Università degli Studi di Ferrara

DOTTORATO DI RICERCA IN
"ECONOMIA E MANAGEMENT DELL' INNOVAZIONE E DELLA SOSTENIBILITÀ "

CICLO XXIX

COORDINATORE Prof.ssa Emidia Vagnoni

ESSAYS ON ENERGY ECONOMICS

Settore Scientifico Disciplinare SECS-P/06

Dottorando	**Tutore**
Dott. Javier N. Valdes Lucas	Prof. Massimiliano Mazzanti

Anni 2014/2016

Università degli Studi di Ferrara

DOTTORATO DI RICERCA
in
Economia e Management dell'Innovazione e della Sostenibilità

In convenzione con l'Università degli studi di Parma

CICLO XXIX

COORDINATORE Prof. Stefano Azzali

ESSAYS ON ENERGY ECONOMICS

Settore Scientifico Disciplinare SECS-P/ 6

Dottorando
Dott. Javier N. Valdés Lucas

(firma)

Tutore
Prof. Massimiliano Mazzanti

(firma)

Anni 2014/2016

CONTENTS

Preface

Many people have contributed directly or indirectly to the realization of this thesis. Academically, I wish to express my gratitude to my supervisor Massimiliano Mazzanti for his support and encouragement over the course of my graduate studies. I would also like to offer my special thanks to Professor Antonio Musolesi and Professor Bruno Maggi, who taught me about econometrics and philosophy of science. I also extend my thanks to the members of the Department of Economics and Managements for their comments, suggestions and support.

I wish to thank Dr. Gonzalo Escribano for several inspiring discussions on energy policy and the process of writing, as well as his helpful comments on my written work. I also wish to express my gratitude to the Institute for East and Southeast European Studies where much of the third chapter was created and written. I am especially grateful to the Universidad Nacional de Educación a Distancia and to my coauthors Dr. Enrique San Martin and Meliyara Garcia Consuegra.

My gratitude also goes to the Universitá degli Studi di Ferrara for their generous financial support over the course of these years.

I am also indebted to my colleagues whose insights influenced my ideas and who were very supportive through their company and friendship. None of my academic success would have been possible without the love and support of my parents, sisters and brother.

Finally and most importantly, I owe the most to Christina, who sacrificed the most because of this.

INTRODUCTION

Energy security and energy policy were closely linked and became inseparable during the 70's and 80's. The importance of this relationship decreased during the 90's when energy policies were designed to increase liberalization of the energy sector relying on market forces, the reduction of state intervention and increased production. During the 2000's the increasing concerns about climate change, the rising energy needs in developing countries and the political instability in key energy producers revived the discussion on the security of energy systems. Today, the situation is even more complex, the challenges posed by the global economics crisis have sharpened global competition for energy sources at a moment when finding a political and economic solutions to climate change are urgent and are critical for the years to come.

These new great challenges force scholars to formulate new ideas and thoughts, which could lead to a novel interpretations of the concept of energy security. As a result, there are new points of view that extend the concept of energy security to new fields including various issues as the energy-poverty reduction, changing unsustainable patterns of production and consumption and the protection and management of natural resources, including water resources. Nevertheless, for most countries energy as a major security factor remains a political issue of great economic importance, and influences how countries design their energy systems and conduct their foreign policies.

One illustrative example for the importance of the energy economy is the case of oil. Oil is an essential source of energy in modern economies, especially in the transportation sector: 80-95 percent of worldwide transport is based on oil products; 50-75 percent of extracted oil is used for transport; all petrochemical products are made of oil; 99 percent of all the lubricants are made of oil products; 95 percent of all the goods we buy in stores were brought there using oil; 99 percent of our food depends on oil contained in fertilizers, for farming the land with machines and the distribution of the product; oil is the most important primary energy source on this planet and represents 36,4 percent of energy consumed worldwide.

Moreover, oil is the most traded commodity in the world and its prices have worldwide impacts. The volatility in 2005-2010 created a high pressure on energy markets that, combined with the great recession of 2008 has highlighted the political dimension of oil, and have resuscitated the fears of the 70's oil crisis. Policymakers know that supplying economies with energy sources in a certain quantity and to a competitive price is a necessary condition to maintain steady economic growth. In this context, energy security has become a focus of international attention and has altered the economic and political relations between producer and consumer countries. Each chapter of this thesis investigates a question triggered or made more salient by those events.

Due to this strait link between economy and energy, a multitude of studies has approached the relation between energy and economic issues. This thesis is devoted to the study of the institutional frame, economic policies and the question of sustainability and its impact on energy supply and the substitution of energy sources. It contains four chapters divided in two parts. The first part is developed from the theories of Public Choice and International Political Economy and is more interdisciplinary in nature than the second part which is characterized by the application of econometric techniques to questions of energy economics.

The first essay of this thesis investigates how global energy governance can have the capacity to reduce energy risk and generate a coordinated response to energy related challenges from an International Political Economy perspective. Throughout the moments of highest volatility in 2009 among consumer and producer countries, policymakers identified the economic system's capacity to resist price hikes as a priority goal. This emphasis resurged the importance of energy security policies and highlighted its repercussions for climate change policies, an area where due to the high degree of interdependence and public good characteristics of energy systems the coordination of energy policies is especially important.

In order to develop the analysis, the essay uses two complementary approaches to analyze global governance: Global public Goods theory and Public Choice theory. The essay focuses on the oil market. The development of modern economies was mainly based on the consumption of hydrocarbons and, as a result, oil played a predominant and transcendental role in the formulation of energy security strategies for producing and consuming countries. The analysis reveal that although for the last years, new institutions have achieved to extend the publicness of consuming, benefits and decision-making, currently, energy security is a Public Transnational Good which will become a Global Public Good only by decision of the actors involved in its governance. For this to happen, an expansion of these publicness characteristics to current institutional arrangements will be necessary without necessarily the inclusion oft new actors.

The second chapter also explores the global energy landscape by linking two major areas of work on the geographies of oil: socially produced scarcity and the ‘new realities’ of oil, with wider geographical inquiries, mainly global energy governance. It explores how even though currently characterized by oversupply, power represents an outstanding key factor in the geopolitics of prices, the interactions amongst energy institutions, the role of supply and demand, and the preferences of the actors involved. The chapter then focuses on what are the consequences of collapsing oil prices for oil-producing countries and how it will affect the major issues related to energy security in the future. It concludes by stating that there is a need to rethink the geopolitics of energy security in order to incorporate the failure of global governance institutions to facilitate cooperation as another cause for re-securitization of energy policies.

The second part of the thesis explores to what extend energy policies have been driven by energy security concerns. Some countries define their energy policy as a combination of three components: competition, energy security and climate change policies. This has resulted in an apparent trade-off between policy goals within which governments have to choose among objectives. Nevertheless, in practice, this is not always the case as some strategies may be complementary, as energy efficiency and energy independence. Nonetheless, a number of other important factors may cause distortions on energy policy development that need to be taken into consideration. Prominent among them is the obscurity and vagueness of the applied concepts of energy security. This may by a source of tremendous noise as monitoring progress towards sustainable energy system requires, in first place, the identification of operational indicators that provide manageable units of information on security, economic, environmental, and social conditions. To that end, multidimensional indexes are becoming increasingly important instruments to assess energy system's security levels. Chapter 3 explores in which degree some of the most well known composite indicators are affected by several methodological choices, which at times result in a lack of robustness of the rankings involved.

More concretely, in a critical analysis of the methodological characteristics of energy security composite indicators chapter 3 contributes to the debate on the construction of energy security composite indicators by providing a better understanding of the various methods that are available. The main task of this essay is the analysis of methodological requirements of a tool that is able to provide quantitative knowledge about energy security in a way that can make heterogeneous threats to energy security commensurable for decision-makers. The analysis frames the energy security definitions employed on multidimensional indicators and describes the main characteristics of the methodology, starting with data normalization to allow comparisons, the weighting of simple indicators, their aggregation and the sensitive analysis.

This critical review should enhance the debate on multidimensional energy security indicators and address the shortcomings of the current state of the art. The results show the lack of standardized methodologies and consensus among scholars regarding the quantification of energy security in a broader definition. This result may be due to the novelty of the research field and the specific difficulties concerning the field of transdisciplinary research. In this regard, an avenue to further research should be the Ecological Economics literature, a branch of knowledge that has been able to create a research framework integrating approaches from diverse disciplines. This underlines the need for enhanced efforts by researchers of different disciplines to incorporate concepts from other areas of study and demonstrates the potential benefits of integrating energy studies in a broadened approach.

The final chapter of this thesis explores the utility of individual indicators to identify the impact of different energy security strategies in the development of renewable energies. Due to increasing pressure from energy price volatility, the rise of energy demand and climate change concerns, the expansion of renewable energies has become one prominent energy security strategy for consumer countries. Nevertheless, despite the huge amount of evidence on the Granger causality between energy and GDP or other factors as urbanization, financial development and trade, energy security reasons behind the support of RES have been poorly investigated.

This is particularly important because from an importing country's perspective, there are two main strategies to reduce energy security risks and both are not exclusive: diversification and independence. Both strategies allow to reduce the risk associated to targeted energy sources and may boost the use of renewable energies, because these are endogenous resources that can displace less sustainable sources, especially in electricity generation. Therefore, we are interested to find out whether energy security factors are driving the replacement of fossil fuels by renewables in the energy mix.

This chapter contributes to our understanding of policy support for renewable energy developing a variety of approaches for the quantification of energy security. The results of applying different energy security indicators, including the ones used in EU energy policymaking are compared. Unlike previous studies, this study reports a long-term relationship between energy security and renewable deployment. The findings suggest that the relationship between energy security policies and Renewable Energy Sources (RES) deployment is far from straightforward and depends on the chosen energy security strategy, which is usually linked to different energy security conceptualizations. Moreover, Granger-causality was determined to run from energy security to total primary energy supply and vice versa in the short term, revealing a dynamic relationship.

Altogether, what can we conclude from this work? Chapter 1 and 2 determine that geopolitical approaches find a niche in the gaps left by the increasing complexities of global energy governance. In this regard, energy geopolitics may be thought of as 'governance by other means', an alternative to failed external energy governance solutions. Moreover, they present the main characteristics that determine the current failure of cooperative energy governance. Chapter 3 present a methodological framework for the construction of energy security indicators for evaluating the economic, social and environmental impacts of policies on energy systems. It also gives policymakers the possibility to balance between different objectives of energy policy allowing them to identify areas of strategic importance and possible synergies between countries. Most prominent, the tool may identify areas of potential cooperation as, for example, the environmental dimensions or dimensions concerning affordability. Because the methodological recommendations can be applied to any energy security composite indicator, they are likely to be of general interest and should advance the field by stimulating a debate while serving as a useful checklist for authors and reviewers. Finally, primary findings of chapter 4 confirm that (i) RES deployment is a consequence of an energy security strategy and not only of environmental concerns, and (ii) within the energy security strategies, the diversification of energy sources is a more coherent strategy for renewable energy deployment than the search for energy independence .

FOREWORD

This thesis consists of four essays on economics focusing on the determinants of policy intervention in energy related issues. I started working on these topics after studying the importance of energy in economic and international political economy literature. Overall, the main message of this thesis as to current public policy discussions is that energy security can play a more relevant role in the transition to more sustainable energy systems. However, as the focus is on policy at the international, regional and national level this work would have no value without presenting some key policy implications.

The four essays contained in this thesis evidence that current energy security strategies have shifted from a traditional view to a modern viewpoint in which not only competitive prices and securing sources of supply are the key objectives. Currently, energy security policy in consumer and producer countries is developed to achieve various purposes ranging from environmental protection to support economic growth. In a general tone, the main policy messages or recommendations based on the analysis are three. The first is the need of an energy policy focused on the long term, control of total consumption/production and energy security constraints. Secondly, the policies must focus on the efficiency improvements rather than rely almost exclusively on the search for alternative fuels. Finally, it is necessary to increase investment in the upstream sector to ensure energy supply and emission reduction.

It is well known that the management of global energy supply and demand will be important for the transition to an energy model which is based less on hydrocarbons. For that reason, in order to avoid a situation where energy governance failure affect climate change negotiations, it is necessary to address the effects of governments' energy security strategies over the global energy supply and demand. In this context, it is necessary that the members of the OPEC as well as the members of the IEA increase their coordination with new and more advanced and influential institutional arrangements. Otherwise, the market would continue to suffer the lack of coordination, running the risk of this "governance by default" to be extended to other areas of energy. The challenge for the members of the IEA and the OPEC will be their capacity to lead a change that will encourage international cooperation in the transition to an energy security increasingly more public in its three aspects, consumption, benefits and decision-making on the most harmonious possible way.

The current apparent lack of consistency of energy policy strategies among consumer and producer countries suggests that it is critical to increase our knowledge about the coherence of energy policy targets. In this regard, this thesis outlines the need to develop a more holistic view of global energy governance in which the environmental and the energy security dimensions are more effectively approached. This approach may guide the current process of re-securitization of energy systems through a path in which energy security policies do not endanger the advances in environmental protection. The idea is to avoid moving forward a non-cooperative governance in which energy security will increasingly be consolidated as a good only reachable by a few states. To do that a first step is the development of new indicators of energy security that embrace the sustainability dimension of the energy systems in the short and long term, including the new challenges to the access to energy, energy poverty and natural resource governance.

In this regard, the results of this thesis outline how the requirements of formal consistence have been underexplored in literature concerning multidimensional energy security indicators, even though they have the same importance as the more general considerations. This arbitrariness in the construction of composite indicators may result in misleading messages to policy makers and may incorporate an excessive degree of subjectivity. This is even more striking since methodological choices are interconnected to other general considerations to such an extent that they determine the meaningfulness and validity of the final indicators.

The findings of this thesis also have key policy implications for the EU: there is a need to find an energy security approach for the EU coherent with renewable energy deployment. To achieve this goal, our results show that it will be necessary to explore strategies that promote both energy security and sustainable energy avoiding policies focussed only on decreasing import dependence. How EU energy policy will affect renewable energy depends on how energy security is framed at the national and EU level. In that sense, a European energy security framework based on solidarity and coordination could increase policy coherence only if the expansion of renewable energy is included as an opportunity to improve energy security through diversification. Moreover, the case study reveals that in the EU the current debate on energy governance is dominated by the dependence on external energy resources due to EU's confrontation with Russia and the threat of a new gas crisis. However, energy independence, as our results show, does not constitute the main security driver in renewable deployment. In this context, a diversification strategy of primary energy sources presents a higher consistency, and probably better results in terms of energy security, than pursuing import independence. Therefore, it is a more coherent strategy to achieve the EU 2020, 2030 and 2050 targets for renewable deployment.

These recommendations, insofar as they are based on evidence on the positive relationship between energy security and renewable energy deployment, have important implications for policies related to the design of a common energy policy at an European level and the development of a global diplomacy to energy governance and the management of natural resource wealth. Mainly, they invite policymakers to reconsider the effectiveness of policies developed at the national level, for projects or services to promote energy security. By instance, to gain more coherence within the economic, political and environmental objectives, the EU should focus on areas that need particular attention from a policy perspective such as the technological and geopolitical dimension of energy security. To do so, it would be necessary to explore strategies such as the diversification of energy corridors, the geographical diversification of energy sources or the socioeconomic and political risk influencing energy markets. Finally, if renewable energy deployment is not only about environment, but also about energy security, it should be easier to persuade the public opinion and member States to reach deployment targets and fight climate change. Moreover, the willingness to pay for renewable energy should increase among European constituencies.

Moreover, this thesis also contributes to the existing literature on the drivers and barriers to innovation. The result shows the impact of national security policy on innovation of renewable technologies by using a variety of indicators of energy security to illustrate the heterogeneous effects of policy intervention on EU member states. The present investigation's main contribution to the empirical literature is the analysis of the relationship among policy drivers of renewable technologies expansion. It is also related to literature on political economy that investigates the effects of European energy policy on its neighborhood. Moreover, the study of global governance complements previous contributions on "resource curse" literature by exploring the heterogeneous political effects of the narratives of scarcity on producing countries. Finally, this thesis contributes as well to the new literature on global energy governance. It provides evidence on the importance of energy security characteristics as a global public good beyond the classical attributes of non-exclusion and non-rivalry.

Future research must try to better understand the relative importance of security policies and national preferences as the driving forces behind technology adoption and development. Another avenue for future research is related to the study of institutional change with the objective of establishing whether certain characteristics of international institutions, such as publicness in consumption, are a particularly important barrier for the development of more inclusive international institutions.

Chapter 1

Evaluating oil governance through the public choice theory

1.1 Introduction:

Scholars had been studying international energy cooperation in the oil field for quite a long time. Most prominent among these studies is the Kehoane seminal work in which he develops the concept of interdependence through its analysis of the oil consumers’ regime dominated by the IEA and the OPEC (Kehoane, 1984). Since then, many studies have addressed the question with a special revival of this field of study on the last ten years. The emergence of global energy governance is due to the current energy dilemma (Bradshaw 2009), characterized by the apparition of new global producers and consumers, climate change concerns and new imbalances within the oil market, that have altered the functioning of both, new and old international institutions. The old institutions are based on the development of little inclusive cooperation, the new by pointing out the inoperability of an approach solely based on market rules as the foundations of governance. This expanding agenda transforms the energy global governance into a more complex field than the management of the interdependence between the producers grouped around the OPEC and the OECD's consumers (Florini & Dubash 2011), or the reduction of the volatility (Luciani, 2011).

Recently, Hancock and Vivoda (2014) signaled the importance to study the role of international organizations related to energy and the regional energy governance. Moreover, Falkner (2014) calls for a focus on how greater synergies between different institutions can be promoted. This study address precisely the limits of multilateral organizations in the oil energy security field analyzing how the existing governance institutions conform a “energy regime complex” examining their capacity to provide energy security as a Global Public Good (GPG). The focus on oil and not on other energy sources is because a small group of oil producing continues to dominate total primary energy supply. To do that, global-level organizations dealing with supply security, demand security and cooperative security are evaluated using GPG theory and Public choice theory.

States have traditionally been in charge of the provisioning of such goods; nevertheless, the current process of growing interdependence requires the development of an analytic approach based on a global perspective (Escribano 2015, Karlson et al 2012). In order to do this, it is necessary to utilize a wide definition of the concept of public good with the objective of adapting the concept to those public goods that transcend national frontiers, what makes GPG not just a technical issue, but also a political one.

Facing the emergence of such a titanic duty, it is necessary to analyze which barriers do currently exist that which are the future obstacles that ought to be overcome by the states and international institutions in order to be able to supply the provision of a global oil security. The idea is to avoid moving forward a non-cooperative governance in which energy security will increasingly be consolidated as a good only reachable by a few states. The following analysis clarify two main questions. The first one is if there are enough existing factors, which let us consider energy security as a GPG. The second question is whether the existence of a political dimension of oil makes the production of an optimum level of security depend on the extent of the public character of the institutions that govern such production.

Other studies have addressed this and similar questions of energy governance with a different focus. Many of them are devoted to single international organizations (Harks 2010; Goldthau and Witte 2011; Van de Graaf and Westphal 2011; Van de Graaf 2012), energy issues at the regional rather than global level (McGowan 2009; Ravenhill 2013) or consider the full ensemble of practices in global energy governance (including national, bilateral and even corporate arrangements) rather than focusing specifically on multilateral organisations (Goldthau and Witte 2010; Lesage et al. 2010a; Dubash and Florini 2011). In a recent study of the limits of multilateral organizations to foster international energy cooperation Wilson (2015) argue that "*the relatively weak contribution of multilateral organizations to global energy governance is explained by the securitized nature of energy issues and nationalistic energy policy regimes associated with it*". Although we agree that nationalistic energy policies are a barrier to energy cooperation we would like to address which aspect of the relative failure of multilateral organizations/energy institutions are linked to the GPG characteristics of energy security.

This article therefore seeks to fill this gap with three main contributions: i) energy security is framed in terms of GPG and from a public choice perspective, ii) we restrict our analysis to oil security as energy sources differ in the problems derived from collective action and iii) we differentiate between different energy security conceptions, namely: supply security, demand security and cooperative security, in order to account for their specific characteristics.

Concerning these questions, the article analyzes which criteria ought to be utilized in order to identify energy security as a GPG and it also characterizes institutions of the oil governance as crucial factors in its supply. In spite of this, firstly, the article characterizes energetic governance as a GPG in contemplation of analyzing the crucial role of institutions in its expansion. The second part of the article characterize these institutions mapping oil security governance. The third epigraph of the paper presents an analysis of the mapped institutions in terms of public choice followed by a fourth section depicted to discuss the results in terms of GPG. Finally, the main conclusions are presented.

1.2 Energy Security as a Global Public Good

The scope of energy global energy governance covers at least five major issues: energy security, economic development, international security, environmental sustainability and domestic governance (Dubash and Florini, 2011; Goldthau, 2013). Some of these objectives may exhibit GPG characteristics and hence require action beyond the national level to avoid the collective action dilemmas associated with such goods (Karlsson-Vinkhuyzen et al., 2012). In the case of environmental sustainability or international security, exist a broad agreement about their characteristics and benefits but in other fields, such energy security it is less clear.

The study of energy security governance depends strongly on the definition of the term, which is widely used, but vaguely defined (Ang & Choong 2015; Cherp & Jewell 2011, 2014) and difficult to measure (Narula 2015). This is because there are several theoretical frames in which the concept adopts different definitions depending on the areas or dimensions in which the concept is utilized (Dike 2013; Barret et al. 2010; Turton and Barreto 2016; Winzer 2012; Bosse & Schmidt-Felzmann 2011). To avoid confusions in this study we adopt a broad, crosscutting approach to the concept of energy security coming from the field of economic security: "*the absence of acute threats to the minimal acceptable levels of the basic values that a people consider essential to its survival*" (Krause and Nye, 1975). All through this work energy security is understood as one of these necessary values for survival, due to the importance of energy supply within the economy. Consequently, energy security has to be understood as a necessary good itself, as well as a good that reinforces other domains, such as human and socioeconomic security (Altaver 2007). This definition allows identification of the energy security issues inside the International Political Economy viewpoint without neglecting both the geopolitical and the global governance perspective. In turn, this definition is in keeping with the seventh Sustainable Development Goal: Ensure access to affordable, reliable, sustainable and clean energy for all.

By analyzing energy security from a GPG perspective the question to clarify is which criteria ought to be utilized in order to identify energy security as a GPG. Public goods are a type of good or service that governments may provide to overcome the incentive to free ride. In the traditional definition, two properties are considered when determining the public character of a good: the non-rivalry and the non-exclusion (Samuelson, 1954). Non-exclusion refers to the inability of excluding an agent from its consuming, and non-rivalry refers to the fact that the consumption of an agent will not decrease the available amount for other agents. Another characteristic that belongs to public goods is the existence of positive externalities, that is the reason why, constantly, public goods have been defined as the opposite, as “public bads” goods that are also non-excludable and non-rival, but negatively affects welfare.

On a global scale, the problem that the provision of public goods face is the absence of a political order hypothesis that extends the notion of public good to the international domain. Therefore, there is no structure of governance able to assure the provision of such goods, but a multi-polar world in which old and new forces rival for oil supply in the most advantageous possible terms (Keohane and Nye, 1977). At the same time, economy, founded on the efficient allocation of scarce resources, presumes the political order as the starting point of the hypothesis (Strange, 1994). The concept of GPG was developed as a tool to avoid difficulties associated to the lack of such hypothesis of departure. Problems derived from collective action have been widely presented in economic literature by different models, being the most influential: the tragedy of the commons (Hardin 1968), the prisoners dilemma (Dawes 1973 and 1975) and Olson's collective action theory (1965). Within the International Political Economy literature, the concept of international public goods orr Global Public Goods (GPG) is a recent development, which supports itself in the work of P. Kindleberger (1968), pioneer in extending the concept of public good to the international scale.

The notion of GPG is related to the process of globalization and the increase of interdependence. United Nations has defined them as those goods extending to all states, socioeconomic groups and generations (Kaul, 2003). Nevertheless, as in the case of public goods, the theoretical rigor of such definition complicates the analysis. Consequently, only a few types of goods, fundamentally common goods, are considered GPG. A less strict definition is the one that considers a public good as global when the latter benefits more than one group of countries and that does not discriminate against any population group or generation (Kaul 2003). Hence, seeing from the point of view of their production, several GPG, as the case for oil strategic reserves are produced by the aggregation of national public goods and international cooperation.

