



UNIVERSIDADE DA BEIRA INTERIOR  
Ciências Sociais e Humanas

# Essays on Globe Energy Consumption and Economic Growth Nexus

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Tese para obtenção do Grau de Doutor em  
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## **Preface**

Imagine a world where the energy distribution channels are abruptly interrupted. Empirically the impacts on globe economic growth are hard to predict. And if we search for an answer in the energy-growth nexus literature we will most likely become confused with the discordant results. There are several pieces of literature supporting the nexus heterogeneity across the countries and numerous reasons pointed out as the main sources of heterogeneity. However, the analyses focusing on globe level have being overlooked. It could be argued that a shrinkage in economic growth will most likely occur given the energy dependence of developed countries and their weight on globe gross domestic product. However, the real globe impacts remain unstudied. For instance, understanding how an energy crisis could impact on globe nexus or examining the globe capacity to recover in direction to the long-run equilibrium could represent an added value for policymakers.

Taking the above cited reasons into account, this thesis aims to provide an assessment on globe energy-growth nexus. Four essays on globe energy-growth nexus have been developed. The topics of research may represent a contribution to the field of integrated energy policies, or to surpass the conflicting results on nexus literate. Given that literature on energy-growth nexus at globe level is almost nonexistent, any assessment on this topic requires an econometric approach which is strongly supported. For this reason, this thesis has a strong empirical component. By following this path of research, robust empirical evidences of globe energy-growth nexus are provided.

This thesis experienced several maturation levels until reaching its final state. For example, in the second year of investigation the research plan was discussed at WIN (Workshop de Investigadores Nascentes) in the SL3E'15 (XVII Seminário Luso-Espanhol de Economia Empresarial) at University of Beira Interior. The thesis advisor and co-advisor provided important contributions, but they are not the only ones who deserve an acknowledgment. All the researchers and unknown reviewers that give their judgments and advice at conferences sessions, meetings and paper revisions are acknowledged.

Several outputs arose from this research. Based on chapter 4, where the globe energy-growth nexus was investigated, one poster was accepted, two conference papers were presented and one journal article published:

- Marques, L.M.; Fuinhas, J.A.; and Marques, A.C. (2014). On the Global Energy Consumption and Economic Growth Nexus: A Long ARDL Bounds Test Approach. Presented at 14<sup>th</sup> IAEE European Energy Conference held in Rome, Italy and published at conference proceedings.

## *Essays on Globe Energy Consumption and Economic Growth Nexus*

- Marques, L.M.; Fuinhas, J.A.; and Marques, A.C. (2015). Does the Energy-Growth Nexus Exists an Globe? Poster acceptance at 2<sup>nd</sup> International Symposium on Energy Efficiency and Energy Related Materials (ENEFM 2015) held in Oludeniz, Turkey.
- Marques, L.M.; Fuinhas, J.A.; and Marques, A.C. (2015). The Globe Energy-Growth Nexus: A Short and Long-Run Analysis. Presented at 2<sup>nd</sup> International Meeting on Energy and Environmental Economics (ME3) in Aveiro, Portugal and published at conference proceedings, ISBN: 975-972-459-8.
- Marques, L.M.; Fuinhas, J.A.; and Marques, A.C. (2015). On the Global Energy Consumption and Economic Growth Nexus: A Long Time Span Analysis. *International Energy Journal*, 15(4), 143-150. Scopus indexed, SJR Q2 (in energy category at the publication year).

From the globe energy-growth analysis in four regions on chapter 5, one conference paper was presented and one journal article published:

- Marques, L.M.; Fuinhas, J.A.; and Marques, A.C. (2016). World Energy-Growth Nexus in Four Aggregates: America; Europe and Central Asia; Pacific Asia; and Africa and Middle East. Presented at XXX Congreso Internacional De Economía Aplicada (ASEPELT 2016) held in Valencia, Spain and published in conference proceedings, ISSN: 2174-3088.
- Marques, L.M.; Fuinhas, J.A.; and Marques, A.C. (2017). On the Dynamics of Energy-Growth Nexus: Evidence from a World Divided into Four Regions. *International Journal of Energy Economics and Policy*, 7(3), 208-215. Scopus indexed, SJR Q1 (in economic, econometrics and finance category in 2016).

From the chapter 7 where the impacts of globalization on globe energy-growth nexus are investigated, one poster and two conference papers were presented and one journal article was published:

- Marques, L.M.; Fuinhas, J.A.; and Marques, A.C. (2016). The Globe Energy-Growth Nexus: Long-Run Globalization Impacts. Presented at 3<sup>rd</sup> International Meeting on Energy and Environmental Economics (ME3) in Aveiro, Portugal.
- Marques, L.M.; Fuinhas, J.A.; and Marques, A.C. (2017). Is There Globalization Impacts on World Energy-Growth Nexus? An Assessment on Economic, Political and Social Globalization Impacts. Poster presented at *Desafios da Gestão Ativa da Procura de Energia: Eficiência e Resposta (GAPEER 2017)* held in Covilhã, Portugal.
- Marques, L.M.; Fuinhas, J.A.; and Marques, A.C. (2017). Augmented Energy-Growth Nexus: Economic, Political and Social Globalization Impacts. Presented at 4th International Conference on Energy and Environment Research (ICEER 2017) held in Oporto, Portugal.
- Marques, L.M.; Fuinhas, J.A.; and Marques, A.C. (2017). Augmented Energy-Growth Nexus: Economic, Political and Social Globalization Impacts. *Energy Procedia*. In press. Scopus indexed.

## *Essays on Globe Energy Consumption and Economic Growth Nexus*

There are two additional outputs, one poster and one conference paper, that do not arise directly from the following chapters but were also evaluated across the thesis development:

- Marques, L.M.; Fuinhas, J.A.; and Marques, A.C. (2017). Energy Consumption and Supply: Are Both Promoting Economic Growth? Poster presented at Encontro Com A Ciência e Tecnologia Em Portugal (Ciência 2017) held in Lisbon, Portugal.
- Marques, L.M.; Fuinhas, J.A.; and Marques, A.C. (2017). Do the Energy Supply Impacts on Economic Growth Equal Than Energy Consumption? An Augmented Energy-Growth Nexus Approach. Presented at 14<sup>th</sup> IAEE European Energy Conference held in Vienna, Austria.

Certainly, after writing this thesis, more outputs will continue to be generated. For instance, a paper based on China's spillovers on globe energy-growth nexus (chapter 6) is under development. Likewise, a book chapter is in progress. It is also planned to continue to disseminate the results in scientific conferences and meetings in the energy field.



## Resumo

A forma como o crescimento económico e o consumo de energia interagem tem sido alvo de interesse crescente nas últimas décadas. O contínuo crescimento económico global associado à deslocação de grandes quantidades de procura para economias emergentes como a Índia e a China colocam novos desafios que carecem de estudo. Neste aspecto, a literatura tem sido escassa, descurando o estudo do nexo energia-crescimento a níveis macroeconómicos mais elevados. Espera-se agora um despertar de interesse no nexo global devido às mudanças nos mercados de energia que estão a ocorrer a nível mundial. Com o intuito de avaliar as interações entre crescimento económico e consumo de energia a nível global foram desenvolvidos modelos bivariados e multivariados. O objetivo desta investigação é não só examinar o nexo no curto e longo prazo, mas também identificar como as decisões de política de energia em alguns países ou mesmo o desenvolvimento da globalização podem ter impactos à escala global. Deste modo, diferentes variáveis foram introduzidas como explicativas do crescimento económico e consumo de energia mundial. A tese procura alertar para a importância de se entenderem os impactos de decisão de política económica a nível global, tendo por base o desenvolvimento de 4 ensaios. Os dois primeiros têm o objetivo de estudar o nexo energia-crescimento a nível global e dividindo o globo em quatro regiões, sem interferência de qualquer outra variável. O terceiro e quarto ensaios introduzem o estudo do nexo energia-crescimento aumentado a nível global. No terceiro ensaio, o crescimento económico e consumo de energia da China foram introduzidas como possíveis variáveis explicativas do crescimento económico e consumo de energia em diferentes regiões do globo. O quarto ensaio, examina os impactos de várias dimensões de globalização no nexo global. As metodologias econométricas utilizadas tiveram em conta o tipo de dados a estudar, em que era esperada a existência de efeitos de endogeneidade bem como quebras estruturais. Também, os objetivos de examinar relações de curto e longo-prazo foram uma influência na escolha de metodologias. Por estes motivos, foram desenvolvidos modelos auto-regressivos tais como Modelos Auto-Regressivos com Desfasamento Distribuído (ARDL) e Vectores Auto-Regressivos (VAR) ou Modelos de Vector com Correção de Erros (VECM) estabelecidos com base em séries temporais ou dados em painel. Os resultados revelam a existência de uma relação bidirecional entre o crescimento económico e o consumo de energia a nível global. Demonstra-se que a existência de relações heterogéneas em diferentes regiões do globo não se deve essencialmente ao uso de diferentes metodologias. No geral, os resultados suportam um caminho de diversificação não só ao nível das componentes de energia primária, mas também a nível de fontes de rendimento económico. Foi também comprovado que existem países que podem influenciar o nexo global, como é o caso da China. Relativamente a fatores que influenciam o nexo foi observado que diferentes componentes da globalização influenciam o crescimento e o consumo de energia global.

## **Palavras-chave**

Nexo Consumo de Energia-Crescimento Económico Global; Efeitos Colaterais da China; Globalização; Séries temporais; Dados em Painel; Modelos Auto-Regressivos; ARDL; VAR; VECM.

## Resumo Alargado

Imaginemos que os canais de distribuição de energia são interrompidos a nível mundial. Que efeitos teria no crescimento económico mundial? Pode-se argumentar que provavelmente o crescimento económico mundial iria desacelerar, pois os países desenvolvidos e com maior peso no crescimento mundial são dependentes de energia e estão entre os principais importadores. Contudo, empiricamente este tem sido um tema pouco abordado, em parte porque o estudo do nexu entre o crescimento económico e o consumo de energia tem sido essencialmente examinado país a país ou em grupos de países. Outro dos fatores que tem retirado a motivação em estudar macro níveis é certamente a dificuldade em reunir dados comparáveis. Mas, os mercados de energia estão são vez mais integrados e países emergentes como a China e Índia estão a deslocar para eles grandes quantidades de energia. Este novo panorama provoca novos desafios e incertezas, nomeadamente relacionados com crescimento económico mundial, políticas integradas de energia ou até a segurança energética da China devido à forte dependência em importação de energia.

O estudo das relações entre consumo de energia e crescimento económico iniciou-se em 1978 quando Kraft and Kraft (1978) examinou as relações de causalidade para os Estados Unidos e concluiu que produto nacional bruto causou consumo de energia durante o período de 1947-1974. Passados dois anos, Akarca and Long (1980) defendeu que os resultados de Kraft and Kraft (1978) eram espúrios ao alterar a amostra estudada em dois anos. A existência de resultados conflituosos tem sido recorrente ao longo dos anos na literatura do nexu consumo de energia-crescimento económico. É frequente encontrar resultados diferentes para o mesmo país ou grupos de países, bastando para isso alterar o período a ser estudado ou a metodologia utilizada. Contudo, a maioria dos resultados existentes na literatura cabem em quatro hipóteses: (i) a *hipótese de feedback*; (ii) a *hipótese de conservação*; (iii) a *hipótese de crescimento*; e (iv) a *hipótese de neutralidade*.

Esta tese pretende então contribuir não só para o desenvolvimento da literatura a nível macroeconómico, mas também testar a utilização de diferentes metodologias em amostras semelhantes e assim fornecer informação que ajude a clarificar se a falta de unanimidade na literatura se deve em parte à utilização de diferentes metodologias. Dado que se espera a existência de um efeito de endogeneidade entre as variáveis, recorre-se ao uso de modelos auto-regressivos. Estes permitem não só acomodar este efeito nos modelos, mas também distinguir entre efeitos de curto e longo-prazo e ainda testar e corrigir os efeitos de períodos históricos que possam ter levado a quebras estruturais. Em resumo, ao longo da tese foram utilizadas as metodologias ARDL, VAR, VECM e ARDL em painel. Numa análise prévia das variáveis, foram feitos testes à ordem de integração, tais como: (i) ADF; (ii) PP; (iii) KPSS; e

(iv) teste de Dickey-Fuller modificado. No caso dos dados em painel foi utilizado o teste CIPS. Durante a modelização, as quebras estruturais e *outliers* foram identificadas com recurso aos testes de quebras estruturais de: (i) Chow; (ii) Quandt-Andrews; e (iii) Bai-Perron. A validade dos modelos foi avaliada com recurso aos seguintes testes: (i) teste de normalidade de Jarque-Bera; (ii) teste de multiplicador de Lagrange de autocorrelação serial de Breusch-Godfrey; (iii) teste ARCH para heterocedasticidade; teste RESET de estabilidade do modelo; e (iv) testes de estabilidade CUSUM. No caso dos dados em painel o fator de inflação da variância foi utilizado para avaliar a existência de multicolinearidade. Também os testes de Pesaran (2004), Greene (2012) e Wooldridge (2010) foram utilizados para avaliar a validade dos modelos.

Quatro ensaios foram desenvolvidos. O primeiro, tinha como principal objetivo analisar empiricamente as relações entre crescimento económico e consumo de energia no maior agregado macroeconómico, o agregado mundial. Para tal recorreu-se à metodologia ARDL que provou a sua utilidade ao identificar os efeitos de curto e longo prazos e também as épocas históricas que causaram quebras estruturais a nível mundial. Por forma a confirmar os resultados, também a metodologia VAR/VECM foi utilizada. Ambas as metodologias revelaram a existência da *hipótese de feedback* no curto e longo-prazo. Assim, não só se prova a estabilidade das relações entre as variáveis como também se verifica que os resultados não foram influenciados pela metodologia utilizada. No segundo ensaio, o globo foi dividido em quatro regiões (América; Europa e Ásia Central; Ásia Pacífico e África e Médio Oriente) com o objetivo de se confirmar ou não a existência de heterogeneidade nos resultados, quando diferentes regiões são submetidas à mesma metodologia. Uma vez mais, recorreu-se à metodologia ARDL, que revelou a existência da *hipótese de feedback* no curto-prazo em todas as regiões. No longo-prazo, verificaram-se evidências da *hipótese de feedback* na América e Ásia Pacífico e da *hipótese de conservação* na Europa e Ásia Central e África e Médio Oriente.

No terceiro ensaio e quarto ensaios procedeu-se à avaliação dos impactos da China e da globalização no nexo mundial. Utilizando os mesmos agregados do segundo ensaio, foram estudados os efeitos colaterais do crescimento económico e consumo de energia da China no globo. Uma vez mais utilizando a metodologia ARDL, verificou-se que o único agregado que não sofre nenhum impacto com origem no crescimento económico e consumo de energia da China é a América. Os resultados revelaram também que o consumo de energia da China tem um impacto negativo no consumo de energia da Ásia Pacífico enquanto que o crescimento económico da China tem impactos negativos no consumo de energia na Europa e Ásia Central. A globalização foi estudada em três das suas dimensões (globalização económica, globalização política e globalização social). Para tal construiu-se um painel com 43 países que procura representar, tanto quanto possível, o globo. Aplicando a metodologia de ARDL em painel, verifica-se que a globalização é um fenómeno com efeitos, essencialmente de longo-prazo, no nexo mundial. Os resultados revelam também que de todas as dimensões, apenas a globalização

política não causa crescimento económico enquanto que a globalização económica é a única a não ter impactos no consumo de energia.

A utilização de modelos autorregressivos revelou-se acertada devido aos efeitos de endogeneidade e à necessidade de efetuar correções de quebras estruturais e *outliers* em todos os modelos. Ao testar as quebras potencialmente relevantes, verificou-se que a crise financeira de 2008 teve impactos generalizados no nexo mundial. Outros períodos históricos, tais como a crise petrolífera de 1979 e o choque do preço de petróleo de 1990, foram também relevantes para explicar o nexo em algumas regiões do globo. Os resultados revelaram-se concordantes ao longo da tese. Globalmente, encontrou-se evidências de cointegração e a hipótese de *feedback* no curto e no longo-prazo verificou-se a nível mundial, acomodando a literatura existente bem como os restantes resultados desta tese. Verificou-se também que a utilização de diferentes metodologias não é a principal causa de heterogeneidade de resultados. Os resultados alertam que, no longo-prazo os impactos podem ainda ser amplificados devido à natureza endógena das variáveis.

A possibilidade de um crescente consumo ineficiente de energia provocado pelo crescimento mundial e expansão da globalização deverá ser tido em conta. Assim, o consumo de energia mundial deve ser monitorizado e medidas preventivas de promoção de eficiência devem ser tomadas. Também as diversificações das economias bem como das fontes de energia primária devem ser promovidas por forma a tornar as economias mais responsivas aos possíveis choques, especialmente em casos como o da China onde a necessidade de garantir segurança energética irá desempenhar um papel importante nos próximos anos. Por fim, o facto de a globalização ser essencialmente um efeito de longo-prazo no nexo consumo de energia-crescimento económico mundial, não deve ser visto como um obstáculo à promoção de medidas no imediato.



## **Abstract**

The way that economic growth and energy consumption interact with each other has been a rising interest in the last few decades. The continuous globe economic growth and the shift in large energy demand to emerging economics such as India and China raise new challenges requiring study. Regarding this, the literature is scarce and the study of energy-growth nexus at higher macroeconomic levels has been overlooked. The worldwide changes occurring in energy markets are expected to raise interest in globe nexus. In order to evaluate the interactions between globe economic growth and energy consumption, bivariate and multivariate models were developed. The aim of this research is not only to examine both short- and long-run nexus behaviours, but also to identify how the energy policies that some countries can follow, or how the development of globalization can have an impact on a globe scale. Following this path, different variables were introduced as explanatory of globe economic growth and energy consumption. By developing four essays, the thesis seeks to raise awareness of the importance of understanding the impact of economic policy decisions at the globe level. The first two essays focus on studying the energy-growth nexus at the globe level and by dividing the globe into four regions, without interference from any other variables. The third and fourth essays introduce the concept of study of the globe augmented energy-growth nexus. Additionally, in the third essay, China's economic growth and energy consumption were introduced as possible explanatory variables of economic growth and energy consumption through different globe regions. The fourth essay, examines the impact of different globalization dimensions on globe energy-growth nexus. The followed econometric approaches considered the data requirements as well as the predictable presence of structural breaks. Moreover, the aim to examine both the short- and the long-run relationships influenced the methodology choice. For those reasons, autoregressive models such as Autoregressive Distributed Model (ARDL), Vector Autoregression (VAR) or Vector Error Correction Model were developed by using time series and panel data. The results reveal a bidirectional relationship between globe economic growth and energy consumption. Moreover, the existence of heterogeneous relationships in different globe regions is proven to mostly not come from the use of different methodologies. Overall, the results support a path of diversification, not only on the used primary energy components, but also on economic outputs sources. It has also been proven that there are countries, such as China, that can influence the globe nexus. Regarding other factors influencing the globe nexus, it was observed that there are different globalization components impacting on globe economic growth and energy consumption.

## **Keywords**

Globe Economic Growth-Energy Consumption Nexus; China's Spillover Effects; Globalization; Time Series; Panel Data; Autoregressive Models; ARDL; VAR; VECM.

# Contents

Acknowledgments.....	v
Preface .....	vii
Resumo .....	xi
Palavras-chave .....	xii
Resumo Alargado.....	xiii
Abstract .....	xvii
Keywords .....	xviii
Contents .....	xix
List of Figures .....	xxi
List of Tables .....	xxiii
List of Acronyms .....	xxv
1 Introduction .....	1
2 Overview on Energy Consumption and Economic Growth Nexus Literature .....	7
2.1 Specific countries and multi-countries energy-growth nexus. Is there a lack at globe level? .....	10
2.2 Evolving into the research based on augmented energy-growth nexus .....	12
Chapter references .....	15
3 Methodology .....	21
3.1 Autoregressive distributed lag approach .....	23
3.2 Vector autoregression approach.....	24
Chapter references .....	25
4 Globe Level Evidence of Energy-Growth Nexus .....	29
4.1 Globe economic growth and primary energy consumption between 1965 and 2013. 29	
4.2 Is there causality between energy and growth on globe level?.....	32
4.3 Does the methodology influence the results?.....	40
4.4 The globe feedback hypothesis evidences.....	47
Chapter references .....	50
5 Dividing the Globe Energy-Growth Nexus into Four Regions.....	53
5.1 America, Europe and Central Asia, Asia Pacific and Africa and the Middle East between 1968-2014 .....	54
5.2 By using the same methodology, are there heterogeneous results on energy-growth nexus for the four globe regions? .....	58
5.3 Is there a future on regional policy integration? .....	69
Chapter references .....	73
6 Augmented Energy-Growth Nexus on the Globe: Are There China's Spillover Effects on Globe Nexus?.....	75

*Essays on Globe Energy Consumption and Economic Growth Nexus*

6.1	Sample analysis from 1970 to 2016 .....	75
6.2	China's energy consumption and economic growth effects on globe nexus .....	81
6.3	How important are China spillover effects on globe nexus? .....	93
	Chapter references .....	95
7	Augmented Energy-Growth Nexus on the Globe: An Assessment on the Impacts of Three Dimensions of Globalization .....	97
7.1	Globalization, economic growth and primary energy consumption analysis from 1971 to 2013.....	97
7.2	What are the impacts of globalization on globe energy-growth nexus? An autoregressive panel approach .....	101
7.3	Economic, political and social globalization as long-run drivers of globe energy consumption and economic growth.....	106
	Chapter references .....	109
8	Discussion on The Globe Energy-Growth Nexus Evidence. What is in the future? .....	111
9	Concluding Remarks.....	117
	References .....	121

## List of Figures

Fig. 1.1 - Globe GDP (OECD, 2017) and primary energy consumption (BP, 2017) 2035 forecast	1
Fig. 1.2 - Europe Brent spot price and Cushing, OK WTI spot prices FOB (EIA, 2014)	2
Fig. 1.3 - Primary energy consumption in % of world total primary energy consumption	3
Fig. 4.1 - Variables in level and first differences	30
Fig. 4.2 - Level and first difference correlograms	31
Fig. 4.3 - ARDL residuals	35
Fig. 4.4 - CUSUM and CUSUM of squares tests	36
Fig. 4.5 - Variables in level and in its first differences	41
Fig. 4.6 - VAR residuals	42
Fig. 4.7 - VECM residuals	43
Fig. 4.8 - Granger causality/Block exogeneity, and Toda and Yamamoto causality tests	45
Fig. 4.9 - Impulse response functions	47
Fig. 5.1 - Variables in level and in its first differences	55
Fig. 5.2 - Level and first difference correlograms	56
Fig. 5.3 - ARDL residuals	60
Fig. 5.4 - CUSUM and CUSUM of squares tests	62
Fig. 5.5 - ARDL models' residuals with dummies	65
Fig. 5.6 - Energy-growth nexus behaviour and the impacts of historical events (author elaboration)	71
Fig. 6.1 - Variables in level and in its first differences	77
Fig. 6.2 - Level and first difference correlograms	79
Fig. 6.3 - ARDL residuals	84
Fig. 6.4 - CUSUM and CUSUM of squares tests	86
Fig. 6.5 - ARDL residuals with dummies	88
Fig. 6.6 - China's economic growth and energy consumption spillover effects on long-run globe nexus (author elaboration)	94
Fig. 7.1 - Panel data residuals	103
Fig. 7.2 - Panel data residuals with impulse dummy	104
Fig. 7.3 - Energy consumption-economic growth summary (author elaboration)	107
Fig. 8.1 - Thesis' contribution to energy-growth nexus literature (author elaboration)	111
Fig. 8.2 - Summary of long-run results scheme (author elaboration)	113



## List of Tables

Table 2.1 - Four generations of methodologies on energy-growth nexus literature .....	9
Table 2.2 - Literature on specific and multi-countries studies on energy-growth nexus .....	11
Table 2.3 - Literature on approximated globe energy-growth nexus.....	12
Table 2.4 - Literature on augmented energy-growth with several variables and EKC hypothesis .....	13
Table 2.5 - Literature on specific-country and multi countries studies with trade openness .	15
Table 4.1 - Descriptive statistics.....	30
Table 4.2 - Integration order tests .....	32
Table 4.3 - Chow breakpoint test.....	37
Table 4.4 - Quandt-Andrews breakpoint test and Bai-Perron global $l$ breaks vs none multiple breakpoint test.....	37
Table 4.5 - Estimated ARDL models .....	38
Table 4.6 - Bounds test .....	39
Table 4.7 - Short-run and long-run elasticities .....	39
Table 4.8 - LR omitted variables test .....	40
Table 4.9 - Johansen cointegration test.....	42
Table 4.10 - Long-run elasticities.....	43
Table 4.11 - VEC model.....	44
Table 4.12 - Diagnostic tests .....	44
Table 4.13 - Variance decomposition .....	46
Table 5.1 - Descriptive statistics.....	54
Table 5.2 - ADP, PP and KPSS unit root tests .....	57
Table 5.3 - MDF unit root tests.....	58
Table 5.4 - Quandt-Andrews breakpoint test and Bai-Perron global $l$ breaks vs none multiple breakpoint test.....	63
Table 5.5 - Chow breakpoint test.....	63
Table 5.6 - ARDL models .....	66
Table 5.7 - Diagnostic tests.....	68
Table 5.8 - Bounds test .....	69
Table 5.9 - Short-run semi-elasticities and long-run elasticities.....	69
Table 6.1 - Descriptive statistics.....	76
Table 6.2 - ADF, PP and KPSS unit root tests .....	80
Table 6.3 - MDF unit root tests.....	81
Table 6.4 - Quandt-Andrews breakpoint test and Bai-Perron global $l$ breaks vs none multiple breakpoint test.....	86

*Essays on Globe Energy Consumption and Economic Growth Nexus*

Table 6.5 - Chow breakpoint test.....	87
Table 6.6 - ARDL models .....	89
Table 6.7 - Diagnostic tests.....	91
Table 6.8 - Bounds test .....	92
Table 6.9 - Short-run semi-elasticities and long-run elasticities.....	92
Table 7.1 - Countries list .....	98
Table 7.2 - Descriptive statistics.....	99
Table 7.3 - Variance inflation factors.....	100
Table 7.4 - First and second generation panel unit root tests.....	100
Table 7.5 - Model numbers.....	102
Table 7.6 - Cross-sectional dependence tests .....	104
Table 7.7 - Driscoll and Kraay panel data estimations.....	105
Table 7.8 - Short-run and long-run elasticities .....	106

## List of Acronyms

ADF	Augmented Dickey-Fuller
AR	Autoregressive
ARCH	Autoregressive Conditional Heteroskedasticity
ARDL	Autoregressive Distributed Lag
ARMA	Autoregressive Moving Average Model
BP	British Petroleum
COP21	2015 United Nations Climate Change Conference
CCEMG	Common Correlated Effect Mean-group Estimator
CIPS	Cross-sectionally Augmented Im, Pesaran and Shin
CSD	Cross-sectional Dependence
DOLS	Dynamic Ordinary Least Squares
ECM	Error Correction Mechanism
EKC	Environmental Kuznets Curve
FMOLS	Fully Modified Ordinary Least Squares
FOB	Free on Board
GDP	Gross Domestic Product
GNP	Gross National Product
KOF	Konjunkturforschungsstelle
KPSS	Kwiatkowski-Phillips-Schmidt-Shin
LM	Lagrange Multiplier
MDF	Modified Dickey-Fuller
MTOE	Million Tonnes of Oil Equivalent
OECD	Organisation for Economic Co-operation and Development
OPEC	Organisation of the Petroleum Exporting Countries
OK WTI	Oklahoma, West Texas Intermediate
PP	Phillips-Perron
PVAR	Panel Vector Autoregression
PVECM	Panel Vector Error Correction Model
RESET	Regression Equation Specification Error Test
UECM	Unrestricted Error Correction Model
USA	United States of America
VAR	Vector Autoregression
VECM	Vector Error Correction Model
VIF	Variance Inflation Factor



# Chapter 1

## Introduction

The world is experiencing a period of change in globe energy markets. According to BP (2014), primary energy consumption will increase 41% between 2012 and 2035 (see fig. 1.1) and growth in energy demand will move towards emerging economies. Additionally, world gross domestic product (GDP) is expected to increase by almost 90% between 2015 and 2035 (OECD, 2017). When faced with this outlook, integrated energy policies are being encouraged. In fact, the integrated energy policies are far from new. For example, in 2013, more than \$1,600 billion was invested worldwide to provide energy and \$130 billion to improve energy efficiency (BP, 2014) given that achieving universal access to the best and most efficient sources of energy is one of the world's goals. However, to face this outlook, a shift in the set of globe policies that are being implemented should not be discarded.

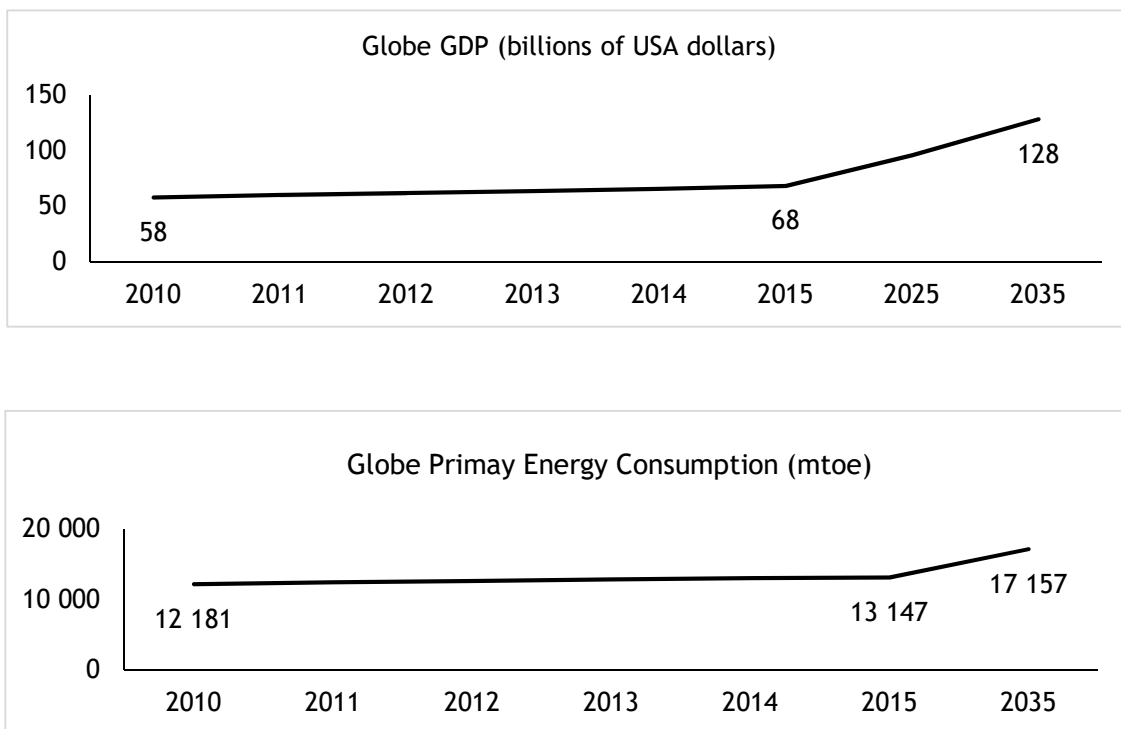


Fig. 1.1 - Globe GDP (OECD, 2017) and primary energy consumption (BP, 2017) 2035 forecast

## *Essays on Globe Energy Consumption and Economic Growth Nexus*

Given that the energy market is changing with increasingly globe energy markets and greater international cooperation, understanding the globe nexus can lead to a new insight on energy policies and promote the cited shift in the set of globe policies. Similar movements of Crude and Brent prices expose the correlation between energy markets (see fig. 1.2). Consequently, energy demand and supply adjustments are being experienced all over the globe. Nevertheless, these effects are not empirically observed in the academic literature. It has become widely accepted that dissimilar conclusions are reached about the energy consumption - economic growth nexus, in different parts of the globe, namely due to the use of different methodologies or data sets and this raises uncertainties about the impact of globe energy policies. But are these the main causes?

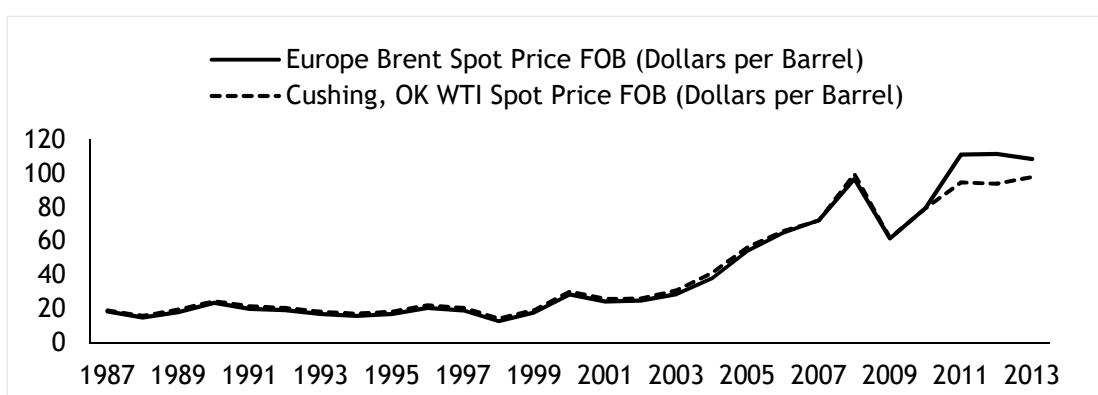


Fig. 1.2 - Europe Brent spot price and Cushing, OK WTI spot prices FOB (EIA, 2014)

Nowadays, energy is an important factor of globalization. International trade promotes relationships between countries, namely the energy dependent ones and the energy producers. With the above cited increasingly globalization in energy markets, it is expected that they will develop throughout the globe in coming years. For instance, the demand for energy will keep growing in emerging economies. Strong growth in Asia will most likely drive increasing energy consumption and, to satisfy this, some oil producers will play a major role by increasing oil supply. Further, political globalization can have an important role in the globe nexus balance due to the possible impacts of some agreements or treaties.

At the 2015 United Nations Climate Change Conference (COP21) summit in Paris in December 2015, the European Union and 195 more countries agreed to limit carbon emissions in order to restrict global average temperature increases. On one hand this agreement incentivised the decarbonization of energy markets through the diversification of the primary energy sources, namely by switching from oil and coal to gas and promoting the renewable ones. On the other hand there is a discouragement caused by the decrease in oil and coal prices. The Organisation

of the Petroleum Exporting Countries (OPEC) oil glut and United States of America (USA) shale oil extraction are one of the main causes of the oil price drop. At this point, new challenges are emerging because the real globe impact of those policy decisions impacts are hard to measure.

The aforementioned facts, in association with high and increasingly relevance that some players have in the energy markets, may lead spillover effects on the globe energy-growth nexus. Currently, the literature that tries to examine these effects at a globe level is scarce. China's case may be especially relevant to trigger interest in the research of the spillover effects on globe nexus. A big parcel from the expected growth in Asia is due to China, which is currently the second largest economy in the globe. Additionally, they have had the largest growth market for energy for years, being the second largest oil consumer country and the first primary energy consumer (see fig. 1.3).

