is rejected, then the null hypothesis of symmetric ESTAR nonlinearity can be tested against the alternative of asymmetric ESTAR nonlinearity by testing H_0: $\varnothing_{2i}$=0 for all *i* against H_1: $\varnothing_{2i} \neq 0$ in equation (A.24).

Emirmahmutoglu and Omay (2014) argue that testing for unit root, the standard *F* critical values cannot be used so they drive the asymptotic distribution using Sieve bootstrap approach to get the empirical distribution of *F* test.

1.2.3. Nonlinearity and structural breaks (OEE)

Omay, Corakci and Emirmahmutoglu (2017) extend the nonlinear method of testing unit root method of Sollis (2004) to heterogeneous panels to allow smooth transition (ST) and threshold autoregressive (TAR) models within a panel approach. Chang's (2004) sieve bootstrap approach has been used to correct for the size distortion yielded by cross-sectional dependence.

Let y_{it} be a panel ST-TAR process, which produced by one of the following smooth transition processes:

Model A: y_{it}= α_{i1}+ $\alpha_{i2}S_{it}(\gamma_i, \tau_i)$ +$\mathcal{E}_{it}$ (A.25)

Model B: y_{it} = α_{i1}+ $\beta_{i1}t$+ $\alpha_{i2}S_{it}(\gamma_i, \tau_i)$ +$\mathcal{E}_{it}$ (A.26)

Model C: y_{it} = α_{i1}+ $\beta_{i1}t$+ $\alpha_{i2}S_{it}(\gamma_i, \tau_i)$ + $\beta_{i1}t$ $\beta_{i2}t$ $S_{it}(\gamma_i, \tau_i)$ +$\mathcal{E}_{it}$ (A.27)

where $S_{it}(\gamma_i, \tau_i)$ is the logistic smooth transition function. $\mathcal{E}_{it}$ is generated applying TAR model as follows:

$\Delta\mathcal{E}_{it}$ = $\rho_{i1}I_{it}\mathcal{E}_{i,t-1}$ + $\rho_{i2}(1 - I_{it})\mathcal{E}_{i,t-1}$+$\eta_{it}$ (A.28)

I_{it} is the Heaviside indicator function such that I_{it}=1 if $\mathcal{E}_{i,t-1} \geq 0$, I_{it}=0 if $\mathcal{E}_{i,t-1} < 0$ and η_{it} is a zero-mean stationary process.

In equation (A.28), if H_0: ρ_{i1}=ρ_{i2} = 0 for all i then $\mathcal{E}_{it}$ and y_{it} contains unit root whereas if ρ_{i1}=ρ_{i2} $<$ 0 for some i, y_{it} is a stationary panel ST-TAR process with symmetric adjustment. However, if $\rho_{i1} < 0$, $\rho_{i2} < 0$ and $\rho_{i1} \neq \rho_{i2}$ for some I, then y_{it} is a stationary panel ST-TAR process with asymmetric adjustment. The structural change is modelled as a smooth transition between various regimes as done by Leybourne *et al*. (1998) hereafter (LNV).

The three models from equations (A.25), (A.26) and (A.27) can be applied in order to examine the following hypothesis:

H_0: y_{it}=μ_{it} , $\mu_{it} = \mu_{i,t-1}$+$\mathcal{E}_{it}$, , μ_{i0}=ψ_i

H_1: $Model\ A, Model\ B, Model\ C$

$\mathcal{E}_{it}$ is assumed to be a stationary with zero mean processes. The LNV test statistic is calculated using twthe o-step method following Sollis (2004):

1. Applying nonlinear least squares, the deterministic components of the preferred model for each of the cross-sectional units is estimated and then collect the NLS residuals by

Model A $\hat{\mathcal{E}}_{it} = y_{it} - \hat{\alpha}_{i1} - \hat{\alpha}_{i2}S_{it}(\hat{\gamma}_i, \hat{\tau}_i)$

Model B $\hat{\mathcal{E}}_{it} = y_{it} - \hat{\alpha}_{i1}\ \hat{\beta}_{i1}t - \widehat{\alpha}_{i2}S_{it}(\hat{\gamma}_i, \hat{\tau}_i)$