Energy security has positive externalities, they are essential for the correct functioning of the current economic system founded on energy extraction and transformation. In this sense, several analyses have demonstrated how, for example, an alteration within the energy process generates considerable negative externalities that create insecurity (Goldthau 2012, Nordhaus 2009). A part of the well know environmental externalities, among the effects of low levels or absence of energy security we can find: the increase of the price of other commodities (Avalos 2014), macroeconomic externalities derived from price volatility (Narayan et al. 2014), sub-production levels due to uncertainty (Luciani 2010 and 2011) and, other economic and political externalities (LeBillon and El Khatib 2004, Sardosky 2008; Maugeri 2012, Fatthou 2014; Reboredo 2015) just to mention a few.

As a response to these challenges, actors have developed different tools in order to face sub-optimal levels of energy security, such as institutional arrangements addressed to establish an energy governance (Bielecki 2002). Nevertheless, this institutional innovation follows a pattern of "punctuated equilibium", characterized by period of fast development, followed by periods of stagnation (Colgan et al. 2012). A classic example from within the different strategies that has been introduced with the aim of lightening problems through governance involving goods with GPG characteristics is the creation of strategic reserves by the members of the IEA. Since the use of the reserves by a state is of little significant impact over the global demand, countries involved in the system of reserves have shared obligations. Otherwise, the cost of provisioning would exceed the benefits of its own constitution as far as its benefits are scattered in global oil demand.

Nevertheless, although the constitution of strategic reserves or the maintenance of spare capacity has effects beyond the frontiers of those countries, they are maintained by national governments in order to influence global supply and demand. Yet, as important they are, the study of oil security and its components has not been systematically analyzed from a global governance perspective (Andrews-Speed 2011). This gap within studies draws growing attention as it can be observed on the increasing literature related to different aspects of global energy governance (Van de Graaf and Colgan 2016).

To address the limits of multilateral organizations in the oil energy security field we explore the characteristics of energy security in terms of GPG beyond the consequences that the non-exclusion and non-rivalry characteristics of energy security have over energy governance. These are technical characteristics of the good, which do not question or take into account the process by which the goods are supplied. From the point of view of this study, such characteristics transform energy security into a "potential" GPG but do not determine the final character of the good. Moreover, they are a decisive factor to the extent that they determine the weakness of energy organizations to provide GPG.

The inclusion of the adjective potential is because our work prefers to utilize a less narrow definition of public goods, in which the latter are a social construct determined according to what is perceived as a public necessity, instead of being determined by their innate characteristics (Wuyts 1992). Therefore, we depart from the following premise: non-rivalry and non-exclusion are too vague concepts to be used in order to define whether a good is public or private. Such characteristics are not innate to goods, but a signal of the potentiality of a good to be public or private. Therefore, they can be modified depending on social preferences. From this perspective, public goods are a social construct that depends on the aggregation of individual preferences and it is public choice the one that determines, ultimately, their production (Stretton and Orchad 1994). Hence, an analysis in terms of GPG must approach, not only the properties of the goods, but also the mechanisms through which the goods are made available, and the costs and advantages that their characteristics represent to different actors. We will depart from these concepts in order to analyze if the characteristics of the different systems of oil security, managed from a myriad of institutions, can be considered a GPG as international security or sustainable development.

1.3 Mapping oil's energy governance.

Energy governance at a global level is increasingly necessary as unilateral decisions of some actors have a great impact over global offer and demand. This impact is not homogeneous over the supply chain and depends mainly the concentration of the market (Hughes and Long 2014). Currently, the components of the value chain of energy systems are expanding beyond the national frontiers of producer, consumer and transit countries, and within these, in a differentiated way, depending on the energy source and in the case of oil depending on the variety of crudes. This process is one of the causes of the generalized failure of markets for allocating resources in ways that deliver important public goods (Bridge, 2015). This process act in conjunction with two other factors: the first one is that governments have devolved to the market the provisioning of public goods. Such as energy security, in search of achieving a higher efficiency in the use of resources. The neo-liberal approach and the context of globalization, summed to the objective of increasing competitiveness, have changed the conception of the market stimulating the integration and overflow of national frontiers. On a second place, state's traditional tools for the provisioning of public goods are not effective anymore. The opening of economies increases the vulnerability produced by the behaviors of other actors, causing the incapability of states to grant by themselves the supply of specific public goods. Moreover, due to the high level of interdependency, the states' tools to manage national offer and demand are not ready to manage a global offer and demand.

Within this context, a global approach must address problems related to market failures at the same time that it resolves the collective action's problems that give shape to the characters that make energy security a potential GPG. A market failure can arise for several reasons, by instance if there are externalities, such as pollution; or if there are inefficiencies associated with the market structure. A government failure can arise if the government selects a policy, such as subsidizing energy, which leads to an inefficient outcome. In certain cases, this outcome may actually reduce overall economic efficiency compared with the status quo. Government failures may arise for a number of reasons. For example, politicians or regulators may simply not have an incentive to pursue efficient policies. In addition, regulators may lack adequate ion. Both market failures and government failures can contribute to the inefficient use of energy resources if they are not rectified (Anthoff and Hahn 2010)

Within the implemented measures to solve these failures, we can distinguish international institutions. Markets require institutions that can preserve the competition, the reduction of costs and the fixation of standards (Goldthau and Witte, 2010). For this reason, during the last decades, states have been acquiring new energy governance tools, mostly with a regional scale, which by trespassing the national scope increase their capacity to affect global offer and demand. These institutions reflect the states' preferences and the interests of those states with higher influence within the institutions. In a context of complex interdependence, such as the oil market, the capability of influencing the construction of an international regime by one actor is low. As mentioned before, this is because there are several interests and power is fragmented. In this context, incentives to cooperate increase, enhancing the apparition of a "complex of energy regimes" defined as "*an array of partially overlapping and non-hierarchical institutions governing a particular issue area*" (Raustiala and Victor 2004)

In a situation of complex of regimens, there is no homogeneous institutional frame, but a fragmented governance limited by the interaction of different institutions that integrate different levels. Some studies have been devoted to map the global governanc arrangements and institutions (Van de Graaf and Colgan 2016), but these mapping do not generally distinguish among energy sources and energy security conceptions. Within the oil field, the different components of the "complex of regimens" can be approximated by institutional arrangements dedicated to provide collective public goods. As energy is viewed as a strategic element of economic security, cooperation is inherent to the definition of energy security. For this reason, we do difference between three categories of cooperation related to three conceptions of energy security: supply security, demand security and cooperative security.

Supply security cooperation is usually pursued by consumer countries and defined as having three main components: affordability, accessibility and availability. Which mean that energy supply should be constant, appropriate in quantity and with an affordable price. Although constant and available are two terms that appeals to the non-interruption of energy supply the concept of affordability is subjective, for that reason it is sometimes accompanied by the specification: "to levels that do not jeopardize national interest or in line with economic development". Demand security is related to factors affecting fundamentally exporting countries and has to do with the assurance of steady, predictable demand. By instance, the OPEC Statute of 1961 includes the security of demand as one of the principal tasks of the organization including "the stabilisation of prices in international oil markets" and "the necessity of securing: a steady income to the producing countries; […] and a fair return on their capital to those investing in the petroleum industry." Cooperative energy security is a relative recent development related to areas where the dialogue between producers and consumers can increase the security of the overall systems. For the moment, cooperative energy security is focused on matters of statistical transparency and preservation of transport routes. Therefore, it is concerned with normative and ideational drivers.

The function of the oil system depends on the institutions created by the most important consuming countries, the biggest producers and the cooperation forums in which both sides of the market are represented. In this sense, new institutions have had a marked expansive character, in which it has prevailed the objective of extending the dialogue amongst new actors, as it can be observed on the recent extension of the G8 into the G20 or the creation of the IEF. While we recognize the existence of multiple international regimes with influence on energy security outcomes in the oil field, this paper focus on the most important intergovernmental organizations with an energy-specific mandate on oil and on the G8 and G20, which coordinates some important dimensions of international energy cooperation at the level of heads of government:

- Security of the supply of consuming countries: OECD, IEA and G-8.
- Security of the demand, according to the preferences of producing countries of the OPEC, GECF y OPAEP.
- Cooperative energy security: G-20, IEF as well as informal networks, such as the World Energy Council (WEC) and World Petrol Council (WPC).

1.4 Energy security and public choice theory

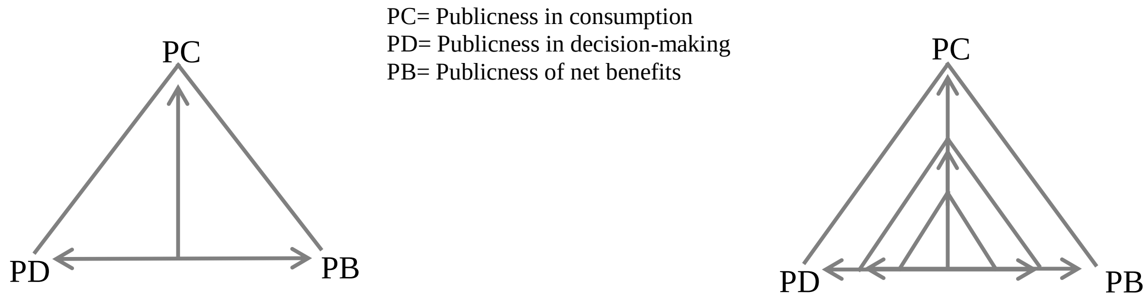
In so far as public goods and specially GPG, are a social construct that depends on the aggregation of individual preferences one way of thinking about institutional agreements is through the theory of public choice. The theory is an attempt to explain decision-making processes within the public goods domain. GPG theory adapts part of this theory through the denominated triangle of publicness. This triangle has as a foundation the fiscal equivalence principle defined by Olson (1965) as: "*The principle suggests that the scope of a Good's benefits be matched with jurisdictional borders. Doing so ensures that those affected by a good can participate in decisions about its provision and that the good reflects local preferences and conditions. Put differently, local public goods should be provided locally, national public goods at the level of the* *central government, and global public goods at the international level".* In order to analyze which criteria has to be mobilized to identify energy security as GPG we will support our ideas on the triangle proposed by Kaul and Mendoza (2003), composed of three different aspects or dimensions that define the public characteristic of public goods:

- The Public character – or the participatory nature – within decision-making. This dimension embraces decision-making over the characteristics of the supply, as we as the quality and distribution of its benefits amongst all agents.
- The public character – or equity – of the distribution of net benefits, It is related to quantitative distribution. It will be higher if society as a whole has access to them and not just certain socioeconomic groups with a specific power of purchase.
- The public character of consumption: this dimension refers to the characteristics of non-exclusion and non-rivalry through agents and groups of agents. If both characteristics are accomplished, the higher the public character of the consume.

From this analysis, it is possible to identify the characteristics of certain components of energy security. Figure 1 shows an example of a public good on the triangle of publicness. The three dimensions are represented by the vortexes and the distance to the center of the triangles indicates its level of publicness. The three characteristics are usually not attended, the triangle on the left only represents an ideal form that is rarely obtained. A consequence of this perspective is that, to be considered as a GPG, energy security must be not only understood under the prism of non-rivalry and non-exclusion, but it also needs to attend, in the best possible way, the three dimensions of the triangle.

We will now analyze the different institutions that conform the complex regimes by dividing the institution in three groups: security of supply, security of demand and cooperative security. In order to do this, we will focus on the main characteristics related to the degree of publicness of the consumption, the publicness of decision-making and publicness of the net benefits.

Figure 1. The triangle of publicness



Source: Kaul I., Conceição,P., Le Goulven, K., et U.Mendoza. R., « *Providing global public goods managing globalization* »

1.4.1 Security of the supply

The IAE is an international organization created by the OECD in 1973, it has two main functions. The first one is the maintenance and improvement of the energy systems in order to face potential interruptions of the supply. The second function is to act as a forum in which development strategies of energy policies will be developed, as well as a forum for exchange of information and technological transfer between its members. Being the exchange of information its main activity through the World Energy Outlook. In fact, due to the stability of petrol markets, the IEA has only activated the system of reserves only three times (Van de Graaf and Lesage 2009). For this, the IEA coordinates part of the energy policies of its 29 associated states, as well as the response measure during periods of high volatility or interruption of the supply. Even though the IEA is an international organization, in practice only member of the OECD are members of the IEA, so, in some ways, both institutions overlap. Its main energy security tool is the oil reserves equivalent to 90 days of the annual average of net importations of ach member. This is one of the entry requirements and part of the system of Coordinated Emergency Response Measures (CERM). Other requirements are the development of policy measures to restrict oil demand in a 10% in case of emergence and the creation of new legislation and the necessary organization to assure that the oil companies that operate within its jurisdiction report all the necessary information. Nordhaus (2009) have interpreted these reserves as a public good supplied by the IEA, which pays its maintenance, although it does it for national interests. In our triangle, this characteristic of the IEA makes the public character of consuming very high. At the same time, the author characterizes the security of the global maritime corridors, whatever it is Ormuz o Malaca, as a public good provided by the US versus the free riding of Asian and

European consumers. Taking into account the fact that the US is in charge of the majority of decisions on the IEA and the existing connections between the NATO and IEA (Woodward 2009, Clifton and Díaz-Fuentes 2011), this reinforces the publicness of the consumption of the agency.

The design of the IEA, as well as the requirements of entrance have been criticized for being institutionally obsolete, since, by pretending to be the institution that reflects the interests of the main global consumers, currently it does not include key actor such as China or India (Van de Graaf, 2012). This makes levels of publicness of consuming to be low in comparison to the ideal form. The publicness of decision-making is also low, not only due to the restricted number of members, but because of the structure of voting of its Strategic Reserves Committee. Such structure is mainly founded on levels of importations of the countries that were members in 1973. Which allows some states to enjoy a decision power superior to the one that they would enjoy nowadays. If it is also true that the agency has consciousness over these failures, the multiple attempts during the 90s to redistribute the votes failed (Bamberger, 2004)

Overlapping the IEA recently, as in the Ukraine crisis, the G8 have taken some initiative in order to increase the energy security of its members[1], the publicness of consumption, benefits or decisions are small. This holds even when the speech of the G7 has an international advocation. By instance, the G8's Global Energy Security Principles, adopted in St. Petersburg in 2006, already address relevant international energy themes: cooperative energy emergency response, including coordinated planning of strategic stocks; transparent, equitable, stable and effective legal and regulatory frameworks; safeguarding critical energy infrastructure; addressing the energy challenges for the poorest populations in developing countries, to cite a few. However, these are just declarations and very little action has been take so far. As a further sign of its low publicness in energy security issues and the instrumetalization of international organization by some actors, in 2014 the G8 summit did not take place in Sochi as planned, as a consequence of the Crimean crisis instead, a G7 summit relocated to Brussels.

1.4.2 Security of the demand

On another side, the OPEC is an intergovernmental organization, formed by 12

[1]http://europa.eu/rapid/press-release_IP-14-530_en.htm

members and in which various countries have become part or left, varying its constitution over time. While it is true that, currently, it functions through a system of quotas, initially, the OPEC did not count with the objective of coordinating a response to the great power of international oil companies (IOS). Within its organizing structure, we can highlight its general secretariat and board of governors. In parallel, Arab countries have also created the Organization of Arab Petrol Exporter Countries (OAPEC), which is a multilateral organization that coordinates energy policies between Arab nations. Initially, the majority of OAPEC's objectives were intent on using oil as a political weapon. Although, currently, its role within energy governance is marginal, due to the institution's decadence since the 70s, due to this, this organization stays out of our frame of analysis. As a small number of oil producer countries integrates the OPEC, the public character of its benefits is very limited. For the OPEC to be considered a real association of producers, new African, Asian and American producers must be included. Likewise, while the new technological developments have expanded the production of petrol into new areas, such as the shale oil, oil sands and ultra-deep water. The OPEC represents the interests of the countries with a tradition of production of hydrocarbons.

Although the formal characteristics of the organization, within the sen of the OPEC the hegemony has always been disputed between doves and hawks, there is no conclusive evidence about its capacity to limit the production of petrol of its members. In fact, its capacity to act as a cartel is, to several authors, limited (Barros et al., 2011; Goldthau y Witte, 2011, Brémond et al. 2011). In fact, the OPEC has been considered as a "rational myth" (Colgan, 2014). That is to say, as the OPEC's objective is to assure the oil demand for its members, it has incentives to act as if it was a cartel, as long as the benefits derived from these actions are not too costly. Nevertheless, there is no enough empirical evidence that it works as such (Alhajji and. Huettner, 2000) and its member aim both economic and political objectives (Wirl 2009).

Moreover, the organization is moderated by Arabia Saudi, which acts as a producer of last resort for being the only producer with an enough leisure capacity to stabilize the global market and compensate the loss of production elsewhere or influence the prices of the global market. The fact that Arabia Saudi has this spare capacity makes the OPEC an institution with a high level of publicness in consume, and it has been interpreted by Goldthau (2012) as a public global good provided by Arabia Saudi, which is who funds its maintenance even if it does it for national interests. Concerning the decision-making, OPEC's power is undermined by the absence of mechanisms to force its members to meet their quotas, being Arabia Saudi the only member able to give a response to this problem due to its spare capacity. In fact, it has been proven the continuous deviations produced when price both goes up or down.

I.4.3 *Cooperative energy security*

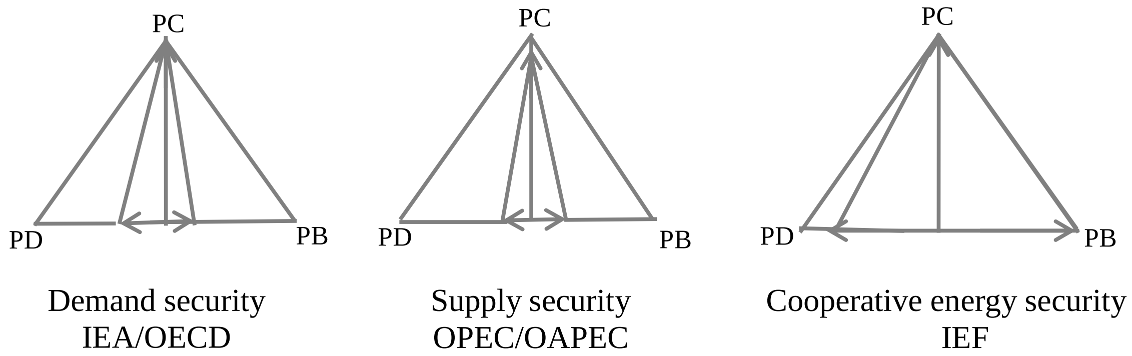
The only institution that reunites hydrocarbons consumers and producers is the International Energy Forum (IEF), an international agreement that groups the signatories of the IEF's Letter. The IEF embraces with its 74 members, around the 90% of global demand and oil production, which demonstrates its high publicness of consume. Its structure has a council conform by 31 members, from which 23 function as members of the executive council and 8 are rotatory members. One of its prominent characteristics, it also affects to the level of the publicness of its decision-making, is that within the 23 members of the executive council we can find 11 of the greatest producers of petrol and gas, 11 of the greatest consumers and the host country (Fattou van der linde 2011). These characteristics make the IEF one of the institutions with the highest level of publicness in decision-making, especially if we compare it with the IEA or the OPEC. In this sense, one of its most important characteristics is that it also gives a voice to important producing countries outside of OPEC, such as Russia, Brazil and Mexico, as well as key importing countries outside the IEA, such as India, China and South Africa, and many other countries from the developing world (Colgan et al. 2012)

Nevertheless, the IEF is not so much an international organization, but rather a biannual reunion of the ministers of energy with a permanent secretary in Riad, in charge of organizing ministerial reunions and promote transparency on energy statistics through the JODI (Fattouh and van der Linde 2011). The initiative to have make the oil market more transparent as an objective redounds in benefits for any of its participants, giving high levels of publicness to its benefits and consume.

The high levels of publicness in the three dimensions are due to the fact that the Forum has specialized on the development of dialogue on issues of transparency. This dialogue forum that not only have been able to implicate international oil companies and national companies, but it has also supported new initiatives that cover the information related to levels of investments and the levels of resources depletion. This data is fundamental in order to make previsions about the levels of future an offer and demand, in fact, the proposals to achieve a more institutionalized oil governance are based on the control of market volatility (Luciani, 2011). In order to solve the problem of volatility the proposals have swiveled from a position, supported during several years by the IEA, in which the exclusive trust on deregulation was favored to another position in which the IEF advocates to stop speculation and to search for a price stabilization that secures benefits for producers and avoid price hikes for consumers. Nevertheless, in as much as the IEF poses the mechanisms through which prices would be decided, neither an explicit strategy of intervention, the IEF is focused on strategies devoted to increase the quality of information which should increase stability in the short and long term (Baccini et al 2013).

Probably this characteristic to conjugate governance through the markets without abandoning the political dimension of oil is the one that makes some authors suggest that the IEF could in a future provide public goods beyond the access to information, as by instance alternative energy infrastructures, or even the maintenance of spare capacities (Harks, 2010). In that case, the level of publicness of consumption, the dimensions more associated to material capacities, will also be expanded.

Figure 2. The oil governance regime complex.



1.5 Discussion

The analysis of the different institutions of governance by means of the triangle of publicness shows clearly how there is a remarkable difference between two confronted approaches that represented by two different types of organizations. On one side, the "return to market" through which consumers and producers must interact under the rules of the market. In this approach, stresses governance through transparency. The second approach on energy governance is based on the control and management of energy, on the side of the demand as well as on the side of the offer, by states. This approach is founded on the management of the political factors that influence international markets by the main consumer and producer countries, with the objective of reducing volatility and improve long-term previsions.

Each of the latter approaches would imply a difference management of the cooperation between different consumers and producers. In the first approach, the political dimension of energy would be diluted. Because of being considered as a barrier to cooperation, the IEF tries to reunite a higher number of actors that share a wide network of interests. Due to this, it specializes in issues related to the correction of market failures, especially the asymmetries of information. The second approach tries to include the political factor, conceiving it as a substantial factor on energy relations, and even considering it as a means to promote cooperation. In fact, the OPEC and the IEA are based on the coordination of the supply and demand, respectively, through the management of their energy policies. In order to do this, they rely on several material resources with the capacity of influencing effectively over the global offer and demand. This control over the chain of production is the one that, at the same time, provides them with the strength to practice political control over other agents.

The institutions linked to material capacities, such as the OPEC and the IEA have a lower publicness of their consumption, benefits and decision-making and function as a club, aspiring to achieve their own interests. While the second group, instead, try to reflect ideal factors, such as the IEF, EITI or the NRC. These institutions, on the other hand, are much more public on their consuming and they are created with the objective of extending transparency and dialogue, hence they have in essence, a clear inclusive character. However, in the other hand, we can see only the IEA and the OPEC counts with the ideational foundations and the material capacities with a proven ability to impact oil markets. On top of the material capacities already mentioned, it is due to the IEA capacity to influence the oil markets through The World Energy Outlook and The Oil Market Reports, and the strategy of the OPEC to support the already commented "rational myth" whose representation is symbolized in the OPEC biannual summit of oil ministers in Vienna.

Currently it seems that the non-cooperative approximation to energy governance is the one that is imposed, reflecting the capacity of a group of actors to superimpose and project their interests (North 1990). In that case, the two main actors are the USA and Saudi Arabia. Both are using their material capacities to inundate the petrol market altering the viability and functioning of the new international institutions founded on the development of a more inclusive cooperation and demonstrating the inoperability of an approach solely based on market rules. This is due to the geographic concentration of oil reserves, which possession gives a position of strength and demonstrate that power relations are in the base of oil security governance, strongly determining the behavior of the oil markets. Thus, the approach based on the market without the capacity of influencing on the global offer and demand has not been able to palliate the impact of higher prices, first during the decade of 2000 and the low prices that are characterizing the beginning of the second part of the current decade.