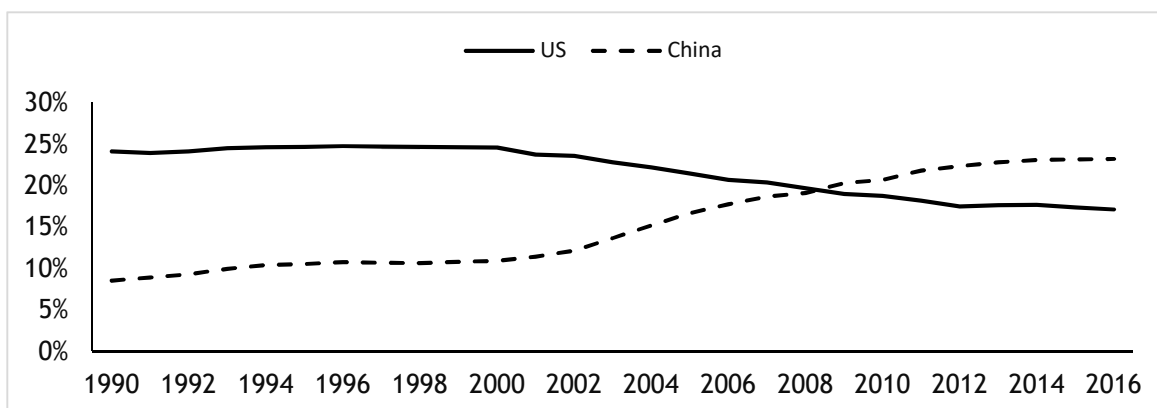


Fig. 1.3 - Primary energy consumption in % of world total primary energy consumption (BP, 2017)

China superseded the USA for the first place in primary energy consumption in 2009 and is still gaining prominence. On one hand, China's primary energy consumption has still been increasing in recent years, while on the other hand it is adjusting its economy to a more sustainable growth pattern by changing from coal to clean energy. Globe demand for coal has slowed, driven by China's demand, which is projected to grow by less than 2% per year over the next decades, compared with over 6% per year (BP, 2017). This not only reflects in China's total primary energy consumption, but also reduces the economic growth. Taking this into account it is quite possible that their decisions on energy policies will have spillover effects across the globe energy-growth nexus.

To make sense of all this outlook, it will be relevant to understand the impacts of increasingly globalization in the energy-growth nexus. In fact, the study of globalization impacts on energy-

growth nexus is not new, however at a globe level it remains unconsidered. With all of this in mind some questions arise:

- (i) Is there a bi-directional causality between energy consumption and economic growth present at a globe level?
- (ii) Are the results on energy-growth nexus heterogeneous for different globe regions when subjected to the same methodology?
- (iii) Are there effects from China's spillover effects on the globe energy-growth nexus?
- (iv) Does the globalization impact on the globe energy-growth nexus?

To answer those questions a research based on autoregressive (AR) models is carried out. Throughout this thesis autoregressive approaches such as autoregressive distributed lag (ARDL) models, vector error-correction models (VECM) and panel ARDL models are followed allowing to examine both short- and long-run behaviours.

In short, the results of the globe energy-growth nexus fit into the traditional *feedback hypothesis*, where bi-directional causality between energy and growth is found, both in the short-run and in the long-run and the energy-growth nexus research on different globe regions confirmed the existence of heterogeneous results. These results highlight that most likely some countries or regions have a higher share of impacts on the globe energy-growth nexus, and it was verified that indeed China's economic growth and energy consumption have long-run impacts on the globe nexus. Given the increasing globalization of energy markets these impacts were not totally unexpected which led to the analysis of the globalization impacts on the energy growth nexus. In fact, different dimensions of globalization were analysed (economic, political and social). The results state that the three dimensions of globalization have long-run impacts on the globe nexus.

The findings suggest that countries should not remain indifferent to the policies that other countries might follow, namely those that can influence the energy market. The increasingly integrated energy policies path is supported. In fact, the development of joint energy policies between some of the globe regions should be considered. Furthermore, in the future the policies to be followed across the globe will most likely need to take into account China's spillover effects.

In the next chapter, a brief reasoning on the energy-growth nexus state of art was developed. Following, a methodology chapter identifies all the used methodologies and the reasons behind the choices. Then four research chapters are presented. In chapter 4 the globe energy-growth nexus is analysed while in chapter 5 the globe energy-growth nexus is analysed by dividing the

## *Essays on Globe Energy Consumption and Economic Growth Nexus*

world in four testable and comparable regions. In chapter 6 and 7, two essays on augmented energy-growth nexus on the globe can be found. Chapter 6 is focused on identifying China's economic growth and energy consumption spillover effects on the globe nexus, while chapter 7 aims to investigate the globalization impacts on the globe nexus. In chapter 8 the overall results and their importance on the globe energy-growth nexus future is discussed. At the end, some concluding remarks can be found.



## Chapter 2

### Overview on Energy Consumption and Economic Growth Nexus Literature

The relationship between energy consumption and economic growth has been studied since the 1970s, when Kraft and Kraft (1978) examined this causality relationship for the United States of America (USA) and found that gross national product (GNP) causes energy consumption over the period of 1947-1974. However, Akarca and Long (1980) pointed out that the results of Kraft and Kraft (1978) were spurious, by changing the time period by 2 years. It was the onset of a lack of consensus on energy consumption and economic growth nexus literature that lasts until the present day.

The research on the nexus evolved around the examination of Granger causality between energy and growth (and vice versa), leading to four testable relationships: (i) the *neutrality hypothesis*; (ii) the *feedback hypothesis*; (iii) the *conservation hypothesis*; and (iv) the *growth hypothesis*. To put it briefly, the *neutrality hypothesis* supports that there is no causality between energy consumption and economic growth. For instance, Śmiech and Papież (2014) found the causality between energy consumption and economic growth thus supporting the *neutrality hypothesis* for 15 European countries. The opposite relationship, known as the *feedback hypothesis*, states that there is bi-directional causality between energy consumption and economic growth and is found in vast areas of literature. Recently, Adams *et al.* (2016) results supports the *feedback hypothesis* for a panel of 16 sub-Saharan African countries between 1971 and 2013 (see table 2.2). The other two identified hypotheses refer to the existence of unidirectional causality. The *conservation hypothesis* suggests the existence of uni-directional causality running from economic growth to energy consumption and the *growth hypothesis* consists of a unidirectional causality running from energy consumption to economic growth.

A good example of the heterogeneous results that could be found in the literature is Ahmed and Azam (2016) who for a sample of 119 mixed-income countries found evidence of *feedback hypothesis* for 18 countries, confirmed the *growth hypothesis* for 25 countries, the *conservation hypothesis* was observed in 40 countries and the *neutrality hypothesis* observed in 36 countries. In addition, new possible relationships have been observed, recently. For instance, Fuinhas and Marques (2013) report the possibility of an “atypical” negative relationship in the nexus due to the non-inclusion of crucial parameters that characterize an economy (see table 2.2). The use

of different data set and econometric methodologies are usually appointed as the causes of the divergent results as stated by Ozturk (2010).

Despite the use of different econometric methodologies being pointed as one of the main causes of conflicting results, to enhance nexus knowledge, different methodologies have been used over the years. Four generations of methodologies (see table 2.1) could be identified (e.g. Mehrara, 2007): (i) studies based on VAR methodology (e.g. Sims, 1972) and Granger causality, assuming stationarity; (ii) studies based on non-stationary series and Granger (1988) cointegration theory using a correction model to test for causality; (iii) studies using multivariate estimators with more than two variables in the cointegration relationship; and (iv) studies based on panel cointegration and panel error correction models. Yu and Hwang (1984), by applying the Sims (1972) technique, find no causal relationship between GNP and energy consumption for USA during 1947-1979, contrary to the Kraft and Kraft (1978) conclusions. In the second generation of methodologies, Cheng and Lai (1997) used non-stationary series and found that causality running from GDP to energy consumption in Taiwan. Also with non-stationary variables Glasure and Lee (1998) found no causal relationship between DGP and energy consumption for South Korea and Singapore.

By using a multivariate analysis, Stern (2000) found a bidirectional causality between economic growth and energy consumption in the USA between 1948-1994. Oh and Lee (2004) studied the Korean energy-growth nexus between 1981 and 2000, through the demand side and production side, by adding real energy prices, capital and labour to the models and found a unidirectional causality running from GDP to energy consumption. More recently, Saidi *et al.* (2017) found a bidirectional causality between economic growth and energy consumption for a panel of 53 countries using GDP per capita, total primary energy consumption, gross fixed capital and total labor force.

Regarding t studies based on panel cointegration for example, Damette and Seghir (2013) found unidirectional causality from economic growth to energy consumption for 12 oil exporting countries, while Mohammadi and Parvaresh (2014) found bidirectional causality between economic growth and energy consumption for 14 oil exporting countries. Likewise, Streimikiene and Kasperowicz (2016) found the bidirectional causality between energy and growth for a panel of 18 European countries.

## *Essays on Globe Energy Consumption and Economic Growth Nexus*

Table 2.1 - Four generations of methodologies on energy-growth nexus literature

Author	Countries	Period	Methodology	Results
<b><i>Based on VAR methodology</i></b>				
Kraft and Kraft (1978)	USA	1947-1974	VAR	Y->EC
Yu and Hwang (1984)	USA	1974-1979	VAR	EC-Y
<b><i>Based on non-stationary series and Granger (1988) cointegration theory</i></b>				
Cheng and Lai (1997)	Taiwan	1955-1993	Granger causality	Y->EC
Glasure and Lee (1998)	South Korea Singapore	1961-1990	VECM	EC-Y EC-Y
<b><i>Based on multivariate estimators with more than two variables in the cointegration relationship</i></b>				
Stern (2000)	USA	1948-1994	VAR	EC<->Y
Oh and Lee (2004)	Korea	1970-1999	VECM	Y->EC
Saidi <i>et al.</i> (2017)	53 countries	1990-2014	Panel VECM	EC<->Y
<b><i>Based on panel cointegration and panel error correction models</i></b>				
Damette and Seghir (2013)	12 oil exporting	1990-2010	Panel cointegration	Y->EC
Mohammadi and Parvaresh (2014)	14 oil exporting	1980-2001	CCEMG	EC<->Y
Streimikiene and Kasperowicz (2016)	18 European countries	1995-2012	Panel FMOLS; Panel DOLS	EC<->Y

**Notes:** Y means economic growth; EC means energy consumption; -> means unidirectional causality; <-> means bidirectional causality; and - means no causality.

Those methodologies are usually based on bivariate and multivariate models. The bivariate approach is both criticized, and recognized as valuable in literature on the nexus. There is a substantial amount of contemporary literature that uses bivariate models in the energy-growth nexus. By using a bivariate approach, Carmona *et al.* (2017) found evidence of bidirectional causality between economic growth and energy consumption in the USA between 1973 and 2015. Likewise, Mohammadi and Amin (2015) found bidirectional causality between economic growth and energy consumption for 79 countries from different growth levels, for a time span between 1971 and 2011. The use of bivariate approaches has been also applied to the study of nexus with different energy sources. Hamit-Hagggar (2016) for a panel of eleven sub-Saharan African countries over the period of 1971-2007, found a unidirectional Granger causality from clean energy consumption to economic growth.

It is interesting to note that until this point of the literature review, a big share of literature including studies with a high number of countries is cited, and none of the authors had the goal to understand the nexus at the most macroeconomic aggregates. Instead, the goals are mainly based on exploring the nexus through different globe regions, making a distinction between Organisation for Economic Co-operation and Development (OECD) and non-OECD countries or even exploring the nexus through countries with different development levels.

## **2.1 Specific countries and multi-countries energy-growth nexus. Is there a lack at globe level?**

For decades, the energy-growth nexus has received considerable attention (e.g. Akarca and Long, 1980; Lee and Chang, 2007; Wang *et al.*, 2016a; Yu and Jin, 1992) and by focusing on dividing the research in country-specific and multi-country studies that has led to a mix of results. For example, Wang *et al.* (2011) found uni-directional causality running from energy consumption to economic growth for China between 1972 and 2006. However, Wang *et al.* (2016a) found bi-directional causality between energy consumption and economic growth for China between 1990 and 2012. Different methodologies, data, and periods to study are of the most advocated causes for heterogeneous results. Examples of literature on specific-country studies supporting the four traditional hypothesis are shown in a resume table (see table 2.2). The following resume tables contains information about authors, studied countries, period of study, main methodologies and causality direction between economic growth and energy consumption.

With regard to the multi country studies, it is also possible to find research supporting the different energy-growth nexus in table 2.2. Further, discordant results are also easy to identify. For example, Omri and Kahouli (2014) found the presence of bi-directional causality between energy and growth for a panel of high income countries, while Ahmed and Azam (2016) by studying 24 high income-OECD countries, found the bi-directional causality only in 5 countries, while evidences of the *growth hypothesis* and *neutrality hypothesis* were found for 4 and 15 countries, respectively. Although it is usual to relate the energy-growth pattern with income categories (Mohammadi and Amin, 2015), the cited results reveal that the income level may not be directly related with the causality direction in every outlook. However, the possible divergence in results caused by different methodologies should be taken into account.

**Essays on Globe Energy Consumption and Economic Growth Nexus**

Table 2.2 - Literature on specific and multi-countries studies on energy-growth nexus

Author	Countries	Period	Methodology	Results
<b>Individual countries studies</b>				
Wang <i>et al.</i> (2011)	China	1972-2006	ARDL	EC->Y
Ahmed <i>et al.</i> (2015)	Pakistan	1971-2011	VAR	Y->EC
Alshehry and Belloumi (2015)	Saudi Arabia	1971-2010	VECM	Y->EC
Wang <i>et al.</i> (2016a)	China	1990-2012	VECM	EC<->Y
Carmona <i>et al.</i> (2017)	USA	1973-2015	Granger causality	EC<->Y
<b>Groups of countries studies</b>				
Fuinhas and Marques (2013)	Algeria Egypt	1965-2010	ARDL	EC-Y EC<->Y
Omri and Kahouli (2014)	65 countries, divided into: High income; Middle Income; Low Income; Globe panel.	1990-2011	Dynamic Simultaneous Equations	EC<->Y EC<->Y Y->EC EC<->Y
Mohammadi and Amin (2015)	79 countries, divided into: High growth; Low growth; Negative growth.	1971-2011	CCEMG	EC<->Y
Adams <i>et al.</i> (2016)	16 Sub-Saharan Africa Countries	1971-2013	Panel VAR	EC<->Y
Ahmed and Azam (2016)	119 countries divided into: High Income OECD countries; High Income Non-OECD countries; Middle income countries; Low income countries.	Diverse between 1960-2012	Frequency Domain Analysis	EC->Y EC-Y Y->EC EC<->Y

**Notes:** Y means economic growth; EC means energy consumption; -> means unidirectional causality; <-> means bidirectional causality; and - means no causality.

The nexus research has advanced in order to solve issues that have arisen and at this point the study of the nexus at a globe level could be useful to help understand the disaggregated divergent results. In fact, some authors have already made an approximation to the study of the globe nexus by using samples with a substantial number of countries (see table 2.3). However, the use of globe aggregated variables is absent.

Table 2.3 - Literature on approximated globe energy-growth nexus

Author	Countries	Period	Methodology	Results
Narayan and Popp (2012)	93 countries	1980-2006	Panel Granger causality	EC->Y
Omri and Kahouli (2014)	65 countries	1990-2011	Dynamic Simultaneous Equations	EC<->Y
Chen <i>et al.</i> (2016)	188 countries	1993-2010	Panel VECM	EC*->Y
Antonakakis <i>et al.</i> (2017)	106 countries	1971-2011	Panel VAR	EC<->Y
Saidi <i>et al.</i> (2017)	53 countries	1990-2014	Panel VECM	EC<->Y

**Notes:** Y means economic growth; EC means energy consumption; -> means unidirectional causality; <-> means bidirectional causality; and \* means negatively causes.

Antonakakis *et al.* (2017) found the *feedback hypothesis* on energy-growth nexus for a panel of 106 countries, as well as Chen *et al.* (2016) who found the same hypothesis for a panel of 188 countries. However, both authors followed a multivariate approach. By using a bivariate approach Narayan and Popp (2012) found a uni-directional causality running from energy consumption to economic growth for a panel of 93 countries, reinforcing the idea that the use of different methodologies or variables are strongly related with the conflicting results. Even a case of energy consumption negatively causing economic growth is reported by Chen *et al.* (2016) for a panel of 188 countries. The literature has been pursuing the causes of the contradictory results for years, which has led to the development of nexus research with a growing number of articles and approaches.

## 2.2 Evolving into the research based on augmented energy-growth nexus

The literature evolved from the traditionally bi-variate models to the inclusion of additional variables leading to the study of augmented energy-growth nexus. The research on energy-growth nexus has been extended by including variables such as the financial development, population, urbanization or industrialization. For example, Shahbaz and Lean (2012) found that financial development, economic growth, industrialization and urbanization increase energy consumption for the Tunisian economy. Islam *et al.* (2013), results suggest that energy consumption is influenced by economic growth, financial development and population level for Malaysia.

Recently, concerns about the decrease in carbon dioxide emission and globalization, among others has led to the inclusion of even more variables to the energy-growth nexus research (see table 2.4). Esso and Keho (2016) examined the long-run relationship between energy consumption, carbon dioxide (CO<sub>2</sub>) and economic growth for 12 African countries from 1971-

2010 and found mixed results. They found that in the long-run, bidirectional causality between economic growth and CO<sub>2</sub> emissions exists for Congo and Gabon, while energy consumption and economic growth cause CO<sub>2</sub> emissions in Benin, Cote d'Ivoire, Nigeria, Senegal, South Africa and Togo. Mirza and Kanwal (2017) found a bidirectional causality between energy consumption, economic growth and CO<sub>2</sub> emissions for Pakistan. Farhani and Ozturk (2015) investigated the causal relationships between CO<sub>2</sub>, real GDP, energy consumption, financial development, trade openness and urbanization for Tunisia over the period of 1971 to 2012 finding positive relationships between CO<sub>2</sub> and GDP not supporting the validity of the Environmental Kuznets Curve (EKC). The EKC hypothesis states that environmental degradation increases during the early stages of economic growth and decreases after a threshold point. In fact, one of the topics under discussion over the last decades is the environment-growth nexus through the use of EKC. For example Apergis and Ozturk (2015) tested and confirmed the EKC hypothesis for 14 Asian countries between 1990-2011. Pablo-Romero and De Jesús (2016) found no evidence of relationship between economic growth and energy consumption rejecting the EKC.

Table 2.4 - Literature on augmented energy-growth with several variables and EKC hypothesis

Author	Countries	Period	Methodology	Results
<b><i>Augmented energy-growth nexus</i></b>				
Shahbaz and Lean (2012)	Tunisia	1971-2008	ARDL; VECM	Y->EC EC<->FD EC<->IND
Islam <i>et al.</i> (2013)	Malaysia	1971-2009	ARDL; VECM	Y->EC FD->EC
Esso and Keho (2016)	12 African Countries	1971-2010	VAR	Y->CO <sub>2</sub> EU->CO <sub>2</sub>
Mirza and Kanwal (2017)	Pakistan	1971-2009	ARDL	EC<->Y Y<->CO <sub>2</sub> EC<->Y
<b><i>EKC hypothesis</i></b>				
Apergis and Ozturk (2015)	14 Asian Countries	1990-2011	GMM	Support the EKC hypothesis
Farhani and Ozturk (2015)	Tunisia	1971-2012	ARDL	Not support EKC hypothesis
Pablo-Romero and De Jesús (2016)	22 Latin American and Caribbean Countries	1990-2011	Standard cubic EKC	Not support EKC hypothesis

**Notes:** Y means economic growth; EC means energy consumption; EU means energy use; FD means financial development; IND means industrialization; -> means unidirectional causality; and <-> means bidirectional causality.

Given that no consensus has been reached on the energy-growth nexus literature, investigating the impacts of other factors on the energy-growth relationships could be a renewed sight on the subject. For this reason, the globalization impacts on energy consumption, caught the researchers' attention, namely by studying developing and developed countries. The study of trade openness impacts on energy consumption, started when Cole (2006) by using the Antweiler *et al.* (2001) theoretical principles, observed that trade liberalization can increase per capita energy use, for a sample of 32 developed and developing countries. Thenceforth, vast literature has been targeted at investigating the relationship between energy consumption, economic growth and trade openness, by using individual countries or a panel of countries studies (see table 2.5).

Various proxies of globalization have been used, for instance imports, exports, trade liberalization, among others. For instance, Sadorsky (2012) by using energy consumption, economic growth, imports and exports found bidirectional causality between energy consumption and exports and between energy consumption and imports for seven South America countries. By using the same variables, Dedeoğlu and Kaya (2013) found bidirectional causality between, energy use and GDP, energy and exports and energy use and imports in 25 OECD countries. Recurring to trade openness, bidirectional causality between energy consumption and economic growth, energy consumption and trade openness and economic growth and trade openness was found by Shahbaz *et al.* (2013) in Indonesia. Likewise, Shahbaz *et al.* (2015) and Kyophilavong *et al.* (2015) achieved the same results for Malaysia and Thailand, respectively. By using a multi-country approach, Nasreen and Anwar (2014) found bidirectional causality between economic growth and energy consumption, trade openness and energy consumption in 15 Asian countries. Recently, Shahbaz *et al.* (2016) examined the relationships between energy consumption, economic growth and three globalization dimensions (economic, social and overall) and found that globalization led to a decline in energy consumption in India between 1971-2012.

Table 2.5 - Literature on specific-country and multi countries studies with trade openness

Author	Countries	Period	Methodology	Results
<i>Individual countries studies</i>				
Shahbaz <i>et al.</i> (2013)	Indonesia	1975-2011	ARDL; VECM	EC<->Y EC<->O Y<->O
Kyophilavong <i>et al.</i> (2015)	Thailand	1971-2012	VECM	EC<->Y EC<->O Y<->O
Shahbaz <i>et al.</i> (2015)	Malaysia	1970-2011	ARDL; VECM	EC<->Y EC<->O Y<->O
Shahbaz <i>et al.</i> (2016)	India	1971-2012	ARDL; VECM	EC<->Y G*->EC G->Y
<i>Panels of countries studies</i>				
Sadorsky (2012)	7 South America Countries	1980-2007	Panel VECM	EC<->Y EC<->O Y<->O
Dedeoğlu and Kaya (2013)	25 OECD Countries	1980-2012	Panel DOLS	EC<->Y EC<->O
Nasreen and Anwar (2014)	15 Asian Countries	1980-2011	Panel FMOLS, panel DOLS and panel VECM	EC<->Y EC<->O

**Notes:** Y means economic growth; EC means energy consumption; EU means energy use; G means globalization; O means trade openness; <-> means bidirectional causality; and -> means unidirectional causality.

Taking into consideration that globalization has impacts on energy-growth nexus, and given that the markets are becoming increasingly integrated, the study of some countries spillover effects on the globe nexus may lead to a new perspective for the policymakers. This is far from new in the literature on other subjects (e.g. Koesler *et al.*, 2016; Mensi *et al.*, 2016; Zhang, 2017). However, the spillover effects research is absent in what concerns to the globe energy-growth nexus.

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## Chapter 3

### Methodology

By considering chapter 2, it is evident that the importance of AR models in the energy-growth nexus is recognized between the authors. For this reason, it was decided to follow these types of methodologies to the analysis the globe energy-growth nexus. Across this thesis the ARDL, VAR/VECM and Panel ARDL methodologies were carried out. Given that these methodologies belong to the AR “family” which specifies that a variable depends on its own previous values, they allow to examine both short-run and long-run behaviours between dependent and independent variables. Additionally, these AR approaches are robust to the presence of endogeneity which is expected to find between economic growth and energy consumption.

Before the model’s development, the variables are evaluated. Summary statistics, including Skewness, Kurtosis and Jarque-Bera, are provided for all variables. The integration order of the variables allows to select the optimal approach and for the time-series cases it is accessed by: (i) Augmented Dickey-Fuller (ADF); (ii) Phillips-Perron (PP); and (iii) Kwiatkowski-Phillips-Schmidt-Shin (KPSS). These unit root tests have been used throughout the literature (e.g. Fuinhas and Marques, 2013; Saidi *et al.*, 2017; Shahbaz *et al.*, 2015). Additionally, a modified Dickey-Fuller (MDF) unit root test could be performed or even be used instead of the three above cited tests. The MDF test follow Perron (1989) and allow to test for unit root in presence of a single break date. The model follows the general null hypothesis:

$$y_t = y_{t-1} + \beta + \zeta(L)(\theta D_t(T_b) + \gamma + DU_t(T_b) + \varepsilon_t) \quad (3.1),$$

where  $D_t(T_b)$  is the one time break dummy variable,  $DU_t(T_b)$  is the intercept break variable,  $\beta$  and  $\theta$  are trend and break parameters, respectively,  $\varepsilon_t$  are the independent and identically distributed innovations, and  $\zeta(L)$  is a lag polynomial representing the dynamics of stationary and invertible Autoregressive Moving Average Model (ARMA) error process. The alternative hypothesis which assumes a trend stationary model with breaks in intercept and trend is specified as follows:

$$y_t = \mu + \beta TREND + \zeta(L)(\theta DU_t(T_b) + \gamma DT_t(T_b) + \varepsilon_t) \quad (3.2),$$

where  $DT_t(T_b)$  represents a trend break variable. Taking the hypothesis into consideration, the general test equation is specified as follows:

$$y_t = \mu + \beta TREND + \theta DU_t(T_b) + \gamma DT_t(T_b) + \omega D_t(T_b) + \alpha y_{t-1} + \sum_{i=1}^k c_i \Delta y_{t-1} + \varepsilon_t \quad (3.3)$$

From this framework four specifications should be considered: (i) non-trending data with intercept break; (ii) trending data with intercept break; (iii) trending data with intercept and trend breaks; and (iv) trending data with trend break. To evaluate the null hypothesis the t-statistic is used. The unit roots in the panel data cases are assessed through the cross-sectional augmented Im, Pesaran and Shin (CIPS) test (Pesaran, 2007). This approach allows to assess the unit roots in presence of cross-sectional dependence and is widely used throughout the literature (e.g. Chen *et al.*, 2016; Damette and Seghir, 2013; Mohammadi and Parvaresh, 2014).

The need to control for structural breaks or outliers is assessed by: (i) visually inspection of the model's residuals; (ii) Chow breakpoint test (Chow, 1960); (iii) Quandt-Andrews breakpoint test (Andrews, 1993); and/or (iv) Bai-Perron Global  $l$  Breaks vs None multiple breakpoint test (Bai and Perron, 2003a). The thesis tries to go further on structural breaks analysis. The Chow breakpoint test tests whether there is a structural change in all the equation parameters. The null hypothesis of no break at the specified breakpoint is evaluated by a F-statistic as follows:

$$F = \frac{(u'u - (u'_1u_1 + u'_2u_2))/k}{(u'_1u_1 + u'_2u_2)/(T - 2k)} \quad (3.4),$$

where  $u'u$  is the restricted sum of squared residuals,  $u'_i u_i$  is the sum of squared residuals from subsample  $i$ ,  $T$  is the total number of observation, and  $k$  is the number of parameters in the equation. The Quandt-Andrews breakpoint tests for one or more unknown structural breakpoint by performing the Chow Breakpoint Test at every observation. Under the null hypothesis of no breakpoint between  $\tau_1$  and  $\tau_2$  the individual test statistics are summarized into the maximum of the individual Chow F-statistics:

$$MaxF = \max_{\tau_1 < \tau < \tau_2} (F(\tau)) \quad (3.5),$$

Additionally, other two tests can be followed, the Exp. Statistics and Ave. statistic. The Bai-Perron Global  $l$  Breaks vs None test the null hypothesis of no breaks against an alternative of  $l$  breaks. The general form of the statistic could be represented as follows:

$$F(\delta) = \frac{1}{T} \left( \frac{T - (l + 1)q - p}{kq} \right) (R\delta)' (RV(\delta)) R^{-1} R\delta \quad (3.6),$$

where  $\delta$  is the optimal  $l$  break estimate,  $(R\delta)' = (\delta'_0 - \delta'_1, \dots, \delta'_l - \delta'_{l+1})$ , and  $V(\delta)$  is an estimate of the variance matrix of  $\delta$ . The statistic distribution is provided by Bai and Perron (2003b), as well as the critical values.

The validity of the time-series models is evaluated through a usually battery of diagnostic tests (e.g. Ahmed, 2017; Fuinhas and Marques, 2012; Shahbaz *et al.*, 2016): (i) Jarque-Bera normality test; (ii) Breusch-Godfrey serial correlation Lagrange Multiplier (LM) test; (iii) Autoregressive conditional heteroskedasticity (ARCH) test for heteroskedasticity; (iv) Ramsey Regression Equation Specification Error Test (RESET) test for model specification; and (v) stability tests of CUSUM and CUSUM of Squares test. For the panel data case, the variance inflation factor (VIF) is used to check for multicollinearity. Additionally, the panels validity is checked for cross-sectional dependence by parametric testing procedure proposed by Pesaran (2004), the groupwise heteroskedasticity in the residuals is checked by Wald statistic as Greene (2012), and the autocorrelation is evaluated by Wooldridge (2010) test for autocorrelation in panel-data models. In fact, following these approaches is usual in literature (e.g. Damette and Seghir, 2013; Fuinhas *et al.*, 2015; Gaspar *et al.*, 2017).

### 3.1 Autoregressive distributed lag approach

As stated before, the ARDL methodology is used to the analyses of both short-run and long-run globe energy-growth nexus. The use of the ARDL approach is far from new on energy-growth nexus literature (e.g. Farhani and Ozturk, 2015; Mirza and Kanwal, 2017; Shahbaz *et al.*, 2016). The ARDL methodology has the advantage to: (i) allow work upon all variables with an integration order lower than 2; (ii) permit to obtain robust results by correcting outliers and structural breaks; and (iii) allow the estimation of the long-run elasticities. The basic form of an ARDL regression could be represented as follows:

$$Y_t = \gamma_0 + \gamma_1 TREND + \sum_{i=1}^k \gamma_{2i} Y_{t-i} + \sum_{i=0}^k \gamma_{3i} X_{t-i} + \varepsilon_{4t} \quad (3.7),$$

where  $Y$  is the explained variable,  $X$  the explanatory variable,  $t$  is the trend variable,  $\varepsilon_{4t}$  is the error disturbance term and  $k$  represents the number of lags. If the variables are cointegrated,

the ARDL could be transformed into an unrestricted error correction model (UECM) in its equivalent ARDL bounds test:

$$\Delta Y_t = \delta_0 + \delta_1 TREND + \sum_{i=1}^k \delta_{2i} \Delta Y_{t-i} + \sum_{i=0}^k \delta_{3i} \Delta X_{t-i} + \delta_4 \Delta Y_{t-1} + \delta_5 \Delta X_{t-1} + \varepsilon_{5t}, \quad (3.8),$$

By following the same steps, it is possible to develop a panel ARDL approach and its equation could be represented as follows:

$$\Delta Y_{it} = \alpha_{1i} + \delta_{1i} TREND + \sum_{j=1}^k \beta_{21ij} \Delta Y_{it-j} + \sum_{i=0}^k \beta_{22ij} \Delta X_{it-i} + \gamma_{21i} \Delta Y_{it-1} + \gamma_{22i} \Delta X_{it-1} + \varepsilon_{1it}, \quad (3.9),$$

where  $Y$  is the explained variable,  $X$  the explanatory variable,  $t$  is the trend variable,  $\varepsilon_{1i}$  denotes the error term and  $k$  represents the number of lags.

### 3.2 Vector autoregression approach

The second approach followed in this thesis is VAR models (e.g. Antonakakis *et al.*, 2017; Saidi *et al.*, 2017; Wang *et al.*, 2016b). In case of use non-stationary variables, the VECM is preferred. The VAR model specification is:

$$X_t = \sum_{i=1}^k \Gamma_i X_{t-i} + \varepsilon_t, \quad (3.10),$$

where  $X_t$  is the vector of the endogenous variables,  $\Gamma_i$  is the coefficient matrix of endogenous variables,  $k$  is the optimal lag number, and  $\varepsilon_t$  represents the residuals. From the several advantages of the VECM approach, two should be highlighted: (i) it distinguishes the short-run effects from the long-run; and (ii) dummy variables may be introduced in order to control for specific periods. The VECM approach, which has the advantage of allowing the system convergence to a long-run equilibrium, could be specified as follows:

$$X_t = \sum_{i=1}^k \Gamma_i X_{t-i} + \Pi X_{t-1} + \varepsilon_t \quad (3.11),$$

where  $X_t$  is the vector of endogenous variables;  $D_t$  is the vector of exogenous variables;  $\Gamma_i$  is the coefficient matrix of endogenous variables, and  $k$  is the optimal lag number. While  $\Gamma_i$  captures the short-run dynamics of the model, the  $\Pi$  captures the long-run relationships.

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## Chapter 4

### Globe Level Evidence of Energy-Growth Nexus

This chapter focuses on the globe aggregate energy-growth nexus, by studying the dynamics between energy consumption and economic growth. Furthermore, it is focused on observing the impacts of historical events on the nexus by controlling for structural breaks in the models. The extensive attention that the nexus has received in recent years has led to the existence of studies that are mainly focused on individual or panels of countries. However, with increasing market globalization, the study of the globe energy-growth nexus is worthy of a greater interest.

The main question of this chapter is: Is there a bi-directional causality between energy consumption and economic growth present at globe level? And is it stable over time? To answer these questions, a bivariate approach is followed because it is the only one that allows individual effects to be studied between energy consumption and economic growth. The use of bivariate models is frequent in the literature (e.g. Fuinhas and Marques, 2012; Odhiambo, 2009; Ozturk *et al.*, 2010).

This research contributes to the energy-growth nexus literature by studying its relationships at globe level by using both the ARDL and the VECM approach. The four traditional hypotheses of the energy-growth nexus were tested.

#### 4.1 Globe economic growth and primary energy consumption between 1965 and 2013

Annual GDP (Y) and primary energy consumption (E) data are used from 1965 to 2013. The variable Y is measured in constant 2005 dollars and its source is the World Bank World Development Indicators. The variable E is measured in tonnes of oil and its source is the BP Statistical Review of World Energy, June 2014. L denotes the natural logarithm and D denotes the first difference operator. Econometric software EViews 9.5 was used. Summary statistics are presented in table 4.1.

Table 4.1 - Descriptive statistics

Statistic	LY	LE	DLY	DLE
Mean	30.975	22.750	0.032	0.025
Median	31.023	22.807	0.034	0.025
Maximum	31.655	23.267	0.062	0.064
Minimum	30.116	22.049	-0.021	-0.012
Std. Dev.	0.442	0.320	0.016	0.020
Skewness	-0.194	-0.349	-0.691	0.123
Kurtosis	1.951	2.378	4.441	2.299
Jarque-Bera	2.553	1.783	7.969	1.106
Probability	0.279	0.410	0.019	0.575
Observations	49	49	48	48

A first appraisal of the variables reveals a strong correlation (0.995) between LE and LY, as well as between DLY and DLE (0.857). Despite the presence of high correlation, this does not mean that cointegration exists.

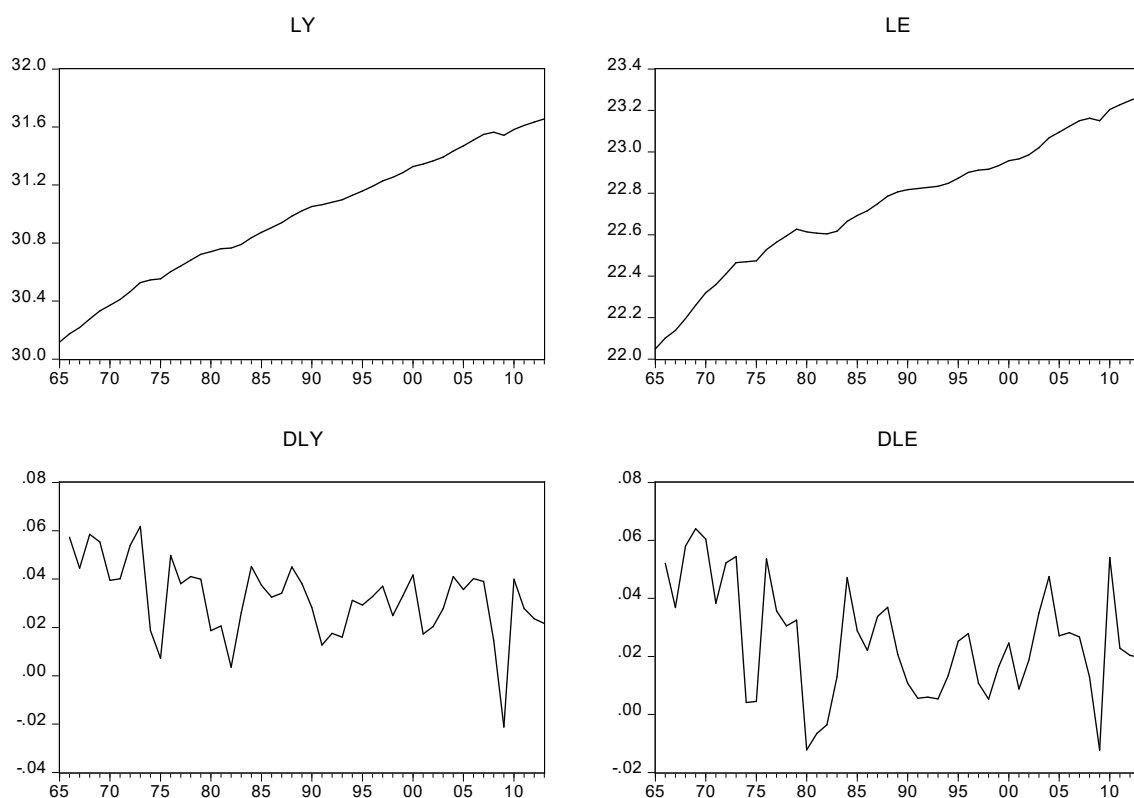


Fig. 4.1 - Variables in level and first differences

To the analysis of the integration order of the variables, we worked on: (i) the graphical analyses of the level variables and their first differences (see fig. 4.1); (ii) the examination of their correlograms (see fig. 4.2); and (iii) ADF, PP, KPSS, and MDF tests (see table 4.2). The latter followed Perron (1989), and allows to handle with a single break date. The presence of structural breaks occurring from well-known historical crises such as the 1970s oil crises, the 2008 financial crisis and the 2009 European sovereign debt crisis, are expected.