Model C $\hat{\mathcal{E}}_{it} = y_{it} - \hat{\alpha}_{i1} - \hat{\beta}_{i1}t - \hat{\alpha}_{i2}S_{it}(\hat{\gamma}_i, \hat{\tau}_i) - \hat{\beta}_{i2}\ t\ S_{it}(\hat{\gamma}_i, \hat{\tau}_i)$

2. Test whether the residuals from the first step have a unit root by applying the TAR model:

$$\Delta\hat{\mathcal{E}}_{it}= \rho_{i1}I_{it}\hat{\mathcal{E}}_{i,t-1} + \rho_{i2}(1-I_{it})\hat{\mathcal{E}}_{i,t-1}+ \sum_{j=1}^{k_i}\delta_{ij}\Delta\hat{\mathcal{E}}_{i,t-j} + \eta_{it}\ . \quad \text{(A.29)}$$

The t-test for Sollis for the ith individual that is used to examining if ρ_{i1}=0 and ρ_{i2} = 0 in equation (A.29) is defined as follow:

t_i= max (t_{i1}, t_{i2})

t_{i1} and t_{i2} are individual t-statistics for ρ_{i1} =0 and ρ_{i2} = 0.

The t-statistics are:

$$t_{ij} = \frac{\sqrt{T-K_I-2}\ (\hat{\mathcal{E}}'_{ij,-1}\ M_{Qij}\Delta\hat{\mathcal{E}}_i)}{(\hat{\mathcal{E}}'_{ij,-1}M_{Qij}\hat{\mathcal{E}}_{ij,-1})^{1/2}(\Delta\hat{\mathcal{E}}'_i M_{X_{ij}}\Delta\hat{\mathcal{E}}_i)^{1/2}}$$

$\Delta\hat{\mathcal{E}}_i = \Delta\hat{\mathcal{E}}_{i1}, \Delta\hat{\mathcal{E}}_{i2}, \ldots, \Delta\hat{\mathcal{E}}_{iT})'$,$\hat{\mathcal{E}}_{ij,-1} = (I_i\hat{\varepsilon}_{i0}, \ldots, I_i\hat{\varepsilon}_{i,T-1})'$, $\hat{\mathcal{E}}_{ij,-2} = ((1-I_i)\hat{\varepsilon}_{i0}, \ldots, (1-I_i)\hat{\varepsilon}_{i,T-1})'$, $Q_{i1} = ((1-I_i)\hat{\varepsilon}_{i2,-1}, \Delta\hat{\mathcal{E}}_{i,-1}, \ldots, \Delta\hat{\mathcal{E}}_{i,-k_i})$,$M_{Qij} = I_T - Q_{ij}(Q'_{ij}Q_{ij})^{-1}Q'_{ij}$, $M_{X_{ij}} = I_T - X_{ij}(X'_{ij}X_{ij})^{-1}X'_{ij}$, $X_{ij} = (\hat{\mathcal{E}}_{ij,-1}, Q_{ij})$ and I_T is an identity matrix of order T.

For examining the null of unit root in equation (36) non-standard individual F-test statistic is used as follows:

F_i= $\left(R\hat{P}_i\right)'[\hat{\sigma}_i^2 R\ (C'_iC_i)^{-1}R']^{-1}\left(R\hat{P}_i\right)/2$

where $C_i = [I_i\hat{\varepsilon}_{i,-1}, (1 - I_i)\hat{\varepsilon}_{i,-1}, \Delta\hat{\varepsilon}_{i,-1}, \dots, \Delta\hat{\varepsilon}_{i,-k_i}]$, $R = [I_2, 0_{2*k_i}]$, $\hat{P}_i = [\hat{\rho}_{i1}, \hat{\rho}_{i2}]'$ where $\hat{\rho}_{i1}$ and $\hat{\rho}_{i2}$are the Ordinary Least Square estimators of $\rho_{i1}$and ρ_{i2}, and $\hat{\rho}_i^2$ is the OLS estimator of ρ_i^2.