These facts take us to reconsider the definition of energy security as a "potential GPG", to define it not so much by its potentiality but by its current attributes. In order to do this, we will be supporting our idea on the different definitions given by Kaul for those goods that go beyond national frontiers (Kaul 2012):

- *Definition 1: Transnational public goods are goods with costs or benefits that extend across national borders.*
- *Definition 2: If a good's public effects pertain to only a particular group of countries, it is a regional public good (if neighboring countries are affected) or club good (if countries with other common features like being land locked or having a high income are concerned).*
- *Definition 3: If the good's public effects are of a global reach or extend beyond generations, it is a global public good.*

We can observe, in these three definitions, how there is a trend in the expansion of the attributes from the definition of transnational goods to the definition of global goods, where a public good acquires its maximum expansion until it reaches future generations.

Supporting ourselves on the characteristics of the different institutional arrangements formerly described, we can say that the governance of the supply and demand security resembles more the definition of a transnational good due to the characteristics of the publicness of the consumption of the IEA and the OPEC, which actions determine the functioning of the global oil market. This is like this due to the fact that both organizations are able to extend their benefits only to specific countries in specific moments. In both cases, this is due to the leading roles that USA and Saudi Arabia play within both organizations. In fact, the current state of the market shows how several OPEC members are not being benefited from the Saudi policy of keeping a market quota. The same happens to the IEA and the unilateral decision of US of favoring the strategy of developing non-conventional resources with the objective of reaching energy independence at the expense of the impact that it may have over other IEA members, by instance Canada or Mexico, the last a candidate country and OECD member. This does not imply that, in practice, the myriad of dedicated international energy regimes conforms an energy regime complex that provides a diverse set of GPG rather than a single international energy regime (Escribano, 2015). Nevertheless, it does not mean either that, in the long run this cannot change and true governance of oil takes place (Harks, 2010).

Within regime complexes, one may distinguish three main types of institutional innovation: the creation of new institutions, the nesting of institutions within others, and the adaptation of existing institutions. The above review signals that as far as material capabilities continue to be hold by two institutions -the OPEC and IAE- the creation of new institutions may not be sufficient if the security of supply and demand institutions do not transfer their authority to the new. The IEF and other cooperative security institution are an example of the lack of incentives to do so and the relegation of these new arrangements to more normative *soft law* areas of cooperation (Wilson 2015)

In the other hand, this chapter shows that the possible change from a transnational energy governance to a club or regional energy governance could take place at least by two different ways. By instance, by reinforcing the capacities of the IEF, as it would extend the publicness of the decision-making and consume, as well as the publicness of its benefits. This would boost the progress to a governance by the market, complementing the last progresses of the initiatives dedicated to resolving the failures of the market, since they have to do with the asymmetry of information. This paradigm of the market is founded on the hypothesis that, through the improvement of the information available to agents, markets become more efficient, being able to provide optimum levels of security and discouraging the use of energy as a political weapon. Nevertheless, in order for this paradigm to provide a sufficient security level to prevent price volatility or the competition for market quotas, there must be a wide consensus over energy security objectives and about how to achieve a harmonization with other dimensions of energy policies.

Nevertheless, on the medium and long run the actual situation of incoordination may change. The existing international organizations such as OPEC and IEA, in so far as dominated and directed to the satisfaction of the necessities of some of their current members, have not been able to fully accommodate the increasing importance of the energy interests of these newcomers and perhaps they will be picked up in IEF (Fattouh and van der Linde 2011). In this case, in order for the IEF to turn into an institution with sufficient influence to assure minimum levels of security, new producing and consuming countries will play a fundamental role in the case they decide to support the development of their material capacities, for example, the coordination of energy policies. This will supply the IEF with a power base able to attract the old and atrophied IEA and OPEC, and even open the dialogue about other energy resources.

Another possibility would be that the "old" institutions gradually increase the degree of publicness of decision-making and/or publicness of net benefits. In the short to medium term this is something not expected, states have proven far less willing to join organizations based on material capacities, by instance Russia and Brazil have refused invitations to join OPEC (Goldthau and Witte 2011) and China still refuses to increase its cooperation with the IEA. Nevertheless, for this to happen, security of supply and security of demand institutions should not forcedly incorporate new members. It would be possible that retaining the low publicness in decision making these organizations decide to increase the level of publicness of net benefits. This approach would be more in line with a hegemonic and more secured approach to oil politics in line with Kindelberger (1986) thesis in which one or a group of countries provides a GPG. Nevertheless, it is not sure if this may happen as current oil governance deficit it is not only due to the control of the material factors but to a combination of material and ideational factors.

Under the current configuration a variety of ways exist in which normative and ideational power can be exercised allowing for multiple equilibriums. In the presence of significant governance failures, approaches that tend to concentrate mostly on material capabilities would be unable to explain normative and ideational transformations. In fact, in these global governance gaps more geopolitical approaches are being used as second-best options, especially when the capacity to effectively affect the behavior of other actors becomes a consistent policy strategy. This means that oil security in whatever their forms (supply, demand or cooperative) may become more regional/ bilateral and less global in nature.

1.6 Conclusions.

The previous analysis show the existing barriers, as well as some of the future obstacles that must be overcome for the supply of a true global oil security governance. These features are important in explaining the dynamics of energy security cooperation, because they limit how international cooperation can develop. Specifically, a genuine global oil security must fulfill the three characteristics of the publicness of consumption, net benefits and decision-making in the broadest possible way. For this to happen, the process of decision-making must be open to a greater number of actors, opening the negotiations about the characteristics of supply to new agents. In order to do this, it is necessary to find solutions to those components that previously formed part of the national or regional domain, and that are mostly associated to material capacities. Thus, it is necessary that the members of the OPEC as well as the members of the IEA increase their coordination with new and more advanced and influential institutional arrangements. Otherwise, the market would continue to suffer the lack of coordination, running the risk of this “governance by default” to be extended to other areas of energy.

The analysis based on the theory of public choice allows to show in which ways the supply of acceptable levels of energy security is not only a technical matter, but also a political one. This fact makes difficult continue to defend a liberal approach to energy security devoted to reduce market failures. In so far as « *a public good is one that the public decide to treat as a public good* » (Malkin and Wildavsky, 1991), energy security will be a GPG by the decision of the actors involved in its governance. In this sense, this article presents two important conclusions.

The first one is that there are enough existing elements to consider that nowadays energy security is being configured more as a transnational good than as a GPG. This is due to the existence of interdependence between states that are being reflected in a complex system of governance on a global level with the capability to extend its potential benefits. Thus, the oil security will be a GPG by decision of the States and, in order for this to happen, it seems necessary that the IEA as well as the OPEC increase the publicness of their capacities or progressively derive part of their competencies to other supranational organizations.

The second conclusion is that the existence of the political dimension in their nature makes the production of optimum levels of security depend on the expansion of the publicness in decision-making and the distribution of net benefits of material capabilities, which, until now, are concentrated on the IEA and the OPEC. By analyzing the capacities of decision, consume and share with the triangle of publicness, we can observe how new institutions have been able to increase the spectrum of beneficiaries to a more heterogeneous set of countries. Nevertheless, these developments have only been produced in areas where a market approach and not a geopolitical approach prevails. Therefore, it would be interesting and necessary to explore other possibilities of progressively including on the agenda new issues associated to material capacities and institutions on which the markets sustain themselves.

Thirdly the analysis demonstrates that in order to increase oil energy security it will be necessary the expansion of the publicness of net benefits derived from the material capacities and not necessary the inclusion of new actors to the current institutional arrangements or the creation of new ones. The implications of this deduction is that although nationalistic energy policies are a barrier to energy cooperation they do not necessarily make impossible the increase of publicness of energy security and therefore may improve global energy governance at least in two ways. The first is by developing institutional innovation as: the creation of new institutions, the nesting of institutions within others, and the adaptation of existing institutions. The second, and maybe more plausible, is developing a more geopolitical regional strategies leaving the global strategies in a second level.

Chapter 2

Energy Security and Geopolitics[2]

2.1 Introduction

Energy issues have been extensively analyzed through a geopolitical prism. Political and economic relations resulting from the geographical distribution of oil resources can be described as a complex, interdependent system of producing, consuming and transit countries. Given that supply disruptions have less of an impact on producer than import countries, energy interdependence tends to have an asymmetrical relationship in the short term. Owning reserves, therefore, is a position of material strength. This asymmetry, however, may dissipate in the long run, as economic growth in producing countries is highly dependent on energy exports, and large consumers can leverage their position as major importers to influence producing countries' energy policies(Escribano & García Verdugo, 2012), as has been highlighted for EU-Russia energy relations (Kropatcheva, 2011; Ericson, 2009). In fact, history shows that oil has a two-fold purpose as a political weapon: for producing countries to put pressure on consumers (as in the case of the 1973 crisis) and for consumers to impose embargoes on producers (as in the cases of Iran and Iraq and, eventually, Libya).

Recent contributions to the geographies of oil show how the debate has evolved from the petro-state thesis to the ‘new realities’ without forgetting two more approaches: what Kennedy called ‘petro-capitalism and economies of security and violence’ and ‘socially produced scarcity’ (Kennedy, 2014). Because these are all major intersecting themes, this article tries to expand that research agenda by linking two major areas of work on the geographies of oil—socially produced scarcity and the ‘new realities of oil’—with wider geographical inquiries, mainly global energy governance.

The central message is that the failure of global governance institutions to facilitate cooperation between consumers and producers is transversal to the elements causing the re-emergence of the term ‘energy security’ (Bridge, 2015). Power relationships are the essence

[2] This chapter has been published as: Escribano, G., & Valdés, J. (2016). Oil Prices: Governance Failures and Geopolitical Consequences. *Geopolitics*, 1-26.

of energy geopolitics and, as such, they are highly influential in determining the behavior of oil markets and flows.

Hence, a geopolitical approach to energy does not necessarily have to be opposed to the research agenda on global energy governance. In fact, criticisms of the geopolitical nature of some ideational or normative energy strategies are commonplace in the European discussion (Del Sarto, 2010; Del Sarto 2015). For instance, the Energy Union, the new European energy strategy, does not develop by following a foreign energy policy. Instead, internal EU market rules by extension create an external energy strategy. This has been termed an inside-out approach, affecting both foreign companies that ‘come and play’ and neighboring states that voluntarily choose to adopt EU rules. This ‘normative power’ allows the EU to export a model that stabilizes energy supply in the terms the EU sets (Far & Youngs, 2015). In the presence of significant energy governance failures, global and/or regional, resorting to geopolitical approaches is a second-best solution to avoid or limit energy security risks. For instance, failure to implement a politically sustainable model of energy governance in countries such as Libya may lead to more geopolitically oriented approaches

We argue that energy power shifts are not only unfolding in the classical geopolitical domain of material capabilities and hard power, but also in the emerging arena of ideational and normative geopolitics. To understand this new power shift—and, therefore, the failure of global governance—it is essential to understand the economics behind oil price movements as part of ‘a narrative constructed for and through prices’ to advance a range of commercial and geostrategic interests (LeBillon & Cervantes, 2009).

Traditional geopolitical approaches tend to concentrate mostly on realist doctrines (interest/security-oriented) that are unable to explain normative and ideational (value-based) transformations. The idea behind our argumentation is that a variety of ways exist in which normative and ideational power can be exercised. Hard (military or economic force) and soft (culture, values, norms) power is a continuum, not a dichotomy (Nye, 2004). Normative geopolitics can be seen as a ‘Soft power with a hard edge’ when the capacity to effectively impact the behavior of other actors becomes a consistent policy strategy (Goldthau & Sitter, 2015). The European Commission is aware of this and tries to apply soft energy power to become a global (or regional) regulator, allowing it to secure energy supplies without a defined external energy policy (Youngs, 2009).

Many observers interpret the complexity of energy relations and the oil price fall since mid-2014 as part of a global struggle to obtain cheap oil resources, with the main importing countries in the vanguard.[3] In this regard, the current article agrees that oil reserves have significant potential to stir or shape geopolitical tensions inside and between states. However, this is so not because of the scarcity of reserves but because of their abundance, situating the major producers at the head of this global struggle (Verbruggen & van der Graaf, 2015).

With this in mind, the article analyzes the complexities of global oil governance, its institutions, the role of supply and demand, and the preferences of the different actors as determining factors in the geopolitics of oil prices. The discussion is divided into three sections. The first section analyzes how geopolitical approaches find a niche in global energy governance and normative gaps. In this regard, geopolitics may be thought of as governance by other means. The second section looks at the geo-economics of oil prices, which has changed its focus from the impact of high oil prices in consumer countries to the consequences of an oil price collapse in key global producers; it also addresses some proposals to govern price volatility. The third section is devoted to the short- and long-term geopolitical consequences of low oil prices in producer countries. The last section concludes with some final remarks on the interactions between energy geopolitics and energy governance and the need to fill the gaps in global energy governance to prevent low prices from resulting in geopolitical volatility.

2.2 Governance by other means

The 'new realities of oil' concept is a recent contribution to geopolitical thinking beyond the petro-state perspective characterized by global shifts in the location of energy production and consumption and how this new shift creates a global energy dilemma: 'how to secure the supply of reliable and affordable energy; and how to rapidly transit towards a low-carbon, efficient and environmentally harmless energy supply' (Bradshaw, 2009;

---

[3] During July-December 2014, oil supply was often among the multiple factors causing a drop in oil prices. See, for instance, International Monetary Fund, Learning to Live With Cheaper Oil Amid Weaker Demand, Regional Economic Outlook Update (Washington DC: International Monetary Fund 21 Jan 2015), available at <http://www.imf.org/external/pubs/ft/weo/2015/01/pdf/c1.pdf>; C.K. Ebinger, World Oil Demand: And Then There Was None, Brookings Blogs (2014) available at: < http://www.economist.com/blogs/economist-explains/2014/12/economist-explains-4>; The Economist, 'Why the Oil Price is Falling', The Economist, The Economist Explains (2014) available at < http://www.brookings.edu/blogs/planetpolicy/posts/2014/10/17-world-oil-demand-ebinger >. Two years later, demand factors are still interpreted as a cause of low prices. See, for example: K. Rogoff. 'What is Behind the Drop in Oil Prices ?', World Economic forum article (2016) available at < https://www.weforum.org/agenda/2016/03/what-s-behind-the-drop-in-oil-prices/>.

Bradshaw, 2010) More recently, Bridge has analyzed the process of securitization into this framework, adding four further elements to geopolitical thinking: i) the generalized failure of markets to allocate resources in ways that deliver important public goods; ii) the effectiveness and sustainability of conventional energy provisioning systems; iii) a growing dependency on imports among key consumers such as China, India and the EU; and iv) the shift from military security to an engagement with a more flexible understanding of 'human security' (Bridge, 2015). This article adds a fifth element transversal to the four previously mentioned: the current 'governance by default' framework implies the failure of institutions to facilitate cooperation in some energy governance areas. Therefore, the failure of global energy governance may be seen not just as another element but as a transverse line of interconnection among the other four elements.

This does not mean that the relative failure is caused by the above-cited elements; rather, it reinforces their effect as a catalyst. This relative failure is explored in greater depth in Bridge and Le Billon (2013), where they analyze how the oil governance deficit is due to a variety of material and ideational factors, more precisely: i) there is a lack of agreement on how to address energy governance; ii) there are different time frames in which actors construct their perspectives and strategies; iii) the global oil economy is perceived as a 'zero-sum game'; and iv) both international oil companies (IOCs) and national oil companies (NOCs) are powerful actors with a level of autonomy rivaling country governments and other stakeholders.

These 'new realities', along with the process of securitization, expand the scope of security, contextualizing the flow of energy in relation to the welfare of national populations (Bridge, 2015). Together with this process of securitization, a complex web of different provisions and institutional arrangements that address the multiple facets of global energy governance has been constructed, allowing for multiple equilibriums due to different power balances in each global energy issue. It is interesting to analyze how normative global energy governance has contributed to the reemergence of energy security.

There is a growing body of literature approaching energy issues from the global energy governance perspective (Abbot, 2011; Baker & Stoker, 2013; Carbonnier, 2011; Cherp et al. 2011; Dubash & Florini, 2011; Escribano, 2015; Florini & Sovacool, 2009; Goldthau & Witte, 2009; Goldthau & Sovacool, 2012; Karlsson & Vinkhuyzen 2010; Lesage et al., 2010a; Lesage et al., 2010b). Global governance can be approached through multiple international political economy perspectives. Keohane argues that effective international institutions tend to arise when conflicts of interest are rare and power is concentrated among a group of actors with similar preferences and interest (Kehoane, 1984). Cox identifies three dimensions whose alignment explains the hegemony of a given actor: material capabilities, ideas and international institutions (Cox, 1996). Strange refers to the composite structural power to shape political economy balances, including soft ideational capabilities (Strange, 1994). This framework is useful because it is related to the classic problem of hegemony in international political economy (Oye, 1986; Krasner 1983). Strange describes a fundamental ('sideways') shift in competition between states from territories and resources to market shares in which industrial and trade policies are more important than foreign or defense policies and where economic partners are becoming more strategically relevant than political or military allies. At the same time, there has been an 'upward' shift in authority from the state to international institutions (Strange, 1995). In all these frameworks, international institutions or regimes have clear geopolitical connotations due to their increased authority.

This is also the case with international energy institutions. The creation of the Organization of the Petroleum Exporting Countries (OPEC) in 1960 and its 1968 decision to nationalize hydrocarbon resources ended the control US companies had over world oil resources (Wirl, 2012). Since then, hegemony amongst oil producers has been shared between OPEC and non-OPEC producers. OPEC was, in this regard, an institutional arrangement (a cartel) intended to maximize its members' income from oil exports. This has had clear geo-economic consequences by transferring wealth from oil consumers to oil suppliers. However, governance of the OPEC itself has seldom been easy, in part because geopolitics also plays within OPEC. Internal hegemony has always been disputed between 'doves' and 'hawks'. Venezuela, Algeria, Iraq and Iran are hawks that have traditionally pushed for higher prices, while doves like Kuwait and the UAE are relatively small countries with high production capacities and reserves, pushing along with Saudi Arabia to maintain demand with reasonable pricing (one that does not decrease in excess the demand for OPEC oil). This confrontation generates incentives to deviate from the assigned quota, and there is no conclusive evidence of their ability to act as a cartel, which many authors consider to be limited (Gil-Alana & Barros, 2011; Golsthau & Witte, 2011), to the point of being considered a 'rational myth' (Colgan, 2014), that is, an illusory or false idea that is perpetuated when certain actors have incentives to do so (Meyer & Rowan, 1977). Currently, OPEC has no mechanism to enforce compliance with quota targets, leaving Saudi Arabia as the only member able to significantly respond to changing market conditions (Dibooglu &

Al-Gudhea, 2007). Other OPEC countries can also decide to react to oil price changes unilaterally, but it would mean questioning Saudi Arabian leadership and would therefore destroy the illusion—as in 1995—that OPEC maintains the capacity to behave as a cartel. In the long term, questioning Saudi leadership would not be possible for any individual OPEC member because the kingdom holds one-third of OPEC's production capacity and an even larger share of its spare capacity.[4]

Since the 1973 oil crisis, non-OPEC producers have increased their share of world oil production. Important emerging players have entered the market in recent years. This has further reduced OPEC's market power and challenged its relevance as an efficient institutional arrangement to provide economic demand security (that oil prices will be compatible with internal economic stability). Despite these changes, Saudi Arabia continues to lead the oil market as a last resort producer, since it is the only supplier with enough spare capacity to stabilize the market and offset the loss of production elsewhere (Mann, 2012). Some authors see this spare capacity as a global public good provided by Saudi Arabia (not OPEC), who pays for its maintenance, even though it is for the sake of its national interests (Goldthau, 2012). In a similar manner, the security of shipping corridors, whether Ormuz or Malacca, would be a public good provided by the US that Asian and European consumers free-ride.

On the demand side, the International Energy Agency (IEA) was created to coordinate the Organisation for Economic Co-operation and Development (OECD) members' response during the 1973 oil crisis. Its main achievement is the creation of strategic reserves as a mechanism to solve energy insecurity situations in the short term. But the IEA has also been called obsolete for not including emerging consumers like China and India (Miller,2011; Van der Graaf, 2012) and internally because the voting structure in the Committee on Strategic Reserves is still based on 1973 oil imports and favors the US (Bamberger, 2004). Some authors have suggested that the International Energy Forum (IEF),

---

[4] It is difficult to provide exact numbers on spare capacity due to the great opacity regarding the production capacity of OPEC countries. For instance, our own OPEC Monthly Oil Market Report offers data on total OPEC crude oil production from direct communication and secondary sources. See, for example, OPEC, OPEC Monthly Oil Market Report April 2016 (Vienna: OPEC 2016) available at <http://www.opec.org/opec_web/static_files_project/media/downloads/publications/MOMR%20April%202016.pdf >. To give a general idea, the EIA estimates that Saudi Arabia usually keeps more than 1.5 - 2 million barrels per day of spare capacity. Energy Information Administration (EIA), What Drives Crude Oil Prices? An Analysis of 7 Factors that Influence Oil Markets, With Chart Data Updated Monthly and Quarterly, Online (EIA 2016) Available at: https://www.eia.gov/finance/markets/supply-opec.cfm.

which includes consumers and producers, could provide alternative energy infrastructures and even maintain idle capacity (Harks, 2010).

However, new issues are emerging in the field of energy security, including renewable energy, sustainability, energy poverty, energy efficiency, and the good governance of energy resources (Carbonnier, 2011). Thus, a growing agenda for global energy governance has been established, with dedicated institutions or arrangements such as the International Renewable Energy Agency (IRENA), the UN's Sustainable Energy For All Initiative (SE4all), and the Extractive Industries Transparency Initiative (EITI). While they may be characterized as normative or ideationally led arrangements, all these initiatives have potential geopolitical implications.

In Cox's terms, some of the institutions mentioned above are linked to material capabilities (such as OPEC's oil reserves and production or the IEA's strategic stocks), while others reflect ideational factors (Cox, 1996), as is the case of the SE4all or EITI. Others, like IRENA, project both the ideational narrative of sustainability and the material capability of renewable energies' installed capacity. In fact, concerning energy, the global realm seems less prone to narrower regional approaches to geopolitical behavior and more receptive to ideational drivers. In this regard, global energy is experiencing two simultaneous transitions that replicate Nye's horizontal and vertical power shifts. A horizontal power shift is a power transition among countries, regions or states. Vertical power shifts are the diffusion of power from states to non-government actors or people and from material to ideational drivers (Nye, 1990).

First is the well-known standard geopolitical horizontal power shift towards new actors, be it new hydrocarbon and renewable energy producers entering the market or new global energy consumption patterns displacing demand towards emerging countries. Energy governance has increased in complexity as the world becomes more multi-polar, and only international energy agreements that reflect this growing multi-polarity can succeed (Lesage et al. 2010b). In fact, in areas where the markets (global or regional) are the main force that regulate energy flows, the trend can be addressed more precisely with the concept of inter-polarity (Grevi, 2009). The global energy landscape is multi-polar and is experiencing a rapid increase in the interdependence of the main energy actors, continuously reshaping the distribution of supply and demand centers and the strategies to ensure energy supplies. These factors, in turn, are considered the main cause of the loss of effectiveness of conventional energy systems (Bridge, 2015).

But there is also a vertical shift towards soft energy power based upon norms and ideational drivers such as sustainable energy development, fighting energy poverty, or the good governance of energy resources. Both shifts are relevant because changing structural global balances of power tends to intensify classical geopolitical nationalist competition (Gilpin, 1987). However, it may also lead to normative competition and a race to the top among soft normative powers, as happened with the provision of a global transparency standard for the management of energy resources among the EU, the US and the EITI. Normative competition is far from being geopolitically neutral. On some occasions, it can turn into 'hybrid competition' that includes classical geopolitical struggles.