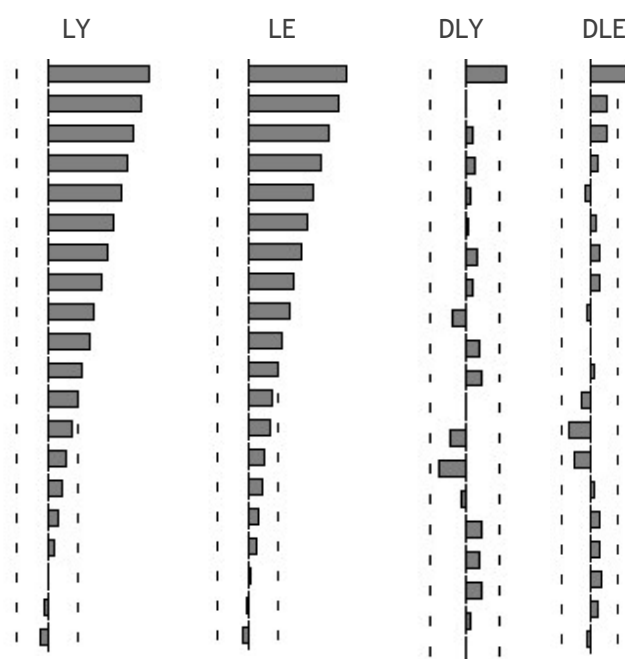


Fig. 4.2 - Level and first difference correlograms

The graphical examinations of the variables and their correlograms are consistent with  $I(1)$  variables. The correlograms of the variables in level show the typical behaviour of nonstationary series with a high autocorrelation coefficient in the first lag that decrease toward zero as the lag increases. To carry the ADF test, the Schwarz criterion is used with a maximum of 9 lags. In the PP test, as well as in the KPSS test, the Bartlett kernel spectral estimation method and Newey-West Bandwidth were used. The null hypothesis rejection of the ADF, PP and MDF tests means that variables are stationary. In contrast, the rejection of the KPSS null hypothesis means that the variables are not stationary.

Table 4.2 - Integration order tests

	ADF			PP			KPSS	
	a)	b)	c)	a)	b)	c)	a)	b)
LY	-2.982	-3.506**	14.031	-3.777**	-3.500**	11.130	0.190**	0.925***
LE	-3.470*	-3.174**	8.872	-3.818**	-2.583	6.081	0.152**	0.918***
DLY	-5.345***	-4.814***	-2.065**	-5.206***	-4.681***	-1.844*	0.102	0.597**
DLE	-4.457***	-4.260***	-2.560**	-4.457***	-4.260***	-2.560**	0.164**	0.365*

	MDF		
	T-statistic	Specification	Break date
LY	-3.899	(i)	2007
LE	-4.085	(i)	2009
DLY	-6.124***	(i)	2009
DLE	-5.480***	(ii)	1981

Notes: a) denotes the test statistic with trend and constant; b) denotes the test statistic with constant; c) denotes the test statistic without tendency and constant; (i) denotes the test with trend and intercept and break at the intercept; (ii) denotes the test with trend and intercept and break at the trend. \*\*\*, \*\* and \* denote statistical significance at 1%, 5% and 10% level, respectively.

The results of the integration order tests show that all variables are I(1), or at least near I(1). Moreover, the MDF test shows for LY a trend and intercept break in 2007, for DLY a trend and intercept break in 2009, for LE a trend and intercept break in 2009, and for DLE it only shows a trend break in 1981. The possible presence of these structural breaks in the variables were initially expected, given the effects of the 2008 economic and financial crisis. It should be noted that international energy markets need to fund themselves in the capital market to meet their high capital investments. This need may have caused several impacts on the nexus.

## 4.2 Is there causality between energy and growth on globe level?

Given that interactions between energy and growth were expected, the use of an ARDL model, approach introduced by Pesaran and Shin (1999) and extended by Pesaran *et al.* (2001) is suitable because it can deal with endogeneity. Additionally, it does not impose a restrictive assumption that all variables should have the same integration order. The use of ARDL models for energy-growth nexus analysis is recurrent in the literature (e.g. Bildirici and Bakirtas, 2014; Mirza and Kanwal, 2017; Ozturk and Acaravci, 2016). The UECM equations in its ARDL bounds test are developed as follows:

$$DLY_t = \alpha_0 + \alpha_1 TREND + \sum_{i=1}^k \alpha_{2i} DLY_{t-i} + \sum_{i=0}^k \alpha_{3i} DLE_{t-i} + \alpha_4 LY_{t-1} + \alpha_5 LE_{t-1} + \mu_{5t}, \quad (4.1),$$

where the expected signs of parameters are  $\alpha_0 \neq 0$ ,  $\alpha_1 \neq 0$ ,  $\alpha_{2i} \neq 0$ ,  $\alpha_{3i} \neq 0$ ,  $\alpha_4 < 0$ ,  $\alpha_5 > 0$ . The parameters  $\alpha_{2i}$ ,  $\alpha_{3i}$  explain the short-run dynamic coefficients, while  $\alpha_4$ ,  $\alpha_5$  explain the long-run multipliers. On one hand, a negative  $\alpha_4$  is expected because it would be consistent with the presence of cointegration. On the other hand, a positive  $\alpha_5$  is expected, given that a negative coefficient would be consistent with a globe *curse hypothesis* where energy consumption most likely drives to less economic growth which is highly unlikely.

$$DLE_t = \beta_0 + \beta_1 TREND + \sum_{i=1}^k \beta_{2i} DLE_{t-i} + \sum_{i=0}^k \beta_{3i} DLY_{t-i} + \beta_4 LE_{t-1} + \beta_5 LY_{t-1} + \mu_{6t}, \quad (4.2),$$

where the expected signs of parameters are  $\beta_0 \neq 0$ ,  $\beta_1 \neq 0$ ,  $\beta_{2i} \neq 0$ ,  $\beta_{3i} \neq 0$ ,  $\beta_4 < 0$ ,  $\beta_5 > 0$ . The parameters  $\beta_{2i}$ ,  $\beta_{3i}$  explain the short-run dynamic coefficients, while  $\beta_4$ ,  $\beta_5$  explain the long-run multipliers.  $\beta_4$  is expected to be negative revealing consistence with the presence of cointegration and  $\beta_5$  is expected to be positive because globe economic growth most likely drives to the development of productive and non-productive activities increasing the energy consumption.

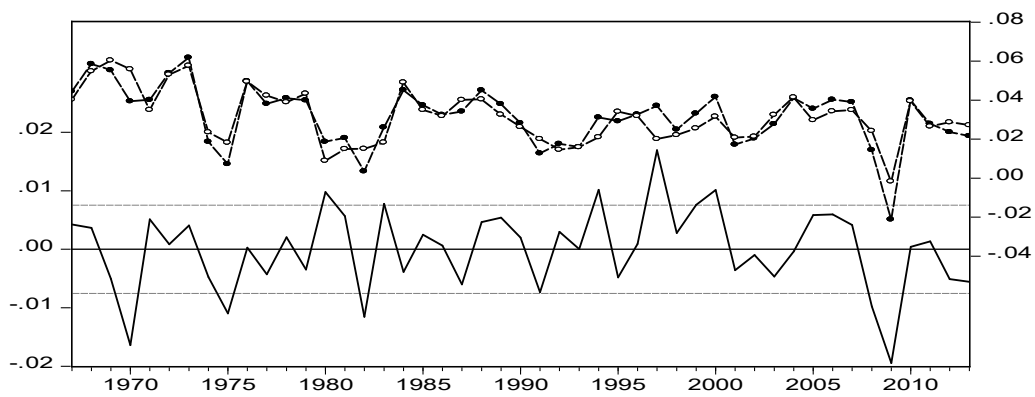
Accordingly, with the data analysis (see section 4.1), it is expected to find structural breaks in the model. For this reason, the need to control for structural breaks will be tested by looking into the ARDL residuals and performing the Chow breakpoint test. It should be noted that, to assess bivariate adequacy, the models should be exhaustively tested for normally distributed errors, serial correlation and autoregressive conditional heteroskedasticity. The validity of the models was evaluated through a battery of diagnostic tests: (i) Jarque-Bera normality test; (ii) Breusch-Godfrey serial correlation Lagrange Multiplier (LM) test; (iii) Autoregressive conditional heteroskedasticity (ARCH) test for heteroskedasticity; (iv) Ramsey Regression Equation Specification Error Test (RESET) test for model specification; and (v) stability tests of CUSUM and CUSUM of Squares test. Additionally, the introduction of crude oil prices (P) in the models was tested. To do so, the crude oil prices in constant 2013 dollars from BP Statistical Review of World Energy, June 2014 was used.

To the series analyses, the Pesaran *et al.* (2001) procedure was followed. Consequently, the general UECM version of ARDL with constant and trend was initially estimated for both models. The Model 1 constant and trend revealed to be statistical significant. However, in model 2 the trend was excluded due to non-statistical significance. A general-to-specific modeling approach was followed, such as by Hendry (1995). Given that the presence of structural breaks is expected, the lag selection using level of information, such Akaike Information Criterion, Hannan-Quinn or Bayesian Information Criterion should not be pursued. Parsimonious models were achieved with one lag. The introduction of additional lags revealed not statistically

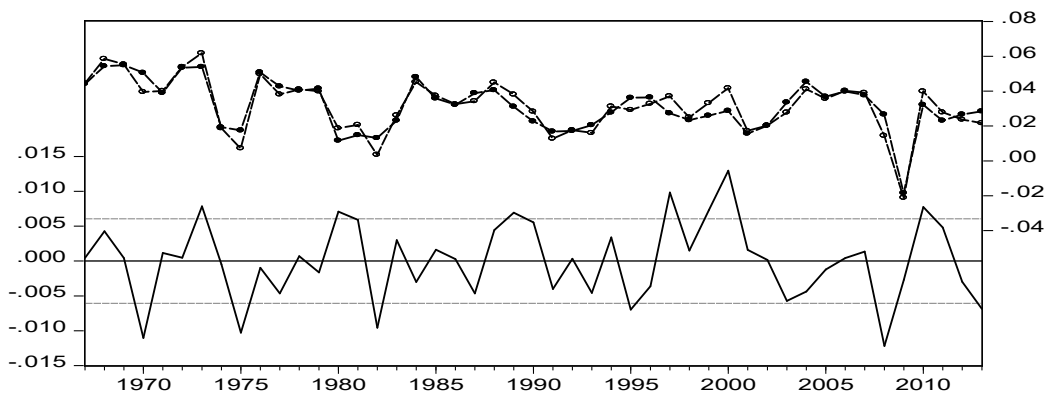
significant. As stated in subsection 4.1, the effects of the 2008 economic financial could have been impacts on the nexus. Their impacts are also suggested by the models' residuals (see fig. 4.3). For this reason, the dummy significance for this period was tested. As expected, it was observed that the introduction of a shift dummy from 2008 onwards (SD0813) is statistically highly significant for model 2. For model 1 a shift dummy from 2009 (SD0913) onwards was introduced.

Model 1

Without dummy:

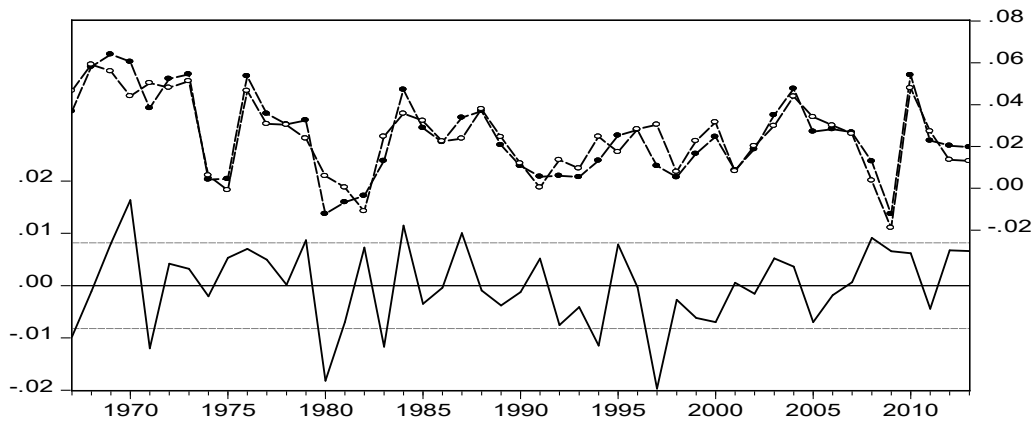


With dummy from 2008 onwards:



Model 2

Without dummy:



With dummy from 2009 onwards:

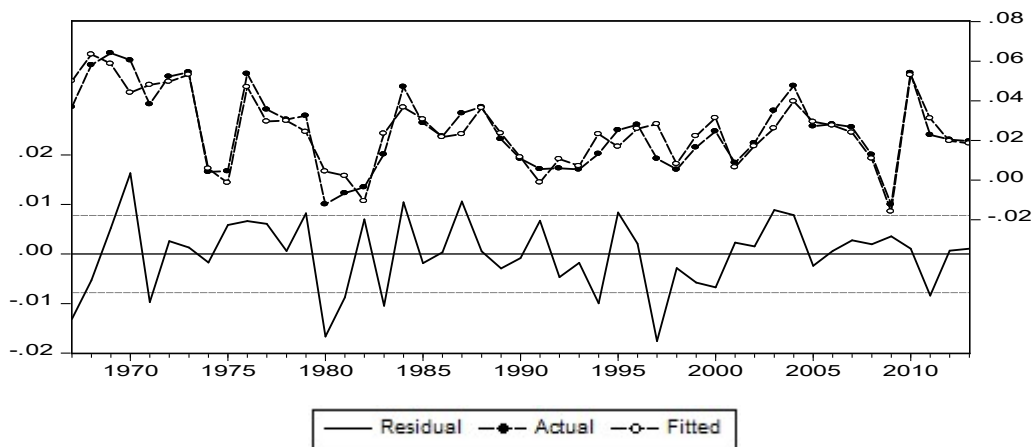
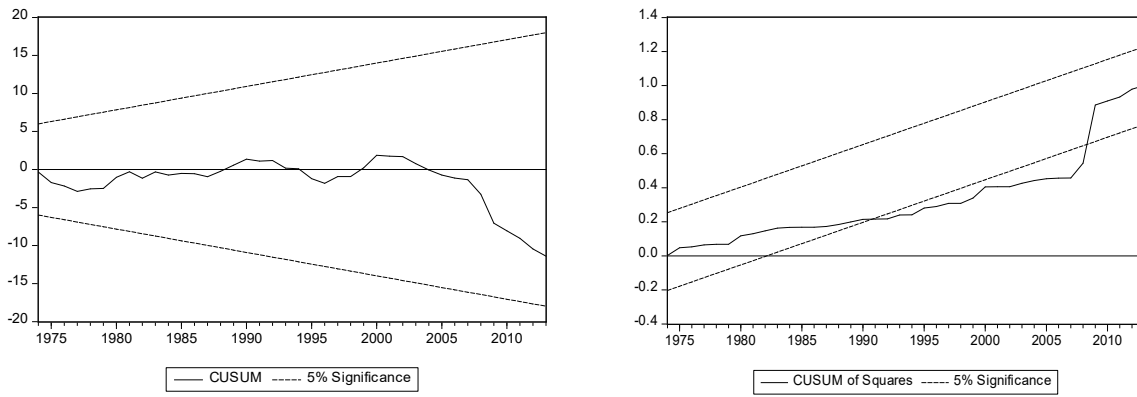


Fig. 4.3 - ARDL residuals

By looking into the residuals corrected by the shift dummies from 2008 onwards (SD0813) and 2009 onwards (SD0913), other possible breaks can be observed. Given that it is expected that historical oil shocks are determinant in the history of the relationship between globe energy consumption and economic growth, further tests were performed. The CUSUM and CUSUM of squares test not only evidence the break near 2008 for both models but also reveals possible breaks near 1990 for model 1 and near 1980 for model 2.

Model 1



Model 2

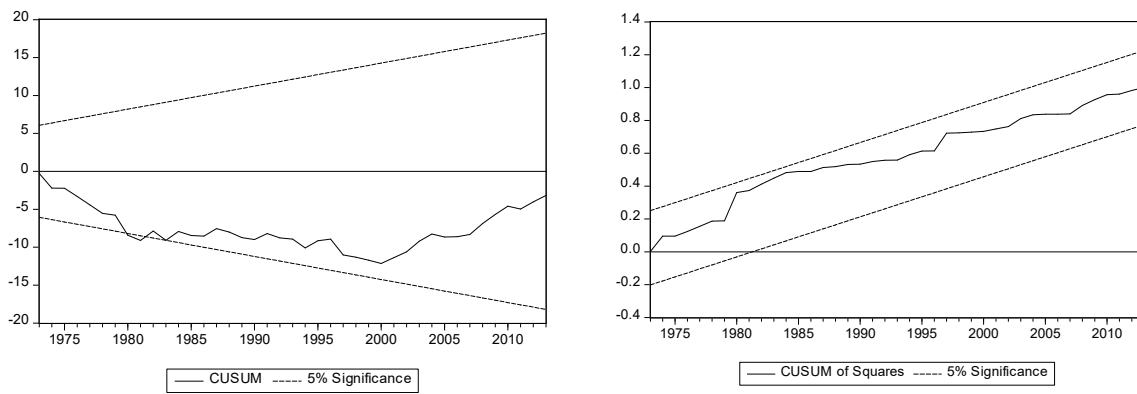


Fig. 4.4 - CUSUM and CUSUM of squares tests

In order to confirm the presence of statistical significant structural breaks, the existence of breaks in 1973, 1980 and 1990 was tested by the Chow breakpoint test (see table 4.3) on the ARDL models, which are robust to endogeneity. Further the Quandt-Andrews breakpoint test and Bai-Perron Global I Breaks vs None are performed (see table 4.4).

Table 4.3 - Chow breakpoint test

Data	Model 1	Model 2
1973	1.501	1.651
1974	1.489	1.739
1979	1.788	0.816
1980	1.901	1.344
1981	1.806	0.612
1989	4.124***	1.500
1990	3.967***	1.472
1991	3.754***	1.546

**Notes:** F-statistic values. \*\*\* denotes statistical significance at 1% level.

The Chow breakpoint test points to the years 1990 as a possible structural break, while the Quandt-Andrews test show a structural break in 1999 for model 1. The Bai-Perron test make aware of 5 possible breaks in model 1 and 4 possible breaks in model 2.

Table 4.4 - Quandt-Andrews breakpoint test and Bai-Perron global *l* breaks vs none multiple breakpoint test

<i>Quandt-Andrews Breakpoint Test</i>			
Model	Maximum LR F-statistics	Maximum Wald F-statistic	Break Date
1	8.308***	58.156***	1999
2	2.790	16.739	1997

<i>Bai-Perron Global <i>l</i> Breaks vs None</i>		
Model	Scaled F-statistic	Estimated break dates
1	8.308*** (5 breaks)	1974; 1981; 1988; 1997; 2005
2	26.461*** (4 breaks)	1974; 1981; 1989; 1997; 2005

**Note:** \*\*\* denotes statistical significance at 1% level.

Taking into account the previous results, the introduction of shift dummy variables starting in 1974, 1981, 1989, 1990, 1997 and 1999 to 2013 were tested. None of these dummies revealed statistical significance in the model 1 with SD0813 and model 2 with SD0913. For this reason, it was decided to keep the models, as restricted as possible, with one shift dummy. The estimated ARDL models are presented in table 4.5.

Table 4.5 - Estimated ARDL models

	Model 1 (Dep. Var. DLY)	Model 2 (Dep. Var. DLE)
Constant	8.296***	0.347***
Trend	0.009***	-
DLY	-	0.972***
DLE	0.623***	-
DLY(-1)	0.342**	-0.585***
DLE(-1)	-0.233*	0.440***
LY(-1)	-	0.084***
LE(-1)	0.281***	-
ECM	-0.481***	-0.130***
<i>Time dummies</i>		
SD0913	-0.030***	-
SD0813	-	0.011**
<i>Diagnostic Tests</i>		
ARS	0.843	0.839
SER	0.006	0.008
JB	[0.992]	[0.547]
LM	[0.384]	[0.327]
ARCH	[0.142]	[0.883]
RESET	[0.498]	[0.480]

**Notes:** Diagnostic tests results are based on F-statistic. [] represent p-value. ARS means adjusted R-squared. SER means standard error of regression. JB means Jarque-Bera normality test. LM means Breusch-Godfrey serial correlation LM test. ARCH means ARCH test. Reset means Ramsey RESET test. Estimated method: least squares. \*\*\*, \*\* and \* denotes statistical significance at 1%, 5% and 10% level, respectively.

Globally, the battery of diagnostic tests indicates that the two models have the desired econometric proprieties of no normally distributed errors, no serial correlation in the residuals and no auto-regressive conditional heteroskedasticity. All coefficients are statistically significant. The error correction mechanism (ECM) in model 1 (coefficient of  $LY_{t-1}$ ) has a magnitude of -0.481 revealing a fast speed of adjustment from short-run disequilibrium to the long-run equilibrium. In model 2 the ECM (coefficient of  $LE_{t-1}$ ) has a magnitude of -0.130 revealing a moderate speed of adjustment. To verify the existence of cointegration between variables an ARDL bounds test was performed (see table 4.6).

Table 4.6 - Bounds test

	Model 1	Model 2
F-statistic	10.603***	7.439**
K	1	1

Notes: k represents number of independent variables in equation estimated. Critical values obtained from Pesaran *et al.* (2001), tables CI(iii) and CI(v). Critical values for unrestricted intercept and no trend for bottom and top are, respectively, 6.84 and 7.84, for 1%; 4.94 and 5.73, for 5%; and 4.04 and 4.78 for 10%. Critical values for unrestricted intercept and unrestricted trend for bottom and top are, respectively, 8.74 and 9.63, for 1%; 6.56 and 7.3, for 5%; and 5.59 and 6.26 for 10%. \*\*\*and \*\* denotes significance at 1% and 5% level, respectively.

The bounds test proves that there exists a long-run relationship between energy and growth by rejecting the null hypothesis of non-cointegration. In model 1, the null hypothesis is rejected at the significance of 1% and in model 2 the rejection of the null hypothesis occurs at the statistical significance of 5%. In short, the existence of long-run relationship between energy and growth is confirmed. To examine the speed of adjustment between LY and LE we estimate both short- and long-run elasticities, which are disclosed in table 4.7.

Table 4.7 - Short-run and long-run elasticities

	Model 1	Model 2
Short-run (DLE+DLE(-1))	0.391***	-
Long-run (LE)	0.585***	-
Short-run (DLY+DLY(-1))	-	0.387*
Long-run (LY)	-	0.648***

Notes: \*\*\*and \* denotes statistical significance at 1% and 10% level, respectively

The short-run elasticities are calculated by adding the coefficients of a differenced variable and of their respective first difference variable. The joint significance is tested by recurring to the Wald coefficient test. The long-run elasticities are calculated by dividing the coefficient of one lagged dependent variable by the coefficient of one lagged independent variable, multiplied by -1. All the elasticities have the expected signs and are highly significant. The model 1 shows that both in short- and long-run the energy exerts a positive impact on growth. A 1% increase in energy leads to an economic growth of 0.391 in short-run and 0.585 in long-run. In model 2 it is also observed that both in short- and long-run the economic growth exerts a positive impact on energy. A 1% increase in economic growth leads to an energy growth of 0.387 in short-run and 0.648 in long-run.

As stated before the statistical significance of “prices” (P) was tested by the LR omitted variables (see table 4.8). The test shows that the bivariate model is the preferred. Only the

variable LP(-1) revealed statistical significance at 10% for model 1. However further tests such t-statistic and f-statistic do not confirm the statistical significance.

Table 4.8 - LR omitted variables test

	Model 1	Model 2
DLP	0.640	0.011
DLP(-1)	0.417	0.840
LP(-1)	2.857*	0.014

Notes:  $\chi^2$ -statistic. \* denotes statistical significance at 10% level.

In order to give robustness to the results, a different methodology is applied in the subchapter 4.3. The VECM approach is followed because it allows to handle with endogeneity such as ARDL models. Further, the VECM approach allow to confront the results with those obtained by the ARDL methodology.

### **4.3 Does the methodology influence the results?**

The use of VECM is recurrent in the nexus literature (e.g. Lee, 2005; Marques *et al.*, 2014; Masih and Masih, 1996). To do so, energy consumption and economic growth must be integrated in the same order. It was observed in the subchapter 4.1 that the variables are near I(1), at least. For this reason, the VECM approach is also performed. To do so, the data presented in subchapter 4.1 was upgraded with 2 more years.

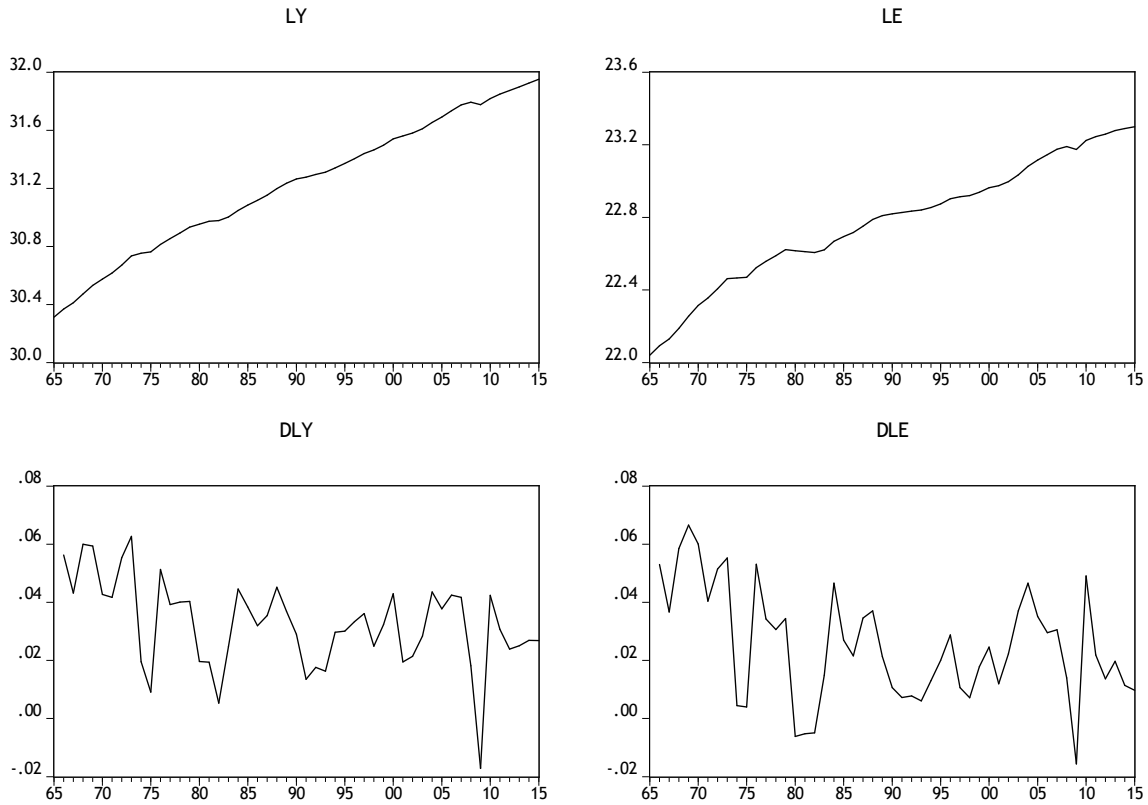


Fig. 4.5 - Variables in level and in its first differences

Now, the data comprises annual observations between 1965 and 2015. There are no significant changes and the variables evidence the same proprieties. From the several advantages of the VECM approach, two should be highlighted: (i) it distinguishes the short-run effects from the long-run; and (ii) dummy variables may be introduced in order to control for specific periods. The VECM approach, which has the advantage of allowing the system convergence to a long-run equilibrium, could be specified as follows:

$$X_t = \sum_{i=1}^k \Gamma_i X_{t-i} + \Pi X_{t-1} + CD_t + \varepsilon_t \quad (4.3)$$

where  $X_t$  is the vector of endogenous variables;  $D_t$  is the vector of exogenous variables;  $\Gamma$  is the coefficient matrix of endogenous variables,  $C$  is the coefficient matrix of exogenous, and  $k$  is the optimal lag number. While  $\Gamma_i$  captures the short-run dynamics of the model, the  $\Pi$  captures the long-run relationships. The residuals are denoted by  $\varepsilon_t$ ,  $X_t = [DLY, DLE]$  and  $D_t = [Constant, SD_y]$ , where  $SD_y$  represents the shift dummies that control for the  $y$  years on the nexus. The need to include shift dummies in the model is expected confirming the impacts of 2008 financial crisis on energy-growth nexus at globe level. All the coefficients are expected

to be  $\neq 0$ . Additionally, the long-run coefficient of the independent variable is expected to be negative revealing the existence of cointegration such as on the ARDL approach.

To test the need to control for these periods, before the Johansen cointegration test, a VAR model was estimated. By using the Schwarz information criteria, 2 lags were selected. The VAR residuals (see fig. 4.6) suggest the presence of a structural break in 2008.

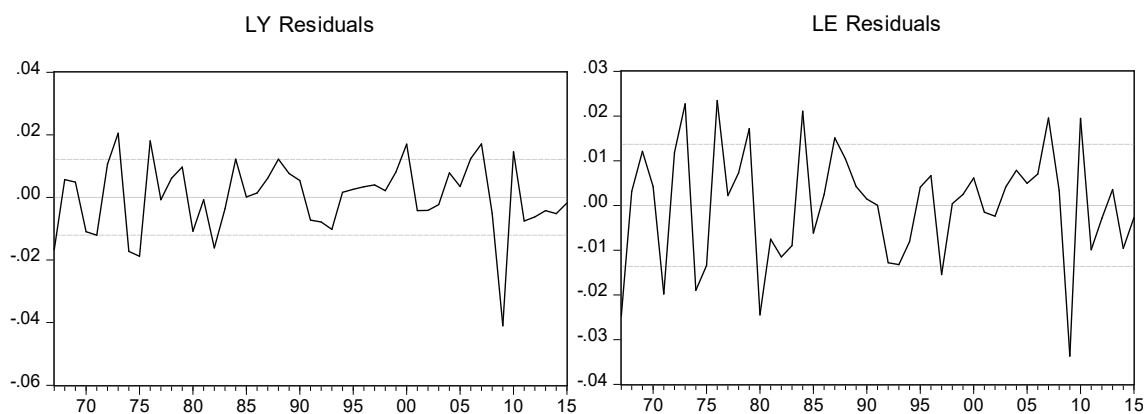


Fig. 4.6 - VAR residuals

The introduction of a shift dummy from 2008 onwards (SD0815) was tested and revealed statistical significance. Contrariwise, the introduction of more shift dummies was tested for the possible breaks detected in the section 4.2.2 thus revealing no statistical significance. Consequently, the Johansen cointegration test (see table 4.9) was performed with the exogenous variable SD0815.

Table 4.9 - Johansen cointegration test

Eigenvalue	H <sub>0</sub> : r	Trace	Max-Eigen
0.3772	0	23.028***	22.732***
0.0127	1	0.295	0.295

**Notes:** r indicates the number of cointegrating relationships. \*\*\* denotes statistical significance at 1 % level. MacKinnon-Haug-Michelis (1999) p-values. Deterministic trend assumption of test: Intercept (no trend) in cointegration equation and test VAR. Exogenous variables: SD0815.

The Johansen cointegration test supports the presence of cointegration. Following the Johansen technique, the normalized long-run cointegration relationships could be estimated. The equations reveal a bi-directional, positive, long-run relationship between energy consumption and economic growth. Given that the variables are on their logarithms, the coefficients can be

interpreted as long-run elasticities (see table. 4.10). We observe that the long-run impacts of energy-consumption on economic growth are higher than the impacts of economic growth on energy consumption.

Table 4.10 - Long-run elasticities

	Model 1	Model 2
Long-run	1.525	0.656

Given the existence of cointegration, the next step is the VEC model estimation. Once more, the principle of parsimony was followed. The 2 optimum lag numbers previously achieved in the VAR model were used with trend as exogenous variables. Once again, the SD0815 variable was introduced as an exogenous variable allowing the behaviour of the model's residuals to be corrected (see fig. 4.7).

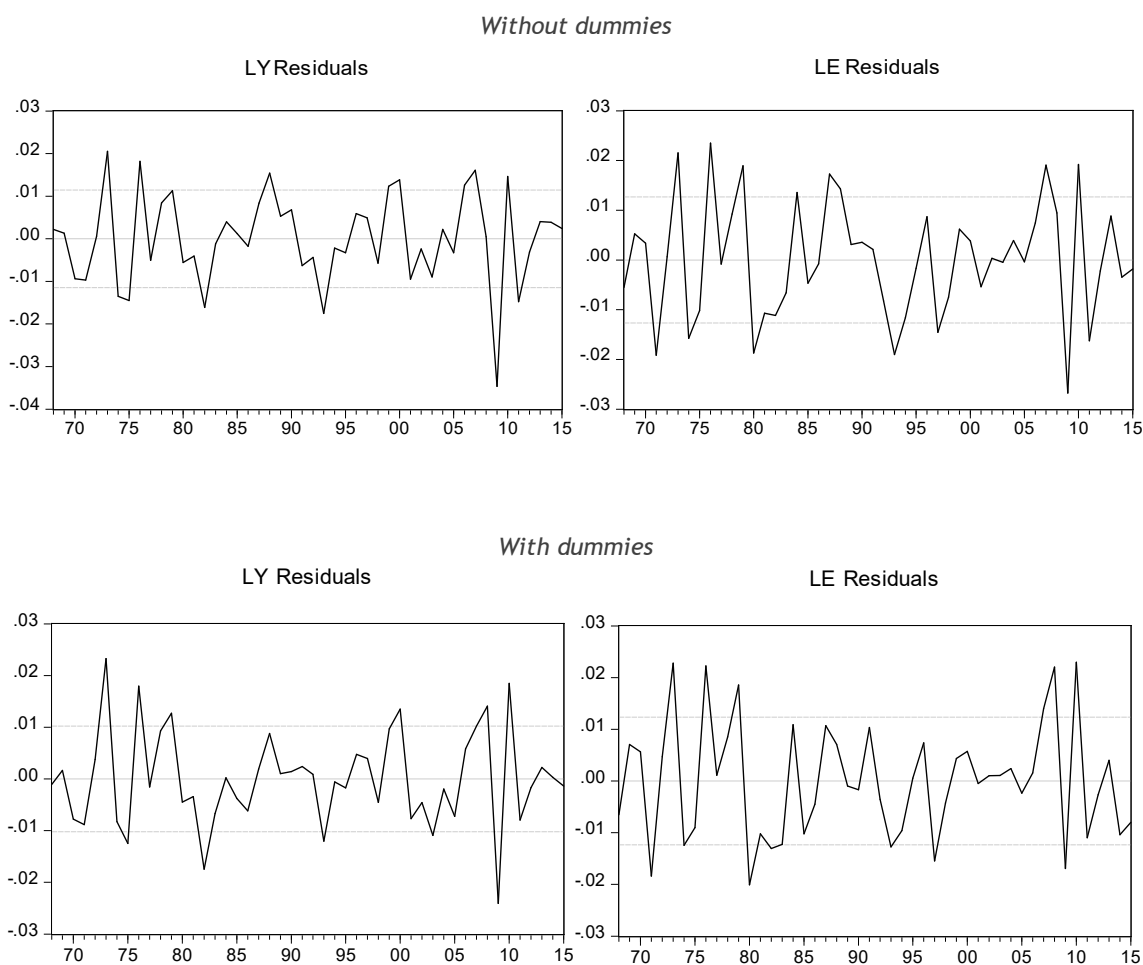


Fig. 4.7 - VECM residuals

The possible breaks detected in the section 4.2.2 were also considered. The shift dummy from 1991 onwards (SD9115) revealed statistical significance and was introduced in the model. The VECM is shown in table 4.11.