The proposed test is used to examine whether y_{it} has a unit root applying *F*-statistic for testing $\rho_{i1} = \rho_{i2}$ = 0 in (A.29) and /or the most significant *t*-statistic from those for testing ρ_{i1} =0 and ρ_{i2} = 0. For each of the models, the mean group statistic is as follows:

$\bar{F}_{jp,a}$=$N^{-1}\sum_{i=1}^{N} F_i$ and $\bar{t}_{jp,a}$=$N^{-1}\sum_{i=1}^{N} t_i$

1.2.4. Testing for unit root in short panels allowing for a structural break

Karavias and Tzavalis (2014) introduce a panel unit root test, which allows for structural breaks in known and unknown date in the deterministic component of the AR (1) model in addition to cross-correlation across error terms. They proposed two test statistics where the break points known and unknown.

1.2.4.1. The date of the break point is known

Let *m* be non-linear AR(1) panel data models, represented as *m*= {*M1*,*M2*}, letting for a common structural break in their deterministic components at time point T_0:

$$M1{:}\, y_i = \varphi y_{i-1} + (1-\varphi)\left(a_i^{(\lambda)} e^{(\lambda)} + a_i^{(1-\lambda)} e^{(1-\lambda)}\right) + u_i \text{ , } i=1,2,..N \quad \text{and} \qquad \text{(A.30)}$$

$$M2{:}\, y_i \varphi y_{i-1} + \varphi\beta_i e + (1-\varphi)\left(a_i^{(\lambda)} e^{(\lambda)} + a_i^{(1-\lambda)} e^{(1-\lambda)}\right) + (1-\varphi)\left(\beta_i^{(\lambda)} \tau^{(\lambda)} + \beta_i^{(1-\lambda)} \tau^{(1-\lambda)}\right) + u_i \text{ ,} \qquad \text{(A.31)}$$

y_{i-1}= $(y_{i0}, \dots . y_{iT-1})'$ is a vector y_i lagged one period back, u_i=$(u_{i1}, \dots u_{iT})'$ is the vector of error terms u_{it}, for all t, $\beta_i e$ is defined as $\beta_i e$ = $\beta_i^{(\lambda)}\tau^{(\lambda)} + \beta_i^{(1-\lambda)}\tau^{(1-\lambda)}$, where e is a (TX1)-dimension vector of unities, and $e^{(\lambda)}$ and $e^{(1-\lambda)}$ are (TX1)-dimension vectors defined, respectively, as follow: $e_t^{(\lambda)} = 1$ if $t \le T_0$ and *0* otherwise. The vectors are produced to gets a probable common break into individual effects of models (A.30) and (A.31), a_i , before and after arises denoted respectively as $a_i^{(\lambda)}$ and $a_i^{(1-\lambda)}$, where λ represents the fraction of the sample that this break takes place. $\lambda \in \mathrm{I} = \{\left[\frac{1}{T}\right], \left[\frac{2}{T}\right], \ldots, \left[\frac{T-1}{T}\right]\}$ for model *M1* and $\lambda \in \mathrm{I} = \{\left[\frac{2}{T}\right], \left[\frac{3}{T}\right] \ldots, \left[\frac{T-2}{T}\right]\}$ for model *M2*, [.] refer to the integer part.

The AR(1) models *M*1 and *M*2 in Eqs. (A.30) and (A.31) can be applied to get panel unit root test statistics that are alike under the null hypothesis $H_0: \varphi = 1$ to the initial condition of the panel y_{i0} and/or its individual effects for all i.

Unit root test statistic of the models *M*1 and *M*2 has the power to reject the null $H_0: \varphi = 1$ in favor of its alternative hypothesis of stationarity, represnted as H_a: φ < 1, around the broken individual effects or linear trends, when H_a: φ< 1 is true.

The unit root test statistics base on following pooled LS estimator of the autoregressive coefficient φ of models (A.30) and (A.31):

$$\hat{\varphi} = \left(\sum_{i=1}^{N} y_{i-1}' \, Q_m^{(\lambda)} y_{i-1}\right)^{-1} \left(\sum_{i=1}^{N} y_{i-1}' Q_m^{(\lambda)} y_i\right), \; m = \{M1, M2\}, \qquad \text{(A.32)}$$

where $Q_m^{(\lambda)}$ is the (*TXT*) within transformation matrix of the time series of the panel y_{it}.