For instance, the current Russian-EU rivalry over Ukraine evolved into open conflict and the annexation of Crimea after Ukraine discarded its inclusion in the Eurasian Economic Union and opted to sign an Association Agreement with the EU. In this case, normative competition between the EU and Russia also affected energy (mainly, but not solely, gas) because Ukraine had decided to stay in the European Energy Community Treaty and, therefore, to gradually adopt European energy norms and regulations. The European soft normative approach has nevertheless been criticized on the grounds that it may have hard consequences for the populations concerned (Tocci, 2008) or may even constitute an empire by example (Zielonka, 2008) or a blueprint for normative hegemony.[5]

This vertical shift towards soft energy power based upon norms and ideational drivers is the basis of the new conception of human security that has boosted the reemergence of the energy security debate. The are two main camps in this debate: scholars defending the multidimensionality of the concept and those emphasizing the need for a narrower definition to make it easier to balance its benefits when compared to other policy objectives. The vertical shift towards soft energy power reflects the struggle for ideational hegemony in the global political economy between an old governance system led by the IEA and OPEC and the 'new realities' characterized by a myriad of energy institutions without clear leaders.

[5] For a historical analysis of normative hegemony, see: C. A. Kupchan, 'The Normative Foundations of Hegemony and the Coming Challenge to Pax Americana', *Security Studies* 23/2 (2014) pp. 219-57. The EU-Russia case is deeply analyzed in H. Haukkala, The EU-Russia Strategic Partnership the Limits of Post-sovereignty in International Relations (London: Routledge 2010).

In this regard, the reemergence of the energy security narrative is part of a struggle to impose a certain geopolitical discourse that only very powerful or hegemonic states can link to an international power practice influencing world order (Mamadooh & Dijkink, 2006). Such a framework of analysis incorporates a new element into the discussion: this article argues that the situation described above indicates a kind of 'default governance' that is able to facilitate cooperation in some areas but not all, and not necessarily in a consistent manner, with some institutional arrangements having different and even conflicting goals. Thus, energy power is diffusing not solely because of the emergence of new suppliers, consumers and transit countries. Poly-centric energy governance is also due to the creation of new institutional arrangements that tend to constrain energy hegemony, sometimes arising from soft power approaches and their related ideational drivers (Goldthau, 2014).

This process is changing the geographies of oil. For instance, the prospect of declining oil demand to reduce CO2 emissions incentivizes the use of alternative resources and causes oil exporters to sell more of their oil regardless of price slumps (Sinn, 2012). In this regard, instead of facing an expected shortage of hydrocarbons, the world still hosts plenty of oil, and the focus has changed from the struggle to obtain cheap oil resources by importing countries to the consequences of an oil price collapse in key global producers. The efforts and mechanisms devoted to securing oil flows through global governance systems have failed, which may indicate that the discourse based on material capabilities and hard power is insufficient in exerting power in a consistent manner in the new oil realm. It is precisely in the gaps left by global governance failures where geopolitical approaches find their niche to propose alternative external governance pathways. To paraphrase Clausewitz, geopolitics may be considered in this regard as governance by other means.

2.3 The Geo-economics of Oil Prices

In early 2010, OPEC established reference prices of $100-110 per barrel, which remained the same during the period 2011-2014. Since the Arab revolutions of 2011, markets have remained tense due to geopolitical uncertainties, but price risk premiums have been diluted over time, as the conflicts in Iraq, Syria and Libya have had a limited effect on production. At the end of 2014, oil prices fell over 50% to the range of $50-60. They reached a minimum of $30 in early 2016 before recovering again to the $40-50 range. Given oil's weight in world trade, the sharp drop represents a momentous redistribution of income between exporters and importers that is altering the balance of global, regional and local geopolitics. The International Monetary Fund (IMF) suggested that 96% of the drop in West Texas Intermediate (WTI) oil prices until October 2014 was mainly due to weak global demand. But from mid-October until early January, the IMF attributed the price decrease to increased supply, attributing 58% of the drop to supply and only 42% to demand (IMF, 2015b).

The IMF's seemingly contradictory arguments can be explained by the fact that insecurity and price shocks in the oil market can be caused, on the one hand, by investors and speculators who generate market distortions, since market prices are rigid, and, on the other, by supply changes rooted in geopolitical factors (Luciani, 2011). Moreover, these two sources of insecurity are often closely related due to the financialization of oil markets and, therefore, to the social construction of scarcity. The degree to which the oil market has become infused by the logic of finance makes speculation on financial markets a decisive factor influencing oil prices to the point that prices reflect positions on paper oil rather than in physical oil markets (Labban, 2011). The 2014 fall in oil prices confirms that one of the consequences of this financialization is the amplification of uncertainty generated by geopolitical factors and, thereby, the power associated with the so-called ‘oil weapon’.

In fact, the more recent economic analyses concur that there are two main causes of the initial drop in prices: the rapid increase in unconventional oil production and the slowing-down of the global economy, particularly Chinese demand for oil (IEA, 2015a; Baffes & Kose, 2015; WB, 2015; EIA, 2014). These two factors have highlighted the fundamental principles of the market: according to different estimates, the oversupply of oil could be between 1-2 million barrels per day out of a global production of 90 million (IEA, 2015b; IEA, 2015c). Traditional geopolitical risks related to access to oil resources have become secondary, and the focus has shifted to OPEC, especially the big Gulf producers. The reason is that in the ‘governance by default’ pattern described above, markets expected a response from OPEC to keep prices high. However, this time, Saudi Arabia and its Gulf Allies reacted by preserving market share rather than by defending high oil prices and adjusting their fiscal budgets to a lower-for-longer oil environment.

The 2014 price fall reveals the failure of the governance mechanisms for oil markets born in response to the oil crisis in the 70’s and, thus, the provision of energy security through the mere liberalization of energy markets. Here, we are making reference to the liberal position on oil governance based on the idea that market mechanisms are sufficient to ensure a reliable and affordable energy supply. The price is therefore a signal of oil scarcity or abundance and is capable of ensuring optimal levels of investments in order to avoid oil shortages. This approach to energy security dominated the liberalization and financialization of commodity markets, including oil, since the 1980s, a period characterized by low oil prices due, first, to the role of Saudi Arabia as a swing producer for OPEC, and in the 1990s due to the increased production that caused a major price collapse coupled with the first Iraq war and the subsequent oil embargo.

During this period, the IEA and OPEC countries maintained a de facto agreement by which low oil prices determined the security of the system by ensuring Saudi dominance in the region in a period of increased political instability (Iran-Iraq war and the Iraqi invasion of Kuwait). The end of the honeymoon between OPEC producers and IEA consumers and, therefore, in the liberal energy security system was due to a shift in Saudi Arabia's energy security strategy from a market share policy to a (high) price defense policy. This strategy was undertaken specially after the Asian financial crisis in 1998, when the decrease in OPEC production raised oil prices to levels comparable to those of the First Gulf War. But if this was not enough to evidence the collapse of the energy governance systems, the second Iraq war and subsequent price escalation in the 2003-2008 period indicated that the liberal energy security system had failed because it would no longer be maintained by the Saudi spare production capacity.

The existence of functioning oil markets capable of sending correct signals to investors through prices is especially important for energy governance because the oil price is the key for investment decisions, and both its volatility and decline jeopardize the viability of billions of investment dollars. The whole energy industry, from upstream to downstream, is plagued with sunken costs. Once the investment is made, oil projects continue to operate until prices fall below the variable costs. A second problem is the time needed to develop projects, which ranges between five and ten years from the time they are approved until they begin operating. This exposes returns on investment to high levels of uncertainty, making it difficult to access finances. Moreover, uncertainty in oil markets forces these projects to be developed largely with internal private resources. Finally, low elasticity of both demand and supply in the short term makes price signals ineffective at balancing the market, meaning it can only be balanced by changes in income and investment, adjustments requiring long periods of time (Fattouh, 2006).

Therefore, prices and quantities are the two concepts upon which these energy security discourses are constructed. This particular use of the term energy security is a powerful framing device: it constructs worlds, normalizes certain practices of resource use, and establishes grounds for intervention (Bridge, 2015). Due to the importance of price stability, all the proposals devoted to increasing energy security through cooperation between producers and consumers have been designed to reduce price volatility. Such a geopolitical approach to energy does not necessarily have to be opposed to the development of genuine global energy governance. The proposals to tackle price volatility have moved from a position favoring exclusive reliance on deregulation and, hence, faith in market mechanisms, to another position asking to curb speculation and to seek a fair price for all parties.[6] The proposed solutions, some of which are more plausible than others, have focused on promoting long-term investment by removing the largest possible number of market failures, especially those related to the problems of imperfect information. In this regard, institutional arrangements such as the JODI that provide for a greater degree of information should be expanded to provide a clearer picture of depletion paths and supply trends in producing regions. The increased transparency should decrease uncertainty and limit speculation (Goldthau & Witte, 2009).

Perhaps the main proposal is to form an international committee to decide on price and price bands that may be beneficial to all parties. However, the proposal does not address the mechanisms that would determine these prices nor an explicit strategy for market intervention (Fattouh & Allsopp, 2009). The most critical problem with a price band is whether it is possible for exporters and importers to agree on a price range. Even if this is accomplished, a second potential problem would be agreeing on how to intervene in the market when the price approaches the bands' lower and upper limits. Finally, once

---

6Defenders of the market mechanism consider that price containment in an attempt to reduce the dependence on oil by subsidizing alternative fuels or creating fuel efficiency standards wastes taxpayer dollars and does little to reduce dependence on oil. The democratization of derivates contracts and the opening of access and removal of subsidies to alternative energy sources is the most effective market-driven approach countries can take to respond to oil price volatility. More-specific proposals include the standardization requirements for the OTC derivative commodities. These measures should enhance market efficiency and improve systemic risk control by displacing swap contracts that are made bilaterally between private counterparties, allowing the holders to bypass exchange reporting requirements and position limits. Position limits have also been considered by policymakers as one of the most effective ways to improve market efficiency. Nevertheless, this proposal attracts the most criticism from the financial industry, which adduces that it may be entirely counterproductive to prevent market manipulation. See: M. A. Levi, D. P. Ahn, N. Loris, D. J. Weiss, and R. McNally, How to Handle Oil Price Volatility. Council on Foreign Relations, Expert Roundup (2012) available at <http://www.cfr.org/oil/handle-oil-price-volatility/p27667>.

mechanisms have been established and agreed upon, deciding how to adjust margins could become another potential problem in the future.

The use of strategic reserves has also been presented as a mechanism to maintain prices at a certain level (Lucciani & Henri, 2011). These reserves do currently exist, but they were created in order to avoid the effect of short-term supply disruptions. For these reserves to be effective and truly have a continued effect on prices, they need to be expanded and need to allow individual investors to become involved in managing them. This proposal, which is attributed to Robert Mabro, requires an operational definition like the one used for a number of years by the US and Saudi Arabia (Bressand, 2010). The agreement establishes that the US provides military assistance in exchange for the Saudis ensuring the flow of oil in order to avoid price hikes during times of emergency, such as the Iranian crisis of the late 70's.

In 2008, the EU founded the SECURE project (Security of Energy Considering its Uncertainty, Risk and Economic implications) in order to find specific solutions to energy security. The project defined price volatility and its fundamental unpredictability as the main obstacle to oil supply security. As part of the project, the program reviewed a new set of proposals to increase oil market security by: i) increasing the amount of oil negotiated on the open market to enhance the physical base for price discovery; ii) increasing reliance on long-term pricing, as such prices are less influenced by the short-term imbalance of supply and demand; iii) providing a higher level of demand security with take-or-pay contracts that ensures income to producing countries, reduces the risk of disruption and improves the investment environment; and iv) promoting vertical integration in order to expand market opportunities to oil companies. Although the analysis concluded that none of these approaches alone is sufficient to stabilize prices, when implemented collectively they may succeed in reducing oil market volatility (FEEM, 2008; OME, 2008).

Ebrahim et al. also suggest the adoption of both supply and demand side policy. For instance, the introduction of a legislative requirement to maintain individual strategic oil reserves could provide insulation from price volatility to companies and industries heavily reliant on oil, combined with demand-side policy strategies that disincentivize oil consumption through tax and subsidy reform, improving sectoral energy efficiency (Ebrahim et al. 2014).

In the current context, the new geopolitical approaches presented above present the fall in oil prices since 2014 as part of a "narrative constructed for and through prices" to advance a range of commercial and geostrategic interests (LeBillon & Cervantes).

The global energy governance proposals are developed from a liberal perspective and are, therefore, devoted to price control in order to avoid the negative consequences of volatility and oil scarcity, not only for the consumer but also for producing countries and regions. Under such an energy security conception, the main risks perceived by investors in the long run are: i) rising demand from developing countries, specially India and China; ii) a decline in conventional sources of oil; and iii) concerns about the impact of climate change policies on fossil fuel consumption. These three factors have constructed a narrative where the focus of the oil governance debate is oil scarcity, with price volatility being a consequence of disruption fears. This perception fostered the development of non-conventional resources to avoid the negative effects of future high oil prices and increased volatility. The continuous increase in oil prices in the 2002-2008 period, with a peak of $145 per barrel, created the perception that a new $100-120 band was "fair" or "natural" in the sense that it was supposed to be the result of supply and demand dynamics in a competitive market. The development of non-conventional resources entails forms of violence different from war but still connected to a specific energy security conception framed on the scarcity of oil resources and securing supply, even when it implies the use of more polluting and GHG emitting extraction techniques (Zalik, 2010).

Nevertheless, these negative consequences are not perceived as risks, because the energy security discourse about the scarcity of oil in a scenario of growing demand requires such extraction practices. Paradoxically, in 2014, the increase in non-conventional production and the financialization of oil markets together created a supply pressure that, followed by the strategic response of Gulf producers to retain market shares, resulted in a sharp drop in prices. In particular, low oil prices are a consequence of the US pursuing energy independence through the so-called unconventional revolution and a shift in Saudi Arabia's market strategy. These two strategies are a response to already mentioned shifts in global energy markets and, unfortunately, are not mere externalities associated with the presence of volatility in oil markets. Rather, they are the consequence of political decisions in response to commercial and geostrategic interests: while for oil importers, it is mainly an economic issue, for oil mono-exporters, it is the viability or potential collapse of their political regimes that is at stake. Importing countries calculate GDP and unemployment impacts, while many exporters experience internal instability and strategic weakening in some of the more unstable parts of the world.[7]

Huber suggested that contemporary debates on the geographies of oil might question the role of violence not as a product but as a generator of scarcity (Huber, 2011). Therefore, from a geo-economic perspective, the key to understanding the evolution of oil prices is Saudi Arabia's reaction to three vectors: supply, demand and geopolitical scenarios. The increase in US unconventional production has altered the structure of global oil flows.[8] While a few years ago, competition between the US and China for control of oil resources appeared to be inexorable, the current reality is that today the US imports hardly any oil and no gas from Africa (Burgos Caceres & Ear, 2012; Hartemi & Wedeman, 2007). In response to increased North American production, producers have redirected their exports to Asia and Europe, flooding the markets and further threatening Saudi Arabia's market share.

The impact of increased supplies on oil prices began to be felt more acutely during the late summer of 2014—the season with the greatest demand for petroleum products—with the accumulation of negative indicators regarding global economic growth. Shrinking growth forecasts for oil demand by the IEA worsened market sentiments. Saudi Arabia had been sending ambiguous signals, and in early-October 2014, it offered discounts on the official selling price of its crude, which was interpreted as the first move in a price war to maintain its share of the Asian market. Information then filtered out that discounts were being offered to European operators. The change in strategy was evident: lower prices to maintain market share in the short term, raise it in the medium term, and recover income once prices recover in the long term. Saudi Arabia has continued to offer discounts to its European and Asian clients during 2015 and 2016.

---

[7] For instance, some forecasts estimate that the impact on GDP is significant and heterogeneously distributed. Within Europe, Central Europe is, *a priori*, the area most benefited, with an impact of up to 3% on Bulgaria's GDP. This impact is somewhat lower, between 1.0 and 1.5%, in Poland and Czech Republic. In the Eurozone, the impact is expected to be 0.9% in Italy and 1.0% in France and Germany, with Spain and Greece being the most significant beneficiaries at 1.5% and 2.2%, respectively. E. Norland, The Geopolitical and Economic Consequences of Lower Oil Prices, (Chicago: Chicago Mercantile Exchange [CME] 2015).

[8] The US has greatly reduced oil imports. Based on net petroleum imports (crude oil and petroleum products), in 2015, approximately 24% of the petroleum consumed by the United States was imported from foreign countries, the lowest level since 1970, the same year U.S. oil production peaked. If the balance is not smaller, it is because of the different crude oil grades. Many US refineries can only refine certain grades, and most of the US national production is light sweet oil. The resulting petroleum products are either consumed in the US or mainly exported to other Caribbean and South American countries.

In the current context of oversupply, the Saudi argument is economically impeccable: producers with higher marginal costs must first adjust their production. The more this reduces new investments in more-costly resources—such as unconventional oil, deep water oil, oil sands and extra-heavy oil, or even oil from the Arctic—the better. Saudi Arabia, Kuwait, Qatar and UAE have the fiscal policy space and foreign exchange reserves to do so, which is not the case for Iraq and Iran, which along with Algeria, Venezuela and Nigeria require prices of $120-130 per barrel to balance their budgets and maintain domestic stability (IMF, 2015b). Given that the energy security conundrum is now more complex and the correction of market failures may not be sufficient, a new perspective on the geopolitics of oil prices seems to be needed.

This article does not discard the impact of a large number of habitual factors, such as short-term demand and supply elasticity, sharp declines in investment, political instability in the Middle East, changes in inventories and expectations regarding changing market conditions (to cite but a few). However, it argues that it may be more insightful to explore the interactions between energy geopolitics and energy governance to prevent low prices from unfolding in geopolitical volatility. In this regard, it is suggested that the fall in oil prices is caused by the interaction of a standard horizontal power shift with a number of normative and ideational factors that defines a new vertical shift in global energy. In the current context, oil reserves have significant potential to stir or shape geopolitical tensions within and between states, yet this is not due to their scarcity but to their abundance (Verbruggen & van der Linde, XXXX). The focus has changed from scarcity to abundance, where producers compete with each other for market shares. The next section explores the impact on the main producer countries (Bradshaw, 2010).

2.4 Geopolitical Consequences: The Short and Long Term

Geopolitical and geo-economic consequences can be significant but not necessarily irreversible. First, the fall in prices could change the geographies of oil by limiting the geographical scope of the unconventional oil revolution within, but especially beyond, North America. After a prolonged period of low oil prices, unconventional firms have successfully adapted to the new price environment and are starting to reinvest at the $50 threshold. The expected consequence is that oil independence will be achieved in the Western hemisphere (ScotiaBank economics, 2014; Bank of Canada, 2015). However, many profitable unconventional fields are not economically viable at those prices, nor are many deep-water and small, marginal conventional wells in which extraction costs are above this price range. Beyond North America, Argentina is already experiencing many difficulties developing the Vaca Muerta shale deposits, and the same is happening with the deep-water Brazilian Presal fields. Lower prices could further postpone their development.

The implications for Canada are also severe. Alberta's oil sands are the third largest oil reserves in the world, with 166 billion barrels in 2014.[9] (These are the largest reserves accessible to IOCs, but the cost of extraction is perhaps among the highest in the industry, at $65-95 bbl in September 2015, with a 60% confidence interval break-even price, although costs are likely lower as of September 2016) (Findlay, 2016). Moreover, Canadian crude oil is linked to the Western Canadian Select (WCS), an index traded approximately $15 to $20 per barrel lower than WTI because WCS quality is lower and it has to be transported. Therefore, many oil sands projects may be operating at a loss, but production is expected to continue, as many projects are designed to operate over a period of 30 to 40 years (EIA, 2015a). To support the losses in the short term, several IOCs have started cost cuts, equity raises, and dividend cuts in order to keep investing and managing debt (Van Loon, 2016). Oil producing states have also reduced their incomes, as the oil industry represented the bulk of their budgets. If prices continue in the $40-60 range, oil production and jobs are expected to be maintained thanks to the fact that Canadian oil makes up approximately 40 per cent of US crude oil imports.

According to some estimates, if needed, US producers would take months to adjust their production, but the impact has been immediate on new projects, many of which were paralyzed, forcing companies to make thousands of workers redundant (EIA, 2015b). There are signs that, being subjected to greater competitive pressure, US producers have been able to improve their efficiency and reduce their profitability thresholds, which would serve to put extra pressure on prices in the medium term.10

The selection of projects based on break-even prices will continue, revealing how far the oil industry will go to adjust its costs. In the case of the US, the technology and scale achieved has already lowered costs, but the same cannot be said for deep-water production, where several operators budgeted for 20% less investment by 2015 (Adams, 2015). The most

9 Alberta Energy, *Facts and Statistics* (2016), available at <http://www.energy.alberta.ca/oilsands/791.asp>.

10 Interview to US oil industry analyst, Nov. 2015.

affected region will be the Arctic. For instance, Shell recently announced the decision to end its activity in the Arctic despite having incurred substantial sunken costs. Most IOCs have decided to stop development plans and divert their investments to more-attractive areas (Milne et al. 2015). Shell's decision leaves ENI as the only player in the region with projects in development. If prices remain low, it will probably affect the geopolitics of the Artic, as oil extraction has been one of the most important factors explaining interest in the region for both private enterprises and states (Bruun & Medby, 2014).

It has also been said that because the unconventional oil production cost structure is closer to industrial processes than to traditional extractive industries, this relative flexibility would allow the US to become a new swing producer by increasing production with price rises and reducing it once prices drop. This new role, played so far by Saudi Arabia, would provide the US with a different geopolitical role to play until its production begins to decline. It means that OPEC will not be the only one able to use free market principles in their own interest. The US now resorts to the so-called oil weapon by establishing a cap on global oil prices by increasing its production, although more due to market responses from the private oil industry than to grand strategies designed in Washington.

On the other hand, it is true that OPEC does not have the market power and political weight it had until a few years ago, but projections suggest that it can recover such an influence in the medium to long term. For instance, the Energy Information Administration of the United States (EIA) has projected that unconventional production will stagnate during the second half of this decade and decline at the end of the 2020s (EIA, 2014). IEA expects that by 2040, OPEC will have an even larger share of oil production and will account for nearly half of it. By then, several of its members will most likely have exhausted the bulk of their resources and will not have production quotas, but this is not the case of the Persian Gulf Countries, which will gradually increase their current figure of 27% of world oil production to 33% by 2040 (IEA, 2014). Current demand for oil can be moderated by the slowdown of the global economy, but the trend in the long term is uncertain. Some commentators see oil supply growing in the medium term but expect declines in demand starting in the medium term due to the implementation of policies and regulations to mitigate climate change, as well as expected disruptions to supply from the increasing market share of electric vehicles and electrified transport. This would cause another oil price crash, according to some commentators, as early as 2023, which would, of course, be essentially permanent (MacDonald, 2016; Randal, 2016; Goldman Sach, 2015).

In the short-term, the prolonged price depression entails negative consequences for the most vulnerable OPEC regimes. Price security is particularly significant for fossil fuel exporting states that in recent years increased state spending on the back of resource revenues. OPEC members such as Libya and Iraq (and within it, Kurdistan) remain in an insecure position: they are not subjected to the discipline of quotas, but neither do their governments have full control over their oil resources. Agreements between Iraqi Kurds and the central government are a confirmation of the de facto oil autonomy the former have achieved. Nevertheless, the dependence on oil sales to finance the war makes Kurds (the only real US military train and assist success) more dependent on Turkey and Iran. The Kurd dependence on these oil sales is due to the region's landlocked condition, with a near total reliance on hydrocarbon revenues, growing rentierism, security threats and internal power struggles (Denise, 2015). As for Libya, ministers of the two rival governments struggling for control of the country fought to represent Libya at the last OPEC meeting, resulting in two oil ministers (representing two governments elected by two parliaments) but no interlocutor; a recent campaign by ISIS-affiliated Libyan groups against oil facilities underscores the oil governance failures in the country (ICG, 2015). Both conflicts are at risk of expanding, which will destabilize other areas in the Middle East and North Africa and affect oil supply in the medium term (Gunes & Lowe, 2015).