Table 4.11 - VEC model

Error Correction:	D(LY)	D(LE)
ECM	-0.265 [-4.598]	-0.347 [-4.994]
D(LY(-1))	-0.049 [-0.195]	-0.651 [-2.158]
D(LY(-2))	-0.580 [2.169]	-0.361 [-1.116]
D(LE(-1))	0.180 [0.854]	0.680 [-2.673]
D(LE(-2))	0.392 [1.783]	0.241 [0.909]
C	-0.183 [-3.600]	-0.253 [-4.126]
Trend	0.009 [4.487]	0.011 [4.764]
SD9115	-0.015 [-2.118]	0.013 [-1.626]
SD0815	-0.020 [-3.290]	0.019 [-2.576]

Note: [] denotes t-statistics.

As expected, highly significant negative error correction terms were observed, which the system converges to a long-run equilibrium after some disturbance. Any disequilibrium is corrected within approximately four years. Some coefficients of VEC lagged variables are not statistically significant. This could mean that, in the short-run, the effects between the variables are weak. However, this result should be analysed with caution due to potential overfitting in the VECM. The model surpasses all the relevant diagnostic tests (see table 4.12).

Table 4.12 - Diagnostic tests

Autocorrelation LM test		Normality tests					
Lags	LM-Stat	Component	Skewness	Chi-sq.	Kurtosis	Chi-Sq.	Jarque-Bera
1	7.226	1	0.203	0.329	3.345	0.238	0.567
2	4.340	2	-0.484	1.873	3.077	0.012	1.886
3	5.408	Joint		2.202		0.250	2.452
4	3.716						
White	Chi-sq.						
Heteroskedasticity	38.370						

To give robustness to our results, the short-run effects were evaluated by Granger causality/Block exogeneity Wald tests as well as by the robust Toda and Yamamoto (1995) procedure (see fig. 4.8). To perform the Toda and Yamamoto procedure, a trend and both SD9115 and SD0815 dummy variables were added to the previous estimated VAR model, as well as one additional exogenous lag.

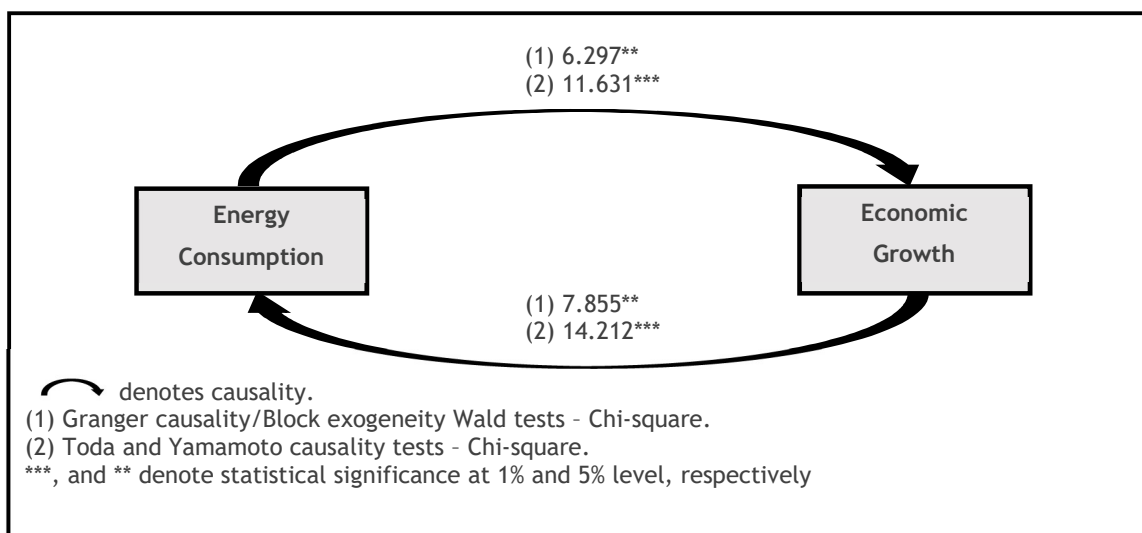


Fig. 4.8 - Granger causality/Block exogeneity, and Toda and Yamamoto causality tests

The Granger causality as well as the Toda-Yamamoto causality results prove that there is endogenous behaviour between the variables. Granger causality was detected and its direction is  $LY \leftrightarrow LE$ . The statistical significance at 1% level revealed by the robust Toda and Yamamoto procedure reinforces the presence of bidirectional causality. Lastly, the VECM variance decomposition and impulse response functions are shown in table 4.13 and fig. 4.8.

Table 4.13 - Variance decomposition

Cholesky ordering:		LY, LE		LE, LY	
Year	S.E.	LY	LE	LY	LE
Decomposition of LY					
1	0.012	100	0	37.838	62.162
2	0.017	99.064	0.936	32.018	67.982
5	0.021	77.116	22.884	28.700	71.300
10	0.028	76.788	23.212	28.134	71.866
Decomposition of LE					
1	0.013	62.162	37.838	0	100
2	0.019	37.535	62.465	11.284	88.716
5	0.027	13.446	86.554	50.969	49.031
10	0.029	12.715	87.285	64.264	35.736

The variables reveal dynamic behaviour, which is a requirement of endogeneity. Consequently, the variance decomposition reinforces the results. With regard to LY, after 2 years, shocks to LY explain around 99% of the forecast error variance when LY ordered first by Cholesky. This impact is reduced to almost 76.8% at the end of the 10<sup>th</sup> year. When LE is ordered in first by Cholesky's ordering, shocks to LY explain only 37.8% of the forecast error variance at the end of the first year. At the end of the 10<sup>th</sup> year, this impact reduces to around 28.1%. With regard to LE we can observe similar responses to the shocks. When LE is ordered first by Cholesky's ordering, after 2 years, shocks to LE explain around 62.2% of the forecast error variance. This impact is reduced to almost 12.71% at the end of the 10<sup>th</sup> year. When LE is ordered in first by Cholesky's ordering, shocks to LE explain only 11.3% of the forecast error variance, at the end of the first year. At the end of the 10<sup>th</sup> year this impact grows to around 64.3%.

While on the one hand economic growth is a complex variable which includes the impacts of several variables, including energy, on the other hand, energy consumption is a variable affected by fewer factors wherein economic growth impacts are not evident. As a consequence, the real energy-growth dynamics should be somewhere between the results obtained by the two Cholesky's ordering. The found differences do not influence our final conclusions.

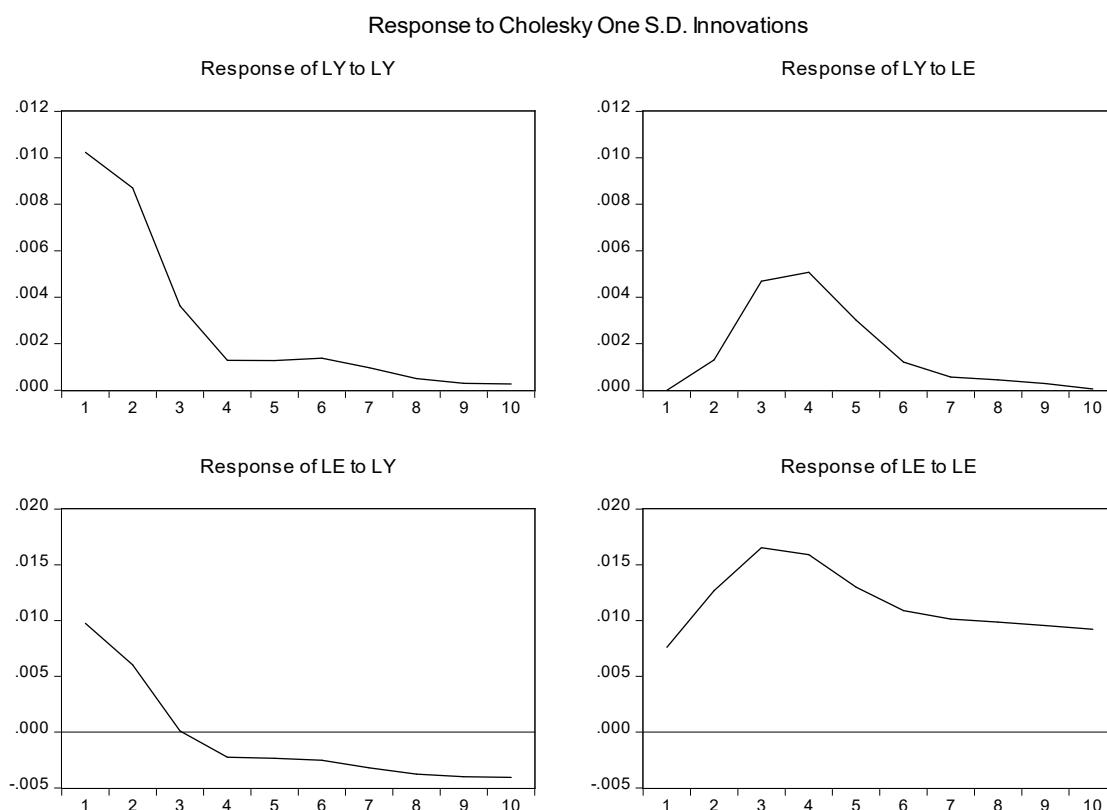


Fig. 4.9 - Impulse response functions

The impulse response-functions both in LY and LE are shown in fig. 4.9. In general, the response to a one standard deviation shock in LY leads to a short-run positive impact, that tend to a null impact on LY and a permanent negative impact on LE. Additionally, the responses to an innovation in energy consumption are also positive in the short-run. However, in the long-run, they tend to be null on economic growth and permanently positive on energy consumption. In short, the results show that the response of economic growth to innovations on both variables are positive and tend to a null effect. In contrast, the responses of energy consumption are persistent throughout the years.

In the next section, the results of sections 4.2 and 4.3 are discussed. Considering the four traditional nexus hypotheses, the research finds statistical evidence for the globe *feedback hypothesis*, both in the short- and in the long-run. Moreover, statistical evidence of structural breaks on the nexus was found.

#### 4.4 The globe feedback hypothesis evidences

The analysis of the globe energy-growth nexus proved to be of particular interest for dealing with the globalization of energy markets. There is a growing trend towards globe policy-making

driven by environmental issues such as carbon emission levels or the implementation of renewable energies. This new outlook leads to new needs in energy-growth research. In addition, the bulk of literature on the energy-growth nexus gives no definite explanations for the heterogeneity of the results found. The main objective of this research is to explore the globe aggregate energy consumption and economic growth behaviours, by highlighting how they interact both in the short- and long-run and unveil the historical periods of crisis that impacts on the whole nexus. Understanding the relationships between energy consumption and economic growth at a globe level can provide new insight into energy policy. To achieve the main goal, an ARDL approach for annual frequency, from 1965 to 2013, and a VEC model approach for annual frequency, from 1965 to 2015, were used.

The globe energy-growth nexus is stable over a long-time period, given that cointegration was found. The revealed dynamics prove that the used methodology was suitable. The application of UECM version of ARDL model is adequate, given that the bounds test shown cointegration between energy and growth. Additionally, the Johansen cointegration test confirms the existence of cointegration and the use of VECM allows to cope with endogeneity. Considering the four traditional nexus hypotheses, the research finds statistical evidence for the globe *feedback hypothesis*, both in the short- and in the long-run. Moreover, statistical evidence of the 2008 financial crisis on the nexus was found.

The 2008 crisis impacted through the bankruptcy of financial companies and the fact that it produced instability in financial markets, namely through the impact on the sovereign debt of some countries. Moreover, a collapse in international globe trade was experienced during this period, which negatively impacted on the transportation sector. As a consequence, energy consumption decreased. Additionally, evidence of 1990 energy crisis impact on the nexus was observed. It should be said that the 2008 crisis was the only period that needed to be controlled in all models. This might be because the 2008 crisis was different in nature from previous crises, specifically the various historical oil shocks. In these historical oil shocks, income transfers between countries were experienced. These acted as a compensation process so that the impact at a globe level was very small. In the 2008 crisis, the globe economy suffered an extreme shock that affected the economic structure and caused a substantial decline in wealth, leading to a prominent globe structural break. The model copes with this occurrence and the globe nexus was shown to be highly stable.

In the short-run, the ARDL elasticities are consistent with bidirectional causality between energy consumption and economic growth. Additionally, the variables exhibit an endogenous nature and similar responses to the shocks. With regard to the long-run, and as expected, an increase in energy consumption promotes economic growth as well as the reverse. This effect, reveals the presence of endogeneity between the variables, once more. The results also reveal that there is a low adjustment speed from any disequilibrium to the long-run equilibrium between the variables, with the adjustment occurring for around five years. Both energy

consumption and economic growth were shown to be important in explaining the variables' behaviour. In addition, innovation impacts on both variables are persistent over the years. However, innovations in energy consumption tend to have positive impacts. These results make us aware that energy consumption as well as economic growth need constant innovations that positively drive their growth. This behaviour suggests that constant technological development can play a positive role on nexus.

In short, our results reveal that the *feedback hypothesis* is present at globe level, both in the short- and long-run. The impacts of energy consumption on economic growth were expected, however the reverse was not so easy to explain. If primary energy consumption increases, as expected by BP (2014), this will most likely lead to globe economic growth, which may increase energy consumption once again. This behaviour can induce inefficient energy consumption, namely by non-productive activities. Therefore, energy efficiency policies are required. Indeed, any energy consumption reduction should be made through an increase in efficiency, otherwise the attempts to apply globe energy policies that lead to sustained globe growth could fail. Although this research does not focus on energy efficiency, it should be said that the possibility of induction of inefficient energy consumption, namely by non-productive activities, over the next years should be taken into consideration. This could be a possible outcome of the endogeneity between energy consumption and economic growth.

The results are consistent with those Narayan and Popp (2012) found, Granger causality running from energy consumption to economic growth for 93 countries, though with a null marginal effect. The omission of data for some countries on globe models seems to influence the results. On one hand, our results differ from Chen *et al.* (2016), that recently took an approach to globe results by studying a panel of 188 countries, where 26 were developed countries, and the other ones were developing countries. They found that augmenting energy consumption causes damage to GDP in the long-run. On the other hand, the results of Antonakakis *et al.* (2017), point to bi-directional causality between total world energy consumption, and economic growth for a panel of 106 countries. This panel encompassed high income, upper middle income, lower middle income and low-income countries and is consistent with the results of our paper.

These findings suggest that countries should not remain indifferent to the policies that other countries might follow, influencing the energy market, namely for those who play a dominant position. Although a regulatory authority does not exist at globe level, these conclusions are important because: (i) there are attempts to achieve the same goals in several countries, for instance increasing energy efficiency and reducing pollution levels; and (ii) the implementation of policies in large groups of countries, such as European Union, can cause globe impacts through a contagion effect. Each country or group of countries has particularities that incentivises their own policies. However, they must be aware that the policies they follow could impact on other countries or regions. To cope with this possibility the first step is to avoid the discordant results in the literature. For this reason, in the chapter 5 a comparative analysis of

the energy-growth nexus in different globe regions is made, by using an identical methodology for each one.

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## Chapter 5

### Dividing the Globe Energy-Growth Nexus into Four Regions

In academic literature on the subject, it has become widely accepted that dissimilar conclusions are reached about the energy consumption - economic growth nexus, in different parts of the globe. However, a valid comparison between the globe regions using the same data frequency and methodology does not exist. In fact, the use of different methodologies in published studies has been cited as one of the main reasons for divergences in their overall results. In response to this scenario, this chapter intends to review the energy-growth nexus globally, by dividing the world into four regions: America (North and South); Europe and Central Asia; Asia Pacific; and Africa and the Middle East. This division allows data to be collected for the entire globe, thus permitting a valid comparison of the findings for each region.

The central question of the research is: are the results heterogeneous for the energy-growth nexus in America, Europe and Central Asia, Asia Pacific, and Africa and the Middle East when subjected to the same methodology? To answer this question, an ARDL bounds test was performed and the short-run semi-elasticities and long-run elasticities estimated.

This chapter contributes to the energy-growth nexus literature by providing comparable results between different aggregates of countries covering the entire globe. In addition, the best-known historical economic events that impacted the nexus in the four regions were examined. Overall, in the long-run, the *feedback hypothesis* was found for America and Asia Pacific and the *conservation hypothesis* for Europe and Central Asia and for Africa and the Middle East. In the short-run, the *feedback hypothesis* was confirmed for all the globe regions. These findings suggest that the use of energy restrictive policies is not advisable for America and Asia Pacific. In Africa and the Middle East, the abundance of natural energy resources is probably hampering economic growth. In addition, the results prove that historical events have had different impacts on each world region, supporting the argument that region-specific policies are needed to deal with crises.

## 5.1 America, Europe and Central Asia, Asia Pacific and Africa and the Middle East between 1968-2014

This research focuses on the globe energy-growth nexus by dividing the world into four regions, namely: (i) America; (ii) Europe and Central Asia; (iii) Asia Pacific; and (iv) Africa and the Middle East. The information available restricted the study of aggregates to those cited. This was done by extracting the gross domestic product (Y) and the primary energy consumption (E) for different regional aggregates from the World Bank's Development Indicators and the BP Statistical Review of World Energy, respectively. Y is measured in constant 2010 dollars and E is measured in tonnes of oil equivalent. To make the variables compatible, the data has been reorganised. The use of homogenous variables is required to meet this chapter's goal of applying the same methodology to different regions. The data comprises annual observations from 1968 to 2014. The prefix "L" denotes the natural logarithm, and "D" denotes the first difference of variables. Eviews 9.5 econometric software was used. Summary statistics are presented in table 5.1.

Table 5.1 - Descriptive statistics

Statistic	America		Europe and Central Asia		Asia Pacific		Africa and the Middle East	
	LY	LE	LY	LE	LY	LE	LY	LE
Mean	30.025	21.714	30.11	21.746	29.465	21.348	27.946	19.936
Median	30.019	21.704	30.146	21.771	29.538	21.348	27.885	20.042
Maximum	30.627	21.98	30.543	21.889	30.439	22.397	28.798	20.945
Minimum	29.287	21.304	29.486	21.352	28.39	20.106	26.966	8.62
Std. Dev.	0.406	0.195	0.307	0.12	0.595	0.636	.0474	0.689
Skewness	-0.159	-0.209	-0.242	-1.608	-0.107	0.003	0.058	-0.364
Kurtosis	1.787	1.802	1.969	5.263	1.826	1.954	2.334	2.012
Jarque-Bera	3.078	3.155	2.539	30.294	2.788	2.142	0.896	2.95
Probability	0.215	0.207	0.281	0.000	0.248	0.343	0.639	0.229
Observations	47	47	47	47	47	47	47	47

Note: Std. Dev. means standard deviation.

The dynamics between energy consumption and economic growth were analysed and the impact of historical events on the various nexus were observed. To do this, the analysis of bivariate models with annual GDP (Y) and primary energy consumption (E) were performed. When the aim is to evaluate the four traditional hypotheses for the energy-growth nexus, bivariate models have the advantage of allowing a direct interpretation of the relationships between variables.

However, the quality of the models should be exhaustively tested, as stated before in the subchapter 4.2.

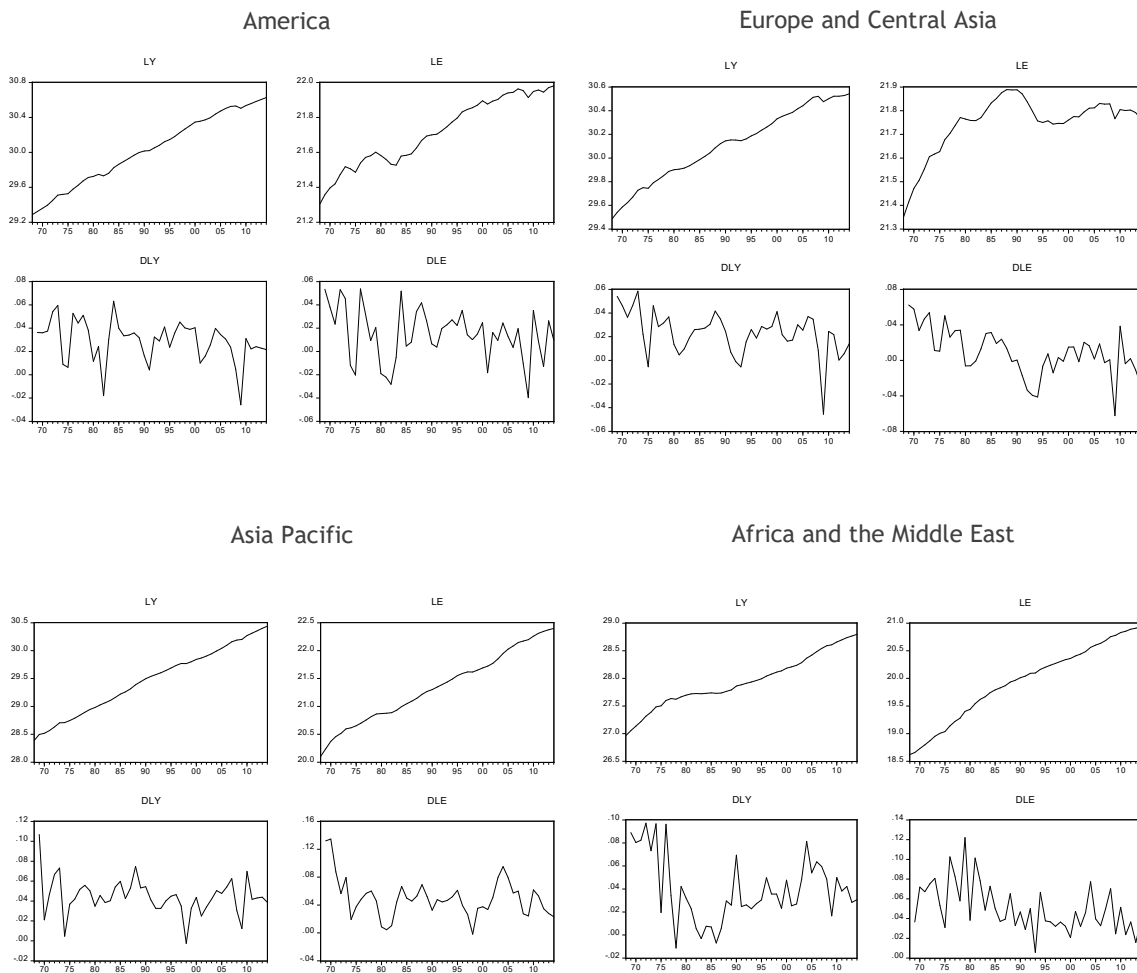


Fig. 5.1 - Variables in level and in its first differences

Once more, the use of an ARDL model, as in Pesaran *et al.* (2001), is suitable because it can deal with endogeneity. To do so, the integration order of the variables was evaluated through: (i) graphical analysis of the level variables, and their first differences (see fig. 5.1); (ii) visual examination of the correlograms (see fig. 5.2) ; (iii) ADF, PP and KPSS unit root tests (see table 5.2); and (iv) MDF test that follows Perron (1989) (see table 5.3).

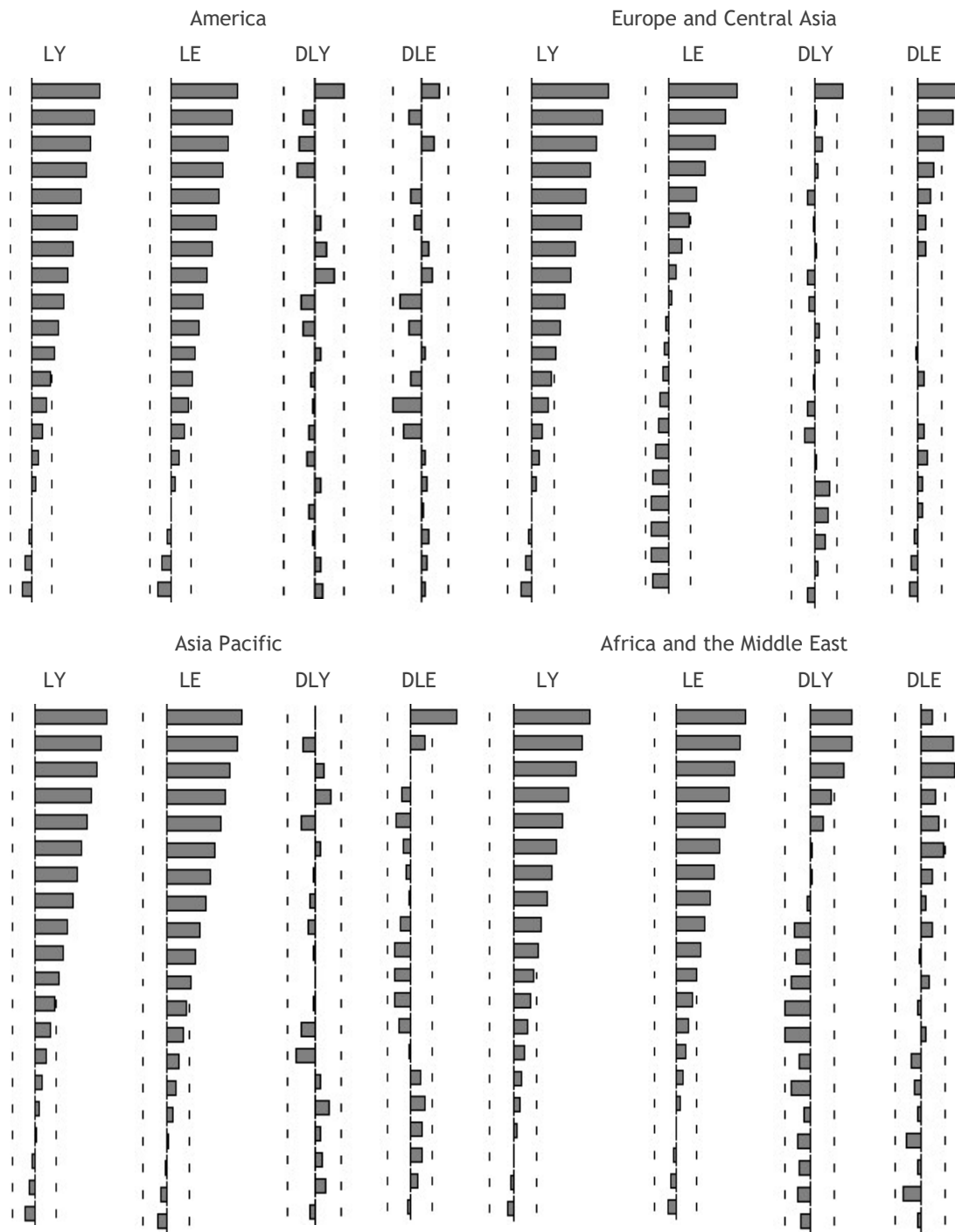


Fig. 5.2 - Level and first difference correlograms.

## *Essays on Globe Energy Consumption and Economic Growth Nexus*

The variables behaviours and their correlograms suggest that the variables are I(1) and there are several structural breaks. For this reason, in first place the ADF, PP and KPSS unit root tests were performed and in second place the MDF test is carried allowing for a first assessment on the possible structural breaks.

Table 5.2 - ADP, PP and KPSS unit root tests

Regions / Variables		ADF			PP			KPSS	
		a)	b)	c)	a)	b)	c)	a)	b)
America	LY	-2.116	-2.198	4.037	-1.304	-2.813*	9.555	0.176**	0.891***
	LE	-2.428	-2.147	4.363	-2.620	-2.074	3.998	0.088	0.885***
	DLY	-5.155***	-4.854***	-2.242**	-5.133***	-4.624***	-1.913**	0.095	0.336
	DLE	-5.605***	-5.538***	-4.471***	-5.612***	-5.540***	-4.403***	0.075	0.250
Europe and Central Asia	LY	-2.502	-2.003	3.386	-2.490	-3.320**	6.671	0.166**	0.889***
	LE	-2.593	-2.697*	0.801	-3.104	-4.716***	1.410	0.190**	0.479**
	DLY	-5.009***	-4.621***	-2.803***	-4.883***	-4.546***	-2.732***	0.096	0.460**
	DLE	-4.719***	-3.916***	-3.893***	-4.764***	-3.795***	-3.772	0.135**	0.583**
Asia Pacific	LY	-2.489	-1.596	16.355	-2.509	-1.687	16.192	0.174**	0.894***
	LE	-3.966**	-0.153	3.948	-4.021**	-1.594	8.219	0.076	0.897***
	DLY	-7.522***	-7.601***	-0.867	-7.530***	-7.556***	-2.341**	0.077	0.272
	DLE	-4.720***	-4.873***	-2.393**	-3.627**	-3.787***	-2.399**	0.110	0.200
Africa and the Middle East	LY	-2.262	-1.605	3.099	-2.501	-1.147	5.444	0.117	0.881***
	LE	-2.134	-2.484	1.045	-1.167	-3.773***	8.467	0.212***	0.879***
	DLY	-4.005**	-4.065***	-1.772*	-3.969**	-4.018***	-2.151**	0.154**	0.169
	DLE	-2.432	-1.455	-1.013	-7.724***	-6.244***	-1.487	0.102	0.556**

**Notes:** a) denotes the test statistic with trend and constant; b) denotes the test statistic with constant; c) denotes the test statistic without tendency and constant. \*\*\* and \*\* denote statistical significance at 1% and 5% level, respectively.

The ADF, PP and KPSS unit root tests suggests that all variables are I(1). Given that structural breaks were expects and they can impact at the stationarity evaluation, the MDF test will provide robustness to the results.

Table 5.3 - MDF unit root tests

Regions		LY	LE	DLY	DLE
America	T-statistic	-4.830**	-3.384	-5.961***	-7.508***
	Specification	(3)	(3)	(3)	(1)
	Break	2008	1992	1982	1983
Europe and Central Asia	T-statistic	-3.984	-3.818	-5.840***	-5.808***
	Specification	(1)	(1)	(4)	(3)
	Break	2009	1991	2009	1998
Asia Pacific	T-statistic	-5.011**	-5.137**	-8.543***	-5.202***
	Specification	(3)	(3)	(4)	(4)
	Break	1997	2002	1998	1998
Africa and the Middle East	T-statistic	-5.373***	-4.305	-7.123***	-9.531**
	Specification	(3)	(1)	(1)	(4)
	Break	1982	1981	1987	1985

Notes: Trend Specification / Break Specification: (1) Trend and intercept / Trend and intercept; (2) Trend and intercept / Trend only; (3) Trend and intercept/Intercept only; (4) Intercept only / Intercept only. \*\*\* and \*\* denote statistical significance at 1% and 5% level, respectively.

The MDF test does not confirm that all variables are I(1) but reveals that they are at the most I(1). Given that there is no homogeneity in the integration order, the use of ARDL approach is suitable. The MDF tests also suggest that the recessions and energy crises of the early 1980s had a worldwide impact. In the case of America, the results suggest that the 2008 financial crisis had an impact on economic growth, and that the recession of the early 1990s had an impact on American energy consumption. Likewise, the 2008 financial crisis impacted on economic growth in Europe and Central Asia. In Asia Pacific, both variables were influenced by the Asian financial crisis of 1997. The use of ARDL methodology allow to handle with the structural breaks by introducing dummies.

## **5.2 By using the same methodology, are there heterogeneous results on energy-growth nexus for the four globe regions?**

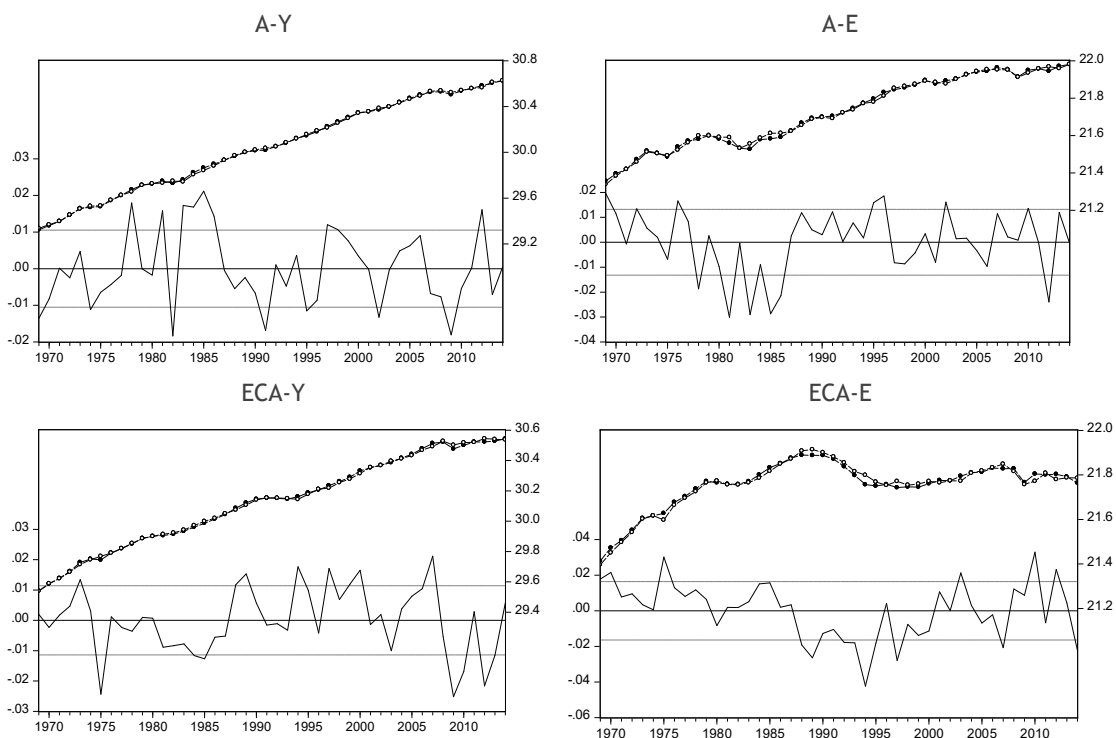
Given the presence of possible I(0) and I(1) variables, the ARDL model approach is followed such as on chapter 4. The ARDL advantages to handle with variables I(1) or near I(1) and structural breaks were extensively discussed, previously. The modelling follows the 4.1 and 4.2 ARDL equations.

Given that structural breaks were expected, a 4-method approach was followed to control for the need to correct the models: (i) visually inspection of the model's residuals; (ii) inspection of the CUSUM and CUSUM of squares tests; (iii) the Quandt-Andrews breakpoint and Bay-Perron

multiple breakpoint test; and (iii) the Chow breakpoint test. The validity of the models was evaluated through a battery of diagnostic tests: (i) Jarque-Bera normality test; (ii) Breusch-Godfrey serial correlation LM test; (iii) ARCH test for heteroskedasticity; and (iv) Ramsey RESET test for model specification.

To test for cointegration the ARDL bounds test was performed. The short- and long-run elasticities were performed to evaluate the presence of causality between both economic growth and energy consumption on the four globe regions.

Following the aforementioned methodology, the ARDL estimation, was performed. To do this, the Eviews 9.5 automatic model selection criteria with 1 max lags was used. The use of 1 max lag allowed the short-run semi-elasticities, and the long-run elasticities to be estimated, without consuming too many degrees of freedom or compromising the quality of the results. The following models have been estimated from equation 4.1: (i) A-Y, in the case of America; (ii) ECA-Y, for Europe and Central Asia; (iii) AP-Y, for Asia Pacific; and (iv) AME-Y, for Africa and the Middle East. Similarly, equation 4.2 leads to the following models: (i) A-E, for America; (ii) ECA-E, for Europe and Central Asia; (iii) AP-E, for Asia Pacific; and (iv) AME-E, Africa and the Middle East. To examine short- and long-run behaviours, short-run semi-elasticities and the long-run elasticities were performed. Given the possibility of structural breaks, the model's residuals have been examined (see fig. 5.3).