Assumption 1. $\{u_{it}\}$ is a sequence of independent and identically distributed (*IID*) random variables with $E(u_{it})$ = 0, Var$(u_{it}) = \sigma_u^2 < \infty$, $E(u_{it}^4) = k + 3\sigma_u^4$, where *K*<∞.

The condition *K*<∞ indicates that the fourth moment of u_{it} exists.

Theorem 1. Assuming that the break point is known and under Assumption 1, we have

$$z(\lambda) \equiv \sqrt{N}\big(\hat{\varphi} - 1 - \beta(\lambda)\big) \xrightarrow{L} N\big(0, C(K, \sigma_u^2, \lambda)\big), \text{ since } N \to \infty \qquad \text{(A.33)}$$

$z(\lambda)$ is test statistic, $\beta(\lambda) = p \lim_{N \to \infty} (\hat{\varphi} - 1) = tr\left[\Lambda' Q_m^{(\lambda)}\right] \{tr\left(\Lambda' Q_m^{(\lambda)} \Lambda\right)\}^{-1}$, for *m*= {*M*1, *M2*},

$$c(k, \sigma_u^2, \lambda) = \left\{k \sum_{j=1}^{T} a_{ij}^{(\lambda)^2} + 2\sigma_u^4 tr(A^{(\lambda)^2})\right\} \{\sigma_u^2 tr(\Lambda' Q_m^{(\lambda)} \Lambda)\}^{-2}$$

where Λ is a (*TXT*) matrix.

1.2.4.2. The date of the break point is unknown

The collection of the break point of the test is the outcome of a sequential testing procedure minimizing the standardized test statistic in Theorem 1. The minimum value of the test statistics $C(k, \sigma_u^2, \lambda)^{-\frac{1}{2}} Z(\lambda)$, for all $\lambda \in I$, defined as *z*, generates the least favorable result for null hypothesis $H_0: \varphi = 1$.

Let $\hat{\lambda}_{\min}$ represent the break point where the minimum value of $C(k, \sigma_u^2, \lambda)^{-\frac{1}{2}} Z(\lambda)$ for all λ is obtained. So the null hypothesis will be rejected if

$$z \equiv \min_{\lambda \in I} C(k, \sigma_u^2, \lambda)^{-\frac{1}{2}} Z(\lambda) < c_{\min,a} \qquad \text{(A.34)}$$

where $c_{\min,a}$ is the left-tail critical value of the limiting distribution of z test at a level of significance a.

1.2.4.3. Serially correlated error terms

- Known break point

An extension of the test statistics has been applied in order to have higher-order correlation in error terms u_{it}.

The vector of errors terms u_i is produced by the autoregressive process as follow:

$u_i = \rho u_{i-1} + \varepsilon_i$ (A.35)

Where ε_i is a vector of independently and identically distributed error terms ε_{it}.

Using (A.31), the models $M1$ and $M2$ become as follow:

$M1^*: y_i = \varphi^* y_{i-1} + \rho^* \Delta y_{i-1} + a_i^* + \varepsilon_i$, t=3, 4,…T and i=1,2,…,N

$M2^*: y_i = \varphi^* y_{i-1} + \rho^* \Delta y_{i-1} + a_i^* + \beta_i^* + \varphi(1-\rho)\beta_i + \varepsilon_i$

Where $\varphi^* = \left(\varphi + \rho(1-\varphi)\right)$, $\rho^* = \rho\varphi$, $a_i^* = (1-\varphi)(1-\rho)\left(a_i^{(\lambda)} e^{(\lambda)} + a_i^{(1-\lambda)} e^{(1-\lambda)}\right)$,

$\beta_i^* = (1-\varphi)(1-\rho)\left(\beta_i^{(\lambda)} \tau^{(\lambda)} + \beta_i^{(1-\lambda)} \tau^{(1-\lambda)}\right)$, and $\Delta y_{i-1} = y_{i-1} - y_{i-2}$.