In the Middle East, this leads to a more balanced geo-economic rivalry between Saudi Arabia and Iran, which may be economically reinforced by the lifting of oil sanctions, despite facing serious challenges to increasing production and being among the most sensitive suppliers to low oil prices. Low prices could have eroded Iran's rivalry with other Gulf producers, thereby raising the cost of not closing the nuclear deal or prolonged and stricter sanctions. The nuclear agreement gives the Iranian regime internal stability and strengthens its position as a regional player, potentially leading to an escalation of tensions with Saudi Arabia.[11] However, low prices are more favorable to Saudi Arabia than to Iran, and although the Saudis tend to follow an economic logic, this is clearly the most positive geopolitical consequence for the kingdom. In contrast, Russian involvement in the Syrian

[11] Even when Saudi and Iranian geopolitical reasoning has lost consistency at the domestic and regional level, the agreement may dissuade cooperation in response to the Islamic State. B. Aras, and R. Falk. 'Authoritarian 'Geopolitics' of Survival in the Arab Spring', Third World Quarterly 36/2 (2015) pp. 322-36; S. Akbarzadeh 'Iran and Daesh: the Case of a Reluctant Shia Power', Middle East Policy 22/3 (2015) pp. 44-54; H. Salavatian, S. N. A. Abbas, and M. Jahanbakhsh, 'Iran and Saudi Arabia: the Dilemma of Security, the Balance of Threat', Journal of Scientific Research and Development 2/2 (2015) pp. 141-9.

conflict, with their open support for Al Assad, has the potential to further destabilize the Middle East, which will directly impact oil supplies in the medium term.

And, of course, the impact has increasingly negative consequences for Russia, probably one of the greatest losers of the oil price fall. If access to Western funding remains closed due to sanctions, Putin may begin to moderate their tactical adventurism in Ukraine and other countries of the post-Soviet space due to the risk of repeating the economic collapse of the Soviet Union. It will also derail the project for a Eurasian Union headed by two mono-exporters of hydrocarbons experiencing serious economic difficulties, Russia and Kazakhstan, and a transit country, Belarus. From the Russian perspective, adding sanctions and the loss of revenue from declining prices to the cost of possible cuts on gas supplies to Europe may prove to be excessively costly for its economy. In fact, the collapse of prices has greatly reduced the cost of Russia's initial offer to Ukraine and facilitated an EU-mediated agreement (Heinrich, 2008). While the most-immediate geopolitical consequences could economically benefit the EU, it is China that will be strengthened the most in the long term. Thus, the fall in prices has already greatly reduced the amount of the contract signed last spring with China to export gas from Eastern Siberia, just before prices would begin to fall.

In the short and medium term, only Europe is in a position to exploit three main advantages. At the economic level, the downward pressure on oil prices represents a positive supply shock that is welcome to avoid the risk of a third recession. Lower energy prices also help European industry regain some competitiveness lost to the US due to lower prices caused by the unconventional oil revolution. Secondly, in the geopolitical arena, the weakening of Russia can help the EU better manage its growing rivalry. If prices were to remain low, the EU may tend to take advantage of Russia's dependence on its gas exports—which are contractually linked to oil prices—to weaken its market power over the European gas market through stricter regulation and implementation of competition policy, reducing the geopolitical dimension to Russia’s gas export policy (Barysch, 2008; Stulberg, 2015). This strategy falls within the framework of a new perception in which energy relations between the EU and Russia are seen as a zero sum game (Casier, 2011).

Finally, the EU may equally be presented with a strategic political opportunity to reduce negative environmental externalities by increasing still-low carbon prices and introducing environmental taxes to partially offset the undesirable effects the oil price fall on energy efficiency. If the Saudi strategy is to inhibit the substitution of hydrocarbons with unconventional or renewable sources or to prevent further oil demand destruction due to improvements in energy efficiency or the electrification of transportation, consumer countries should avoid this result. Both the US and the EU can implement fiscal policies as a means to counter the loss of competitiveness of its energy sources, whether renewable or fossil (Gause III, 2015). Renewable energy sources, like nuclear, are sources of energy indigenous to the EU that are produced at almost zero marginal cost: once the investment is made, there is no price volatility or correlation with other fuels, nor declines, nor associated emission reductions (Escribano et al., 2013). These resources generate soft energy power, in Nye’s sense of attracting other countries and even companies to an energy model like that of the EU, and this is more attractive for emerging economies than those mainly based on fossil fuels (Nye, 2004).

In Latin America, Venezuela will most likely experience reduced profitability in heavy crude from the Orinoco belt, and it will face increased competition in Asia due to the consequent cost-discounts and the terms and conditions of the special agreements it has with China. US light oil fracking has displaced Venezuelan heavy crude, forcing Venezuela to seek new markets. Venezuela's problem is that its heavy oil can only be processed in certain refineries, thereby reducing its export options. By replacing exports to the US with exports to China—increasing transportation prices and relying on loans-for-oil—PDVSA has linked the fate of the country to Asian demand.

Existing evidence indicates that there is a political cycle in which high prices facilitate nationalization and low prices liberalization, potentially weakening the appeal of the neo-extractivist models of some ALBA (Bolivarian Alliance for the Peoples of Our America) countries and, in general, of nationalist policies in the other production models. The IMF warns that with a fixed exchange rate, Ecuador and Venezuela will have to strengthen their monetary policy frameworks to prevent depreciation leading to higher inflation, thereby forcing them to adapt to a prolonged period of deteriorating terms of trade (IMF, 2015a). In this context, low prices represent an existential threat to Chavez's legacy in Latin America, especially after his successor Mr. Maduro lost the recent legislative elections (Escribano, 2013).

Mexico's energy reform may not have the desired effect, at least in the short to medium term. The new status of PEMEX oil and regulatory changes now allow IOCs to enter the market, which, until recently, has been closed. However, development forecasts are based on a price scenario of $100 per barrel. Amid expectations that some of the sites will ultimately not be exploited, there are plans to delay public tenders until the environment is more favorable for investments. At the moment, PEMEX may consider lowering the wages of its workers, who have the support of the country's strongest union, which could put the government in a serious predicament if they were to call a strike (Malkin, 2015).

Something similar occurs with ultra-deep-water fields in Africa, which could experience a significantly reduced investment in new projects and returns from those already operating. In particular, Nigeria and Angola would be economically weakened, damaging expectations of whether many African countries will be able to replicate the emergence of Gulf of Guinea producers, from Equatorial Guinea to Sierra Leone. Furthermore, Nigeria, which is conducting a war against Boko Haram that has recently spread to Niger and is encountering a renewed conflict with the Niger Delta rebels, needs additional financial resources to compensate for the loss due to low oil prices. The flow of investments may also be reduced in sub-Saharan Africa, one of the areas with the largest growth potential. Large oil reserves have been discovered in Mozambique, Tanzania and Angola, followed by other smaller fields that are already operational in Chad, Ghana and Equatorial Guinea.

The development of the energy sector in these regions has been spectacular, but now the most export-dependent governments are being forced to reduce their budgets, which together with higher expected inflation, can provoke large protests and destabilize local governments (IEA, 2014 World Energy Outlook). If the extraction of oil resources comes to a halt in the new African oil regions, the geopolitical competition between China and the US for energy resources in Africa could completely disappear in the short term, with China becoming the strategic energy market for African oil (Carmody & Owusu, 2007; Myers, 2014).

2.5 Final remarks

This article has tried to link two areas of work on the geographies of oil: socially produced scarcity and the ‘new realities’ of oil with global energy governance. It argues that geopolitical approaches find a niche in the vacuum left by the complexities of global energy governance and that such a failure adds a new transversal element causing the reemergence of oil geopolitics as ‘governance by other means’ as an alternative to failed external energy governance solutions, given the generalized failure of markets to allocate resources and deliver global public goods. Regarding oil, the main governance efforts have been devoted to reducing oil price volatility through liberalization, financialization and increased transparency to mitigate the effects of incomplete information. Unfortunately, this market approach has not been sufficient to stabilize prices and increase efficiency.

Energy power shifts are not just unfolding in the classical geopolitical domain of material capabilities and hard power. The emergence of soft energy power in the form of attractive energy models linked to sustainability, transparency or universal access constitutes a vertical power shift intimately related to global normative energy governance. This process is closely related to the shift from military security to 'human security'. The new geographies of oil erode the authority of the institutions providing security of supply to markets: IEA's and OPEC's influence in world oil markets has decreased to the point of being considered respectively obsolete and a 'rational myth". Institutions devoted to increasing cooperation among producers, consumers and transit countries such as the IEF or the Energy Charter have proven unable to make a difference under the 'new realities'.

For instance, the prospect of declining oil demand and stranded assets imposed by environmental policies to reduce CO2 may push prices down. The current low oil prices may be facilitating polices aimed at the adjustment of energy prices so that they reflect negative externalities. These policies will directed toward the international objectives of reducing climate change. Institutional advances in ensuring transparency in oil governance are another example of a 'vertical' or 'upward' authority shift from hard to soft energy power, represented by multi-stakeholder initiatives such as EITI or the US and EU enacting stricter legislation regarding oil-related payments from companies to producer countries.

Chapter 3

Arbitrariness in Multidimensional Energy Security Indicators

3.1 Introduction

This article is motivated by the abundance of methodologies proposed to construct energy security (ES) composite indicators. In a recent survey of the literature Ang & Choong (2015) identifies 53 ES indicators on a survey of 104 studies from 2001 to June 2014. Their conclusions signal that their development is still in the stage of infancy from a methodological perspective. The aim of this article is to contribute to the debate on the construction of ES indicators by providing a better understanding of the various methodologies that are available.

There is a fundamental division in the ES indicators literature between those who choose to extend the concept of ES and those who do not. This decision in effect divides the indicators research community into two camps. The ones focused on one of the core “dimensions” or “aspects” of ES as the economic or security of supply dimension and the ones extending the concept to a multidimensional perspective. Contrary to the approaches proposing a concept of ES rooted on the threats to national energy supply, by instance, to geopolitical risks of short-term disruption to international (i.e. cross-border) flows of oil and gas, multidimensional analysis modifies the object of security: it contextualizes the circulation of energy in relation to the welfare of the national population, the impact on environment or the regulatory framework.

The concept of ES that is adopted in the multidimensional studies is what has been identified with a broadened definition of the concept. The characteristic of this approach is the expansion of the scope of security far above the standard definition of prices and quantities. For that reason, altogether with the risk associated to energy supply, new dimensions are included in order to embrace the impact of energy systems to factors essentials to the reproduction of social and economic life. Moreover, multidimensional studies can be divided between the aggregators, who believe that a composite indicator can indeed capture reality of energy systems and is meaningful. Particularly they argue that they are extremely useful in garnering the attention of policy makers. Besides, the non-aggregators who believe one should stop incorporate dimensions as the meaningfulness of the concept decrease.

The ambition of this article is the identification of the main methodological challenges for the production of a composite indicator able to provide meaningful quantitative knowledge about energy security. From a critical analysis of the methodological characteristic of composite indicators, the level of consistence and arbitrariness of the different methodologies for the construction of composite indicators are evaluated, with a special attention to the interrelations between the ES concept and the aggregation techniques applied. The reason to focus on this specific branch of the literature is that multidimensional indicator construction implies the inclusion of very different data, usually expressed in different scales and therefore requiring the use of specific methodological tools to handle such features.

The main task of all ES indicators is to provide quantitative knowledge about ES in a way that can make heterogeneous threats to ES commensurable. Nevertheless, the conclusions of this study prove the high level of arbitrariness in the methodological choices and the lack of consistency between such choices and the argued energy policy targets. Furthermore, the study notes the absolute necessity to develop a more consistent approach signaling the main drawbacks of the indicators review.

To do that, the article reviews the main methodological steps for the construction of ES composite Indicators in 16 studies. The first section describe the methodology applied in this study. It frames the ES concept used on multidimensional indicators and describes the main characteristics of the methodology, starting with data normalization to allow comparisons, the weighting of simple indicators, their aggregation and the sensitive analysis. As in Böhringer & Jochem (2007) this article will focus on the characteristics of the data and the meaningfulness of the final indicators in the sense of Ebert & Welsch (2004). Section three presents a resume of the main characteristics of the indicators reviewed. Fourth section present a discussion of the different methodologies signaling their consistence with respect to the formal requirements. Finally, the last section presents the main conclusions.

3.2. Methodology

Although in the last 10 years has been a period of intense proliferation of ES indicators or indexes, it has not been systematically followed by a discussion on the methodology behind the construction of such indices. In the literature, the criteria for the constructing appropriate ES indicators have been poorly discussed and only some contribution exist on this topic. This contrast with the development of the quantitative analysis on other scientific areas, especially ecological indicators, that during the 90 was object of intense research (Böhringer & Jochem, 2007; Singh, 2012).

The first discussion on the methodological challenges of creating comprehensive ES indicators is rather recent, and appear in Sovacool & Mukherjee (2011), Cherp (2012), and Sovacool (2012). This public discussion raised various sources of disagreement amongst energy experts: i) selection of indicators; ii) priorization of areas; iii) weighting procedure; iv) scoring; v) the use of quantitative versus qualitative methods; vi) scale; vii) comprehensiveness; viii) temporality and context; ix) data quality and availability.

Following the debate Cherp & Jewell (2013) highlighted that any quantification of ES requires certain methodological choices, staring by the election between concerns: facts and perceptions and the scope: generic and specific. Moreover, the authors present a five stages procedure for the construction of a ES index: i) defining ES for the purpose of the assessment; ii) delineating vital energy systems; iii) identifying vulnerabilities of vital energy systems iv) selecting and calculating indicators for these vulnerabilities; v) interpreting the indicators to answer the questions posed by the assessment. During the subsequent steps the construction of the analysis is confronted to many methodological choices, among which the selection of indicators, choice of weights or aggregation procedure are notable examples.

The first three stages are intrinsically connected to the definition of the term ES which definition is rather vague and subjective (Chester, 2010). As ES indicators may be constructed to respond to the characteristics of specific countries or regions ES is a highly context-dependent concept. For that reason, in any methodology the first should be devoted to present a definition that allows to identify the main characteristics that energy systems need to have the adjective of "secure". Moreover, changes in the concept over time, as a result of the evolution of energy systems and energy landscape, are expected (Alhaji, 2008). The importance of giving a clear definition of the concept lies in the identification of threats and risks that will define the indicators choice and their relationship in the subsequent steps.

The technical characteristics of composite indicators construction are addressed more deeply in Narula & Reddy (2015). Reaching the same conclusion as Winzer (2012) and Sharifuddin (2014), the authors carry out a comparative assessment of various ES composite indicators finding that the resulting country rankings vary widely across indices. The perhaps unsurprising result, is mainly due to differences in the use of different simple indicators, weights and normalization methods (Gómez-Limon & Sánchez Fernandez, 2010).

In this paper emphasis will be placed on the requirements for ES indices that have to do with the normalization, aggregation, and weighting of the simple indicators. Nonetheless, the issues related to these three procedures are not independent and are associated to previous methodological choices (Nardo et al. 2005). The objective of these critical steps in is to reduce the sources of uncertainty and imprecise assessment related to the normalization aggregation and weighting as much as possible.

The process of transforming the variables in a way which would make the comparison possible could be done by standardization or normalization. For this, different transformations of the variables can be used, but the choice of one or another method does affect the final output and each method has its own contras and pros. By instance, ranking signifies a loss of information on absolute levels and the impossibility to draw any conclusion about difference in performance. Using Re-scaling or Min-Max solves this problem but the minima and maxima could be unreliable outliers, and have a distortion effect on the normalized indicator, disadvantage shared by the Distance to a reference normalization method. Therefore, as pointed out by Nardo et al. (2005) the normalization of data implies a value judgment, as different scales could not be harmonized in a meaningful manner.

The choose of the weights is the following step in the construction of composite indicators. Weighting involves potentially normative 'quotas of substitution' (Freudenberg, 2003) defining the relationship between indicators. Ang & Chong (2015) report that the most used method in weights assignment in ES indicators is equal weights. Such as any other weighting scheme, the equal weighting scheme implies, in interplay with choices about the transformation and substitutability, specific trade-offs between the dimensions, that can and should be made explicit, and might be considered reasonable or not (Decancq & Lugo, 2010).

To change the importance of different dimensions, weights can also be set in an arbitrary, but unequal way. Commonly used methods for unequal weighting include weights based on statistical models and weights based on public/expert opinion. In their review of the literature Ren and Sovacool (2014) reports that usually researchers or policy makers decide to give more weight to dimensions that are deemed to be more important. In that case, the choice of unequal weights is based on the normative assumption that all countries value some "objective" dimensions equally and above the "subjective" dimensions.

The type of aggregation employed is strongly related to the method used to normalize the individual indicators. By far the most widespread linear aggregation is the summation of weighted and normalized individual indicators (Ang & Chong, 2015). With this method the score of an aspect can be a simple average of the scores of its elements, reflecting the equal importance attached to the various elements within each aspect. Although widely used, this aggregation imposes restrictions on the nature of individual indicators. In particular, Ebert & Welsch (2004) have shown that the use of linear aggregations yields meaningful composite indicators only if all data is expressed on a partially comparable interval scale.

Based on the interpretation of composite indicators as representations of a preference ordering on states, the criterion proposes that ordering should be invariant with respect to admissible transformations of the underlying variables. By instance in the case of CO2 emissions the ordering should not vary if the indicator is expressed on tons per capita or kilograms per capita. Indices which represent such orderings are called meaningful. Table 1 provides an overview of the Ebert & Welsch (2004) aggregation rules for variables with respect to scale and comparability: interval-scale non-comparability (INC), interval-scale full comparability (IFC), ratio-scale non comparability (RNC), and ratio-scale full comparability (RFC).

Table 1. Aggregation rules for variables by Ebert and Welsch (2004)

	Non-Comparability	**Full comparability**
Interval scale	Dictatorial ordering	Arithmetic mean
Ratio scale	Geometric mean	Any homothetic function

The distinction has to do with the characteristics of the data. Data in interval scales do not have any natural zero point (as temperature degrees) unlike ratio scales (by instance percentages). The comparability of scales means that the relationships of every indicator to be aggregated are known and constant. For example, energy consumption per capita and CO2 emissions per capita have in some countries a positive correlation but little is known about the relationship of diversification of energy imports and CO2 emissions (Ebert & Welsch 2004; Bohringer & Jochem, 2007).

However, this minimal methodological requirement is not satisfied. By instance many Sustainable Development Indices violate these qualifying conditions: whereas the aggregation of variables measured in ratio-scale without being comparable would call for a geometric mean, indices are often based on a (misleading) arithmetic mean (Bohringer & Jochem, 2007; Singh, 2012). Regarding ES, Ang & Choong (2015) is the only reference to date, in their survey of the literature they identified that 83% of the 53 indicators on their survey employed the arithmetic mean. Nonetheless, any study has specifically addressed this question so far.

Another undesirable feature of additive aggregations is the implication of full compensability, such that poor performance in some indicators can be compensated for by sufficiently high values in other indicators. For instance, the degree of substitutability between energy consumption and import dependence may not be exactly the same as the degree of substitutability between CO2 emissions and change in land area.

This feature should be in line with the definition of the concept of ES operationalized. By instance, in a conceptualization of the term: “the uninterrupted availability of energy sources at an affordable price” (IEA, 2014). The preposition “at” involve that the availability and affordability should neither be compensable. Besides, the IEA definition continues: “Energy security has many dimensions: long-term energy security mainly deals with timely investments to supply energy in line with economic developments and sustainable environmental needs” (IEA, 2014). Here the compensability is defined by the adverb “in line” which does not fully specify the degree of compensability between energy security, economic developments and sustainable development, but the definition implied that a certain degree of compensability exist. Therefore, the operationalized definition should indicate the range of possibilities so that the researcher can choose the aggregation method most suited to their need.

The use of the different aggregation methods also limits the normalization technics. Following Nardo (2005) not all normalization techniques can be combined with the arithmetical mean, the geometric mean or any semi-compensability function as concave average do not allow for a meaningful aggregation of the parameters. Table 2 shows the possible combinations of the most used normalization techniques.

Table 2. Possible combination of aggregation functions and Normalization techniques.

Aggregation	**Normalization**
Linear	Z-Score, Min-Max, Borda Count, Distance from the Leader, Distance from the Mean

Geometric	Borda Count, Distance from the Leader, Distance from the Mean
Concave Average	Z-Score, Min-Max, Distance from the Leader

As all reviewed techniques have their drawbacks and may affect the final ranking, to avoid this effect, it is possible to calculate all the possible combinations and check for the robustness of the results assessed. This process reduces the uncertainty associated to the choice between the different possible combinations. By instance Luzzati & Gucciardi (2015) use a frequency distribution as a tool to communicate the uncertainty of the ranking to the decision-makers. A more sophisticated statistical method is the uncertainty analysis based on Monte Carlo analysis used in Marozzi (2015), but there are more (Nardo, 2005; Saisana et al. 2005). This robustness or sensitivity analysis is the last step in the construction of composite indicators and is crucial as it determines whether all the previous work has led to a meaningful indicator.

These requirements of formal consistence have the same importance as the more general considerations on the construction of composite indicators expressed by Cherp and Jewell (2013). Additionally, as has been shown, both general and formal requirements are interconnected and affect the outcome to such extend that they determine the meaningfulness and validity of the final indicator. This arbitrariness in the construction of composite indicators result in misleading messages (Saisana & Saltelli, 2011).

3.3 Survey:

The following composite indicators have as common characteristic their multidimensionality although not all of them share the same dimensions. The main characteristics explored are: i) the existence of a definition of ES; ii) the dimensions included; iii) the kind of data with regard to the classification on scale/ratio and comparability/non-comparability and; iv) the aggregation, normalization and weighting procedure. It should be noted that there are other indicators for ES and sustainable energy policy indicators measuring the multidimensionality of the energy policy, but those do not aggregate the individual indicators and therefore have been left out of this analysis (APERC, 2007; Streimikiene et al. 2007; Vera & Langlois, 2007; Patlitzianas et al. 2007; Martchamadol & Kumar, 2012; Chuang & Ma, 2013; Portugal-Pereira & Esteban, 2014). The main characteristics of the indicators are resumed in Annex 1.

3.3.1 Gnansounou 2008

The study is focused on the ES for 37 industrialized countries on 2003. Its multidimensionality is expressed by five dimensions each one having five indicators in RNC: energy intensity, diversity, climate change, transport sector diversity and vulnerability of electricity systems. In order to aggregate such individual indicators into a composite indicator they are normalized using a Min-Max technique and then aggregated using the root mean square of the five relative indicators, with equal weighting. This aggregation technique will be afterwards used by Cabalu (2010). Moreover, the study gives no clear definition of ES and utilized the term of energy vulnerability instead of ES with a very general definition, although the concept and previous work is discussed.

3.3.2 Oinamics (2005):

Oinamics is a risk company and therefore the study does not focus on methodology, nevertheless it is included as to the author´s knowledge it is one of the first studies quantifying ES from a multidimensional perspective. The study gives a clear definition of the used concept of ES as "the ability of a country to protect itself from, or quickly recover from, sudden or prolonged shocks to the country's energy supply or infrastructure" (Oinamics, 2005, p.11). The indicator is designed to cover the characteristics of central and south European countries. The normalization method is the distance to the leader and employs different weighting, giving more importance (double) to the economic factor GNI. The aggregation technique is linear aggregation of the 12 indicators in an INC resulting in a final maximal score of 13 points.

3.3.3 Sovacool & Brown 2010.

Sovacool & Brown focused on OECD countries and their concept of ES relies on the definition of the five included dimensions, in their words "energy security should be based on the interconnected factors of availability, affordability, efficiency, and environmental stewardship". Each concept is analyzed deeply and associated to the 10 indicators in RNC and normalized with a simple scoring exercise: either directional changes or z-scores, to then rank each year´s country performance. The methodology of this article compared to the others here reviewed is quite obscure as far as no formula is given. By instance the aggregation procedure is linear aggregation with equal weighting but it is not explained, a positive point is that at least they criticize their own methodology.

3.3.4 Vivoda 2010

To authors knowledge, this is the first indicator designed on a global scope. It is composed of 44 indicators grouped into a variety of dimensions: energy supply, demand and management efficiency, economic, environment, human security, military security, socio cultural, political, technological and international policy. The indicators are RNC. They are normalized into three different scores: low, medium, and high with no formal aggregation and equal weights. Nevertheless, it is possible to asses if a country has a low, medium or high level taking into account all the 44 results. Moreover, the study provides no explicit definition of ES, instead, it makes reference to the work of von Hipel (2008), explaining the theoretical framework behind the concept of ES and its necessary expansion to include human security and international policy as new dimensions.