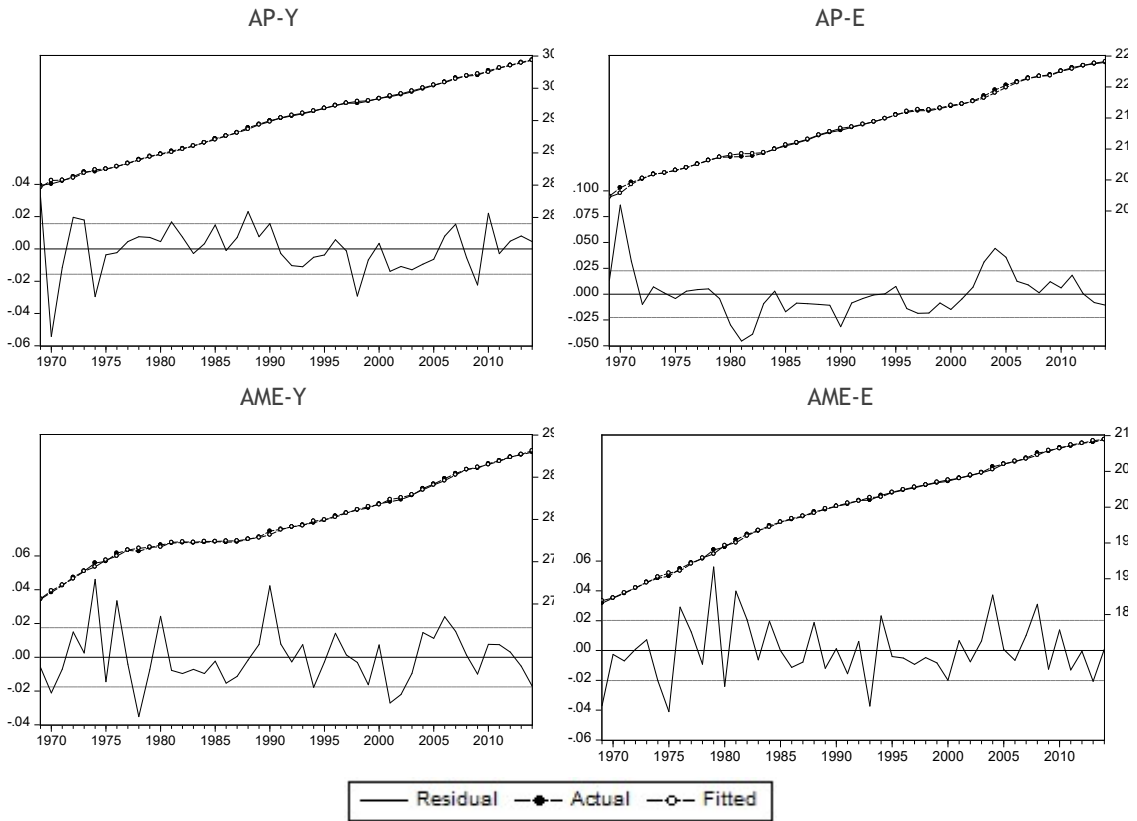
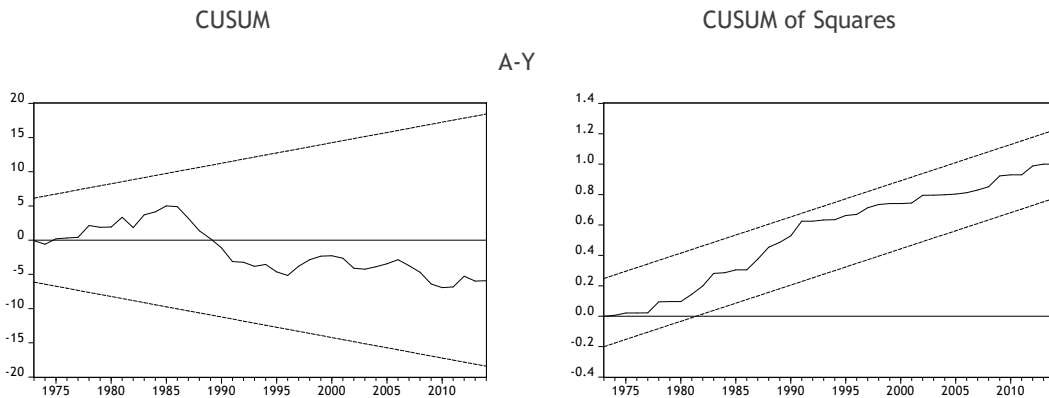


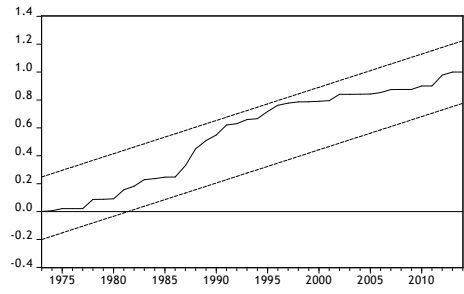
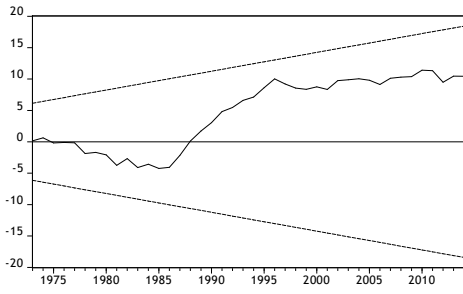
Fig. 5.3 - ARDL residuals

The model's residuals are consistent with the presence of structural breaks, namely in the explanatory models of energy consumption, around the years 1980 and 1990. The most evident cases are A-E and ECA-E. Additionally, there is evidence of some outliers that need to be controlled for. Before the breakpoint tests, the CUSUM and CUSUM of Squares to confirm the existence of structural breaks.

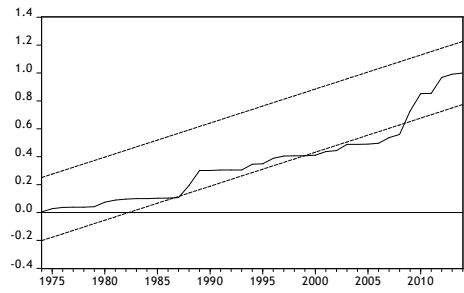
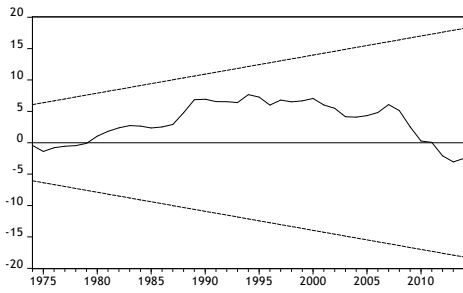


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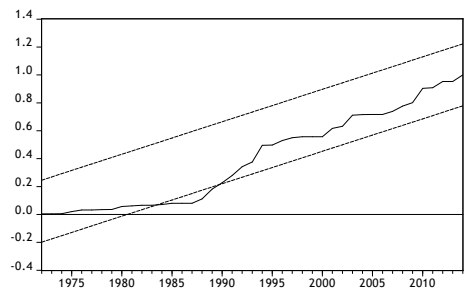
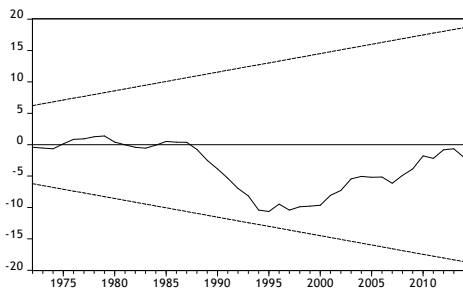
A-E



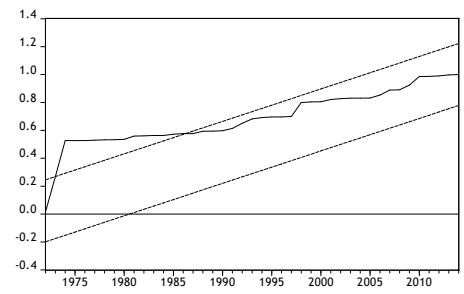
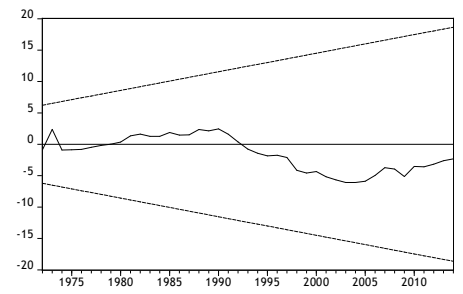
ECA-Y



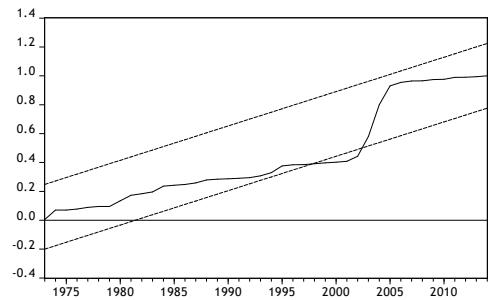
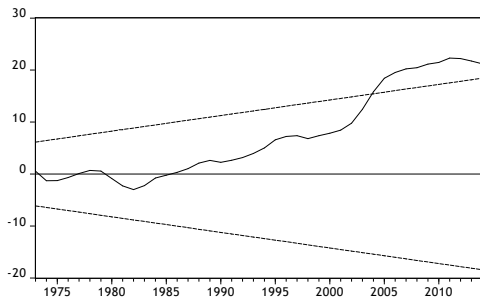
ECA-E



AP-Y



AP-E



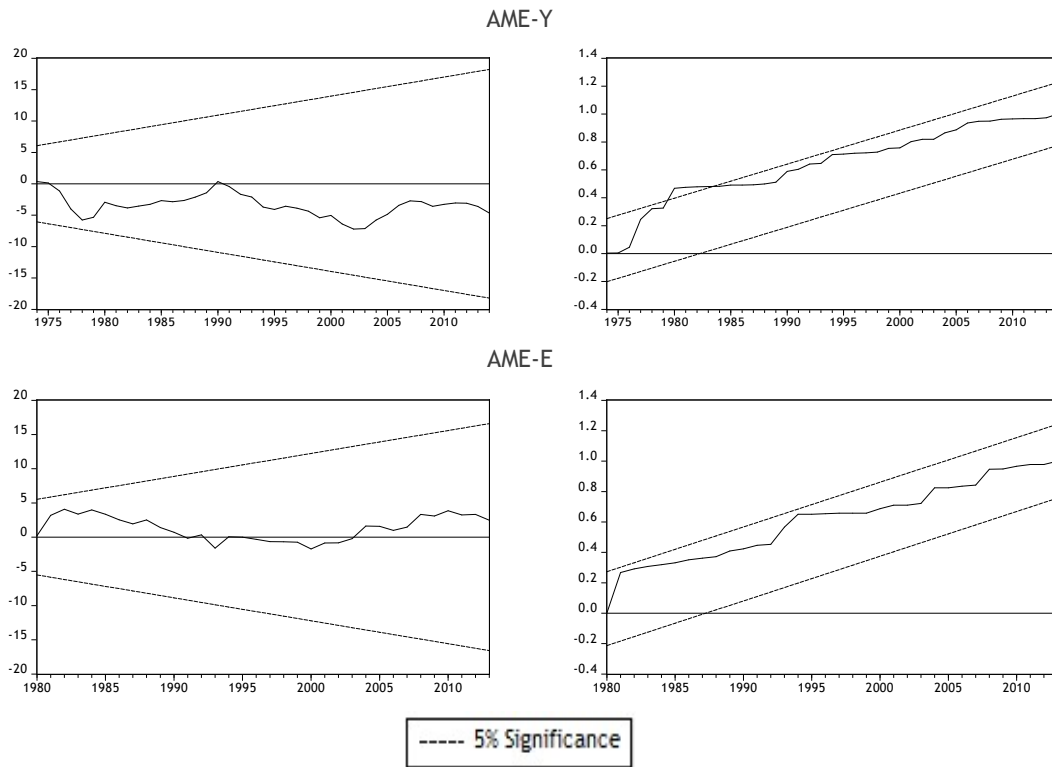


Fig. 5.4 - CUSUM and CUSUM of squares tests

At this point, the existence of structural breaks is evident. Structural changes are observed in the 80s for America and Europe and Central Asia, and additionally in the 90s for Europe and Central Asia and Asia Pacific. To confirm the presence of structural breaks and their respective starting years the Quandt-Andrews breakpoint test and Bai-Perron Global I Breaks vs None multiple breakpoint tests (table 5.4) are performed.

*Essays on Globe Energy Consumption and Economic Growth Nexus*

Table 5.4 - Quandt-Andrews breakpoint test and Bai-Perron global *l* breaks vs none multiple breakpoint test

<i>Quandt-Andrews breakpoint tests</i>			
Model	Maximum LR F-statistics	Maximum Wald F-statistic	Break date
A-Y	4.614**	18.696**	1987
A-E	8.379***	33.513***	1987
ECA-Y	4.725***	23.626***	2001
ECA-E	13.265***	39.795***	1988
AP-Y	3.067	9.202	1991
AP-E	11.643***	46.574***	1980
AME-Y	3.912***	19.558**	1977
AME-E	6.260**	12.520**	1976

<i>Bai-Perron Global l Breaks vs None Breakpoint Tests</i>		
Model	Scaled F-statistic	Estimated break dates
A-Y	18.696** (1 break)	1987
A-E	33.513** (1 break)	1987
ECA-Y	48.942** (5 break)	1975; 1988; 1994; 2002; 2009
ECA-E	39.795** (1 break)	1988
AP-Y	9.202** (1 break)	1991
AP-E	54.944** (2 breaks)	1980; 2003
AME-Y	28.645** (5 breaks)	1976; 1982; 1991; 2000; 2006
AME-E	15.520** (1 break)	1976

Notes: \*\*\* and \*\* denote statistical significance at 1% and 5 %, respectively.

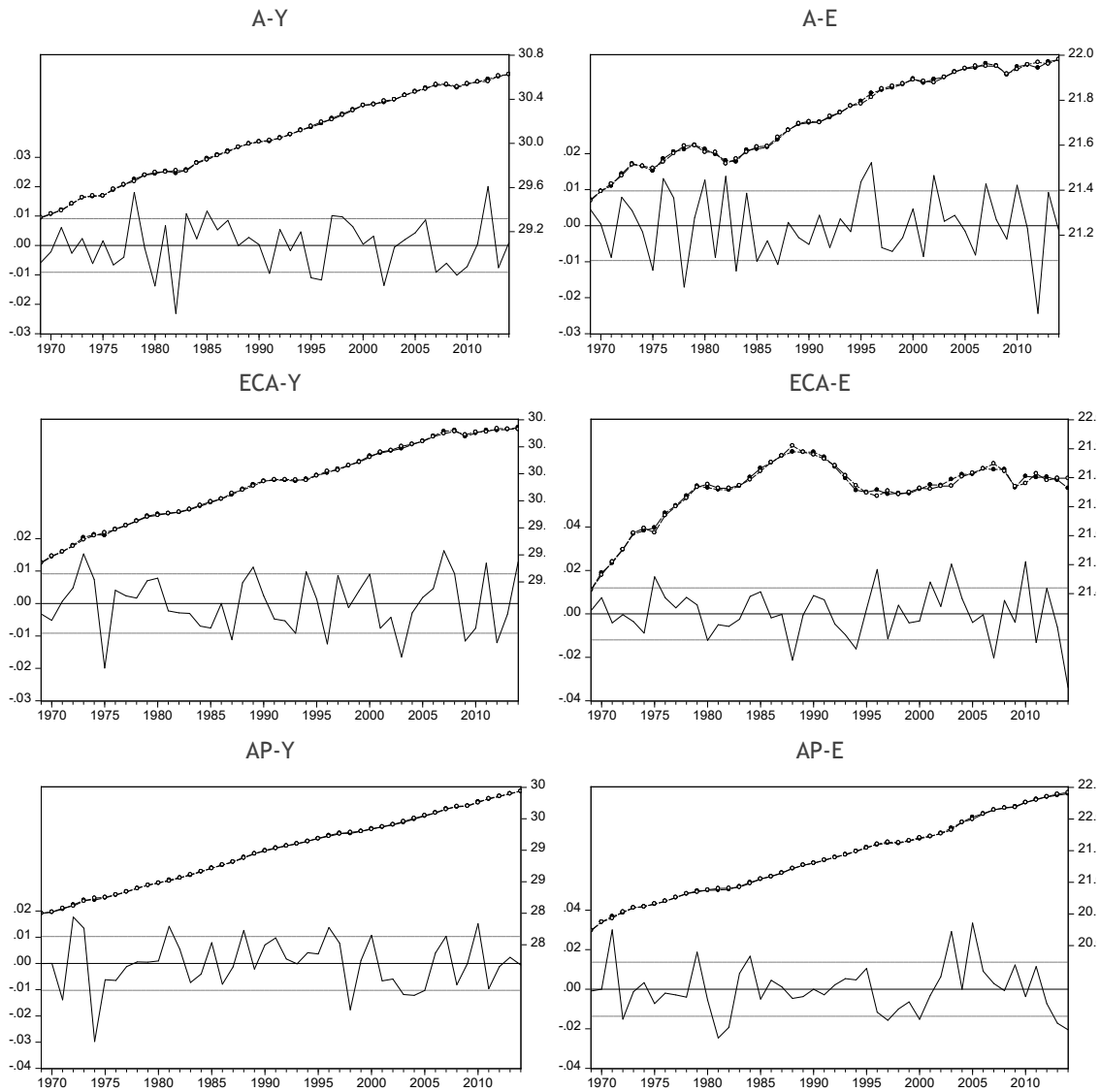
Some possible structural breaks are identified, namely in the second oil shock (1979) and oil price shock (1990) periods. The America aggregate reveals a structural break in 1987. Europa and Central Asia results are consistent with structural breaks in 2001 and 1988. Additionally, possible breaks in 1975, 1994 and 2009 should be considered. In the Asia Pacific the results reveal possible structural breaks in 1991, 1980 and possibly in 2003. Finally, in Africa and the Middle East, a structural break in 1976 was found. Additionally, there are possible breaks in 1982; 1991; 2000; and 2006. These are consistent with the structural breaks found in the chapter 4. In order to confirm the structural breaks starting years, the Chow Breakpoint Test is performed.

Table 5.5 - Chow breakpoint test

Data	A-Y	A-E	ECA-Y	ECA-E	AP-Y	AP-E	AME-Y	AME-E
1973	0.880	1.554	0.070	1.460	10.395***	10.566***	-	1.282
1974	0.887	1.751	0.530	1.602	3.380**	10.758***	0.854	0.694
1979	1.298	2.539*	1.074	4.098**	0.365	10.648***	1.073	3.002*
1980	1.326	2.804**	1.048	4.630***	0.384	11.643***	1.038	2.522*
1981	1.413	2.761**	0.755	4.117**	0.383	9.966***	0.858	1.710
1989	2.579*	3.769**	2.618**	12.191***	1.647	7.158***	1.756	0.618
1990	2.251*	2.863**	1.495	9.164***	1.929	7.067***	1.629	0.261
1991	1.694	2.400*	1.496	8.178***	3.067**	8.589***	1.783	0.253

Notes: F-statistic values. \*\*\* denotes statistical significance at 1% level.

Shift dummies were introduced for all identified structural breaks and by looking into the model's residuals some outliers were identified and controlled with impulse dummies. The non-statistical significant variables were removed. The models' residuals after the dummies correction are shown in fig. 5.5.



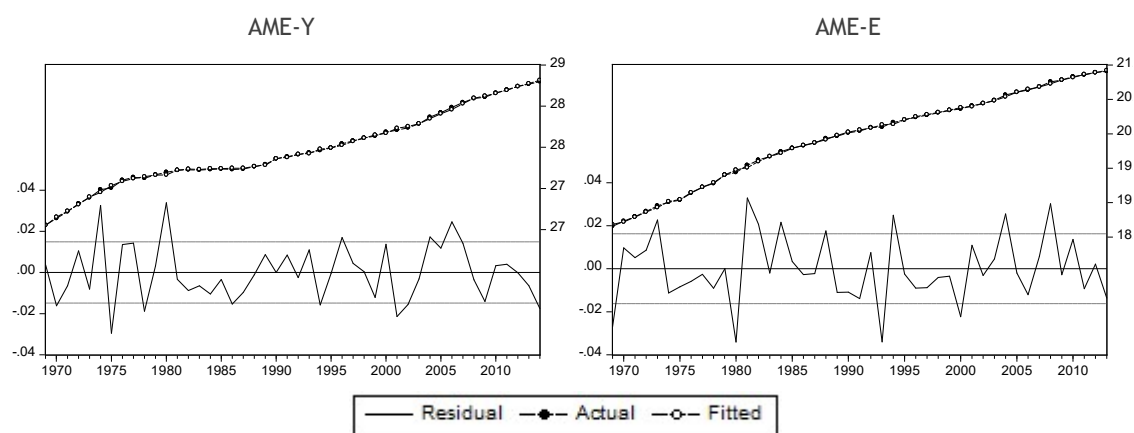


Fig. 5.5 - ARDL models' residuals with dummies

By visually comparing the ARDL residuals (fig. 5.3) before dummies and after dummies corrections (fig. 5.5), the residuals' stabilization is evident for most of the models. The models' coefficients are shown in table 5.6.

Table 5.6 - ARDL models

	A-Y	A-E	ECA-Y	ECA-E	AP-Y	AP-E	AME-Y	AME-E
Constant	-1.870***	2.590***	4.413***			-1.899***	4.367***	
Trend			0.004**				0.009***	
DLY		0.904***		0.993***		0.957***		0.336***
DLE	0.806***		0.563***		0.442***		0.416***	
LY(-1)		0.125***		0.101***		0.175***		0.041***
LE(-1)	0.225***		0.040		0.040***		-0.084*	
ECM	-0.099***	-0.293***	-0.178**	-0.14***	-0.026**	-0.152***	-0.102***	-0.058***
<i>Time Dummies</i>								
<i>America</i>								
SD8714	-0.022***	0.030***						
SD8014	0.017***	-0.025***						
<i>Europe and Central Asia</i>								
SD0814			-0.019***					
SD9414				-0.026***				
SD8914				-0.032***				
SD8714			0.012***					

	A-Y	A-E	ECA-Y	ECA-E	AP-Y	AP-E	AME-Y	AME-E
<i>Time Dummies</i>								
<b>Asia Pacific</b>								
SD9114	-	-	-	-	-0.022***	-	-	-
SD7914	-	-	-	-	-	-0.033***	-	-
SD7014	-	-	-	-	-0.034**	-	-	-
ID2009	-	-	-	-	-0.025**	-	-	-
ID2004	-	-	-	-	-	0.041***	-	-
ID1990	-	-	-	-	-	-0.026*	-	-
ID1970	-	-	-	-	-0.056***	0.085***	-	-
<b>Africa and the Middle East</b>								
SD7714	-	-	-	-	-	-	-0.043**	-
SD7614	-	-	-	-	-	-	-	0.044***
ID1990	-	-	-	-	-	-	0.043***	-
ID1979	-	-	-	-	-	-	-	0.041***

Notes: \*\*\*, \*\* and \* denote statistical significance at 1%, 5% and 10% level, respectively.

## *Essays on Globe Energy Consumption and Economic Growth Nexus*

In general, the models revealed normally distributed errors, no serial correlation in the residuals, and no autoregressive conditional heteroskedasticity (see table 5.7). By using the correlograms, the possibility of serial correlation in the AP-E model was analysed in detail. No statistical significance was revealed. For this reason, serial correlation was not considered a problem.

Table 5.7 - Diagnostic tests

	A-Y	A-E	ECA-Y	ECA-E	AP-Y	AP-E	AME-Y	AME-E
ARS	0.763	0.819	0.745	0.795	0.684	0.757	0.720	0.557
SER	0.010	0.010	0.010	0.012	0.010	0.014	0.015	0.016
JB	0.184	0.398	0.754	1.886	2.591	3.975	1.026	0.056
LM	0.350	3.993	1.871	0.041	2.641*	0.891	0.320	0.671
ARCH	0.224	0.084	0.662	1.154	0.248	0.152	0.413	0.770
RESET	1.213	0.041	1.047	1.549	0.027	0.034	0.787	0.412

**Notes:** Diagnostic tests results are based on F-statistic. ARS means adjusted R-squared. SER means standard error of regression. JB means Jarque-Bera normality test. LM means Breusch-Godfrey serial correlation LM test. ARCH means ARCH test. Reset means Ramsey RESET test. \* denotes statistical significance at 10% level.

The results revealed that America experienced permanent shifts in the energy-growth nexus caused by the second oil shock of 1979 and the 1987 stock market crash. In the Europe and Central Asia aggregate, the nexus was similarly impacted by the 1987 crash. Additionally, the period after 1994 also needed to be controlled. In this period, economic growth and energy consumption recovered after the major recession of 1990, with economic growth increasing faster than energy consumption. Moreover, the 2008 financial crisis impacted Europe and Central Asia by causing a decrease in both economic growth and energy consumption. Asia Pacific experienced impacts from both the first and second oil shocks (1970 onwards and 1979 onwards). Additionally, the period from 1991 onwards, corresponding to the end of the Gulf War, impacted the Asia Pacific nexus. In Africa and the Middle East impacts on the nexus from the second oil shock were also observed. Additionally, Asia Pacific, and Africa and the Middle East experienced several disturbances in the nexus which were revealed in the model's residuals and needed to be controlled using impulse dummies.

The ECM's are consistent with the presence of cointegration, given that the coefficients are negatively and statistical significant. To confirm the presence of cointegration the ARDL bounds test was performed (see table 5.8).

Table 5.8 - Bounds test

	A-Y	A-E	ECA-Y	ECA-E	AP-Y	AP-E	AME-Y	AME-E
<b>F-statistic</b>	8.567***	19.365***	2.563	6.664***	11.402***	7.406**	15.025***	25.824***

**Notes:**  $k=1$ , where  $k$  represents the number of independent variables in equation estimated. Critical values for no intercept and no trend -for bottom and for top are, respectively, 4.81 and 6.02, for 1%; 3.15 and 4.11, for 5% and 2.44 and 3.28 for 10%. Critical values for unrestricted intercept and no trend for bottom and for top are, respectively, 6.84 and 7.84, for 1%; 4.94 and 5.73, for 5% and 4.04 and 4.78 for 10%. Critical values for unrestricted intercept and restricted trend for bottom and for top are, respectively, 6.1 and 6.73, for 1%; 4.68 and 5.15, for 5% and 4.05 and 4.49, for 10%. \*\*\* and \*\* denote statistical significance at 1% and 5% level, respectively.

The bounds test revealed the presence of cointegration at the statistical significance of 1% for models A-Y, A-E, ECA-E, AP-Y, AP-E, AME-Y and AME-E. The short-run semi-elasticities and long-run elasticities are presented in table 5.9. The short-run semi-elasticities correspond to the coefficient of the first differenced variable. The long-run elasticities are calculated by dividing the coefficient of the lagged independent variable by the coefficient of the lagged independent variable, multiplied by -1.

Table 5.9 - Short-run semi-elasticities and long-run elasticities

	A-Y	A-E	ECA-Y	ECA-E	AP-Y	AP-E	AME-Y	AME-E
<b>Short-run</b>	0.806***	0.904***	0.563***	0.993***	0.442***	0.957***	0.416***	0.336***
<b>Long-run</b>	2.259***	0.427***	0.227**	0.726***	1.504***	1.156***	-0.834*	0.712***

**Notes:** \*\*\*, \*\* and \* denote statistical significance at 1%,5% and 10% level, respectively.

All coefficients of short-run semi-elasticities revealed statistical significance at a 1% level. With respect to long-run elasticities, the coefficient of the model AME-Y revealed statistical significance at a 10% level, which must be considered inconclusive, and from model ECA-Y revealed statistical significance at 5% which was considered inconclusive, taking into account the absence of cointegration. All other long-run elasticities coefficients revealed statistical significance at 1%. In summary, our results reveal that, in the long-run, there is evidence of bi-directional causality between energy and growth in America and Asia Pacific, while in Europe, Central Asia, and Africa and the Middle East, there is causality running from economic growth to energy.

### 5.3 Is there a future on regional policy integration?

This chapter is of particular interest because it provides directly comparable outcomes for different globe regions, and offers an alternative perspective to the literature in which

different results have been found for the same countries or regional aggregates. The use of different methodologies has been acknowledged as one of the main causes of this divergence in overall results. However, the results reveal that this divergence in previous results does not only originate from the use of different data or methodologies. The chapter provides a new perspective on the nexus of energy consumption and economic growth in four globe regions, by highlighting both the short- and long-run effects. Using the ARDL bounds test approach with annual time series data from 1968 to 2014, the globe energy-growth nexus was analysed by dividing the world into four regions: America; Europe and Central Asia; Asia Pacific; and Africa and the Middle East.

The use of four regions reveals how historical events have impacted the different regions (see fig. 5.6). The heterogeneity of the impact on each regional aggregate is evident. It should be noted that none of the historical oil shocks needed to be controlled for Europe or Central Asia, which is consistent with the presence of unidirectional causality running from economic growth and energy consumption. In the aggregates of Asia Pacific, and of Africa and the Middle East, the nexus appears to be more susceptible to disturbances. For Africa and the Middle East, the shift dummies indicate specific behaviour in which, after 1976, energy consumption grew rapidly and economic growth decelerated. In short, the results support the argument that periods of crisis have different impacts on each regional aggregate and therefore require different policy approaches.

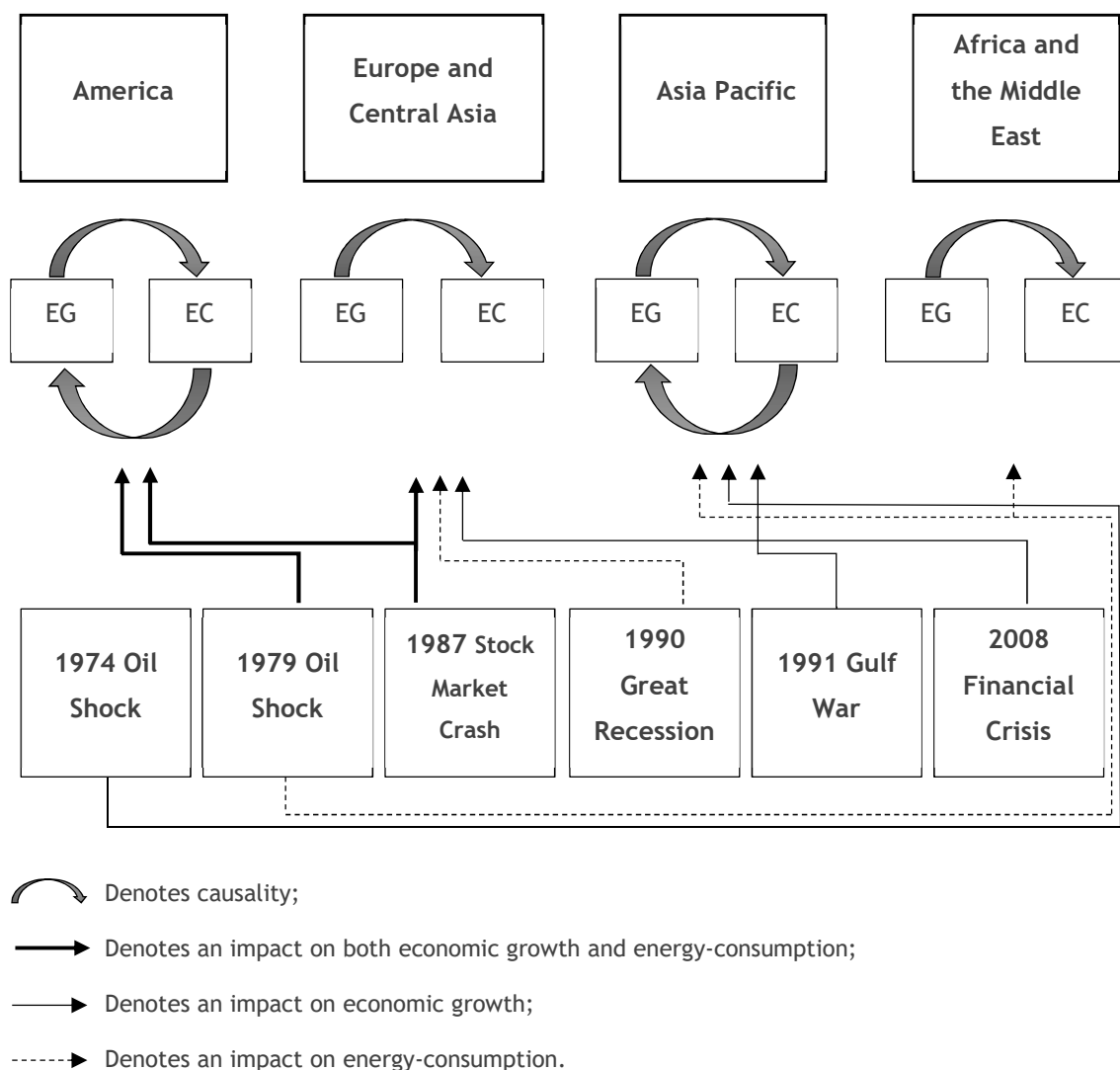


Fig. 5.6 - Energy-growth nexus behaviour and the impacts of historical events (author elaboration)

In the short-run, bi-directional causality between energy consumption and economic growth was generally found. However, heterogeneous results were found in the long-run. A long-run bi-directional causality between energy and growth was found for America and Asia Pacific. The presence of cointegration and statistically significant long-run elasticities revealed the robustness of the results. Both America and Asia Pacific revealed a strong energy dependence, given that their elasticities are superior to 1. On one hand the results are consistent with those found by Saidi *et al.* (2017) who asserts that there is bidirectional causality between energy and growth in American countries. On the other hand, these results are slightly different from those obtained by Fang and Chang (2016) who found the presence of unidirectional causality running from economic growth to energy consumption for a panel of 16 Asia Pacific countries reinforcing the sample importance on the heterogeneous results.

Restrictions on energy consumption should be strongly discouraged, particularly in the case of America, which demonstrates a high elasticity. Furthermore, such impacts could persist for years, because a reduction in energy consumption will probably cause a deceleration in economic growth and thus lead to a further reduction in energy consumption, given that the results indicate the existence of endogeneity. For these cases, the results suggest that reductions in energy consumption should be made by improving energy efficiency.

For Europe and Central Asia, and Africa and the Middle East, the direction of causality was found to be from economic growth to energy consumption. These results suggest that growth in Europe and Central Asia may lead to an inefficient increase in energy consumption. Recently, Saidi and Hammami (2015) found that increased GDP causes increased energy consumption globally in Europe, Asia, Latin America, the Caribbean, the Middle East, North Africa and the Sub-Sahara region for a sample of 58 countries. These results are consistent with those found in this chapter. In addition, this research goes further by considering the entire globe and testing the hypothesis of energy consumption causing economic growth.

In the case of Africa and the Middle East, the results also reveal that, not only does energy consumption not cause economic growth, but that any increase in energy consumption tends to reduce economic growth. This seems to be a case where an excess of energy resources becomes a “curse” that constrains economic growth. This is consistent with the effects observed after 1976, when energy consumption accelerated and economic growth decelerated. These results are consistent with Fuinhas *et al.* (2015) who found the *curse hypothesis* for a panel of oil producers. These are poorly diversified economies. For instance, according to the World Bank, 97% of Angolan exports come from oil accounts. Nowadays, low oil prices, civil wars and even high fiscal spending in some African and Middle Eastern countries have contributed to a slowdown of growth. Promoting diversification may help to change the energy-growth nexus in this region.