Under the null hypothesis $H_0: \varphi = 1$, models $M1^*$and $M2^*$ imply the following panel data process:

$y_{it} = y_{it-1} + \rho \Delta y_{it-1} + \varepsilon_{it}$ *and* $y_{it} = (1-\varphi)\beta_i^* + y_{it-1} + \rho \Delta y_{it-1} + \varepsilon_{it}$ *since* $\varphi^* = 1$ *and* $\rho^* = \rho$.

- Unknown break point

The $z^*(\lambda)$ is defined as follow when the break point is unknown:

$$z^* \equiv \min_{\lambda \in I^*} \Omega_{11}^{-1}(k, \sigma_u^2, \lambda) Z^*(\lambda), \qquad \text{(A.36)}$$

$\Omega_{11}(k, \sigma_u^2, \lambda)$ is the (1,1) element (submatrix) of $\Omega(k, \sigma_u^2, \lambda)$. $\lambda \in \mathrm{I} = \{\left[\frac{1}{T}\right], \left[\frac{2}{T}\right], \dots, \left[\frac{T-1}{T}\right]\}$ for model *M1* and $\lambda \in \mathrm{I} = \{\left[\frac{2}{T}\right], \left[\frac{3}{T}\right] \dots, \left[\frac{T-2}{T}\right]\}$ for model *M2,* [.] refer to the integer part.

Based on this test statistic, the null hypothesis will be rejected if $Z^* < c^*_{\min,a}$, where $c^*_{\min,a}$ is a left-tail critical value of the limiting distribution of z^* at a significance level a.

To obtain critical values $c^{*}_{\min,a}$, the bootstrap simulation method will be applied. For model $M1^{*}$, this method relies on the following steps:

1. Calculate the following regression under $H_0 : \varphi = 1$:

$$\Delta y_i = \rho^{*}\Delta y_{i-1} + \varepsilon_i, \ i=1,\ldots N \qquad \text{(A.37)}$$

depended on the pooled LS estimator, and get the vector of centred residuals $\bar{\varepsilon}_i = \hat{\varepsilon}_i - \frac{1}{N}\sum_{j=1}^{N}\hat{\varepsilon}_j$, for i=1,…,N.

2. Resample with replacement from vector $\bar{\varepsilon}_i$and represent the bootstrap samples by ε^{*}_i.

3. Calculate the values of vector of error terms u^{*}_i from vector ε^{*}_i using the following regression model:

$$u^{*}_i = \rho^{*}u^{*}_{i-1} + \varepsilon^{*}_i, \quad i=1,\ldots,N \qquad \text{(A.38)}$$

considering the initial values of u^{*}_{i2} to be $u^{*}_{i2} = \Delta y_{i2}$

4. Calculate recursively the values of y^{*}_i using the following:

$$y^{*}_i = y^{*}_{i-1} + u^{*}_i, \ i=1,..,N \qquad \text{(A.39)}$$

5. Estimate the minimum of the following statistic:

$\sqrt{N}\Omega_{11}^{-\frac{1}{2}}(k, \sigma_u^2, \lambda)(\tilde{\varphi}^{*(b)} - \tilde{\varphi}^{*})$, for all $\lambda \in I$,

where $\tilde{\varphi}^{*(b)}$ is the estimator of φ^{*} with the bootstrap sample, while $\tilde{\varphi}^{*}$is its sample estimator, explined before.

Table A.1 The exact critical values of UO test statistics.