3.3.5 Augutis et al. 2011 and Augustis et al. 2012

Designed to asses if the closure of Ignalina Nuclear Power Plant has had a multifaceted impact upon ES of Lithuania, the study does not provide a clear definition of ES, instead some reason and citations are included to support the inclusion of the different blocks. The index is confirmed by 68 individual indicators in RNC and grouped in the technical, economic and sociopolitical dimensions. The raw indicators are normalized using a range from 1 to 15, where normal state is defined by 11–15 points; pre-critical state by 6–10 points; critical state by 1–5 points. Threshold values are identified on the base of technical regulations, normative documents of equipment exploitation and expert assessment in percentage. As in the previous work of Arperguis et al. (2009) the overall ES indicator corresponds to a nested model with different levels of aggregation: Equal weights between dimensions, weights as energy share within technical and economic dimensions, and equal weights in the sociopolitical dimension. In all levels levels linear aggregation is applied.

3.3.6 Sovacool et al. (2011) and Sovacool (2013a and 2013b)

These three articles use the same methodology for the same group of Asian countries using the same indicators. Their concept of ES relies on the work of Vivoda (2010) and Sovacool (2011) and offer the following definition: “how to equitably provide available, affordable, reliable, efficient, environmentally benign, proactively governed and socially acceptable energy services to end-users”. The authors collected data for 20 indicators in RNC for the period 1990 to 2010 in five-year increments for 18 countries. The methodology normalizes the data using the Min-Max procedure and aggregates them using linear aggregation but any formula or detail are given. Nevertheless, the different authors stated that the maximum value possible is 500, which means that they probably used a nested model, by first using the mean in each dimension and then aggregating the dimensions with equal weighting, if not the maximum value would be 2000.

3.3.7 Institute for 21st Century Energy

The Institute for 21st Century Energy 2012 and the successive editions of 2013 and 2015 produces an indicator for 25 mostly industrialized countries. The normalization procedure is “distance from the mean” taking the mean among countries in 1980 as reference. This feature allows the comparison of countries but also of different time periods. The indicators have 8 categories, mainly associated to economic but also environmental issues composed by 29 metrics in the last edition of the international index (2015) and 37 in the US version (2015). IN their methodology different weights are assigned taking as reference both analysis and expert judgment, nevertheless these references are not further detailed. But the US index and the international index differ as the latter does not include the R&D dimension because the data is not available. So the international index includes in general higher weights than the US index for the remaining dimensions. The aggregation method is linear aggregation. As for many other reviewed indices no definition is given, and the only reference to the concept of ES is the index identifying the major areas of risk to US energy supply.

3.3.8 Sheinbaum-Pardo et al. (2012)

The sustainable energy indicator designed for Mexico by Sheinbaum-Pardo et al. is not a strict ES indicator but introduce the question of ES. It is included here as it contains the economic, environmental and social dimension of ES. No definition of sustainability or ES appears but the theoretical framework is built over the concept of sustainability developed by the OLADE, CEPAL and GDF (2000). The inclusion of energy independence, diversification of energy sources and secure energy exports revenue among other variables, highlight a sustainability vision not centered on an ecological economics point of view. For that reason, the indicators have the same weight: social indicators are treated in a same way as environmental and economic ones, but different normalization methods are applied, by instance: in order to normalize the depletion of fossil fuels it is assumed that 45 years would be equivalent to one, the highest possible value. On the other hand, the indicator for renewable energy sources is normalized under the CEPAL’s criterion: it is equal to one, if a share of

50% of national energy consumption is covered by renewable energy sources. As usually, data is RNC and country performance is defined using a weight average.

3.3.9 The Energy Architecture Performance Index

This index includes the energy system performance of 125 countries using 18 indicators defined across each side of the energy triangle: the economic growth and development, environmental sustainability, and energy access and security, comprising six indicators per sub-index or dimension. In theory the full methodology behind the EAPI is available online at the WEF webpage nevertheless the information is scarce.

The computation of this composite indicator involves linear aggregation, first at the sub-level and then at the overall ES level. A set of normalization methods are applied to individual indicators in order to aggregate them –these include min-max, standardization and percentile rankings. The document explains that the methodology for some of the indicators have been revised in the 2015 edition, but there are no detailed explanations about how the methodology has changed. These recalibrations made that comparisons with previous editions of the EAPI not possible. Within the overall aggregated EAPI score, each of the scores across each of the three baskets receives equal priority and weighting. Within each sub-index, indicators are allocated a different weight. The data utilized is RNC.

3.3.10 Selvakkumaran & Limmeechokchai (2013)

Constructed for scenario analysis, the study relies on the extension of the following definition “ability of an economy to guarantee the availability of energy resource supply in a sustainable and timely manner, with the energy price being at a level that will not adversely affect the economic performance of the economy” APERC (2007). The methodology is suited to evaluate ES along three main themes: oil security, gas security and sustainability in Sri Lanka, Thailand and Vietnam. Each theme consists of five sub-indicators in RNC. These values are then normalized using a scaling technique as in Cabalu (2010) where the minimum value is set to 0 and the maximum to 1. Then each theme or dimension is computed as the mean average of the five sub-indicators and the values transformed to a 0–100 scale.

3.3.11 Kamsamrong & Sorapipatana (2014)

The Composite indicator relies on the definition of the APERC (2007) and the physical economic and environmental security dimensions. This study focuses only on the security of primary energy supply for electricity generation in Thailand. The RNC data is normalized using the Min-max transformation and the composite index is computed as the root mean square of the five relative indicators with equal weights. The only exception appears in the Indicator for net energy import dependency where as in Jansen et al. (2004) authors employ a modified Shannon index using as weight the share of net imported energy for each primary energy supply source in a country.

3.3.12 Sharifuddin (2014)

The scope of this article are 5 Asian countries. As in Sovacool et at. (2011) the definition relies on the definition of the dimensions included “Energy security is conceptualized for this study as having at least five core aspects: availability, stability, affordability, consumption efficiency and environmental impact”. But no clear definition is incorporated in the analysis. The indicator is composed by 35 indicators in RNC, representing 13 elements and grouped into five aspects. The Z scores normalization is utilized and the result are used as a variable of the standard normal distribution with mean of 0 and variance 1. The indicators associated to energy sources are weighted according to their share in the energy mix, but when there are no fuel components the equal weights are used. Individual indicator scores are aggregated into scores of elements, then into scores of aspects and then into the global ES indicator applying weight average.

3.3.13 Yao & Chang (2014)

The framework provides an indicator for ES evaluation in China covering the availability, applicability, acceptability, and affordability. The definition is “An ‘energy secure’ nation is a nation that has affordable energy resources with an adequate amount of fossil fuels, nuclear energy, and Renewable resources, technologies applicable to energy harnessing and utilization, and, at the same time, addresses social and environmental concerns”. The 4-As framework has twenty indicators in RNC, five indicators under each “A.” Equal weights are given to the indicators; and the normalization is done with a scoring scale from 1 to 10 using a monotonic transformation. The aggregation method for each dimension is a linear average of each of the 5 indicators. Instead of aggregate the dimensions to provide an overall ES index, the authors provided an imbalance index, defined as: the area of a diamond taking the highest score for each A—actual total area’ divided by the ‘area of a diamond taking the highest score for the A. The lower the index, the more balanced the four dimensions of each period.

3.4. Evaluation

The above review of indicators although not exhaustive gives an overview of the different procedures developed to quantitatively asses the ES levels on a multidimensional perspective. The scope of indicators varies from studies focused on two dimensions as the security of supply and economic dimensions or economic and environmental, to studies including five dimensions or even more.

Only few studies provide a proper definition of the concept of ES on which the methodology is based. By instance, Yao & Chang (2014), Selvakkumaran & Limmeechokchai (2013), Sovacool et al. (2011), Sovacool (2013a and 2013b) and Oinamics (2005) provide such definition being the clearest and concise the one of Oinamics (2005) and Yao & Chang (2014). Most of the review studies build their definition on the enumeration of these dimensions but lack of a formal or more concise definition: Sheinbaum-Pardo et al. (2012) Sharifuddin (2014), Institute for 21st Century Energy (2012), Augustis et al. (2011) and Augustis et al. (2012), Gnansounou (2008) and Sovacool & Brown (2010). A third group of studies do not give any definition and state that their work is built on the concept of ES given by previous studies.

This lack of clarity can lead to misunderstandings and be interpreted as a lack of formality. One of the reason is that the definition should incorporate the motivation to aggregate the indicators according to thematic areas. In absence of such theoretical justification it may be more adequate to utilize a statistical processing to assemble the indicators according to the characteristics of the data and not a subjective judgement without theoretical fundament.

The definition may also affect the election of the weighting method. In the literature exist a variety of weighting methods, the most utilized are represented in table 3. As noted by Marozzi (2014), there is still very little agreement among social scientists on methods for weighting. The most used weighting method in our sample, Equal weighting, could mean that: i) there are no theoretical or practical grounds for choosing unequal weights, ii) partial indicators are considered to be equally important, or iii) there is insufficient knowledge about the issue to be measured. Is this second explanation the most used between the review indicators, as far as the indicators as seen of equal importance.

Table 3. Approaches to set the weights

Data-driven	Hybrid	Normative
1. frequency	7. self-stated	4. equal or arbitrary
2. statistical	8. Hedonic	5. expert opinion
3. most-favorable		6. price based

This means that in the above definitions there are no priorities regarding the dimension and although the fact that the economic factors are usually presented first, they have the same importance as the others. In the cases where the weights are decided by other criteria, the most common is the set of weights regarding qualitative criteria, mostly "expert opinion" (Institute for 21st Century Energy 2012, 2013 and 2015; Augutis et al. 2011 and Augustis et al. 2012). Nevertheless, in these cases, the judgment is not fully explained, neither stated in the definition as in the IEA definition example in section 2. These may mean that there is a lack of coherence between the definition and the qualitative analysis which may be a source of misunderstandings and further policy incoherence.

This links directly to the next issue the aggregation method. Since multicriteria evaluation is multidimensional in nature, it allows to take into account interactions between different areas of study, especially economic, political and environmental dimensions. As in the ecological economics literature, according to the aggregation procedure chosen, weak or strong sustainability concepts can be operationalized (Martinez-Alier et al., 1998), and the same can be said for the political or social dimensions. This depends on the degree of compensability allowed by the aggregation procedure and the weighting method. The first determines if one dimension can compensate the others. In other words, if certain characteristics of the energy systems are deemed critical, and not really substitutable by other dimension. The second determine the importance of each dimension in the final composite indicator. Therefore, high compensability between two dimension with equal distribution may have similar effects as lower compensability with a high unequal distribution in the final ES indicator.

Non-compensability has been used by ecological economist to operationalize the concept of strong sustainability (Munda, 1997). Such a definition is based on the assumption that certain sorts of 'natural capital' are deemed critical, and not readily substitutable by man-made capital (Barbier & Markandya, 1990). So it may be worth asking if the commonly use of full compensability aggregation methods respond to the operationalization of a weak sustainability concept. If that is so, it would be then better to made it explicit in the definition –as in the IEA example: "Energy security has many dimensions: long-term energy security mainly deals with timely investments to supply energy in line with economic developments and sustainable environmental needs" (IEA, 2014) Nevertheless, this weak sustainability conception seems not to be the one operationalized by the above authors as far as in the set of the weights the most common procedure is the equal weighting as partial indicators are considered to be equally important.

But this is not the only issue regarding the aggregation procedure. None of the studies reviewed above do use an aggregation procedure that fulfil the requirements of Ebert and Welsch (2004). All the indicators above involve RNC indicators which means that the geometrical mean is the only meaningful aggregation procedure. Moreover, in many of the cases mentioned above - namely those involving strictly positive RNC variables - meaningful indices –in the sense of Ebert and Welsh- could be obtained by computing the geometric mean of the normalized or raw indicators. In this regard, if the objective was to generate a value between (0,1) the normalization could be instead applied to the aggregated metric. This would reduce the influence of the normalization procedure in the final metric and would allow to identify more easily such influence.

In the other hand, in the case where the variable is not strictly positive or the normalization is considered necessary the use of certain normalization procedures is restricted. As previous commented in contrast to the linear aggregation the use of the geometric aggregation requires the use of specific normalization methods. This would require that indexes as the one of should not only reconsider the aggregation but also the normalization procedures far as the Min-Max normalization cannot be applied with a geometrical mean in a meaningful manner.

Therefore, the use of the aggregation mean comes to solve two main issues. First it allows the operationality of a concept more in accordance with a broad vision of ES. This concept is associated with the strong ecological economics tradition but also with a more geopolitical and human security based conception of the term. It allows therefore to integrate the different perspectives associated to the concept and expressed in Cherp & Jewel (2011) as: Sovereignty, Robustness and Resilience.

It should be noted again that the aggregation mean procedure combined with specific normalization methods is the only way to produce meaningful composite indicators in the sense of Nardo (2005). Even would be preferred in certain cases to do not apply the aggregation procedure to the raw indicators in order to eliminate any influence of the normalization procedure in the final metric (Ebert & Wells, 2004).

Having said this, it is possible to argue that the use of the linear aggregation and equal weighting should be preferred as long as it facilities the communication of the results. The reason to do that would be avoid that the complexity of the indicator construction challenges the comprehensiveness of policy makers or other nonacademic audience. In this cases it would be therefore advisable to test the validity of the index, allowing to verify if the ranking of countries is robust respect to the selection of summary, normalization, aggregation and weighting methods. Nevertheless, none of the above indicators present such a robustness check.

Finally, even though this short review takes into account only multidimensional ES indicators, other ES indicators base on a narrower conception of ES also suffer from the same bias. By instance indicators as the Oil import risk index (Zhang et al. 2013), the Oil Import Vulnerability Index (Ediger & Berk, 2011) and the diversification index of Cohen et al. (2011) to cite a few, employ additive aggregation procedures even when their data is RNC. This means that some of the methodological issues described in this section generally affect to the literature on ES indicators and not just Multidimensional ES indicators.

3.5 Conclusions

Measuring any ES concept from an economic perspective is a fundamental problem since its value is not reflected in any price and the line between what should be included as an ES issue is still undefined. This feature extends the scope of the study to areas ranging from Ecological Economics, International Political Economy or human security and goes beyond neoclassical economics including a broad set of factors impacting socioeconomic systems.

In order to incorporate such notions to the analysis of specific energy systems multidimensional indexes are becoming increasingly important. Nevertheless, the first conclusion of this study is theoretical assumptions and methodological choices in many cases do not provide a coherent framework of analysis. After the exploration of the definitions of ES, dimensions, data, aggregation, normalization and weighting procedure of various ES indicators. This study shows how the main failures detected in this studies are connected to the aggregation methodology, which in turn question the formulation of the ES approach and theoretical assumption behind the very concept of ES.

These shortcomings lead to the second conclusion: the requirements of formal consistence have been underexplored in the ES literature even when they have the same importance as the more general considerations. This is all the more striking given the fact that, methodological choices are interconnected to the more general considerations to such extend that determine the meaningfulness and validity of the final indicators. This arbitrariness in the construction of composite indicators may result in misleading messages to policy makers and may incorporate an excessively degree of subjectivity.

In order to assess the impact of authors subjectivity, it would be recommended to develop a robustness check of the results, something that none of the reviewed construction procedures include. This robustness check has as main aim reduce the uncertainty associated to the methodology employed. Surprisingly, this critical survey revealed that none of the reviewed ES studies provides a composite indicator methodology allowing for the construction of a meaningful ES metric.

This results reveals that there is a need to re-elaborate the construction of ES composite indicators in order to make it consistent with the kind of data of the individual indicators employed. In order to do this, it is imperative that the construction procedure assures the consistency between the concept of ES and the aggregation and weighting procedures. A proposed first step would be to include a clear definition of the concept being operationalized, for what it would be useful not only a definition of the term but also a clarification with regard to the importance given to each dimension. The reason to do that is to prevent the jeopardize any of the elements included in the definition.

The lack of a standardized methodology and consensus between scholar regarding the quantification of ES in a broader definition may be due to the novelty of the research field. In this regard an avenue to further research should be the Ecological Economics literature. Due to the rising concerns on the anthropogenic impact on the environment a plethora of studies have developed composite indicators designed to measure such impacts from a multidimensional perspective. The review of such studies should boost the debate on multidimensional ES indicators and address the shortcomings of the current state of the art. This underlines the need for enhanced efforts by researcher in different disciplines to incorporate concepts from other areas of study and demonstrates the potential benefits of integrate energy studies in a broadened approach.

Chapter 4

Energy security and renewable energy deployment in the EU[12]

4.1 Introduction

Energy systems in the EU are largely managed at the national level. This fragmented context leads to policy conflicts, whereas a coordinated European energy security framework could increase policy coherence (Strambo et al., 2015). For this reason, the EU's energy policy is becoming increasingly directed at a supranational level, as shown by the setting of common energy targets for 2020, 2030 and 2050. This attempt to homogenise EU energy policy forces member States to adapt their energy sectors to a new context characterized by a continuous commitment to develop Renewable Energy Sources (RES) without neglecting their energy security preferences. These efforts have evolved from the support of research and development (R&D) to the support of RES deployment through regulatory incentives such as Feed-in Tariffs. Therefore, researchers agree that the EU's current state of RES development has largely been achieved only because of member States' commitment towards the three goals of the EU energy policy: competitiveness, security of supply and sustainability (Popp, 2002; Johnstone et al; 2010; Popp et al. 2011; Nesta et al. 2014).

Nevertheless, the energy security factors behind the support of RES have been less investigated (Marques et al. 2010; Marques & Fuinhas, 2010; Marques & Fuinhas, 2012; Aguirre & Ibikunle, 2014). This article aims to fill that gap concerning the effect of energy security drivers on RES deployment, conceptualizing RES as a generic response to energy security threats. Its relevance lies in the fact that the main driver responsible for RES deployment is not set *ex ante* or *a priori* but rather explored using econometric regression techniques that unveils a non-expected, counter-intuitive finding. The article identifies energy security strategies, and not environmental concerns, as the main driver on current RES deployment in the EU. It also allows the identification of areas of strategic importance and possible synergies between policy choices, raising the important issue of consistency

[12] Another version of this chapter has been published as: Lucas, J. N. V., Francés, G. E., & González, E. S. M. (2016). Energy security and renewable energy deployment in the EU: Liaisons Dangereuses or Virtuous Circle?. *Renewable and Sustainable Energy Reviews* 62, 1032-1046.

between individual EU member States energy policies and a common European energy security policy.

The idea behind this article is the following: one of the main reasons for the lack of significant results in existing studies on the effect of energy security on RES is the use of inappropriate proxies. Energy security is a multidimensional concept that cannot be reduced to one indicator – in particular, to import dependence ratios. Thus, this article aims not only to compare alternative energy security indicators (ESI) but also to capture the various dimensions that generate policy support for RES. In this context, it is closely related to previous studies on RES drivers and barriers insofar as it estimates the effects of various ESI, which are closely related to socio-economic and country-specific variables, on the deployment of RES in the EU. Furthermore, the article extends this research agenda to address the issue of RES deployment from an energy security perspective compared to the traditional sustainability prism. In this regard, the article explores strategies that would simultaneously promote energy security and sustainability, overcoming the trade-off that allegedly limits the achievement of both.

The key role played by variables related to energy security in the development of renewable energy in the EU partially contradicts almost all earlier empirical findings (Marques et al. 2010; Marques & Fuinhas, 2010; Aguirre & Ibikunle, 2014) and have clear policy implications for a common European energy policy. In order to find a European energy security approach coherent with RES deployment it will be necessary (i) to explore strategies that promote a sustainable and secure energy supply, such as the diversification of primary energy sources; and (ii) avoid other strategies focused on decreasing import dependence like supporting domestic coal or developing European shale gas resources.

More precisely, the article hypothesizes that the relationship between energy security policies and RES deployment is far from straightforward and depends on the selection and weight given to each energy security target. To test this hypothesis, the article follows an innovative approach: instead of setting energy dependency as proxy for energy security policies, it recurs to different ESI used in EU energy policymaking or in the energy security literature. The reason for introducing a variety of indicators is that past studies (Bigano, 2010; Winzer, 2012; Narula & Reddy) report significant differences depending on the ESI chosen. Combining ESI with country-specific energy sector data, we examine national investment in RES for 21 EU countries. We expect that the use of a wide range of ESI will allow to make a distinction between different energy security concepts and dimensions, and determine whether the use of import dependence as the only proxy variable to represent the energy security dimension represents a source of potential bias. Finally, we want to know what strategies related to energy security present a higher consistency with RES deployment.

The article starts by introducing existing theoretical models and empirical evidence on the relationship between energy security and RES in section 2. Section 3 discusses some drivers and barriers that influence the demand for RES within a country. Section 4 follows with the data description, including different ESI, and presents the methodological approach. Regression results are presented and discussed in section 5. Section 6 presents the final remarks regarding the coherence between energy security and RES deployment in the EU, while section 7 concludes with its policy implications. Our primary findings confirm (i) that RES deployment is a consequence of a mix of energy security strategies and not only of environmental policies; and (ii) that within energy security strategies, the diversification of energy sources through renewable energy deployment is a more coherent strategy than the search for an energy independence based on RES.

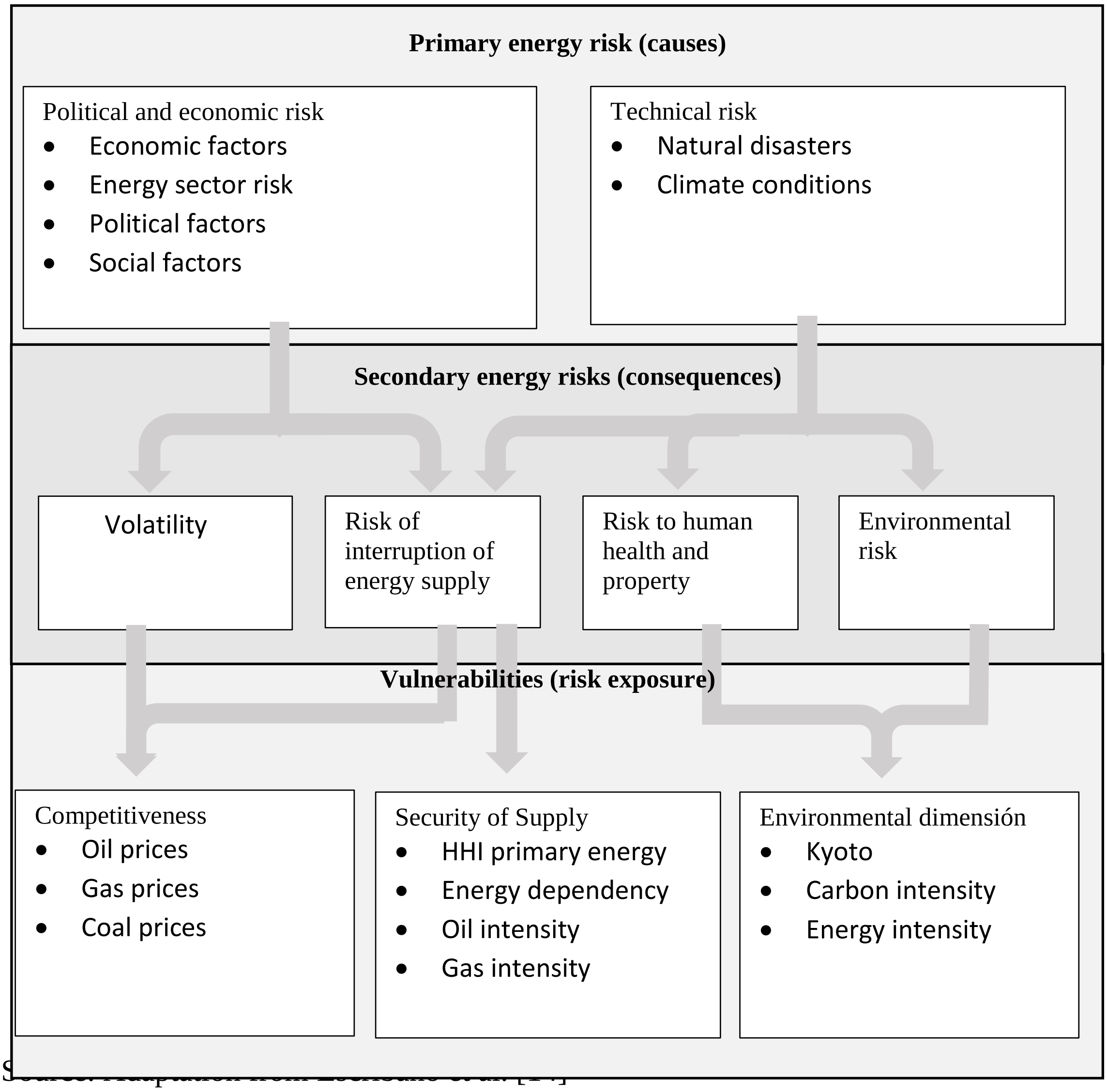
4.2 Background

4.2.1 Theoretical Literature

The main body of literature on energy security focuses on the geopolitics of fossil fuels, and the relationship between RES and energy security has been poorly analysed (Johansson, 2013). However, it is not difficult to introduce RES in conventional energy risk frameworks. Escribano et al. (2013) break down energy risks into primary (socioeconomic or technical causes), secondary (interruption of energy supply or environmental, property and human health damages due to primary energy risks), price volatility and vulnerabilities (exposure) finding RES could mitigate energy risks in every layer of their “causal taxonomy of energy risk (Fig. 1)”.