The heterogeneity of the nexus throughout the globe was confirmed, revealing that the use of different methodologies is not the main cause of the heterogeneous results in the literature. In fact, the research makes clear that there are heterogeneous results even when the same methodology is applied. In addition, it was observed that historical events, such as the oil shocks, had different impacts on each regional aggregate. In short, the results indicate that the impact of historical periods of crisis are fairly heterogeneous across the globe. Regarding the common linkages previously found in the literature, we observed that in the long-run: (i) the *feedback hypothesis* is present in America and in Africa and the Middle East; and (ii) in Europe and Central Asia and in Africa and the Middle East, the *conservation hypothesis* was found.

The chapter is thus of interest to those devising integrated energy policies. The results show that a future path of integrated energy policies can be followed such as in previous chapters. However, there are some limitations, in particular avoiding those that involve restrictive energy consumption policies, as stated above. In fact, the results support the need to develop joint energy policies for America and Asia Pacific, where similar nexus were found. Moreover, the possibility of Europe and Central Asia sharing joint policies should be considered. For Africa and the Middle East, the creation of specific energy policies is recommended. Lastly, a concern regarding globe energy inefficiency arises due to the causality of economic growth on energy consumption. There is a need to increase efficiency in energy consumption thus preventing inefficient development caused by growth in energy consumption due to non-productive activities.

Given that the results are supporting the integration path in energy policies, it could be important to understand the impact of globalization at globe level. In fact, this topic is addressed in the chapter 7. Additionally, the spillover effects of the policies followed by some countries, namely those who play dominant roles in the energy markets in both sides, consumption and supply, should be considered given that this is a subject in deficit in the literature. Taking this into consideration, a first approach on this subject is developed in chapter 6.

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## **Chapter 6**

### **Augmented Energy-Growth Nexus on the Globe: Are There China's Spillover Effects on Globe Nexus?**

In the current perspective of development of research on augmented energy-growth nexus, trying to find some answers for the conflicting results in the literature, analysing the spillover effects of some specific countries on globe energy-growth nexus could raise a new perspective to the policymakers, namely in what concerns to the development of integrated energy policies. The study of countries spillover effects is non-existent on globe energy-growth nexus where countries such as the richest ones, the biggest exporting or importing and the biggest oil producers and consumers can develop big influence.

Taking this into consideration, this research aims to study the China's spillover effects on energy-growth nexus; namely the China's economic growth and energy consumption impacts on the globe. According to World Bank World Development Indicators, China is the second largest economy in the world, with the largest growth market for energy for fifteen consecutive years (BP, 2016). However, in 2016 China experienced the slowest rate of energy consumption growth in 20 years. Given China's greatness, it is possible that this slow down impact on globe energy-growth nexus and gives rise to the main question of research: Does China's economic growth and energy consumption impact on the globe energy-growth nexus?

To answer the main question, an ARDL bounds test was performed and the short-run semi-elasticities and long-run elasticities estimated. On one hand, the results support the conclusions of chapter 5. On the other hand, it is observed that China's economic growth and energy consumption has long-run spillover effects on Europe and Central Asia, Pacific Asia and Africa and the Middle East.

#### **6.1 Sample analysis from 1970 to 2016**

The chapter focuses on the study of China's economic growth and energy consumption nexus on the four regions previously studied in chapter 5: i) America (North and South); (ii) Europe and Central Asia; (iii) Asia Pacific; and (iv) Africa and the Middle East. The data comprises

annual observations from 1970 to 2016. The gross domestic product (Y) and the primary energy consumption (E) were extracted from World Bank's Development Indicators and the BP Statistical Review of World Energy, respectively. Y is measured in constant 2010 dollars and E is measured in tonnes of oil equivalent. The prefix "L" denotes the natural logarithm, and "D" denotes the first difference of variables. Eviews 9.5 econometric software was used. Summary statistics are presented in table 6.1.

Table 6.1 - Descriptive statistics

Statistic	America		Europe and Central Asia		Asia Pacific		Africa and Middle East		China	
	LY	LE	LY	LE	LY	LE	LY	LE	LY	LE
Mean	30.026	21.743	30.328	21.762	29.614	20.899	28.425	20.038	27.912	20.559
Median	30.258	21.747	30.326	21.772	29.699	20.942	28.329	20.090	27.896	20.535
Maximum	30.834	21.983	30.758	21.889	30.348	21.639	29.238	21.012	29.911	21.849
Minimum	29.531	21.395	29.765	21.471	28.694	20.029	27.576	18.730	26.069	19.144
Std. Dev.	0.393	0.184	0.289	0.092	0.488	0.493	0.447	0.666	1.209	0.797
Skewness	-0.174	-0.178	-0.187	-1.391	-0.298	-0.131	0.297	-0.346	0.077	0.146
Kurtosis	1.781	1.584	1.900	5.016	1.859	1.656	2.074	2.051	1.723	1.901
Jarque-Bera	3.147	4.172	2.643	23.115	3.247	3.675	2.369	2.703	3.243	2.529
Probability	0.207	0.124	0.267	0.000	0.197	0.159	0.306	0.259	0.198	0.282
Observations	47	47	47	47	47	47	47	47	47	47

To define the best approach to the study on the dynamics between energy consumption and economic growth and China's economic growth and energy consumption, the variable's order of integration was analysed. The same approach of the previous chapter was followed. First of all, the graphical analysis of the level variables and their first differences was conducted (see fig. 6.1). Secondly the variables correlograms are examined (see fig. 6.2). Finally, the ADF, PP and KPSS unit root tests (see table 6.2) and MDF test that were performed (see table 6.3). Relevant differences from the results of the section 5.1 are not expected.

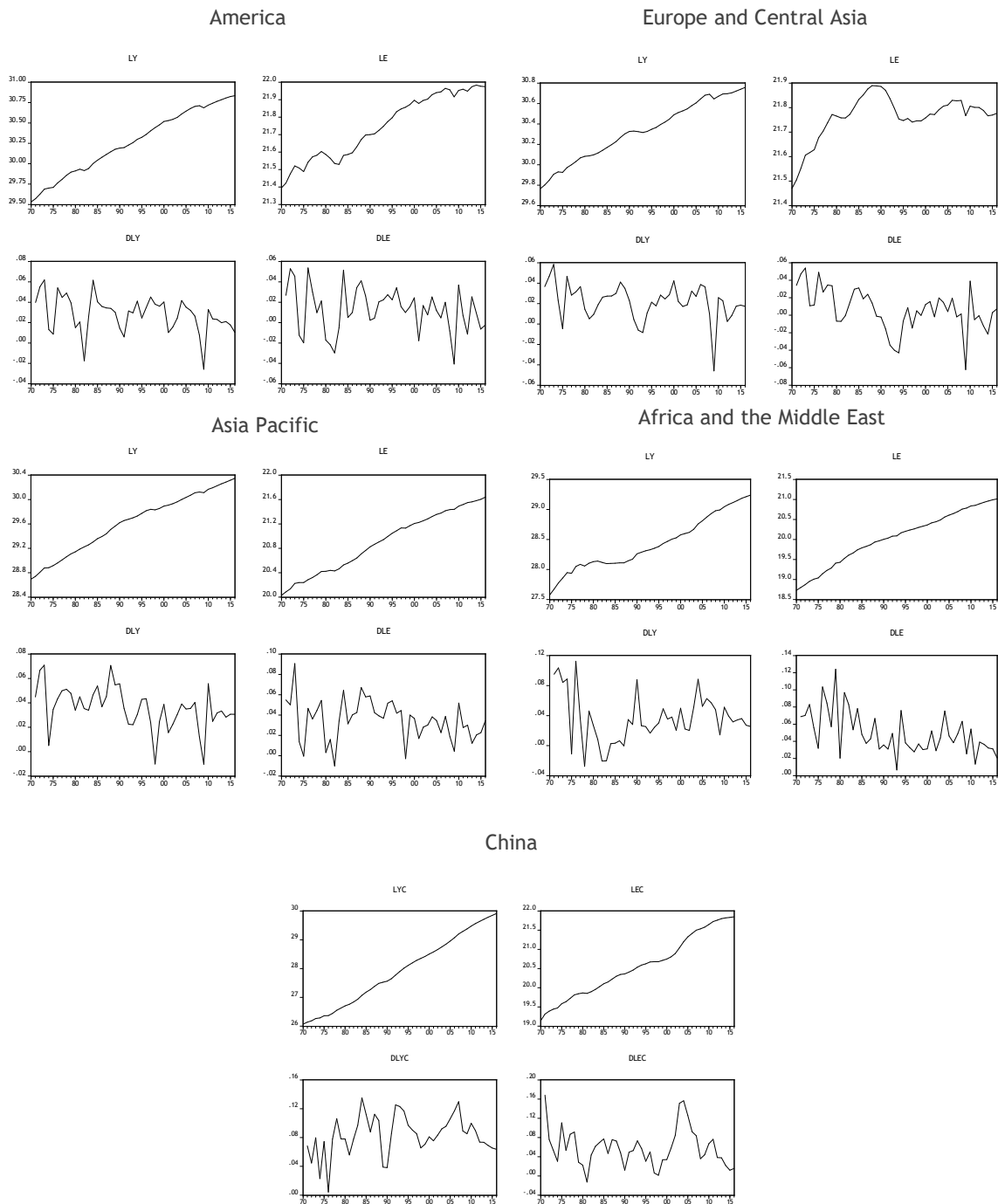
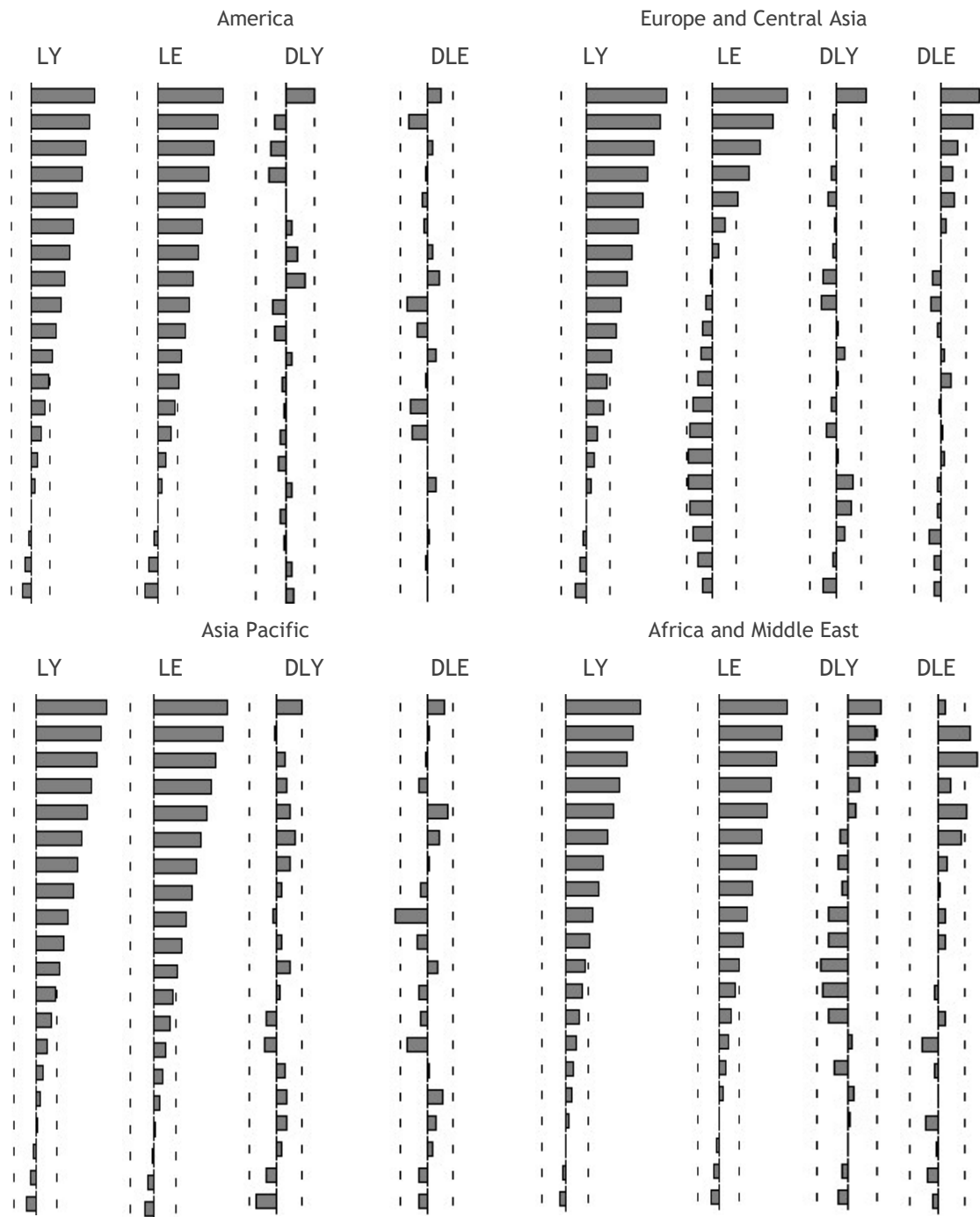


Fig. 6.1 - Variables in level and in its first differences

As expected, the America, Europa and Central Asia, Asia Pacific and Africa and Middle East behaviours are similar to the variables in chapter 5. For the China case, the behaviours are consistent with the presence of structural breaks, namely near 1980, 2000 and 2008. Additionally the variables behaviours suggest that they are  $I(1)$ .



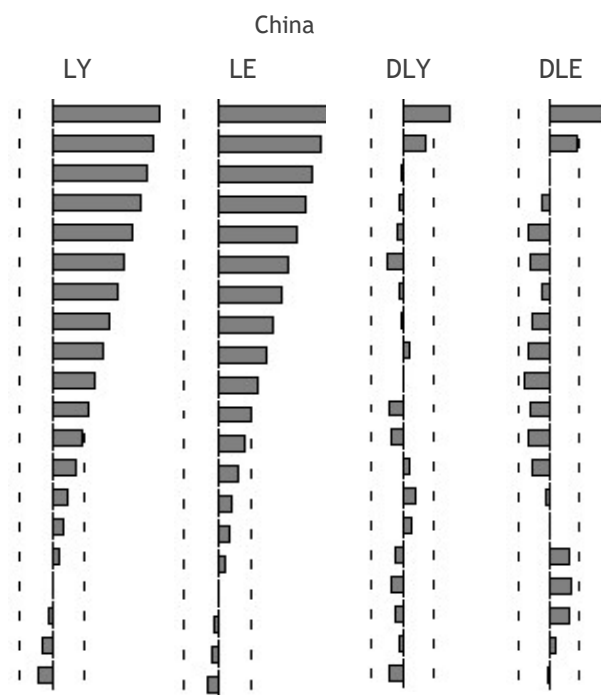


Fig. 6.2 - Level and first difference correlograms

The correlograms are consistent with the behaviours observed in fig 6.1 by supporting that the variables are  $I(1)$ . Additionally, the ADF, PP and KPSS tests provide additional information on variable's order of integration. Further, the MDF test is performed providing some information on the presence of structural breaks.

*Essays on Globe Energy Consumption and Economic Growth Nexus*

Table 6.2 - ADF, PP and KPSS unit root tests

Regions / Variables	ADF			PP			KPSS		
	a)	b)	c)	a)	b)	c)	a)	b)	
America	LY	-2.018	-2.565	10.764	-1.434	-3.293**	9.180	0.193**	0.892***
	LE	-1.647	-1.721	3.873	-1.820	-1.721	3.873	0.111	0.878***
	DLY	-5.064***	-4.660***	-2.303**	-4.944***	-4.371***	-2.004**	0.097	0.397*
	DLE	-5.607***	-5.498***	-4.536***	-5.542***	-5.421***	-4.456***	0.067	0.231
Europe and Central Asia	LY	-3.063	-1.619	3.483	-2.567	-2.138	7.187	0.132*	0.890***
	LE	-3.037	-2.910*	1.861	-2.807	-3.804***	1.211	0.169**	0.378*
	DLY	-4.856***	-4.647***	-2.719***	-4.710***	-4.533***	-2.637***	0.057	0.316
	DLE	-4.697***	-4.202***	-4.105***	-4.711***	-4.136***	-4.012***	0.134*	0.450*
Asia Pacific	LY	-1.326	-3.248**	4.257	-1.341	-3.283**	11.262	0.223***	0.886***
	LE	-0.965	-1.826	11.728	-1.132	-1.826	10.278	0.149**	0.891***
	DLY	-5.659***	-4.903***	-1.497	-5.571***	-4.903***	-1.470	0.073	0.643**
	DLE	-5.581***	-5.427***	-1.675*	-5.552***	-5.423***	-2.109**	0.099	0.308
Africa and Middle East	LY	-1.484	-0.053	3.468	-1.904	-0.586	5.233	0.166**	0.878***
	LE	-2.066	-4.329***	1.218	-1.817	-4.516***	8.332	0.202**	0.881***
	DLY	-4.884***	-4.949***	-3.169***	-4.844***	-4.922***	-2.955***	0.129*	0.122
	DLE	-2.455	-1.696	-1.348	-8.059***	-6.517***	-1.956**	0.122*	0.605**
China	LY	-3.618**	0.225	3.310	-3.146	1.023	16.542	0.141*	0.888***
	LE	-2.636	-0.052	2.945	-2.174	-0.824	6.960	0.119*	0.883***
	DLY	-3.305*	-3.405**	-1.100	-4.052**	-4.012***	-0.844	0.128**	0.234
	DLE	-3.947**	-4.027***	-2.620***	-4.013**	-4.089***	-2.620***	0.083	0.088

**Notes:** a) denotes the test statistic with trend and constant; b) denotes the test statistic with constant; c) denotes the test statistic without tendency and constant. \*\*\* and \*\* denote statistical significance at 1% and 5% level, respectively.

The ADF, PP and KPSS tests raises doubts on some variables integration order, such as Asia Pacific growth or Africa and Middle East energy consumption. Given that some variables may not be I(1) but only near I(1), the ARDL model is the best choice to handle with possible variables with different integration order.

Table 6.3 - MDF unit root tests

Regions		LY	LE	DLY	DLE
America	T-statistic	-5.360**	-2.910	-5.881***	-7.508***
	Specification	(1)	(3)	(4)	(1)
	Break	2008	1992	2007	1983
Europe and Central Asia	T-statistic	-4.124	-3.647	-5.862***	-5.569***
	Specification	(1)	(1)	(4)	(3)
	Break	2003	1991	2009	1999
Asia Pacific	T-statistic	-5.473**	-3.707	-6.449***	-6.902***
	Specification	(1)	(3)	(3)	(3)
	Break	1989	1987	2009	1982
Africa and Middle East	T-statistic	-5.313**	-4.585**	-7.170***	-9.942***
	Specification	(3)	(2)	(1)	(4)
	Break	1981	1984	1985	1985
China	T-statistic	-3.680	-2.978	-4.702**	-6.013***
	Specification	(2)	(1)	(2)	(1)
	Break	2015	2003	1982	2002

Notes: Trend Specification / Break Specification: (1) Trend and intercept / Trend and intercept; (2) Trend and intercept / Trend only; (3) Trend and intercept/Intercept only; (4) Intercept only / Intercept only. \*\*\* and \*\* denote statistical significance at 1% and 5% level, respectively.

The MDF test confirms that all variables are at the most I(1), as expected. Additionally, it reveals that the 1980 energy crisis, together with the 2008 financial crisis, has impacts in all globe regions. These results are in accordance with the MDF tests of previous chapter.

## 6.2 China's energy consumption and economic growth effects on globe nexus

Such as in chapter 5, the ARDL approach is suitable because the variables are I(0) and I(1). As stated before, the ARDL advantages to handle with variables I(1) or near I(1) and structural breaks were extensively discussed in previous chapters. Let “YCHN” mean China’s economic growth and “ECHN” mean China’s energy consumption. The new general UECM in its equivalent ARDL bounds test are:

$$\begin{aligned}
 DLY_t = & \alpha_0 + \alpha_1 TREND + \sum_{i=1}^k \alpha_{2i} DLY_{t-i} + \sum_{i=0}^k \alpha_{3i} DLE_{t-i} + \sum_{i=1}^k \alpha_{4i} DLYCHN_{t-i} \\
 & + \sum_{i=0}^k \alpha_{5i} DLECHN_{t-i} + \alpha_6 LY_{t-1} + \alpha_7 LE_{t-1} + \alpha_8 LYCHN_{t-1} \\
 & + \alpha_9 LECHN_{t-1} + \mu_{10t},
 \end{aligned} \tag{6.1}$$

where,  $k$  represents the number of lags defined by empirical knowledge of the variables and  $\mu$  represents the disturbance terms assuming white noise and normal distribution. The expected signs of parameters are  $\alpha_0 \neq 0$ ,  $\alpha_1 \neq 0$ ,  $\alpha_{2i} \neq 0$ ,  $\alpha_{3i} \neq 0$ ,  $\alpha_{4i} \neq 0$ ,  $\alpha_{5i} \neq 0$ ,  $\alpha_6 < 0$ ,  $\alpha_7 > 0$ ,  $\alpha_8 \neq 0$ ,  $\alpha_9 \neq 0$ . The parameters  $\alpha_{2i}$ ,  $\alpha_{3i}$ ,  $\alpha_{4i}$  and  $\alpha_{5i}$  explain the short-run dynamic coefficients, while  $\alpha_6$ ,  $\alpha_7$ ,  $\alpha_8$  and  $\alpha_9$  explain the long-run multipliers. On one hand, a negative  $\alpha_4$  is expected because it would be consistent with the presence of cointegration. On the other hand, a positive  $\alpha_5$  is expected, given that a negative coefficient would be consistent with a globe *curse hypothesis* where energy consumption most likely drives to less economic growth which is highly unlikely.

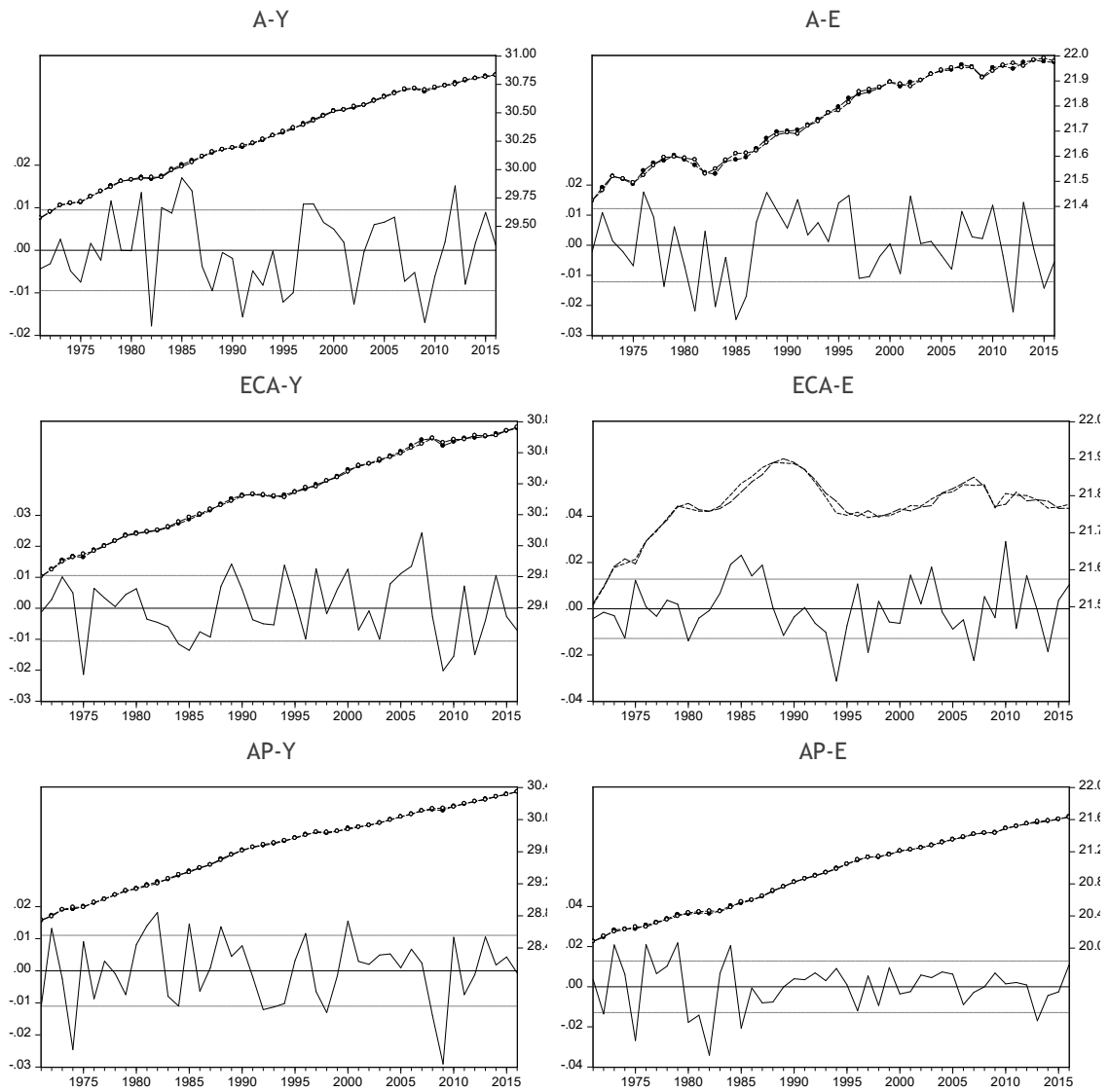
$$\begin{aligned}
 DLE_t = & \beta_0 + \beta_1 TREND + \sum_{i=1}^k \beta_{2i} DLE_{t-i} + \sum_{i=0}^k \beta_{3i} DLY_{t-i} \\
 & + \sum_{i=0}^k \beta_{4i} DLYCHN_{t-i} + \sum_{i=0}^k \beta_{5i} DLECHN_{t-i} + \beta_6 LE_{t-1} + \beta_7 LY_{t-1} \\
 & + \beta_8 LYCHN_{t-1} + \beta_9 LECHN_{t-1} + \mu_{10t},
 \end{aligned} \tag{6.2},$$

where the expected signs of parameters are  $\beta_0 \neq 0$ ,  $\beta_1 \neq 0$ ,  $\beta_{2i} \neq 0$ ,  $\beta_{3i} \neq 0$ ,  $\beta_{4i} \neq 0$ ,  $\beta_{5i} \neq 0$ ,  $\beta_6 < 0$ ,  $\beta_7 > 0$ ,  $\beta_8 \neq 0$  and  $\beta_9 \neq 0$ . The parameters  $\beta_{2i}$ ,  $\beta_{3i}$ ,  $\beta_{4i}$  and  $\beta_{5i}$  explain the short-run dynamic coefficients, while  $\beta_6$ ,  $\beta_7$ ,  $\beta_8$  and  $\beta_9$  explain the long-run multipliers.  $\beta_4$  is expected to be negative revealing consistence with the presence of cointegration and  $\beta_5$  is expected to be positive because globe economic growth most likely drive to the development of productive and non-productive activities increasing the energy consumption.

To identify the structural breaks that need to be controlled, once more the 4-method approach was followed; (i) visually inspection of the model's residuals; (ii) inspection of the CUSUM and CUSUM of squares tests; (iii) the Quandt-Andrews breakpoint and Bay-Perron multiple breakpoint test; and (iv) the Chow breakpoint test. The validity of the models was evaluated through a battery of diagnostic tests: (i) Jarque-Bera normality test; (ii) Breusch-Godfrey serial correlation LM test; (iii) ARCH test for heteroskedasticity; and (iv) Ramsey RESET test for model specification.

In order to perform the ARDL models, the Eviews 9.5 software was used with automatic model selection criteria with 1 max lags, such as on the previous chapter. The following models have been estimated: (i) A-Y, in the case of America; (ii) ECA-Y, for Europe and Central Asia; (iii) AP-Y, for Asia Pacific; and (iv) AME-Y, for Africa and the Middle East. Similarly, equation (2) leads to the following models: (i) A-E, for America; (ii) ECA-E, for Europe and Central Asia; (iii)

AP-E, for Asia Pacific; and (iv) AME-E, Africa and the Middle East. A first assessment on the model's structural breaks was made by examining the model's residuals (see fig 6.3) and CUSUM and CUSUM of squares tests (see fig. 6.4).



*Essays on Globe Energy Consumption and Economic Growth Nexus*

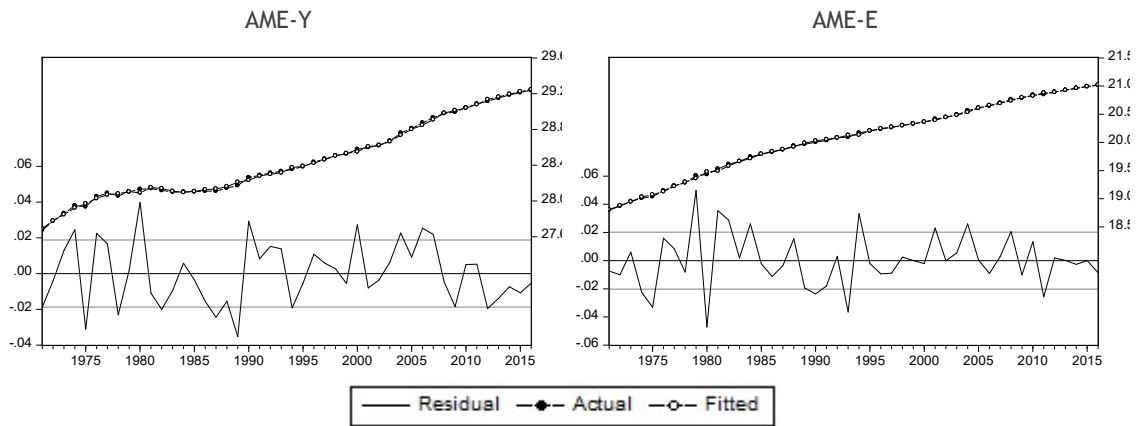
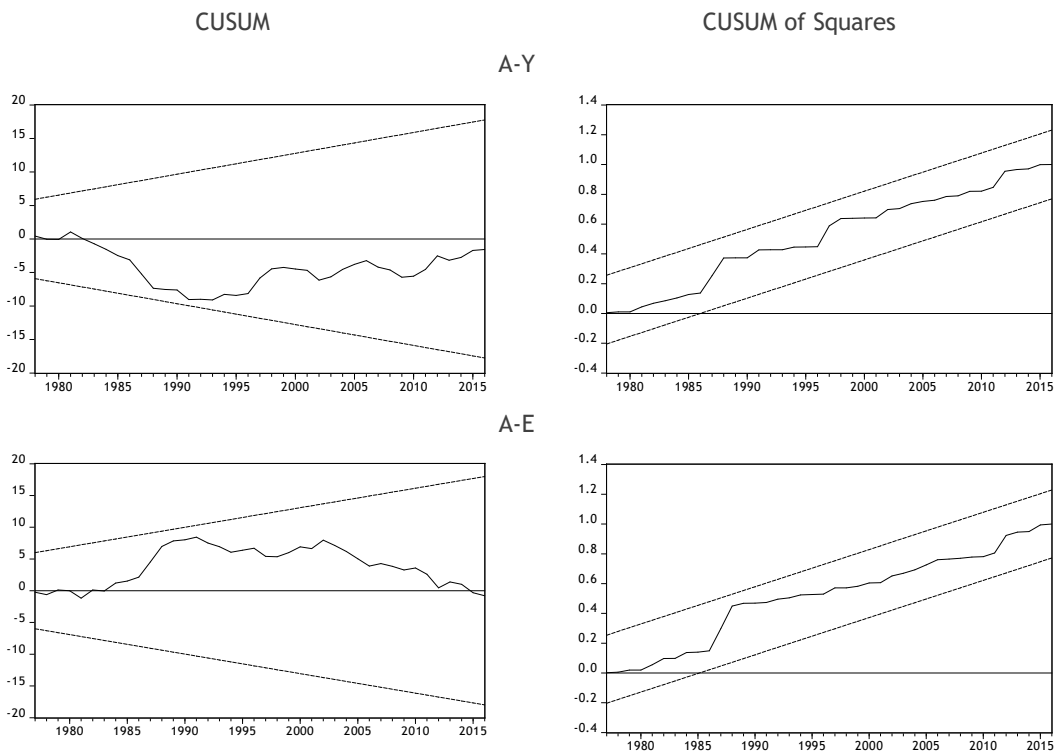


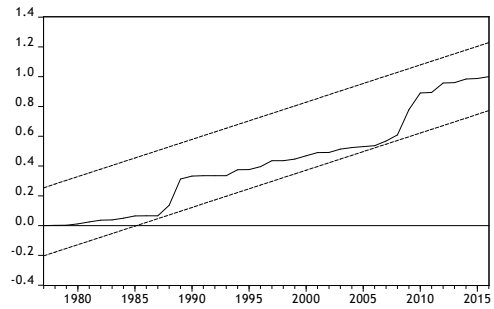
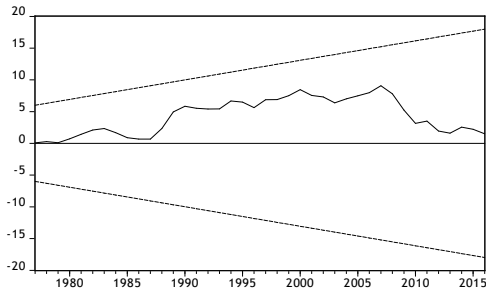
Fig. 6.3 - ARDL residuals

The model's residuals are consistent with the presence of structural breaks, as expected. Before the breakpoint tests, the CUSUM and CUSUM of Squares to confirm the existence of structural breaks.

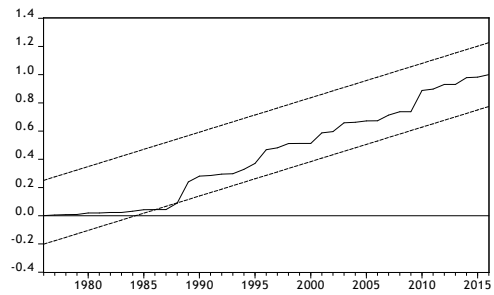
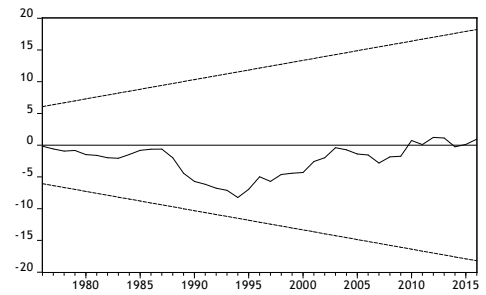


# Essays on Globe Energy Consumption and Economic Growth Nexus

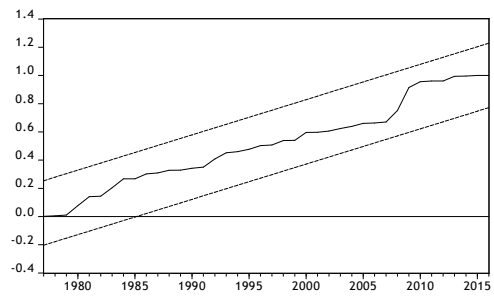
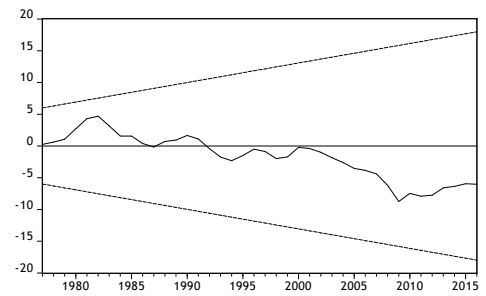
### ECA-Y



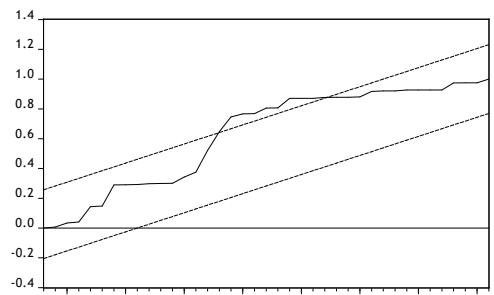
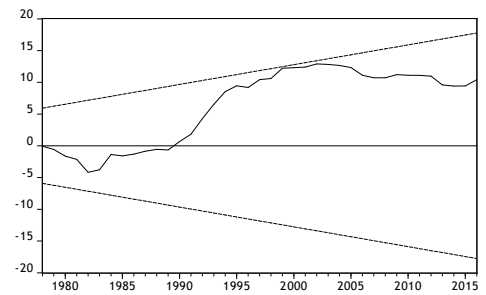
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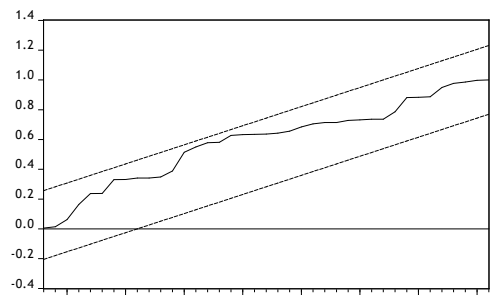
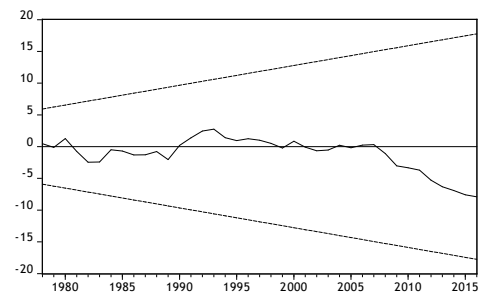
### AP-Y



### AP-E



### AME-Y



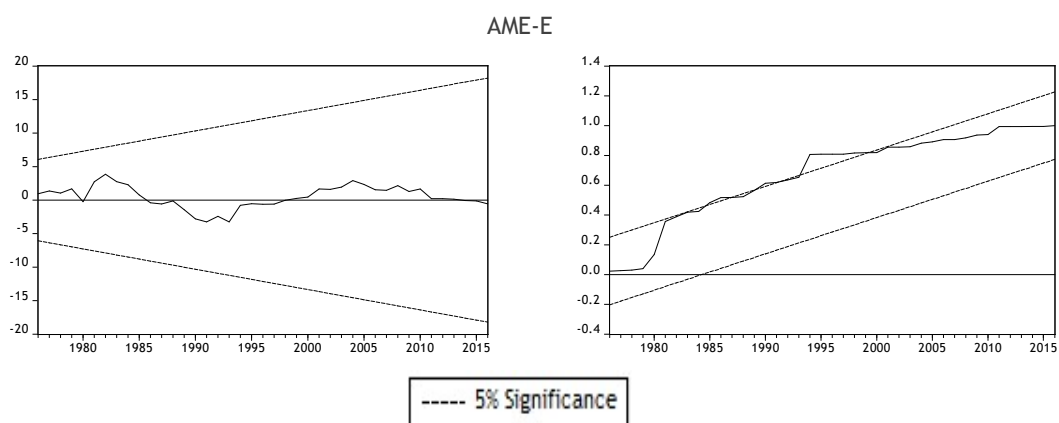


Fig. 6.4 - CUSUM and CUSUM of squares tests

The presence of structural breaks is evident in the models' stability. In accordance with the information revealed by the MDF unit root test, the 1980 and 2008 impacts are observed across different regions.