Only intercept							
T/N	5	10	15	20	25	50	100
1%							
5	−4.35	−3.61	−3.27	−3.04	−2.89	−2.61	−2.34
	(-3.26)	(-2.80)	(−2.58)	(−2.48)	(-2.400	(−2.21)	(−2.08)
10	−2.65	−2.33	−2.19	−2.12	−2.06	−1.93	−1.83
30	−2.44	−2.21	−2.10	−2.04	−2.00	−1.90	−1.80
50	−2.45	−2.22	−2.11	−2.05	−2.00	−1.92	−1.82
70	−2.47	−2.23	−2.12	−2.07	−2.02	−1.91	−1.83
100	−2.47	−2.24	−2.14	−2.07	−2.03	−1.91	−1.84
5%							
5	−3.05	−2.74	−2.59	−2.50	−2.43	−2.30	−2.15
	(−2.76)	(−2.47)	(−2.33)	(−2.26)	(−2.21)	(−2.08)	(−2.00)
10	−2.31	−2.10	−2.02	−1.96	−1.92	−1.82	−1.76
30	−2.20	−2.04	−1.96	−1.91	−1.88	−1.80	−1.74
50	−2.22	−2.05	−1.97	−1.93	−1.90	−1.83	−1.76
70	−2.23	−2.06	−1.99	−1.94	−1.91	−1.83	−1.78
100	−2.24	−2.07	−2.00	−1.95	−1.92	−1.83	−1.78
10%							
5	−2.64	−2.45	−2.35	−2.30	−2.25	−2.18	−2.07
	(−2.51)	(−2.30)	(−2.20)	(−2.15)	(−2.11)	(−2.02)	(−1.95)
10	−2.14	−1.98	−1.92	−1.88	−1.85	−1.77	−1.74
30	−2.08	−1.94	−1.88	−1.85	−1.82	−1.76	−1.72
50	−2.09	−1.96	−1.90	−1.87	−1.84	−1.79	−1.73
70	−2.11	−1.97	−1.91	−1.88	−1.85	−1.79	−1.75
100	−2.12	−1.98	−1.92	−1.89	−1.86	−1.79	−1.76

Table A.2 The exact critical values of test statistics for Model A in OEE test.

T/N	$\bar{t}_{1p,a}$					$\bar{F}_{1p,a}$				
	5	10	15	25	50	5	10	15	25	50
1%										
30	−3.307	−3.053	−2.903	−2.791	−2.693	8.998	7.652	7.083	6.556	6.086
50	−3.115	−2.905	−2.792	−2.719	−2.616	7.925	6.953	6.499	6.133	5.711
70	−3.074	−2.866	−2.756	−2.674	−2.598	7.825	6.783	6.340	5.958	5.617
100	−3.046	−2.832	−2.736	−2.657	−2.564	7.596	6.610	6.235	5.876	5.488
150	−2.980	−2.799	−2.724	−2.638	−2.556	7.328	6.411	6.194	5.788	5.414
200	−2.978	−2.801	−2.721	−2.642	−2.543	7.335	6.501	6.111	5.833	5.376
5%										
30	−3.010	−2.855	−2.771	−2.697	−2.625	7.483	6.744	6.379	6.058	5.767
50	−2.897	−2.749	−2.688	−2.623	−2.558	6.777	6.250	5.958	5.722	5.433
70	−2.866	−2.717	−2.652	−2.582	−2.534	6.702	6.090	5.832	5.558	5.333
100	−2.822	−2.681	−2.633	−2.566	−2.511	6.626	5.949	5.737	5.454	5.243
150	−2.785	−2.667	−2.612	−2.556	−2.499	6.388	5.905	5.658	5.422	5.197
200	−2.787	−2.665	−2.606	−2.553	−2.486	6.435	5.860	5.650	5.384	5.155
10%										
30	−2.883	−2.752	−2.702	−2.643	−2.585	6.829	6.329	6.058	5.834	5.578
50	−2.779	−2.673	−2.620	−2.576	−2.523	6.319	5.899	5.701	5.513	5.293
70	−2.746	−2.638	−2.594	−2.542	−2.499	6.186	5.737	5.582	5.364	5.195
100	−2.728	−2.615	−2.576	−2.523	−2.475	6.111	5.639	5.478	5.270	5.096
150	−2.691	−2.599	−2.559	−2.506	−2.468	5.948	5.589	5.429	5.226	5.069
200	−2.692	−2.592	−2.545	−2.505	−2.458	5.978	5.564	5.398	5.213	5.028

*Table A.3 the c*ritical values of distribution minλ∈I N(0, R) for Karavias and Tzavalis panel unit root test with break.

α(%)	T							
	Panel A (for model M1)				Panel B (for model M2)			
	10	15	25	50	10	15	25	50
1	-2.91	-2.95	-2.98	-3.05	-2.92	-2.97	-3.04	-3.10
5	-2.15	-2.33	-2.37	-2.43	-2.31	-2.38	-2.43	-2.49
10	-1.83	-2.00	-2.04	-2.10	-1.99	-2.07	-2.11	-2.16

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