First, decentralised renewable energy facilities are less insecure than highly centralised conventional ones concerning physical failure or sabotage (primary energy risk). Second, with the only exception of hydropower, renewables are considerably safer than conventional energy sources in case of an accident (secondary energy risks). Third, renewables are ‘zero marginal cost’ technologies that do not need ‘fuels’ to produce power and are thus not affected by price volatility in international energy markets, unlike oil, natural gas or coal. Furthermore, they could be used to balance the price volatility inherent to fossil fuels, with which they are uncorrelated. Finally, renewables could reduce energy vulnerability through the diversification of the energy mix regarding both technologies and energy sources. Thus, even if sustainability is not included (as it should) in a comprehensive energy security definition, renewable-associated risks are lower than those of conventional energy sources.

Figure. 1. A causal taxonomy of energy risk.



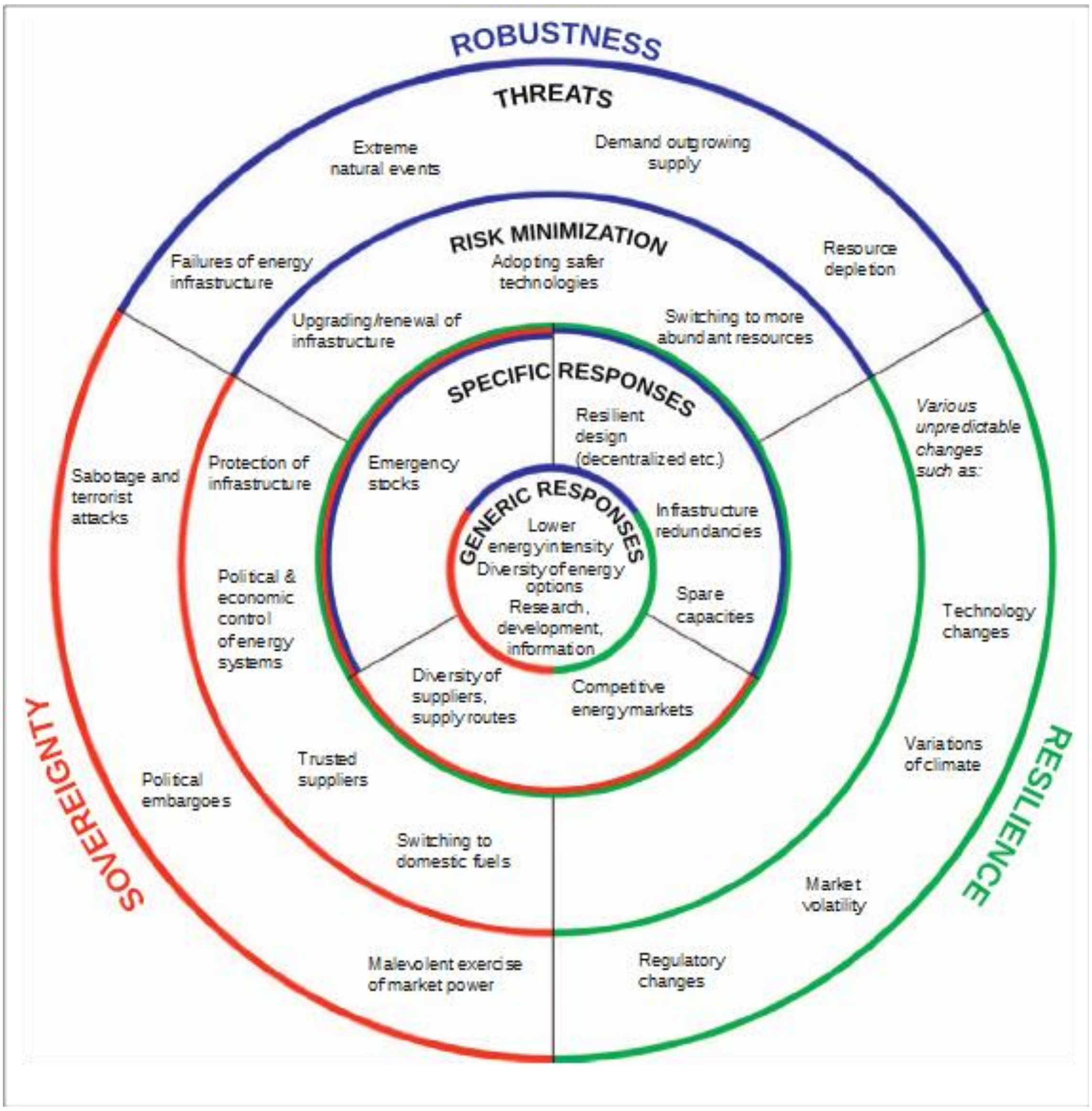
A new framework to analyse energy security has been developed by Cherp and Jewell (2011). They point out that currently three main points of view on energy security coexist: Sovereignty, Robustness and Resilience (Fig 2). Each perspective identifies different key risk for energy systems. Problems related to oil security have historically shaped the "Sovereignty" perspective on energy security rooted in international relations theories and political science. The “Robustness” perspective threats are seen as ‘objective’, predictable and measurable, allowing for the quantification of energy risks. The third perspective, titled “Resilience”, is based on the uncertainty and non-linearity of energy systems, markets, technologies and societies. It searches for generic features of energy systems such as flexibility, adaptability, diversity that ensure protection against uncertainty.

RES could contribute to improve energy security in each of the aforementioned three dimensions addressing most threats to energy security. Regarding Sovereignty, as a domestic and decentralised energy supply, RES are less vulnerable to the use of energy as political weapon or to physical attacks. Even in the case of transnational RES flows, its own nature (electricity in most cases) limits their capacity to serve as a driver for power politics, contributing instead to diversify geographical origins, corridors and energy sources. Besides, the atomization of the RES industry compared to the oligopolistic nature of conventional energy firms could help to prevent market power abuse.

Robustness threats could also be mitigated introducing RES in the energy system, although it must be kept in mind that, from a technical point of view, RES need some back up capacity due to its fluctuating nature. From left to right regarding Robustness threats in figure 2 the decentralised nature of RES, as it has already mentioned, with more sites of smaller size, could reduce the risk of technical failures. However, against extreme natural events the result is not that clear: on one side, the geographical scattered pattern of RES deployment could avoid most facilities being caught in the same event; on the other side, some RES, like windmills, could trip (disconnect) automatically with high speed gust of wind that could be supported with ease by conventional energy infrastructures. The smaller size and decentralization of RES could also play a role if demand outgrows supply, as RES facilities could be built faster and nearer demand centres minimizing power line needs. As a negative point, RES are not completely dispatchable due to its fluctuating nature, limiting its viability in case of non-interruptible energy consumption requirements. Finally, the threat of resource depletion is perfectly matched with RES as main modern renewable energies (wind and solar) are inexhaustible resources.

In the Resilience dimension RES could help to address unpredictable changes such as technology changes, variations of climate or market volatility. RES are cutting edge technology being at the forefront of research and development (R&D) programs. Thus it is possible that a technological change in energy, even a game changer, could appear from this field. Renewable sources allow technological diversification too, with different technologies competing and exploring alternative development pathways. RES neither use 'fuels' to produce power, nor release CO_2, as there is no combustion to generate power, strongly contributing to reduce energy risk related to climate change or to energy price volatility, as it was mentioned above. The only Resilience threat that could not be dealt better with RES than with conventional energy sources are regulatory risks. However, the problem here is more the fact that the regulatory framework has been working for conventional energy sources since its beginning, than the own features of RES. An energy source, conventional or unconventional, suffering from abrupt, frequent, quick or unexpected changes in its regulatory framework will bear an increase in its risk levels.

Figure 2. Three perspectives on Energy security



Source: Cherp & Jewell [15]

As it has been shown, from a general point of view RES have a huge potential to increase energy security with positive externalities outweighing most of the time their (not so) higher cost compared to conventional energy. Let's focus now in the concrete case of climate change, one of the most pressing concerns related to energy nowadays.

The role of RES within the relationship between energy security and climate change policies has recently been the subject of heated discussion (Strambo t al., 2015; Cherp & Jewel, 2011; Darmani et al. 2014; Månsson et al., 2014; Ren & Sovacool, 2014; Ang & Choong, 2015; Eleftheriadis & Anagnostopoulou, 2015; Sovacool & Dworkin, 2015). Currently, there is no agreement on whether a complementarity or a trade-off exists between these two dimensions (Böhringer & Keller, 2011; Böhringer & Bortolamedi, 2015; Guivarch & Monjon, 2015; Lima & Portugal-Pereira, 2015). In order to conceptualize this relationship some theoretical frameworks have been constructed. For instance, Brown and Huntington (Brown & Huntington; 2008) examine the complementarity between climate change and energy security policies. Their theoretical model conceptualises the existence of complementarity among energy security targets and individual RES technologies within a context of trade-off between the two policy dimensions: reduction of CO_2 vs. reduction of energy prices. According to the authors, RES contribution to either objective (or both) is a consequence of their different costs and technical characteristics. The trade-off that must be managed is diversifying energy sources to minimize the risk of a supply disruption or price shock. To that end, Brown and Huntington present an energy mix in which the optimal share of each technology is reached when the marginal cost in the energy mix is equal to the value of the additional energy security and the reduction in greenhouse gas emission that it provides. Although it is a theoretical model, the difficulties in measuring energy security levels must be highlighted.

In line with the precedent model, Röpke (2008) presents a cost benefit analysis of policy objectives in electricity markets. Developing the framework of analysis by Tishler et al. (2006) and De Nooij et al. (2007), her research focusses on supply security problems that arise from decentralized renewable energy grid integration. Measuring energy security by the (social) damages of outages, energy security is associated with supply interruptions. One important assumption behind Röpke's model is that the costs associated with the development and maintenance of the electricity grid should be considered part of RES deployment costs. Applying the model to the German electricity system, the costs associated with the expansion of the electricity grid due to the deployment of RES exceed the induced welfare gains from the maintenance of a constant supply security level.

Conversely, Bauen (2006) suggests that complementarity exists between climate policies and energy security policies. In his words "*the stronger the Green House Gas policy, the more positive the effect on security of supply is likely to be*". Nevertheless, the reverse of this relationship does not work. Therefore, the technological solutions to the dilemma between energy security and sustainability may consist of a range of options that will evolve over time, depending on technological trends and security risks. This argument is partially in contradiction with Correljé and Van der Linde (2006), who stated that RES development in Europe is stimulated by security of supply reasons. More precisely, they argue, *"[r]esearch and development efforts are basically geared towards reducing the import dependency and increasing energy system flexibility."* In this article, environmental policies are considered part of energy security policies: "*[n]evertheless, in addition to energy policy specifically, trade and foreign relations and security policy are also part of the energy security tool-set, as is environmental policy."*

Constantini et al. (2007) follow a Portfolio-Based Approach for assessing energy security levels under different scenarios. For this purpose, they define energy security in the classical terms of availability of a regular supply of energy at an affordable price, and distinguish two main categories: dependency and vulnerability of gas and oil supplies. This specification allows them to differentiate between different sources of risk. They conclude that reducing energy imports due to energy efficiency policies would affect European future energy security, as would technological investments on the supply side. This view highlights the role of oil and gas as main sources of risk and ignores the potential associated with other energy sources as renewables.

This article assumes that all of the above energy security frameworks may be right, representing different concepts on the subjective trade-off between energy security and the economic and environmental dimensions of energy policy. In this context, the definition of energy security and its associated strategies could be one of the most important, if not the main, driver/barrier in RES deployment. Therefore, energy security policies can spur the deployment of RES to achieve certain desired results, for instance, increasing the technological or geographical diversification of the energy system, decreasing the effect of oil volatility on growth and inflation, or reducing the carbon intensity of the economy.

4.2.2 Empirical evidence

The current academic debate on the use of RES and energy security issues is dominated by studies on economic modelling of RES deployment (Böhringer & Bortolamedi, 2015; Guivarch & Monjon, 2015; Meade & Islam, 2015), their role in possible future energy systems (Jewel et al. 2014; McCollum et al. 2013; Martínez et al. 2015), their optimal contribution in energy supply portfolio (Huang et al., 2007; Awebuch & Yang, 2007; Jansen & Seebregt, 2010; Abolhosseini & Heshmati, 2014; Novacheck & Jhonson, 2015) and, more recently, their geopolitical implications (Scholten & Bosman, 2016). Regarding the empirical evidence, the literature stresses the importance of policy interventions (Nesta et al., 2014; Zhao et al., 2013; Kilinc-Ata, 2016) and market liberalization (Carley, 2009; Sanyal & Ghosh, 2013). Yet these studies focus more on promoting RES through policy instruments as feed-in-tariff or quotas, or the challenges associated with their market and system integration, largely ignoring the energy security aspect.

But there are also some studies analysing the different ways in which energy security and RES deployment interact. Nevertheless, they only perform an analysis of the energy security drivers as a secondary objective. In addition, the search for empirical evidence has been focussed on the relationship between RES and one of the many possible objectives of energy security policies, energy independence (or reducing energy dependence).

For instance, a great deal of research has been performed to test the hypothesis that energy security promotes RES deployment by including the indicator of import dependency as one of the independent political variables (Marques et al. 2010; Marques & Fuinhas, 2010; Aguirre & Ibikunle, 2014; Gan et al. 2007; Chien & Hu, 2008). For instance, Marques et al. (2010) and Marques and Fuinhas (2010) analyse 23 EU countries including the candidates to the EU adhesion with different results. The results of Marques et al. (2010) confirm that energy dependency has a positive effect on RES development. However, in Marques and Fuinhas (2011), the results are not statistically significant for energy price and energy import dependency variables.

Popp et al. (2011) measured the investment on RES by using the annual variation in installed renewable energy capacity per capita. This study measures the effect of technological change on RES deployment. Among other variables, the study determines the effect of energy security using as explanatory variables the share of imported energy in total energy supply and the production per capita of coal, natural gas, and oil. Nevertheless, their findings show no significant results.

In their recent analysis of RES deployment drivers, Aguirre and Ibikunle (2014) follow the previous studies of Marques et al. (2010) and Marques and Fuinhas (2011 & 2012) including as explanatory variables a set of public policies, energy import dependence, energy prices and fossil fuel participation in the electricity mix. Their results show significant evidence for the effect of public policies aiming at climate change mitigation, but are not significant for the energy security variable, energy dependence. Concerning the participation of fossil fuels in the electricity mix, their findings corroborate the negative effect of fossil fuels on RES deployment, but they do not find significant results for the variables connected to energy import prices. Based on the evidence of their study, they conclude that environmental concerns are more relevant than is energy security for countries in their sample.

The fundamental reason for including a broad range of ESI instead of arbitrarily considering one indicator rather than others is that each energy security concept defines its own policy objectives and strategies. In that sense, energy independence, the proxy used in the reviewed literature, could not even be an energy security target for most of the EU members because they are historically energy importers. In this respect, Bigano et al. (2010) follow a different strategy; they initially use a wide range of indicators to assess whether different policies that affect energy efficiency performance also have an effect on different ESI for 16 EU countries. Their work has two main implications for our purposes. First, they show the differences in the measurement of energy security by using different indicators, i.e., countries may have high levels of energy dependence but a highly diversified energy supply. Second, the study shows that policies for improving energy efficiency or carbon efficiency have non-significant effects on all energy security dimensions. This is a very interesting result considering that most of the literature uses the level of energy dependence as a proxy for energy security. In our view, the differences in their results are explained by the fact that an exact and unique definition of energy security, and therefore the use of a single specific indicator, is almost impossible because energy security is a complex, multidimensional and evolutionary concept which allows several subjective interpretations

To summarize, the several channels through which energy security affects innovation and deployment in RES call for the inclusion of a broad set of potential interactions in the empirical specification of the econometric model. Currently, there is no agreement in the literature, and therefore energy security targets could be viewed as a driver or a barrier. Depending on the level of analysis (national, regional or global), chosen dimension (availability, accessibility, affordability or acceptability) or indicator (economic, environmental or security of supply-based indicators) and, in particular, the specific circumstances of each energy system (e.g., composition of the energy "mix", key energy partners and geopolitics, and resource endowments), results may change. Nonetheless, supply disruption concerns are not the only energy security factor that determines RES deployment. The next section presents some energy security drivers of and barriers to RES deployment and its effects.

4.3 Determinants of Renewable Energy Deployment

4.3.1 Conceptualizing energy security

Currently, a variety of energy security definitions coexist, and the literature is rapidly growing[13] without having a common or unique security indicator able to embrace them all (Ang & Choong, 2015). Moreover, measuring the levels of security associated with any concept of energy security from an economic perspective is a fundamental problem because the value of energy security is not reflected in any price (Böhringer & Keller, 2011; deNooij et al. 2007) and the use of multiple indicators generates an aggregation problem (Kruyt et al., 2009). However, many energy security indices have been constructed, being many of them country or region specific (Anf & Choong, 2015). Although some characteristics of energy security could be measured, the problem is that the contour defining energy security remains undefined, if only because the energy system is not isolated from environmental or political dimensions. There is no consensus on whether the interactions of energy security and the environmental and economic dimensions of energy policy may be part of energy security concerns.

Most likely, the best framework of analysis to address the energy security aspects of RES is the one adopted by Johansson (2013a & 2013b), in which energy systems are not merely an object exposed to security threats but instead a subject generating or enhancing

[13] After reviewing 104 articles from 2001 to 2014, Ang and Choong [17] reported that energy security has been an actively studied area and its definition is characterized by being contextual and dynamic in nature.

insecurity. Energy systems could act as a generator of insecurity due to the economic importance of energy, the physical and technical characteristics of the energy carriers and the environmental consequences of energy use. However, as we will see next**,** there is significant opposition to the subjective perspective, in which the concept is extended to other dimensions beyond the security of supply or demand. For that reason energy security has been conceptualized as everything about managing conflicts and commonalities between the different dimensions of energy security (Sovacool & Saunders, 2014).

The narrowest visions conceptualizing energy security in terms of availability and accessibility and accessibility to energy resources remain dominant. This approach is held by many actors in the energy sector such as the Department of Energy & Climate Change (DECC) (2009), which defines energy security in the following terms: "*Secure energy means that the risks of interruption to energy supply are low*". Other points of view extend the concept of energy security to new fields but contain secure energy supplies as the core of the concept. Examples of these concepts include the approach developed by the IEA: "*Energy security is defined in terms of the physical availability of supplies to satisfy demand at a given price"* (IEA, 2001). An additional example is from Mabro (2008): "*Security is impaired when supplies are reduced or interrupted in some places to an extent that causes a sudden, significant and sustained increase in prevailing prices"*. Milov (2005) alludes to the International Atomic Energy Agency, presenting a more sophisticated definition after highlighting that there is no clear-cut definition of the concept: *"Experts from the International Atomic Energy Agency define it as a concept aimed to protect customers against any interruptions in their energy supplies due to emergencies, terrorism, underinvestment in infrastructure, or poor organization of markets"*. From this point of view, the concept is developed within new areas or dimensions, such as a timeframe of risk sources, differentiating from short and long-term energy security, or the classification between technical, regulatory and human threats. However, perhaps the most relevant area of these new developments is the social dimension represented by initiatives such as *Sustainable Energy for All*, which focussed on energy poverty and final consumers' protection (Sovacool & Saunders, 2014; Brazilian et al., 2014; Gonzales-Eguino, 2015). For instance, the energy security social dimension in the EU ensures that the final product (energy services) meets end-consumer needs, particularly the socially disadvantaged (Natorski et al. 2008).

For the EU, the definition of an energy security policy and its respective indicators should be able to evolve and adapt to increasing dependence on external suppliers. In this respect, as a consequence of the recent events involving Russia and the Ukraine, the European Commission has recently published an in-depth study of European energy security, which defines energy security as the "*uninterrupted access to energy sources at an affordable price*" (EC, 2014). This definition skips the environmental dimension and is far from the vision promoted in recent years in which "*...energy supply security must be geared to ensuring... the uninterrupted physical availability of energy products on the market, at a price which is affordable for all consumers (private and industrial), while respecting environmental concerns and looking towards sustainable development"* .

Concerning the studies about EU energy security, currently there is not a unique or official set of indicators; therefore, different indicators have been used depending on the context. Nevertheless, the EU is working on their development; the most complete group of indicators is the European Commission Occasional Paper, "Member States' Energy Dependence: An Indicator-Based Assessment" (EC, 2013). To assess the subjective energy concept of the EU and recreate the European energy security framework for our purposes, it is interesting to use ESI that are being used in decision making at the European level. Additionally, to capture different concepts, other indicators commonly used in the academic literature are also included because energy systems have been largely managed at the national level.

4.3.2 Energy Security Indicators (ESI)

The indicators used in this study come from three main sources. Table 1 summarizes the indicators, classifying them by their relationship to each energy policy dimension: environmental sustainability, energy security and competitiveness. These three different sources have been included to cover European subjectivity and different national and academic visions.

The main source is the European Commission Occasional Paper, "Member States Energy Dependence: An Indicator-Based Assessment" (EC, 2013), in which various indicators are discussed. These indicators are used to capture the subjective energy security concept of the EU. The European Commission report classifies the indicators in three dimensions: security of energy supply, energy and carbon intensity of the economy, and contribution of energy products to the trade balance. It is interesting to highlight that a large part of the variables included in past studies (Marques et al. 2010; Marques & Fuinhas, 2010; Marques & Fuinhas, 2012; Aguirre & Ibikunle, 2014; Huang et al., 2007; Carley, 2009; Johnstone et al, 2010; [3,6–9,46,62] are included in the European Commission report (EC, 2013) and have not been interpreted from an energy security point of view. Instead, they have been interpreted from an environmental or purely economic perspective because they are not exclusively used as ESI. For that reason, these studies are used as the second source of variables to be analysed from an energy security perspective. The last source that feeds our study is the specialised literature on gas and oil. Chester (2010) argues that the energy security literature is marked by a dominant focus on securing supplies of two primary energy sources, oil and gas (UNDP, 2004; Yerguin, 2006; IEA, 2008). Hence, we use the specific indicators used by Costantini et al. (2007) to measure energy security levels related to these two energy sources.