Table 6.4 - Quandt-Andrews breakpoint test and Bai-Perron global *l* breaks vs none multiple breakpoint test

<i>Quandt-Andrews Breakpoint Tests</i>			
Model	Maximum LR F-statistics	Maximum Wald F-statistic	Break date
A-Y	-	-	-
A-E	5.560***	33.359***	1987
ECA-Y	3.252*	19.509*	2009
ECA-E	4.565***	22.823***	1989
AP-Y	3.555**	21.329**	1992
AP-E	-	-	-
AME-Y	-	-	-
AME-E	8.449***	42.244***	1981

<i>Bai-Perron Global <i>l</i> Breaks vs None Multiple Breakpoint Tests</i>		
Model	Scaled F-statistic	Estimated break dates
A-Y	-	-
A-E	60.434** (5 break)	1979; 1985; 1994; 2002; 2011
ECA-Y	190.412** (5 break)	1980; 1988; 1995; 2001; 2011
ECA-E	76.507** (5 break)	1977; 1988; 1994; 2000; 2010
AP-Y	126.500** (5 breaks)	1978; 1984; 1990; 2000; 2009
AP-E	-	-
AME-Y	-	-
AME-E	50.038** (2 break)	1980; 1988

Notes: \*\*\* and \*\* denote statistical significance at 1% and 5 %, respectively.

It was not possible to run the Quandt-Andrews and Bai-Perron breakpoint test for the A-Y, AP-E and AME-Y models, due to limitations arising from the model that have been defined as optimal. For these models, there is raised interest in performing the Chow Breakpoint Test (see table 6.5). It is worthwhile to note that Bai-Perron breakpoint test reveal a great number

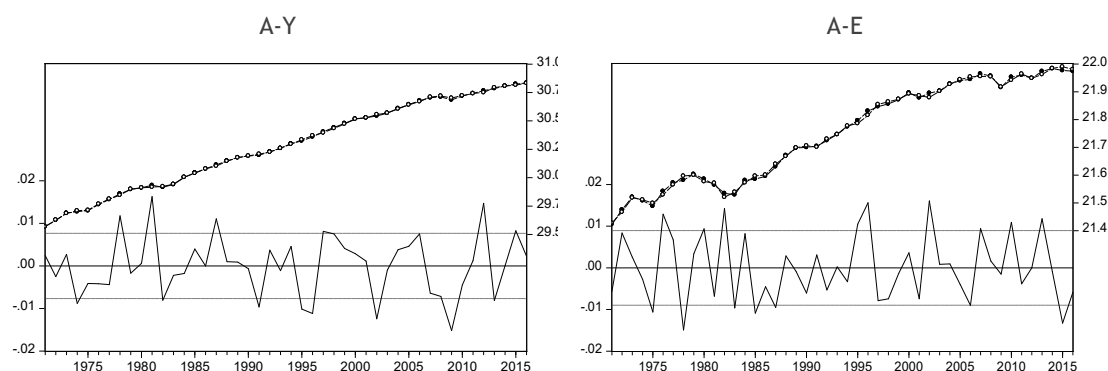
of possible breaks when compared with the table 5.4, that is most likely an outcome of China energy consumption and economic growth on the models.

Table 6.5 - Chow breakpoint test

Data	A-Y	A-E	ECA-Y	ECA-E	AP-Y	AP-E	AME-Y	AME-E
1979	0.644	1.087	1.065	0.445	2.312*	2.455**	2.665**	2.770**
1980	0.616	1.190	1.196	0.446	3.528***	5.482***	2.571**	3.158**
1981	3.392***	1.189	1.322	0.775	2.706**	4.929***	3.379***	8.449***
1989	1.660	1.627	1.567	4.565***	2.850**	5.351***	2.513**	3.047**
1990	1.697	1.489	0.328	2.422*	2.978**	5699***	2.982**	2.593**
1991	1.801	1.692	0.224	2.265*	3.280**	4.920***	1.989*	2.064*

**Notes:** F-statistic values. \*\*\*, \*\* and \* denotes statistical significance at 1%; 5% and 10% level, respectively.

It was not possible to carry out the Chow breakpoint test at the beginning of the series. Moreover, the Chow breakpoint test was not used to confirm the possible breaks arising from the 2008 financial crisis because closer to the end of the series the robustness of the test decreases. For both cases, some shift dummies are tested for their adequacy in the models, taking the models' residuals and the statistical significance of the dummies as a guide. The Chow breakpoint test was used to test for structural breaks arising from 1980 energy crisis and 1990 oil price shock, revealing that Asia Pacific and Africa and Middle East experienced impacts in both periods. Additionally, the period of 1990 should also be analysed for the Europe and Central Asia aggregate.



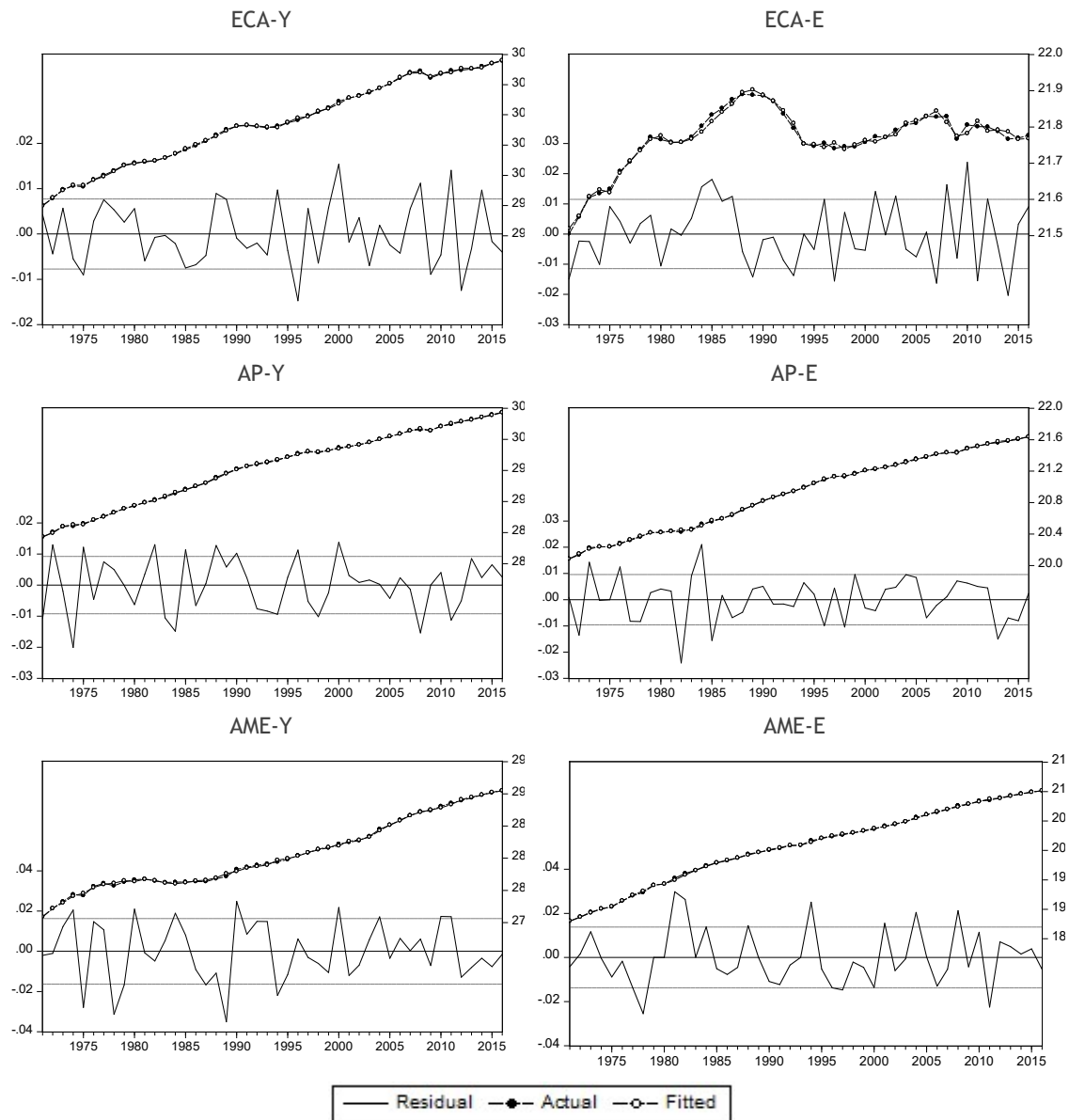


Fig. 6.5 - ARDL residuals with dummies

Taking into account all the collected information on possible structural breaks, the shift dummies for those periods were tested. The non-statically significant variables were removed. Additional there was the need to control some outliers with impulse dummies. The models were kept as narrow as possible. The residuals of the corrected models show greater stability compared to the fig. 6.3. The results of the ARDL models are shown in the table 6.6.

Table 6.6 - ARDL models

	A-Y	A-E	ECA-Y	ECA-E	AP-Y	AP-E	AME-Y	AME-E
Constant	-1.565**	2.515***	3.029***		2.121***	-6.001***	4.656***	
Trend						-0.009**		
DLY		0.969***		0.946***		0.796***		0.275***
DLE	0.699***		0.594***		0.582***		0.378**	
DLYCHN			-0.069			0.191***	-0.463***	0.252**
DLECHN			-0.041	0.112**			0.066	
LY(-1)		0.101		0.071**		0.286***		0.054***
LE(-1)	0.265***		0.093***		0.062		-0.121**	
LYCHN(-1)			0.028*			0.102***	0.063**	0.019
LECHN(-1)			0.052**	0.015			0.191***	
LYCHN	0.000	0.002		-0.031*	-0.015			
LECHN	0.011	0.000			0.059***	-0.051**		-0.007
ECM	-0.146***	-0.261***	-0.226***	-0.074*	-0.142**	-0.194***	-0.276***	-0.097***
<i>Time Dummies</i>								
America								
SD8716	-0.028***	0.029***						
SD8316	0.025***							
SD8016		-0.029***						
ID2012		-0.022**						

	A-Y	A-E	ECA-Y	ECA-E	AP-Y	AP-E	AME-Y	AME-E
<i>Time Dummies</i>								
<b>Europe and Central Asia</b>								
SD0916			-0.014*					
SD0816			-0.039***					
SD7516			-0.016**					
ID1994			-0.033***					
<b>Asia Pacific</b>								
SD8016	-	-	-	-	0.025***	-0.043***	-	-
ID2009	-	-	-	-	-0.032***	-	-	-
ID1975	-	-	-	-	-	-0.035***	-	-
<b>Africa and Middle East</b>								
SD0816	-	-	-	-	-	-	0.039***	-
SD8116	-	-	-	-	-	-	-0.033*	-
SD7616	-	-	-	-	-	-	-	0.051***
ID1993	-	-	-	-	-	-	-	-0.042***
ID1980	-	-	-	-	-	-	-	-0.056***
ID1979	-	-	-	-	-	-	-	0.034**

Notes: \*\*\*, \*\* and \* denote statistical significance at 1%, 5% and 10% level, respectively.

The models' ECMs are negatively and statistically significant which is consistent with the presence of cointegration. It should be said that the model ECA-E only reveal statistical significance at 10% level. Notwithstanding the presence of cointegration is assessed by the ARDL bounds test (see table 6.8).

With regard to the structural breaks, for the America case, it was observed impacts from the second oil shock (1979) and 1987 stock market crash. For Europe and Central Asia, it was observed impacts of the 2008 financial crisis by causing a decrease in both economic growth and energy consumption. Further, the period of 1990 revealed no need of shift dummy but 1994 needed to be controlled with an impulse dummy. Asia Pacific, needed to be controlled for the second oil shock (1979 onwards) and for the periods of 1975 and 2009. In Africa and the Middle East impacts on the nexus from the first and second oil shocks were also observed. Additionally, Africa and the Middle East needed to be controlled for several disturbances in the nexus which were revealed in the model's residuals and controlled by using impulse dummies.

Table 6.7 - Diagnostic tests

	A-Y	A-E	ECA-Y	ECA-E	AP-Y	AP-E	AME-Y	AME-E
ARS	0.826	0.846	0.819	0.789	0.734	0.791	0.766	0.717
SER	0.007	0.009	0.007	0.011	0.009	0.009	0.016	0.013
JB	0.145	1.995	0.984	1.134	1.115	1.279	1.152	2.265
LM	0.324	2.952*	2.903*	1.548	2.462*	2.924*	2.000	0.311
ARCH	0.413	0.263	0.012	0.109	0.090	0.482	2.051	0.003
RESET	0.555	0.061	0.178	0.583	0.383	1.120	0.029	0.374

**Notes:** Diagnostic tests results are based on F-statistic. ARS means adjusted R-squared. SER means standard error of regression. JB means Jarque-Bera normality test. LM means Breusch-Godfrey serial correlation LM test. ARCH means ARCH test. Reset means Ramsey RESET test. \* denotes statistical significance at 10% level.

The models revealed normally distributed errors, no serial correlation in the residuals, and no autoregressive conditional heteroskedasticity (see table 6.7). By using the correlograms, the possibility of serial correlation in the A-E, ECA-Y, AP-Y and AP-E models was analysed in detail. No statistical significance was revealed. For this reason, serial correlation was not considered a problem. To confirm the presence of cointegration the ARDL bounds test was performed.

*Essays on Globe Energy Consumption and Economic Growth Nexus*

Table 6.8 - Bounds test

	A-Y	A-E	ECA-Y	ECA-E	AP-Y	AP-E	AME-Y	AME-E
<b>F-statistic</b>	5.662***	7.162***	10.890***	12.217***	7.822***	9.207***	20.897***	20.965***

**Notes:** k=3, where k represents the number of independent variables in equation estimated. Critical values for no intercept and no trend for bottom and for top are, respectively, 3.42 and 4.84, for 1%; 2.45 and 3.63, for 5% and 2.01 and 3.10 for 10%. Critical values for unrestricted intercept and no trend for bottom and for top are, respectively, 4.29 and 5.61, for 1%; 3.23 and 4.35, for 5% and 2.72 and 3.77 for 10%. Critical values for unrestricted intercept and restricted trend for bottom and for top are, respectively, 4.3 and 5.23, for 1%; 3.38 and 4.23, for 5% and 2.97 and 3.74, for 10%. \*\*\* denotes statistical significance at 1% level.

All the models reveal the presence of cointegration at the statistical significance level of 1%. To examine the impacts of China's energy consumption and economic growth on the four aggregates, the short-run semi-elasticities and the long-run elasticities were performed (see table 6.9).

Table 6.9 - Short-run semi-elasticities and long-run elasticities

	A-Y	A-E	ECA-Y	ECA-E	AP-Y	AP-E	AME-Y	AME-E
<i>Short-run</i>								
DLY	-	0.969***	-	0.946**	-	0.796***	-	0.275***
DLE	0.699***	-	0.594***	-	0.582***	-	0.378***	-
DLYCHN	-	-	-0.069	-	-	-	-0.463***	0.252**
DLECHN	-	-	-0.041	0.11**	-	-	0.066	-
<i>Long-run</i>								
LY	-	0.388***	-	0.955***		1.477***	-	0.557***
LE	1.820***	-	0.412***	-	0.439	-	-0.438*	-
LYCHN	0.003	0.009	0.124**	-0.421**	-0.107	0.528***	-0.229**	0.191
LECHN	0.072	0.002	0.229**	0.208	0.412**	-0.044***	0.692***	-0.067

**Notes:** \*\*\*, \*\* and \* denotes statistical significance at 1%, 5% and 10% level, respectively.

Some short-run semi-elasticities were not shown given that in the model optimization the lagged variables were removed due to their statistically non-significance. The relationships between the variables were only considered for those with elasticities statistically significant at 5% level, at least. In the short-run there is bi-directional causality between energy consumption and economic growth, while in the long-run there is bi-directional causality for the America and Europe and Central Asia aggregates. For the Asia Pacific and Africa and Middle East aggregates, there is causality running from economic growth to energy consumption.

With regard to China's energy consumption, it was observed that it only causes Europe and Central Asian energy consumption, in the short-run. In the long-run, China's energy consumption causes economic growth in Europe and Central Asia, Asia Pacific and Africa and

the Middle East, while having a negative effect on Asia Pacific economic growth. China's economic growth causes energy consumption, while negatively causes economic growth in Africa and the Middle East, in the short-run. In the long-run, China's economic growth causes Europe and Central Asia economic growth. The same is seen in Asia Pacific. However, it is observed that China's economic growth negatively causes energy consumption in Europe and Central Asia and economic growth on Africa and Middle East. These results are discussed in the next section.

### **6.3 How important are China spillover effects on globe nexus?**

The chapter's main goal was to begin an analysis of the China's economic growth and energy consumption spillover effects on the nexus globe, which is inexistent in the literature. However, the spillover effects are a topic under current discussion in several fields of research. For example Koesler *et al.* (2016) explored the international spillover effects of increased energy efficiency in Germany and Zhang (2017), investigated the interregional carbon emission spillover effects in China.

The use of the ARDL bounds test approach proved to be of particular interest given the presence of cointegration. On one hand, by following the ARDL methodology, it was possible to examine both short-run and long-run effects of China's economic growth and energy consumption on four aggregates (America; Europe and Central Asia; Pacific Asia, Africa and Middle East). On the other hand, it allows to confront the results with those obtained in the chapter 5 that, by being concordant, confirms the models' robustness. The results not only are consistent with short-run and the long-run energy-growth nexus found in chapter 5, but also are consistent in their historical impacts.

Using the ARDL bounds test approach with annual time series data from 1970 to 2016, the traditional *feedback hypothesis* on energy-growth nexus was observed across the globe, in the short-run. Additionally, the same hypothesis was observed for America and Europe and Central Asia, in the long-run. On Asia Pacific and Africa and Middle East, the *conservation hypothesis* was found, in the long-run. These results were concordant with the chapter 5, results which are evident in the signals and magnitude of both short- and long-run elasticities. Moreover, most of the shift dummies and impulse dummies introduced in the models are the same of the chapter 5. The breakpoint tests reveal the existence of bigger instability in the models. Despite this, a restricted approach led to the introduction of a number of dummies near to those introduced in chapter 5. It should be said that for the Asia Pacific aggregate less periods needed to be controlled, most likely because China was removed from the aggregate.

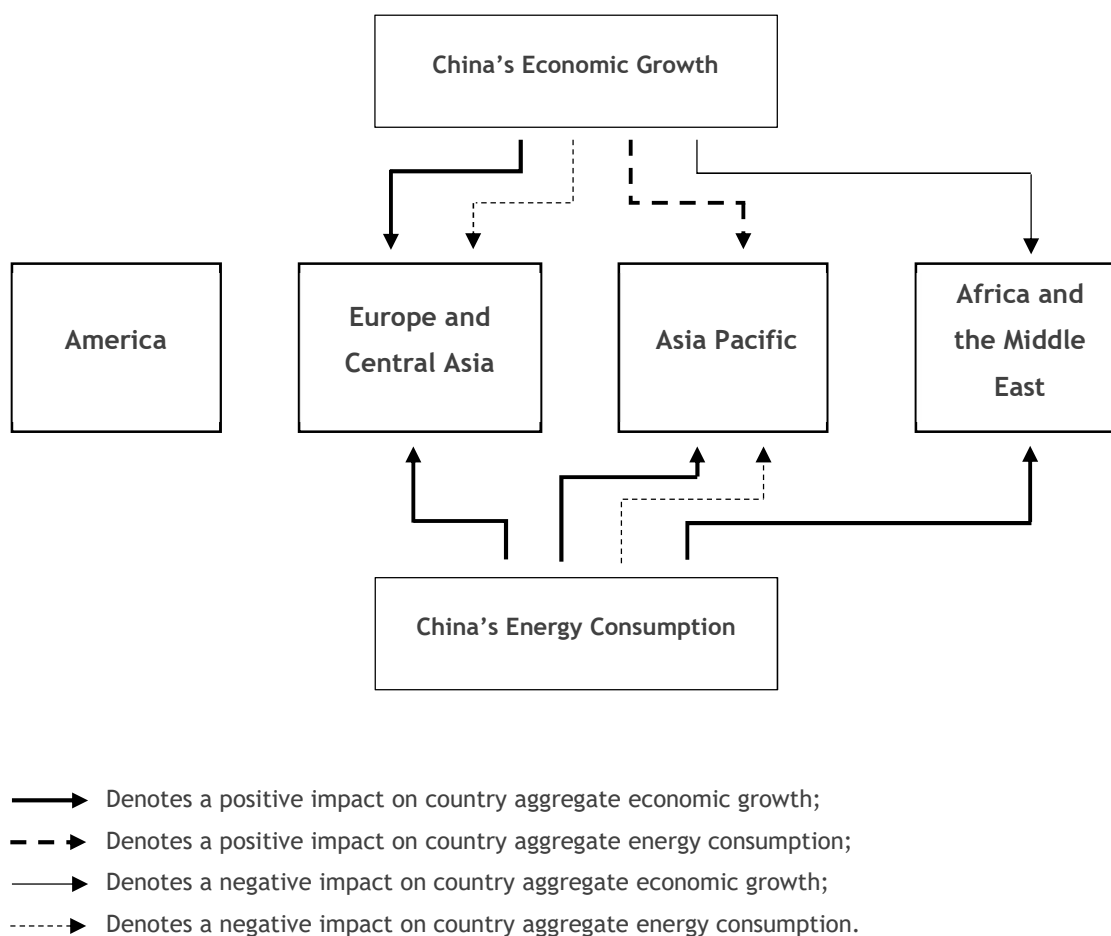


Fig. 6.6 - China's economic growth and energy consumption spillover effects on long-run globe nexus (author elaboration)

When regarding the spillover effects of China's economic growth and energy consumption on globe nexus (see fig. 6.6), merely the America aggregate seems to be immune to any impacts. Additionally, those impacts are essentially a long-run phenomenon most likely impacting at the aggregates nexus over years, given the slow speed of adjustment to the long-run equilibrium. Overall the results make us aware that China's growth and energy consumption may have some negative impacts on Europe and Central Asia and Pacific Asia energy consumption and even with Africa and Middle Eastern growth. Given that this is a first assessment on China's impacts at globe nexus, further deep research is advisable to fully understand the impacts, namely the negative ones. In fact, this research should most likely be extended to others such as the top oil producers or top oil consumers.

The results support that the countries should not be indifferent to the policies that China may follow, namely for Europa and Central Asia where energy growth will most likely be reduced by China's growth. Policymakers should be aware that China's policies may impact all over the

globe, which indirectly may cause a restriction on economic growth. Additionally, Africa and Middle East growth seems to be negatively influenced by China's growth. For this reason, to devise jointly policies is advisable. Taking this into account the results supports the development of integrated energy polices, such as seen in the previous chapters.

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## Chapter 7

### **Augmented Energy-Growth Nexus on the Globe: An Assessment on the Impacts of Three Dimensions of Globalization**

Considering the previous chapters, increasing the globalization on energy policies is most likely the best path to follow. For this reason, it could be important to understand the impact of globalization at globe level. In fact, the globalization impacts on energy-growth nexus attracted the researchers' attention because: (i) the increasingly globe energy markets and greater international cooperation, raises uncertainties about the impact of globe energy policies; and (ii) the study of augmented energy-growth nexus with globalization could help to understand the conflicting results found in literature.

Taking into consideration the above-mentioned reasons, the augmented energy-growth nexus including globalization should be examined allowing to find the balance between energy consumption, economic growth and the different globalization dimensions (economic, social and political). This fact leads to the central question of this paper: Which are the impacts of economic, social and political globalization on energy-growth nexus? Recently some authors studied the impacts of globalization on energy-growth nexus (e.g. Doğan and Deger, 2016; Kyophilavong *et al.*, 2015; Shahbaz *et al.*, 2014), however there is a scarce or non-existent knowledge on the impacts of different globalization dimensions on the nexus.

To examine the augmented energy-growth nexus, a panel data with 43 countries that encompasses yearly data from 1971 to 2013 is used. By following an ARDL approach, the short- and long-run behaviours are examined. The results found evidence of *feedback hypothesis* on energy-growth nexus both in short- and long-run. In addition, the results support that economic, political and social globalization have long-run impacts on energy-growth nexus.

#### **7.1 Globalization, economic growth and primary energy consumption analysis from 1971 to 2013**

The chapter uses annual data, from 1971 to 2013, for 43 countries (see table 7.1) around the world. It should be said that the used sample was limited by their availability for the different

variables. Notwithstanding, the sample encompasses countries from different world regions, development level and oil producers and consumers. The main goal is to make the sample closest possible from a world indicator. The econometric analysis was performed by using Stata 13.0.

Table 7.1 - Countries list

Algeria	France	Peru
Argentina	Germany	Philippines
Australia	Greece	Portugal
Austria	India	Saudi Arabia
Bangladesh	Indonesia	Singapore
Belgium	Ireland	South Africa
Brazil	Israel	Spain
Canada	Italy	Sweden
Chile	Japan	Thailand
China	Korea, Rep.	Turkey
Colombia	Malaysia	United Kingdom
Denmark	Mexico	United States
Ecuador	Netherlands	Venezuela, RB
Egypt, Arab Rep.	Norway	
Finland	Pakistan	

The used variables are the following:

- (i) Gross Domestic Product per capita (YPC) - Corresponds to GDP per capita (constant 2010 US\$) obtained from World Bank.
- (ii) Primary Energy Consumption per capita (EPC) - computed by dividing primary energy consumption by total population. The sources of the variables are BP statistical review of world energy 2016 workbook and World Bank, respectively.
- (iii) Globalization (G) - To measure globalization the Konjunkturforschungsstelle (KOF) index of globalization (<http://globalization.kof.ethz.ch/>) was used. The KOF overall index is based on economic globalization, social globalization and political globalization. It includes components such as, trades, foreign direct investment, import barriers, number of embassies in a country, international treaties, among others. The use of KOF index as a globalization proxy is recurrent in the literature (e.g. Ahmed *et al.*, 2016; Chang *et al.*, 2015; Doğan and Deger, 2016).

### *Essays on Globe Energy Consumption and Economic Growth Nexus*

(iv) Economic Globalization (EG) - To measure economic globalization the Economic Globalization index from KOF Index of Globalization was used (<http://globalization.kof.ethz.ch/>).

(v) Political Globalization (PG) - Is the Political Globalization index from KOF Index of Globalization (<http://globalization.kof.ethz.ch/>).

(vi) Social Globalization (SG) - Corresponds to the Social Globalization index from KOF Index of Globalization (<http://globalization.kof.ethz.ch/>).

The prefix “L” denote natural logarithm and “D” denote first difference of the variable. Summary statistics are presented in table 7.2.

Table 7.2 - Descriptive statistics

Variables	Obs.	Mean.	Std. Dev.	Min.	Max.	Skewness	Kurtosis
LYPC	1849	9.220	1.361	5.472	11.425	-0.740	2.629
LEPC	1849	0.532	1.192	-4.588	2.628	-0.784	3.221
LG	1849	4.026	0.363	2.456	4.529	-0.894	3.717
LEG	1849	3.953	0.426	2.211	4.580	-1.204	5.164
LPG	1849	4.280	0.285	3.005	4.589	-1.287	4.273
LSG	1849	3.782	0.614	1.858	4.536	-1.042	3.791
DLYPC	1806	0.022	0.036	-0.173	0.215	-0.686	6.662
DLEPC	1806	0.020	0.051	-0.283	0.671	1.350	19.545
DLG	1806	0.013	0.033	-0.258	0.269	1.58	17.327
DLEG	1806	0.011	0.037	-0.156	0.268	0.767	9.361
DLPG	1806	0.011	0.062	-0.631	0.555	1.140	28.626
DLSG	1806	0.018	0.058	-0.127	0.655	5.366	40.016

The VIF was computed to check for multicollinearity (see table 7.3). There are several recommendations for acceptable levels of VIF in the literature. One of the most common and the most tolerant one is a value of 10. Taking this into consideration, the results indicate that multicollinearity is not a problem.

*Essays on Globe Energy Consumption and Economic Growth Nexus*

Table 7.3 - Variance inflation factors

Variables	DLYPC				DLEPC			
LYPC	-	-	-	-	3.45	2.52	1.35	4.24
LEPC	3.38	2.71	1.27	4.02	-	-	-	-
LG	3.38	-	-	-	3.45	-	-	-
LEG	-	2.71	-	-	-	2.52	-	-
LPG	-	-	1.27	-	-	-	1.35	-
LSG	-	-	-	4.02	-	-	-	4.24

Notes: The Stata commands *regress* and *vif* were used.

The Maddala and Wu (1999) panel unit root test and the second-generation panel unit root tests of cross-sectionally augmented Im, Pesaran and Shin (CIPS) (Pesaran, 2007), were used to assess the order of integration of the variables (see table 7.4).

Table 7.4 - First and second generations of panel unit root tests

Variables	Level		First differences	
	Without trend	With trend	Without trend	With trend
<i>Maddala and Wu (1999) Panel Unit Root Tests</i>				
LYPC	125.360***	49.362	916.366***	-18.264***
LEPC	176.678***	80.624	1452.414***	1321.519***
LG	88.325	32.155	1301.391***	1192.768***
LEG	112.088**	49.449	1147.334***	1054.385***
LPG	123.166***	116.938**	1264.657***	1050.674***
LSG	58.912	50.973	1366.413***	1178.380***
<i>Pesaran (2007) Panel Unit Root Tests</i>				
LYPC	5.260	8.827	-18.264***	-17.470***
LEPC	-2.758***	-1.645*	-25.102***	-23.857***
LG	-3.649***	-0.377	-28.528***	-27.637***
LEG	-0.956	2.668	-25.343***	-24.188***
LPG	-4.413***	-3.471***	-28.851***	-27.525***
LSG	-3.052***	0.019	-28.795***	27.782***

Notes: \*\*\*, \*\* and \* denote statistical significance at 1%, 5% and 10% level, respectively.

The unit root tests revealed only LPG is undoubtedly I(0). All other variables may be I(0) or I(1) or even borderline. It was clear that all variables are at the most I(1). The use of a panel UECM form of an ARDL model allow to perform models with I(0), I(1) and borderline variables.

## 7.2 What are the impacts of globalization on globe energy-growth nexus? An autoregressive panel approach

The ARDL models are ideal to deal with borderline variables as in this case, and allow to correct for outliers or even structural breaks by adding impulse and shift dummies. The use of panel ARDL is recurrent in energy-growth nexus (e.g. Attiaoui *et al.*, 2017; Bildirici and Kayıkçı, 2013; Menegaki and Tugcu, 2017). The aim of this chapter is to study both the short- and long-run relationships between economic growth, energy consumption and globalization. The ARDL models allows to identification of the short- and long-run relationships and could be represented as follows:

$$\begin{aligned}
 DLY_{it} = & \alpha_{1i} + \delta_{1i}TREND + \sum_{j=1}^k \beta_{21ij}DLY_{it-j} \\
 & + \sum_{i=0}^k \beta_{22ij}DLE_{it-i} + \sum_{i=0}^k \beta_{23ij}DLX_{it-i} + \gamma_{21i}LY_{it-1} + \gamma_{22i}LE_{it-1} \\
 & + \gamma_{23i}LX_{it-1} + \varepsilon_{1it},
 \end{aligned} \tag{7.1},$$

$$\begin{aligned}
 DLE_{it} = & \alpha_{1i} + \delta_{1i}TREND + \sum_{j=1}^k \beta_{21ij}DLE_{it-j} \\
 & + \sum_{i=0}^k \beta_{22ij}DLY_{it-i} + \sum_{i=0}^k \beta_{23ij}DLX_{it-i} + \gamma_{21i}LE_{it-1} \\
 & + \gamma_{22i}LY_{it-1} + \gamma_{23i}LX_{it-1} + \varepsilon_{1it},
 \end{aligned} \tag{7.2},$$

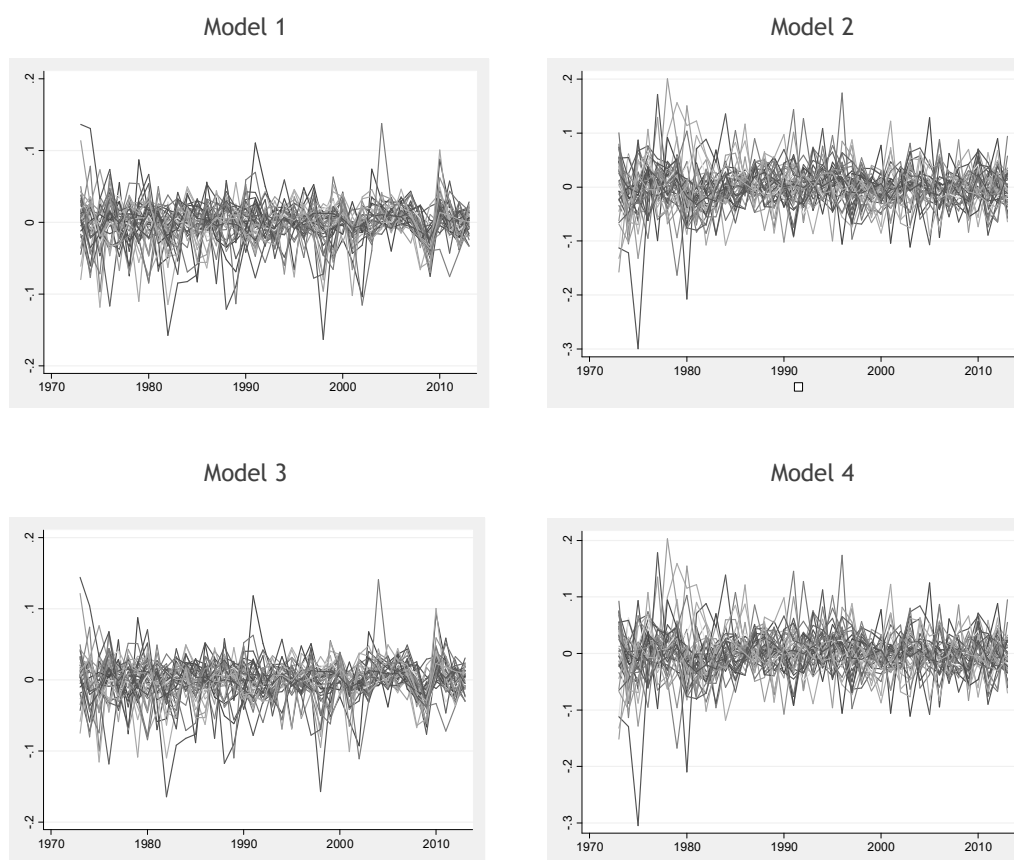
where  $\alpha_{1i}$  denotes the intercept,  $\delta_{1i}$  the trend coefficient and  $\beta_{2kij}$  and  $\gamma_{2im}$  the estimated parameters.  $\varepsilon_{1it}$  denotes the error term.  $X$  is the vector of globalization dependent variables (i.e. LG, LEG, LPG and LSG). The coefficients  $\gamma_{21i}$  and  $\gamma_{21i}$  are expected to be negative revealing the presence of cointegration. All the other coefficients are expected to be  $\neq 0$ . Accordingly, eight models are produced (see table 7.5).

Table 7.5 - Model numbers

Models	Dep. Var DLY	Dep. Var. DLE
With G	1	5
With EG	2	6
With PG	3	7
With SG	4	8

To define the best estimator for this case, the presence of fixed effects was tested. Additionally, the need to control for outliers was evaluated by analysing the models' residuals. Further, the cross-sectional dependence (CSD) was tested by Pesaran cross section dependence test.

Following the abovementioned approach, the presence of fixed effects was tested by analysing specific country impacts which revealed to have statistical significance. For this reason, new models with fixed effects were estimated. The residuals of the models 4-8 (see fig. 7.1) reveal the need to control for an outlier in Saudi Arabia in 1975 (IDSAU1975).



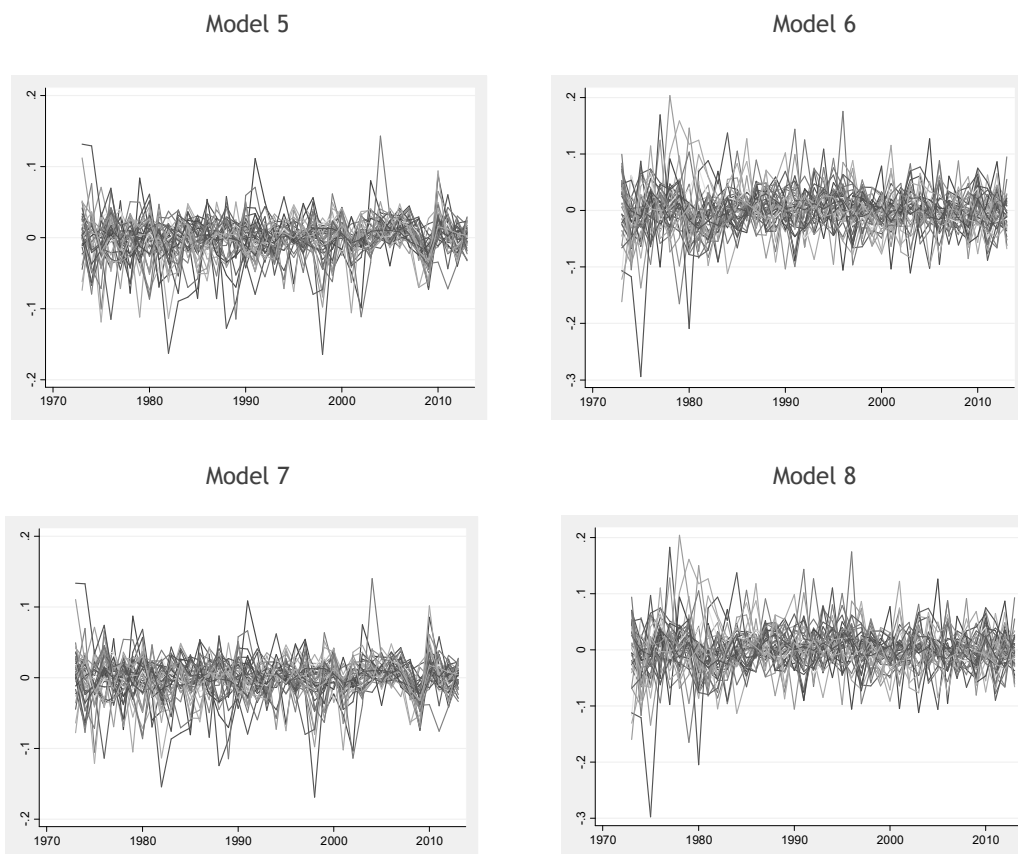
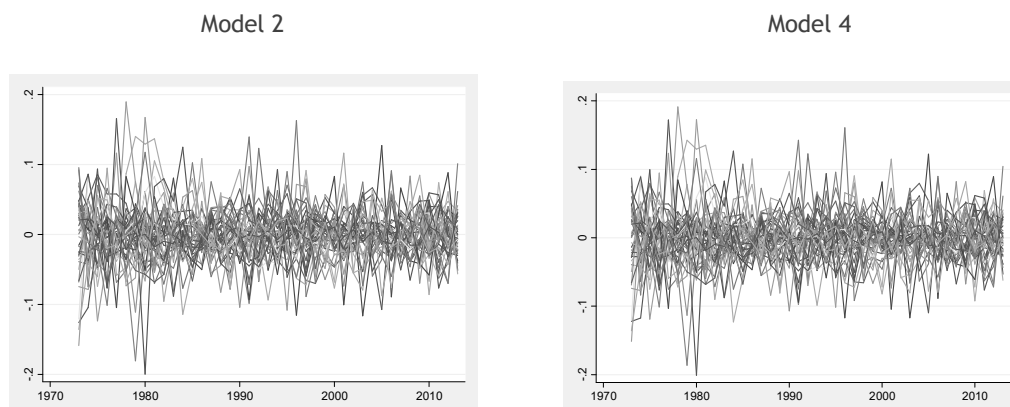


Fig. 7.1 - Panel data residuals

After the correction for 1975 in Saudi Arabia no more impulse dummies were introduced, given that the other possible outliers have smaller magnitude as could be observed in fig 7.2. For this reason, it was opted for keep the 2, 4, 6 and 8 models restricted.



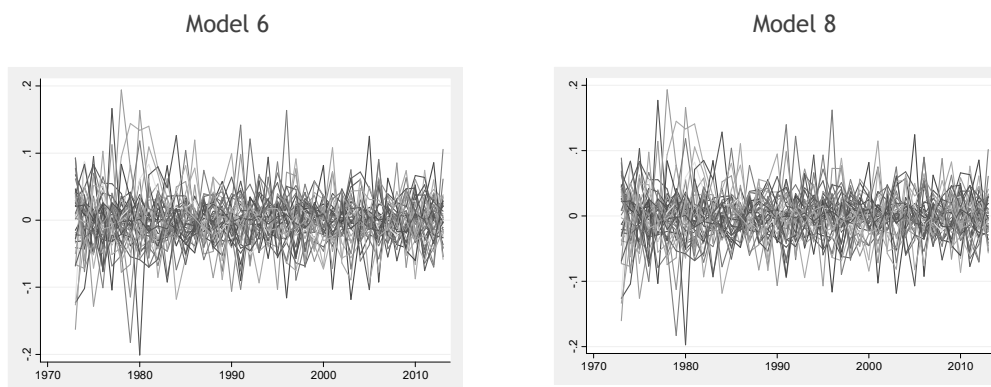


Fig. 7.2 - Panel data residuals with impulse dummy

To test for CSD the Pesaran CSD test as was performed (see table 7.6). All the eight models revealed cross-sectional dependence. Given the confirmed presence of fixed effects and cross-sectional dependence a panel regression with Driscoll and Kraay (1998) standard errors was performed. This approach as an error structure that makes the estimation robust not only to the presence of cross-sectional dependence, but also heteroskedasticity and autocorrelation.

Table 7.6 - Cross-sectional dependence tests

Models	F-statistic
1	21.417***
2	23.146***
3	22.374***
4	21.240***
5	11.217***
6	11.429***
7	11.121***
8	11.364***

**Notes:** Stata commands *xtreg* and *xtcsd* were used. F-statistics values. \*\*\* denotes statistical significance at 1% level.

The panel regression models with Driscoll and Kraay (1998) standard errors are presented in table 7.7. The variable IDSAU1975 was introduced in the models 4-8 revealing statistical significance at 1%.

Table 7.7 – Driscoll and Kraay panel data estimations

	Dep. Var. DLY				Dep. Var. DLE			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Constant	0.151**	0.172**	0.162***	0.202***	-0.567***	-0.464***	-0.512***	-0.446***
Trend	-	-	-	-	-0.001***	-0.001***	-0.001***	-0.001***
DLY					0.607***	0.613***	-0.617***	0.611***
DLE	0.310***	0.308***	0.314***	0.311***	-	-	-	-
DLG	-0.015	-	-	-	0.024	-	-	-
DLEG	-	-0.047	-	-	-	-0.022	-	-
DLPG	-	-	-0.005	-	-	-	0.273**	-
DLSG	-	-	-	0.014	-	-	-	0.003
DLY (-1)	0.261***	0.265***	0.264***	0.261***	-0.063	-0.060	-0.059	-0.059
DLE (-1)	0.014	0.013	0.009	0.010	0.002	0.002	0.004	0.000
DLG (-1)	-0.012	-	-	-	-0.017	-	-	-
DLEG (-1)	-	0.053**	-	-	-	-0.030	-	-
DLPG (-1)	-	-	-0.011	-	-	-	-0.013	-
DLSG (-1)	-	-	-	-0.015	-	-	-	0.005
LY (-1)					0.048***	0.048***	0.050***	0.048***
LE (-1)	0.011*	0.016**	0.016**	0.012*	0.047***	-	-	-
ECM	-0.029***	-0.027***	-0.022**	-0.029***	-0.061***	-0.052***	-0.058***	-0.056***
LG (-1)	0.031***	-	-	-	0.047***	-	-	-
LEG (-1)	-	0.021***	-	-	-	0.020***	-	-
LPG (-1)	-	-	0.010	-	-	-	0.025***	-
LSG (-1)	-	-	-	0.019***	-	-	-	0.016***
<i>Impulse Dummy</i>								
IDSAU1975	-	-	-	-	-0.317***	-0.324***	-0.311***	-0.315***

Notes: Stata command xtscs was used. \*\*\*, \*\* and \* denote statistical significance at 1%, 8% and 10% level, respectively.

The results are consistent with the presence of cointegration, given that ECM are negative and statistically significant. The ECMs bigger or equal than -0.06 reveal a slow speed of adjustment. To the analysis of the variables' speed of adjustment, both short- and long-run elasticities are estimated and disclosed in table 7.8.

Table 7.8 - Short-run and long-run elasticities

	1	2	3	4	5	6	7	8
Short-run (DLE+DLE(-1))	0.324***	0.321***	0.323***	0.321***	-	-	-	-
Long-run (LE)	0.366***	0.571***	0.720***	0.416***	-	-	-	-
Short-run (DLY+DLY(-1))	-	-	-	-	0.527***	0.538***	0.541***	0.535***
Long-run (LY)	-	-	-	-	0.739***	0.882***	0.801***	0.794***
Short-run (DLG+DLG(-1))	-0.027	-	-	-	0.018	-	-	-
Long-run (LG)	1.050***	-	-	-	0.791***	-	-	-
Short-run (DLEG+DLEG(-1))	-	0.006	-	-	-	-0.038	-	-
Long-run (LEG)	-	0.758***	-	-	-	0.324*	-	-
Short-run (DLPG+DLPG(-1))	-	-	-0.016	-	-	-	0.012	-
Long-run (LPG)	-	-	0.467**	-	-	-	0.495***	-
Short-run (DLSG+DLSG(-1))	-	-	-	-0.001	-	-	-	0.008
Long-run (LSG)	-	-	-	0.634***	-	-	-	0.325***

Notes: Stata command *nlcom* was used. \*\*\*, \*\* and \* denotes statistical significance at 1%, 5% and 10% level, respectively

The elasticities calculation form was described in section 4.2. All the highly statistical significant elasticities have the expected signs. All models reveal that energy consumption causes economic growth both in short- and long-run. The reverse is also true. Additionally, it is observed that globalization also causes economic growth and energy consumption in the long-run. These results are scrutinized in the next section.

### **7.3 Economic, political and social globalization as long-run drivers of globe energy consumption and economic growth**

This chapter proves the existence of stable relationships between energy consumption, economic growth and globalization. This has particular interest in explaining how the three variables interact with each other at globe level, which may reveal to be important to face the actual outlook of expected economic growth, energy supply increase and intensification of globalization level.

Based on a sample of 43 countries from 1971 to 2013, the augmented energy-growth nexus with globalization was examined. The results were obtained for a long-time span and by a recent panel data estimator. The use of panel ARDL approach proved to be adequate given that the results are consistent with the existence of cointegration, given that the ECMs are negative and statistically significant. Additionally, the ECMs reveal that the relationships between energy consumption and economic growth require a long adjustment time to return to equilibrium, which is consistent with the results of previous chapters. For this reason, the effects of any shock on the variables will remain for years.

In the long-run, the results reveal that there is bi-directional causality between energy consumption and economic growth (see fig. 7.3). An increase of economic growth will boost energy consumption and the reverse is also true. These results are reliable with the presence of endogeneity, which reinforces that any impact on economic growth or energy consumption may have persistent effects over the years. Additionally, it was found that globalization is a driver of both economic growth and energy consumption. In fact, the results seem to indicate that globe economic growth is globalization dependent, given that the long-run elasticity is over that 1. However, when globalization is disaggregated it is observed that only economic globalization and social globalization causes economic growth, as well as political globalization and social globalization causes energy consumption.

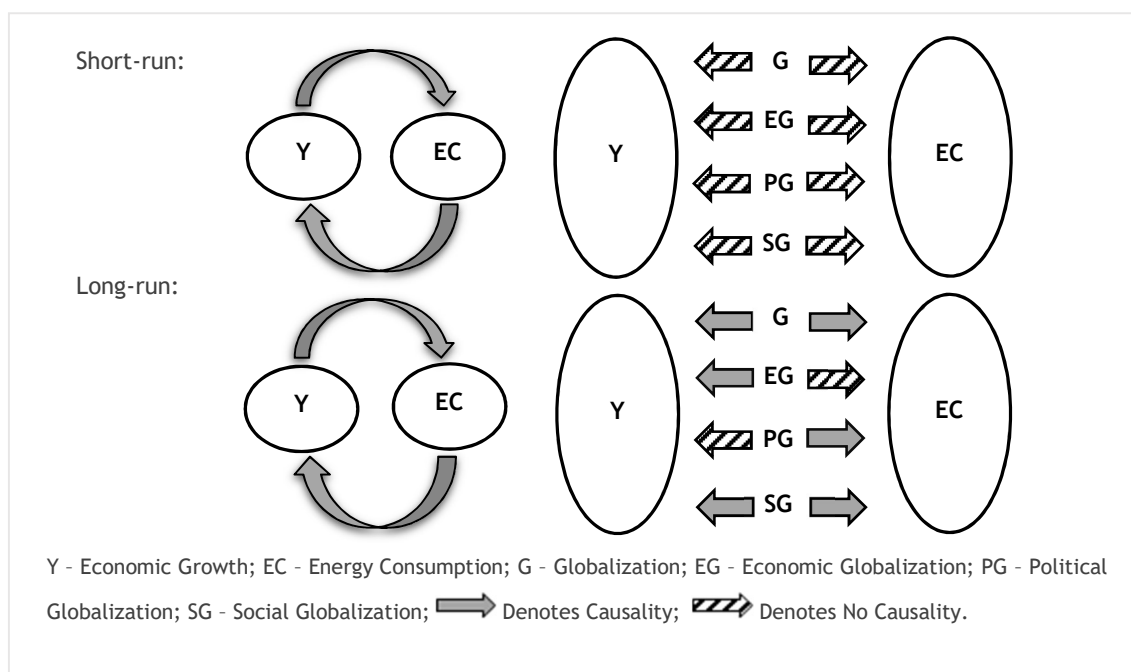


Fig. 7.3 - Energy consumption-economic growth summary (author elaboration)

Regarding to the short-run, it is observed that there is bi-directional causality between energy consumption and economic growth. However, the short-run elasticities reveal that globalization does not drive energy consumption and economic growth. In fact, none of the examined globalization dimensions have impacts on energy-growth relationships, in the short-run.

In short, evidence of the traditional *feedback hypothesis* on energy-growth nexus was found both in short- and long-run. In addition, globalization drives both economic growth and energy consumption in the long-run. In fact, it is observed that globalization is essentially a long-run phenomenon. There are some authors whose research is slightly close to this one. The results of this research are consistent with them. For example, Cole (2006) found that trade liberalization promotes economic growth and energy consumption for a panel of 32 developed and developing countries. Shahbaz *et al.* (2014) found that there is reciprocal causality between energy consumption and trade openness for a panel of 91 countries. Additionally, this chapter goes further than the cited authors by analysing the different impacts of different globalization dimensions on energy-growth nexus, at globe level. There are some authors that followed this approach at lower macroeconomic level, revealing heterogeneous results. For example, Doğan and Deger (2016) found no causality between energy consumption and globalization for a panel with Brazil, Russia, India and China.

Overall the results fit into those obtained in the previous chapters, given that the results are consistent in warning that any restrictions on energy consumption should be avoided. The chapter results also reveal that globalization should be encouraged in order to promote economic growth. Notwithstanding, it should be said that political globalization does not directly cause economic growth, revealing that the creation of embassies, inter-governmental organizations, participations in United Nations Security Council or even the creation of international treaties is not leading to economic growth. However, political globalization causes energy consumption both in short- and long-run, which in its turn may contribute to economic growth.

Once more, it should be warned that economic growth may lead to inefficient energy consumption, namely by non-productive activities, due to the bidirectional causality. Preventive measures on inefficient energy consumption should be taken because it could be an outcome of the endogeneity between energy consumption and economic growth. Additionally, the promotion of globalization will most likely increase this possibility. The results also show that the nexus have a limited responsiveness to the shocks, requiring a long period to return to equilibrium. When more data is available it will be possible to go further with this research by making the sample closest to a globe measure. Additionally, understanding the impacts of disaggregated globalization on the nexus in different development levels could be a future path of research.

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*Essays on Globe Energy Consumption and Economic Growth Nexus*

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## Chapter 8

### Discussion on The Globe Energy-Growth Nexus Evidence. What is in the future?

Given that the literature on energy-globe nexus is scarce, in this thesis we have attempted to use different approaches with the methodologies, data and variables. The goal was to subject the data to different methodologies thus avoiding the general literature criticism that different methodologies and data usually provides different results. The essays are organized from the most general research topic to the most specific one (see fig 8.1), leaving some possibilities for further research.

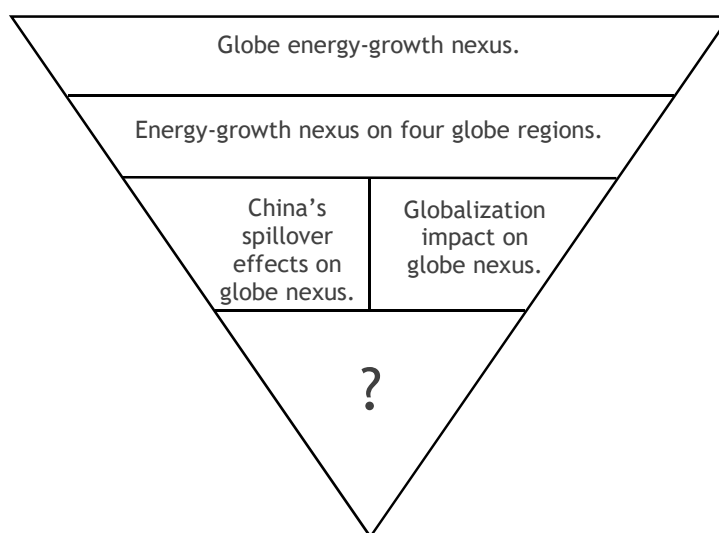


Fig. 8.1 - Thesis' contribution to energy-growth nexus literature (author elaboration)

By using globe aggregate variables from 1965 to 2013, the energy-growth nexus is analysed by the ARDL and VECM approaches. These two approaches are robust to the found endogeneity. Furthermore, the globe was divided into four regions which were analysed by the ARDL approach. To do so, variables from 1968 to 2014 were used. Once more by using an ARDL approach, China's economic growth and energy consumption variables were added to the developed regional models. To do so all the previous variables were updated to a sample from 1970 to 2016. Finally, the impact of different globalization dimensions on globe energy growth nexus was analysed by a panel ARDL methodology for a panel of 43 countries from 1971 to 2013. As stated before, the use of methodologies based on autoregressive models such as ARDL, VECM

and panel ARDL, revealed their interest by dealing with endogeneity. A summary of the long run results is represented in figure 8.2.

Globally, cointegration between globe energy consumption and economic growth was found, revealing that globe energy-growth nexus was stable across the entire long-time span analysed. Furthermore, the *feedback hypothesis* was observed both in the short- and long-run. Accordingly, any constraining energy policy will most probably hamper economic growth. Making use of efficiency gains could be a possibility. However, it is not clear whether this will impact on economic growth. In fact, this will need further investigation. The research also revealed a short-run positive response to innovations, which tend to negatively impact in the long-run. These results accommodate the four regional aggregates nexus where *feedback hypothesis* was found in America and Asia Pacific, in the long-run. Additionally, in Europe and Central Asia and Africa and the Middle East, the *conservation hypothesis* was found, in the long-run. It should be noted that by introducing the China's impacts on the models thus removing them from Asia Pacific aggregate, it is possible to perceive the *feedback hypothesis* for Europe and Central Asia and the *conservation hypothesis* for Pacific Asia. In the short-run, the *feedback hypothesis* was verified, except for Africa and the Middle East where there is a neutral relationship. It should be noted that by using the same data span and source and the same methodology one, it was concluded that the use of different methodologies is not the main cause of the heterogeneous results in the literature. Indeed, the research makes clear that there are heterogeneous results even when the same methodology is applied.

This thesis has the merit of being focused on testing for several historical periods potentially relevant in explaining the complexity of the nexus. And they have been proved to have impacts on energy-growth nexus. The 1979 oil shock or the 1990 oil price shock have heterogeneous impacts across the globe. However, the 2008 financial crisis was apparently the one that had globe impacts. In fact, there were models where this period was the only one that needed to be controlled. This not entirely unexpected because there was a period, between 2007-2008, of collapse of international trade due to uncertainties in the financial markets. These behaviours not only highlight the impact of a possible abrupt stop in oil supply, but also reveal itself as a signal of globalization power. It is worthwhile to note also that the globalization impacts on globe energy-growth nexus is essentially a long-run phenomenon. Globalization was proved to drive both economic growth and energy consumption in the long-run. Maybe this is one of the main reasons why the 2008 financial crisis was revealed to have long-run impacts on nexus.

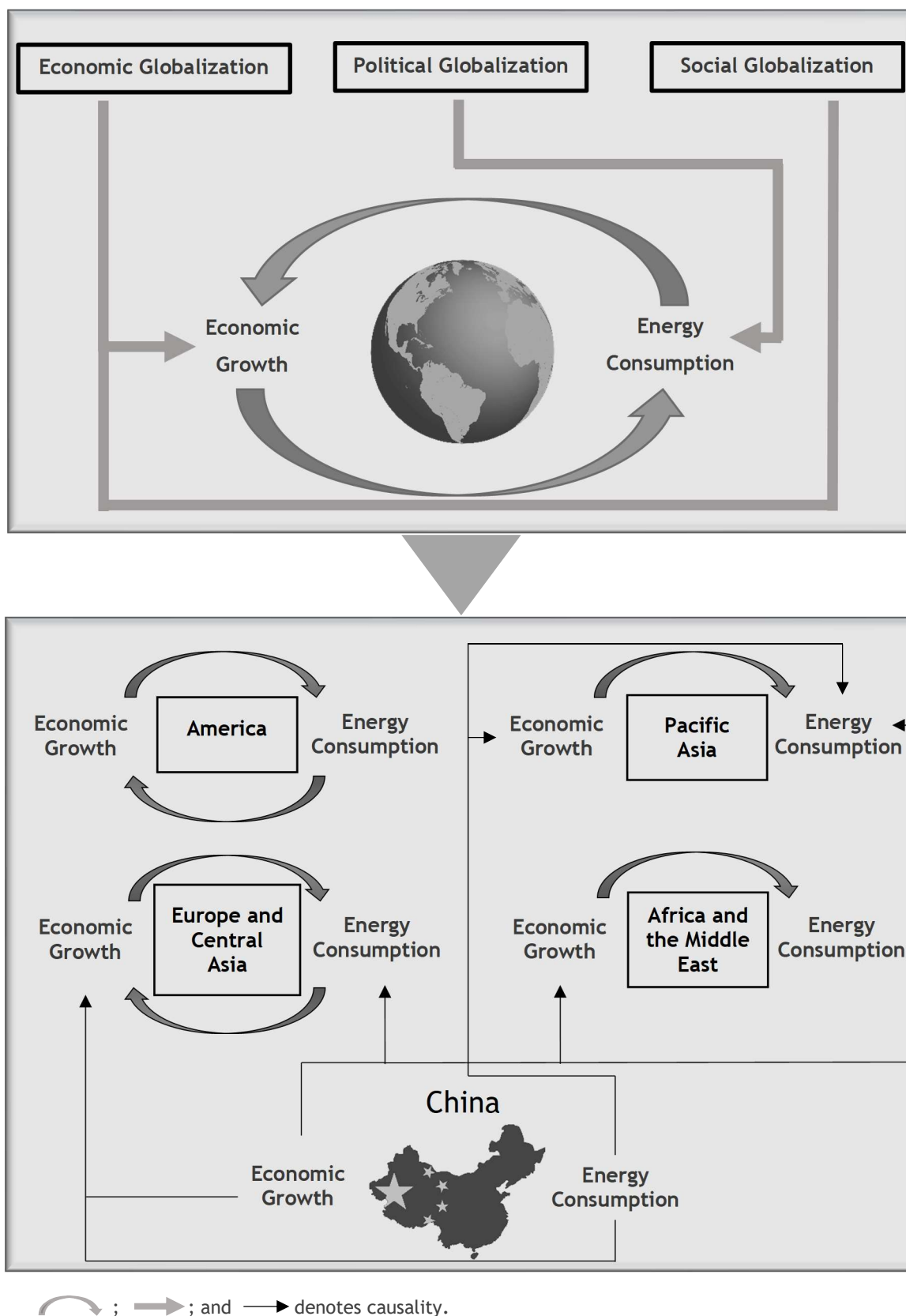


Fig. 8.2 - Summary of long-run results scheme (author elaboration)

The results are consistent with the possibility that some globe regions or countries have a greater share of impact on the globe nexus than others, or even influence the nexus in other regions, given the heterogeneity of results observed across the four globe regions. In fact, this is one of the main reasons to test China's economic growth and energy consumption spillover effect on the four globe regions. The impacts were analysed both in the short-run and long-run. The results reveal that China's spillover effect is essentially a long-run phenomenon, and only America was not affected by China's economic growth or energy consumption on this nexus.

Overall, the entire research is consistent with the existence of *feedback hypothesis* on globe energy-growth nexus. Accordingly, the results make it clear that globe constraining energy policies will most probably hamper economic growth. Despite this, short-run small effects could be experienced, while in the long-run the impacts can be amplified by the endogenous nature of the variables. Improving energy efficiency is a potential way of overcoming this. In fact, increasing the efficiency of energy consumption should be a globe goal to prevent inefficient energy consumption caused by economic growth.

Until 2025, the non-renewable fuels oil, coal and gas will remain as the mains components of primary energy consumption (BP, 2017). Despite the use of oil and coal having the tendency to decline, gas usage will remain and continue to grow. Additionally, fossil fuel prices have risen over the past decade and this trend is set to continue. Those effects will most likely promote the diversification in energy sources, which is the same path to be taken by energy markets according to the results. In fact, the trend for diversification already exist, in great share driven by the Paris agreement to globally reduce the carbon emissions. The search for improvement in environmental quality should be balanced and monitored in the reduction of energy inputs, otherwise, the globe economic growth could be hampered.

The promotion of diversification will help to make economies more responsive to the shocks by improving the adjustment speed on energy-growth nexus. The slow speed of adjustment on energy-growth nexus is evident in the entire research. Furthermore, from an energy security point of view, diversification should be promoted, namely for countries such as China and India that will become increasingly import-dependent over the next decades. Moreover, for those countries that will play a dominant role in energy markets, it should be important to create blocs to ensure that no country negatively influences the market.

The results highlight that, in the long-run, China's growth will most likely reduce European and Central Asia energy consumption, which indirectly may cause a restriction on economic growth. Moreover, Africa and Middle Eastern growth may be hampered by China's growth. In the end, a group of countries may have the power to create a globe recession, for example China's primary energy suppliers. On one hand, by creating internal reserves management policies, China will withdraw supremacy to primary energy producers because China has energy import

dependence and if for some reason China's energy consumption and economic growth are restricted that will most likely impact at globe nexus and consequently influence globe development. On the other hand, China's policymakers should be aware that their decisions have globe impacts and every country should take into account the China's impact on their own policies, namely countries from Europe and Central Asia and Africa and the Middle East who can experience negative impacts from China's policies, as earlier stated. To handle this, agreements must be reached that contribute to economic stability that will help Europe and Central Asia to counteract the possible negative impacts.

The energy-growth nexus in the studied globe regions, supports the creation of integrated energy policies, namely for America and Asia Pacific. On one hand, America is the only region where no China's spillover effect is verified, and it can be seen as an incentive to develop independent policies. On the other hand, both America and Asia Pacific have similar nexus behaviours where no restrictive energy policies should be followed because they are likely to hamper economic growth and their effects may persist for years.

There are countries with different levels of globalization and for this reason it is not possible to promote homogenous globalization strategies for the entire globe. Notwithstanding, the results makes us aware that when the aim is for economic growth, the focus must be settled on economic and social globalization. The absence of short-term impacts should not be taken as an obstacle to take some globalization policies because the long-run result depends on the policies followed today. Policymakers should consider the found causalities to monitor energy consumption and promote economic growth. For the economic globalization case, the promotion of trades, foreign direct investment or the avoidance of hidden import barriers, and taxes on international trades, is recommended. In social globalization, promoting international tourism and emigration or even internet and television use may be the path to follow. Political globalization encompasses the number of embassies in a given country, participation in international organization and international treaties. At this point some relevance to the OPEC oil glut should be given, that by this way it may impact on globe growth.

The OPEC oil embargo where the oil exportations to the USA stopped, was proven to have impacts on nexus namely in Asia Pacific. In 2017, OPEC controls 42 percent of the world's oil supply, 61 percent of its exports, 80 percent of proven oil reserves, and are currently producing too much oil, namely due to the USA shale oil extraction. In consequence, oil prices have dropped, and some argue that OPEC cannot control it anymore. If this excessive oil production is not controlled, that may have a negative impact on Asia Pacific growth just as happened during the OPEC oil embargo. Also, Africa and the Middle East may expect a hampering in their economic growth given the evidence that the abundance of natural energy resources leads to a reduction in their economic growth. Additionally, the price incentive to promote diversification no longer exists, for a while. That could work such as kind of a trap for energy

dependent countries that may choose to keep depending largely on oil producers, thus transferring to oil producers the ability to influence the globe nexus.

The bulk of results highlight the possibility of a growth in energy demand on non-productive activities. Also, this could happen if globalization continues to expand. For this reason, overall results warn that growth in non-productive energy demand should be monitored. Globalization, economic growth and energy consumption drive to one more interestingly triangle in the energy-growth nexus research. There are countries where globalization promotes a reduction in energy consumption, but globally that does not occur. Once more, here emerge difficult choices in managing between the best policies that each country can follow, and the best policies to promote globe growth.

## Chapter 9

### Concluding Remarks

The thesis research aims to add to energy-growth nexus knowledge, about that nexus at globe level, helping the policymakers to face new emerging challenges. There are several energy issues and high uncertainty related with economic growth, regional integration and the challenge coming from China, namely due to its dependence on energy imports and rising concerns on energy security. This thesis intends to contribute to these three topics. The option to develop an empirical thesis allowed us to provide empirical global evidence thus contributing to the literature on nexus macro levels. Likewise, by dividing the globe in four testable regions a contribution on regional integration is provided. Furthermore, an assessment on China's spillover effects on globe nexus was made, providing valuable information on some possible globe impacts related with their energy dependence. Certainly, the energy globalization impacts will raise some new globe challenges. The last topic in the thesis on globalization impacts on globe nexus aims to provide useful information related to both short- and long-run effects.

By using different autoregressive approaches, four essays were produced providing a new insight on the energy-growth nexus. The use of ARDL, VAR, VECM and panel ARDL approaches proved their interest to explain the globe-energy-growth nexus. Furthermore, the thesis provides useful information to clarify whether the lack of unanimity in literature is due to the use of different methodologies. In this thesis, the results achieved reveal consistence when subjected to different methodologies.

The thesis' goals were summarized in four main questions in the introductory chapter. Each essay was developed with the aim to answer one question. Right now, let us retrieve those questions and the respective answers. In short:

1. The *feedback hypothesis* between energy consumption and economic growth is present at globe level. The globe nexus proved to be stable across the years. Furthermore, it is proven that the results do not vary across methodologies.
2. The globe was divided into four regions and by using the same methodology for all, heterogeneous results were observed. The results support that the use of different methodologies is not one of the main drivers of heterogeneous nexus results in different globe regions.
3. China' energy consumption and economic growth impacts on globe energy-growth nexus, except for the America aggregate. These results raise awareness that there are

countries or groups of countries that most likely have the ability to influence the globe nexus thus promoting or hampering globe growth.

4. Globalization drives both globe energy consumption and economic growth on the long-run. Despite, globalization promoting globe growth, it addresses a serious concern because if globalization continues to grow it may lead to inefficient energy consumption. In fact, the energy consumption inefficiency seems to be one of the most relevant topics at macro levels.

How to manage between the best policies that each country can follow and the best policies to promote globe growth will be a topic under discussion in the forthcoming years. For this reason, the research is not complete, requiring further investigation. Some suggested future path of research arises:

- a) It is of increasingly importance to understand the spillover effects of other regions or countries on globe energy-growth nexus, namely those with high shares of globe GDP, the biggest exporting or importing and the biggest oil producers and consumers.
- b) Expanding the globe augmented energy-growth nexus with variables such as financial development, population, urbanization, industrialization, among others, because this is an emergent topic, capturing the researchers' attention and at globe level remains underdeveloped.
- c) When more data is available the results of globalization impacts on globe energy-growth nexus should be confronted with new results from an expanded database, closer to a globe measure, because the chosen countries present in the used sample were restricted by data availability.

A final note to highlight is that the most relevant difficulty felt throughout the development of these essays was always the availability of data. For example, it was difficult to make the variables comparable in order to divide the globe into four regions. Usually data for primary energy consumption and economic growth for the same aggregates is not provided and it is not easy to fully define the countries that compose some aggregates. It is most usual to have revealed data on the most developed countries and the information on a relevant number of small countries provided together and characterized as "other". This raises difficulties when defining what is inside of those data aggregates. Maybe in the future, data on all countries will be similarly provided, following the increasing interest in regional integration and their policy challenges.

We are confident that the produced contents unleash the academics interest in understanding the nexus at macro levels. Therefore, any fluctuation experienced by the globe-energy growth,

driven by the changes occurring in the next decades, will no longer provide surprising outcomes. Accordingly, we are convinced that in the next few years the developing countries, such as China and India, will play a major role in the globe nexus research because it is important to examine the shift of large amounts of energy that we are experiencing.



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