Table 1. Energy Security Indicators (ESI)

Dimension	Indicator	Resume
Environmental	Kyoto protocol	Dummy variable
	Energy Intensity	Energy Consumption per GDP
	Carbon Intensity	Green House Gas Emissions (as CO_2 equivalent) per GDP Green House Gas Emissions (as CO_2 equivalent) per capita
Security of Supply	Energy Dependence	Energy Net Import (% TPES)
	Gas Energy Intensity	Gas Cons. per $ of GDP Gas used per capita
	Oil Energy Intensity	Oil Cons. per $ of GDP Oil used per capita
	HHI primary energy diversity index	Index that represents the level of diversity of the energy mix of an economy. The values range from 0.2 to 1, 0.2 being the most diversified and 1 the more concentrated..
	Contribution of Coal/Oil/Ga/ Nuclear to Electricity generation	Share of electricity from Coal/Oil/Gas/Nuclear sources as part of total electricity generation in Mtoe
Competitiveness	Oil Price	Annual average of daily Brent price per Mtoe
	Gas Price	Annual average of daily German import price per Mtoe
	Coal Price	Annual average of daily Northwest Europe market price per Mtoe
	GDP per capita	GDP per capita in one year

4.3.2.1 The environmental dimension

It is widely accepted that RES are promoted due to the commitment by European countries to reduce GHG emissions. Nevertheless, there is no clear evidence that increasing use of renewable energy sources is effective in this context (Jaforullah & King, 2015). However, although this commitment has influenced RES deployment in some countries, the main instrument to reduce GHG emissions is the EU CO_2 trading scheme. However, the EU commitment to climate change objectives became stronger after the signature of the Kyoto Protocol, initially binding emissions commitment to limit GHG. Since its signature, the Kyoto Protocol has boosted RES development, displacing more polluting sources from the energy mix. For that reason, as in past studies (Popp et al. 2011; Nesta et al. 2014; Aguirre & Ibikunle; 2014), a dummy variable has been used for the year, indicating whether a country has ratified the Kyoto Protocol.[14]

Energy intensity is used by the EU as an indicator of energy consumption and energy efficiency. Low energy intensity means low energy use per unit of GDP/per capita, implying that the economy is less influenced by changes in energy prices and energy disruptions. The effects of both variables (energy use per unit of GDP and energy use per capita) in RES deployment are uncertain because large energy use and/or growing energy needs due to population/GDP increases could be supplied either by traditional energy sources or by renewable energy (Marques et al., 2010; Aguirre & Ibikunle, 2014; Carley, 2009). To make our results comparable to past findings, energy consumption by sector was not considered.

The European Commission report included carbon intensity of the economy as an indicator that measures the average amount of GHG emissions necessary to generate one unit of GDP. *Ceteris paribus*, higher carbon intensity of its energy sector implies increased vulnerability of a member State to more stringent climate-change mitigation policies and a higher likelihood of facing negative consequences in terms of inflationary pressures and competitiveness losses (Huang et al. 2007).

4.3.3.2 Competitiveness

Distinguishing between competitiveness and energy security dimensions is difficult

[14] Ratification dates are taken from the website of the U.N. Framework Convention on Climate Change. unfccc.int/files/kyoto_protocol/status_of_ratification/application/pdf/kp_ratification20090601.pdf.

because energy prices are core components of both. We assume that energy prices are good indicators of latent factors affecting international energy markets that are not represented by other ESI already included such as the level of energy offer and demand, political stability or marginal extraction cost. For that reason, it is interesting for our purposes to test whether high oil and natural gas prices foster RES deployment. As in previous studies (Marques et al., 2010; Marques and Fuinhas, 2011; Aguirre & Ibikunle, 2014), we consider coal, gas and oil prices. We expect the increase in commodity prices to boost the adoption of RES technologies because an increase in oil prices makes the substitution of exhaustible energy sources with sustainable energy more profitable. To assess the effect of overall economic well-being, we include GDP per capita.

4.3.2.3 Security of supply

The 2013 Occasional Paper section devoted to security of supply focusses on three indicators of energy security: energy import dependency, the degree of diversification of energy sources, and the degree of diversification in the electricity mix. Import dependency shows the extent to which a country relies upon imports to meet its energy needs. The theory suggests that higher reliance of a country on energy imports requires a higher level of RES deployment to improve that country's energy independence, but as we have highlighted previously, the results are contradictory. We will analyse later the pros and cons of using this variable alone.

The second variable introduced, to measure the degree of diversification, is the Herfindahl–Hirschman Index, or HHI indicator. As reported by Kruyt et al. [50], the HHI is widely used (Neff, 1997; Grubb & Butler, 2005; Percebois, 2006; Lefevre; 2007; Sovacool, 2009; Bird et al. 2005). We utilize the index to assess the diversification of primary energy sources. We expect less-diversified economies to increase the deployment of RES as a means of managing their dependence on other energy sources.

The Index is calculated as follows:

$$HHI = \sum_{i=1}^{N} x_i^2$$

Finally, we introduce as independent variables the share of fossil fuels and nuclear energy sources in electricity generation to assess the degree of diversification in the electricity mix. As past studies (Marques et al., 2010; Aguirre & Ibikunle, 2014; Huang et al. 2007; Carley, 2009) have, we use the contribution of coal, oil, natural gas and nuclear energy sources to the electricity generation in a country because this enables capturing the individual effect of each energy source on RES deployment. It is expected that the lobby power of fossil fuel technologies acts as a barrier to RES deployment (Sovacool 2009; Ren & Sovacool, 2014; Nesta et al. 2014) and to nuclear energy, which can also be considered a "green" technology (Aguirre & Ibikunle, 2014).

Some of the selected indicators could overlap with other dimensions. The variable energy intensity in addition to sustainability, may reflect the affordability and the security of supply of the energy system. As figure 2 shows, this is because some instruments of energy security are generic and may affect different areas. For instance, more energy intensive systems may be seen as less efficient and may be more vulnerable to resource depletion or price volatility. Therefore, it is possible to classify the indicators with respect to the dimensions they focus on, signalling in some cases their multidimensionality[15].

4.4. Data and methodology

We use data collected from several sources: Eurostat Database, United Nations Statistics Division and BP Statistical Review of World Energy 2012. Although the focus is on the EU, the list of countries included is restricted by data availability: Austria, Belgium, the Czech Republic, Denmark, Estonia, Finland, France, Greece, Germany, Hungary, Ireland, Italy, Luxembourg, the Netherlands, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden and the United Kingdom[16].

We use RES contribution to Total Primary Energy Supply (TPES) per year as the dependent variable. Data for specific RES contribution to TEPS are not used because the article considers the overall energy security effects. Other candidates for dependent variable are the level of renewable energy produced (Bird et al., 2005) or the per capita investment in RES-installed capacity (Popp et al. 2011). As stated by Aguirre and Ibikunle (2014), the use of RES Contribution to TPES instead of other measures is preferred for two reasons. First, policy targets are focussed on achieving a certain share of RES in the TPES. Second, it is expected that RES progressively displace more-polluting energy sources in the energy mix. Table 2 presents the variables included in each dimension, summarizing their

[15] This multidimensionality can be seen clearly in Kruyt et al [50], figure 2.

[16] We do not include in our dataset Cyprus, Bulgaria, Latvia, Lithuania, Malta or Rumania, countries for which data are available only after the 1990s.

descriptive statistics.

Table 2. Summary Statistics

Dimension	Variable	Name	Obs	Mean	Std. Dev.	Min.	Max.
Dependent variable							
	RES contribution to TEPS	LogREs	483	-1.298	0.448	-2.355	-0.441
Sustainability							
	Energy Intensity per capita	CO_2pc	482	11.98	4.417	6.074	34.981
	Carbon intensity per capita	Energypc	482	4.063	1.586	1.791	10.397
	Kyoto protocol dummy variable	Kyoto	483	0.650	0.477	0	1
	Energy intensity per GDP	EnergyGDP	480	193.025	127.152	66.560	850.806
	Carbon intensity per GDP	CO_2GDP	480	611.456	496.918	138.059	3214.169
Competitiveness							
	GDP per capita	GDPpc	479	27.531	15.552	4.386	88.417
	Oil price	OilP	483	50.675	29.396	17.910	113.558
	Coal price	CoalP	483	58.337	30.784	28.79	147.673
	Gas price	GasP	483	4.9876	3.112	1.878	11.561
Security of Supply							
	Contribution of coal to electricity generation	CoalElec	483	0.349	0.268	0	0.961
	Contribution of oil to electricity generation	OilElec	483	0.066	0.099	0	0.586
	Contribution of gas to electricity generation	GasElec	483	2.698	4.330	0.001	17.690
	Contribution of nuclear to electricity generation	NuclearElec	483	0.209	0.229	0	0.789
	Gas economic intensity	GasEco	480	97.219	141.065	0.337	644.119
	Gas physical intensity	GasPh	482	2.698	4.330	0.000	17.690
	Oil economic intensity	OilEco	480	170.512	243.154	5.921	1222.719
	Oil physical intensity	Oilph	482	0.004	0.007	0.000	0.031
	Energy import dependence	ImpDep	483	0.539	0.300	-0.518	0.995
	HHI diversity index	HHI	483	0.326	0.076	0.202	0.614

The analysis begins with the detection of non-linearities and outliers. Because we detect signs of Skewness and Kurtosis in our dependent variable, a logarithm transformation is applied to address asymmetry. To determine the model specification, and to avoid problems of collinearity in the final model, a simple Ordinary Least Squares (OLS) regression is performed and checked for collinearity, calculating the centred variance inflation factors (VIFs) for the independent variables specified in a linear regression model. Following Chajerte and Hadi (Chatterjee & Hadi, 2006), a variable is considered problematic if its VIF is 10.0 or greater. The results of our first set of independent variables are reported in table 4. The model specification (A) shows very high values for some variables. It is therefore necessary to drop some of the variables; the remaining ones are reported in Model (B). The new model's VIF is significantly smaller than Model (A), which means that multicollinearity is not an issue. Moreover, the GDPpc and the GasPh in the model have a VIF value slightly greater than 10, breaking the rule of Chajerte and Hadi. Because we are interested in using the GDP variable as a control variable and we have already dropped the Oil vulnerability variables, we decided to keep these two variables. We will consider that issue in our final regressions.

OilPh, GasPh) are the mean sources of potential bias.

Table 3. Variance inflation factors. Model A (left) and Model B (right)

Model A			Model B		
Variable	VIF	1/VIF	Variable	VIF	1/VIF
GasPh	81.3	0.012299	GasPh	1.4	0.08774
CO_2GDP	65.57	0.015251	GDPpc	9.56	0.10458
OilPh	63.87	0.015656	Energypc	7.96	0.125581
Energy GDP	62.58	0.015979	CoalElec	7.79	0.128378
GasEco	36.92	0.27085	CO_2pc	7.6	0.131642
OilEco	27.98	0.035743	GasEco	5.7	0.175404
GasPh	26.09	0.038331	GasElec	3.28	0.304601
OilPh	22.71	0.044041	NuclearElec	2.86	0.349731
Enegypc	19.37	0.051638	ImpDep	2	0.499004
GDPpc	18.16	0.055052	HHI	1.82	0.54963
CO_2pc	11.75	0.085085	Kyoto	1.63	0.613491
CoalElec	8.59	0.116452	OilP	1.57	0.635985
CoalP	7.72	0.129529	OilElec	1.5	0.668507
GasElec	3.56	0.281208	Mean VIF	4.97	
NuclearElec	2.98	0.335664			
ImpDep	2.19	0.456854			
HHI	2.18	0.458931			
Kyoto	1.85	0.539815			
OilElec	1.64	0.610581			
Mean VIF	24.58				

Once collinearity problems are avoided, a test for heteroskedasticity is performed using the Modified Wald test for heteroskedasticity because it works when the normality of the errors assumption is violated. The results confirm the existence of heteroskedasticity in our data panel. The following step is to test for the existence of serial correlation in u_{it}, using the Wooldridge first difference test for serial correlation in panel data (Wooldridge, 2002). The test indicates the presence of country-specific autocorrelation that needs to be removed (i) by taking first differences if the correlation is of order one or (ii) using a dynamic approach to address it. We decide to use a simple panel-data model with a first-order autoregressive component that controls for the dependence of t with respect to t-1. Finally, Pesaran's (pesaran, 2004) cross-sectional dependence test, Friedman's statistic (1937), and the test statistic proposed by Frees (1995) are used to test for cross-sectional independence in the panel finding that the error terms are contemporaneously correlated. Potentially allowing for the country's fixed effects, our model is the following:

$$res_{it} == \propto + \gamma ECO_{it} + \theta ENV_{it} + \varphi SEC_{it} + \mu_i + \varepsilon_{it} \quad \text{(eq. 1)}$$

where i = 1...N indexes countries and t = 1...T indexes time. res_{it} is the logarithm of the RES contribution on TPES for each country i and year t. Our explanatory variables are divided into ECO_{it}, a vector of Economic variables; ENV_{it}, corresponds to sustainability variables; SEC_{it}, corresponds to Security variables; μ_i is the country-specific effects; and ε_{it} corresponds to the error terms.

4.5. Estimation and results

The data described above were used to estimate Eq. (1) using Stata. We use the Feasible Generalized Least Squares (FGLS) and Partial Correlated Standard Errors (PCSE) methods to estimate our fixed effects models. The PCSE is an alternative FGLS and involves using Prais–Winsten estimates instead of OLS when autocorrelation is specified to determine parameter estimates, but replacing the Prais–Winsten standard errors with PCSE. Both methods allow for contemporaneous correlation and heteroskedasticity across the instruments and time series autocorrelation within the regressors. Following Reed and Ye (2011), we decide to use PCSE because we are interested in estimating the confidence intervals and FGLS for coefficient estimates. We also run a Random Effects Model (RE) with an AR(1) disturbance using the GLS estimator of Baltagi and Wu (1999).

Table 4. Regressions results using PCSE, FGLS and RE

Estimator	PCSE	FGLS	PCSE	FGLS	RE
Dependent Variable					
Log CRES					
CO_2pc	-0.0242***	-0.0242***	-0.0624***	-0.0621***	-0.0441***
	(0.00753)	(0.00722)	(0.00826)	(0.00681)	(0.00739)
Energypc	0.0250	0.0250	0.168***	0.167***	0.113***
	(0.0292)	(0.0296)	(0.0198)	(0.0222)	(0.0278)
Kyoto	-0.00473	-0.00473	-0.00492	-0.00485	0.0240*
	(0.0522)	(0.0441)	(0.0465)	(0.0534)	(0.0125)
ImpDep	-0.235***	-0.235***	-0.222***	-0.224***	-0.432***
	(0.0560)	(0.0549)	(0.0460)	(0.0541)	(0.0610)
HHI	-0.702***	-0.702***	-0.557***	-0.559***	-0.837***
	(0.191)	(0.176)	(0.184)	(0.194)	(0.198)
GasEco	0.000536**	0.000536	0.000227	0.000230	0.000579*
	(0.000231)	(0.000349)	(0.000169)	(0.000214)	(0.000319)
Gasph	-0.0197**	-0.0197*	-0.00708	-0.00724	-0.0272**
	(0.00991)	(0.0113)	(0.00952)	(0.00894)	(0.0113)
CoalElec	-0.240**	-0.240**	-0.649***	-0.647***	-0.306***
	(0.0983)	(0.101)	(0.102)	(0.0993)	(0.103)
OilElec	-0.274***	-0.274***	-0.244***	-0.242**	-0.279***
	(0.0954)	(0.0968)	(0.0840)	(0.116)	(0.101)
GasElec	-0.279***	-0.279***	-1.014***	-1.008***	-0.409***
	(0.0753)	(0.0776)	(0.139)	(0.0983)	(0.0859)
NuclearElec	-0.563***	-0.563***	-1.122***	-1.117***	-0.821***
	(0.121)	(0.145)	(0.0952)	(0.0982)	(0.136)
OilP	0.00414***	0.00414***	0.00490***	0.00490***	0.000240
	(0.000868)	(0.000782)	(0.000783)	(0.00100)	(0.000200)
GDPpc	0.00567**	0.00567**	-0.00828***	-0.00826***	0.00401
	(0.00254)	(0.00271)	(0.00231)	(0.00226)	(0.00266)
Constant	-0.541***	-0.541***	-0.407***	-0.411***	-0.457***
	(0.101)	(0.109)	(0.109)	(0.120)	(0.123)
Observations	479	479	479	479	479
R-squared	0.944		0.818		
Wald chi2	416580.68	4684.77	9.65e+07	597.12	242.15
Country FE	YES	YES	NO	NO	
Time FE	YES	YES	YES	YES	

Notes: ***, **, * represent significance at the 1%, 5% and 10% levels, respectively.

In the PCSE model, the autocorrelation parameter may be constant across panels or different for each panel. Following the recommendation of Beck and Katz (1995), we decide to estimate one AR parameter for all panels instead of panel-specific autoregressive parameters. Even after having employed the series of Unit Root tests, there remains a presence of heterogeneous p in the logRES variable. Table 4 presents the results. Columns (1) and (2) include country and time fixed effects, and columns (3) and (4) only time effects for the PCSE and FGLS models. Column 5 presents the results for the Random Effects Model.

The results are robust across regressions; the coefficient estimations have the same sign and similar standard deviations in all models except for the GDPpc variable, which shows different results, not clearly indicating a possible causality link. The first two columns present the results for the within country variation. Both PCSE and FGLS estimations present similar levels of significance except for the GasEco and GasPh variables, which lose explanatory power when the FGLS model is run. When the between variation is observed by omitting the country-specific effects, the power of explanation of some variables increases because the differences between countries are greater than within them. That is true of the Energypc variable that becomes significant and of CO_2pc and the contribution to electricity generation by source. All of these variables increase their explanatory power except for the case of OilElec, which remains at the same levels.

The Random Effect model is a short estimation of the combination of within and between variations. The main differences from the other regressions are the increase in the significance level of the Kyoto variable, GasEco and GasPh, but with a change in the sign of the Kyoto variable. Moreover, the contribution of coal, oil, natural gas and nuclear energy sources to the electricity generation decreases their explanatory power; finally, the OilP and GDPpc variables become not significant.

Table (5) presents different selected specification models for the PCSE regression including country and time effects. We decide to introduce the variables by dimensions. Column (1) introduces variables linked to the environmental dimension: the Kyoto protocol, CO_2 per capita and energy per capita. As independent variables, they show a decrease in the coefficient of approximately one-third with respect to the model with all the variables (Column 5). As before (column 1 table 4), the Kyoto and Energypc variables have no significance power. The CO_2pc variable reveals that when an economy becomes more pollutant in terms of CO_2, it shows more resistance to the switch to RES. The interpretation is that carbon-intensive economies become more dependent on cheaper fossil fuels. This path dependence process, along with the brown lobby efforts, discourages RES support because it is more cost effective to continue using cheap fuels than using RES[17]. Conversely, higher carbon intensity increases the vulnerability of a member State to climate-change mitigation policies. Alternatively, to the extent transition to a cleaner energy system is costlier, the more prone it is to negative consequences in terms of inflationary pressures and competitiveness loss. However, our results suggest that this mechanism cannot offset the cost advantages of a carbon-based economy

Columns (2) and (3) introduce the variables linked with the security of supply dimension. The results for HHI are robust, being strongly significant in both Models (2) and (5). Conversely, GasEco, GasPh are not significant. ImpDep is significant but with a coefficient approximately two and three times smaller than the HHI variable. As it has been highlighted before, reducing import dependency is only one of the multiple potential targets of an energy security policy. Nevertheless, energy dependency is commonly used in the literature as the only proxy of energy security, reducing the multidimensionality of the concept. The results of our regressions show that to the extent that import independence is materially impossible, the diversification of the energy supply plays a major role for RES support in the EU's policy. This result holds even when the share of each of fossil fuel and nuclear energy in electricity generation is included (column 5). In fact, when comparing all of the coefficient estimates for all variables, the HHI appears to have the greater effect in RES development. These results are in line with theoretical models affirming that RES deployment increases the energy security of systems by the diversification of energy sources (Escribano et al., 2013). In the interpretation of the negative coefficient, it is important to understand that a high HHI index means lower diversity and vice versa. Therefore, the diversification of energy supplies in EU countries fosters RES deployment. Similarly, a decrease in the diversification of the primary energy supply causes a reduction in RES deployment.

17 It must be kept in mind that there are also green lobbies. However, their relevance or financial muscle is much lower that their fossil fuel counterparts.

Table 5. Selected model specifications for the PCSE estimator

	(1)	(2)	(3)	(4)	(5)
Dependent variable LogCRES					
CO_2pc	-0.0317***				-0.0242***
	(0.00737)				(0.00753)
Energypc	0.0282				0.0250
	(0.0299)				(0.0292)
Kyoto	0.00857				-0.00473
	(0.0553)				(0.0522)
ImpDep		-0.280***			-0.235***
		(0.0512)			(0.0560)
HHI		-0.836***			-0.702***
		(0.196)			(0.191)
GasEco		0.000131			0.000536**
		(0.000208)			(0.000231)
GasPh		-0.0124			-0.0197**
		(0.00886)			(0.00991)
CoalElec			-0.525***		-0.240**
			(0.0872)		(0.0983)
OilElec			-0.242**		-0.274***
			(0.103)		(0.0954)
GasElec			-0.399***		-0.279***
			(0.0873)		(0.0753)
NuclearElec			-0.564***		-0.563***
			(0.136)		(0.121)
OilP				0.00640***	0.00414***
				(0.000362)	(0.000868)
GDPpc				0.00203	0.00567**
				(0.00270)	(0.00254)
Constant	-0.585***	-0.398***	-0.717***	-1.175***	-0.541***
	(0.0647)	(0.0740)	(0.0422)	(0.0742)	(0.101)
Country FE	YES	YES	YES	YES	YES
TIME FE	YES	YES	YES	YES	YES
N	482	479	483	479	479
R-squared	0.935	0.932	0.914	0.911	0.944
Wald chi2	697822.24	202166.80	28503.61	113249.11	416580.68

Notes: ***, **, * represent significance at the 1%, 5% and 10% levels, respectively.

Column (3) includes the share of fossil fuels by source and nuclear energy in the electricity mix. The result agrees with other studies; the coefficients for coal and oil are negative, supporting the hypothesis of the brown lobby (Huang et al., 2007; Sovacool &

Saunders, 2014 & Sovacool, 2009). In most countries, coal power represents the core of the brown lobby. Coal's participation in electricity generation has decreased from an average of 43% in 1990 to 34% and 28% in 2002 and 2011, respectively. Moreover, it appears that this effect is going to persist as long as the value of Kw/h of coal internalizes its pollution cost.[18] Nevertheless, its reduction to levels below 25% would increase, rather than decrease, the degree of diversification. When all of the variables are included (column 5), the effect of the variables decreases and becomes equal among coal, oil and gas sources. However, for the NuclearElec variable, the effect is almost double. This result can be explained by the low Kw/h cost of nuclear power and the absence of CO_2 emissions in its generation, which makes it an important competitor for RES (Karakosta et al., 2013). This result also means that for European policymakers, the risk associated with nuclear energy generation did not represent a threat to the energy-system security level because the technical and environmental risk and externalities are not reflected in the price or in choosing alternative, and safer, energy sources.

Finally, columns related to the competitiveness dimension are introduced in columns (4) and (5). The results were inconsistent for the GDP variable in table 4. Here, the significance is non-existent or below the 1% level of significance in the model with all the variables, which means that an interaction can exist. This is an expected result because the VIF coefficient is greater than 10 (table 3). In the case of the OilP, the results are robust, and the variable is significant at the 1% level in both columns (4) and (5).

To continue, we will discuss the results in accordance with the classification of the three dimensions. The variables linked to the environmental dimension of energy security present a low level of explanation compared with the other dimensions, particularly security of supply. Concerning the negative coefficient of CO_2pc in all models, one explanation may be that it is a consequence of how GHG emissions reduction can be exhausted or discarded. That is, the use of other energy sources such as nuclear and gas pollute less in terms of CO_2, than does coal, the traditional source for electricity generation and the main source of CO_2 emissions. The decarbonisation of the economy by the shift from fossil fuels to a less polluted energy sector thorough RES deployment is a costly strategy only strongly promoted when other options have been achieved. In this sense, it could be more efficient to adopt and encourage energy efficiency measures or even the adoption of other technologies to reduce

18 Clearly, this is not happening today in the CO_2 markets. In June 2008, the daily average price of one tonne of CO_2 was 22€. However, in 2014, it was 6€ and now (June 2015) is approximately 7€ (http://www.sendeco2.com/uk/precio_co2.asp?ssidi=3)

emissions, for example, with combined cycles that generate gains in efficiency and reduce CO_2 emission levels. Once these efficiency gains are achieved, RES deployment may be the next step to decarbonising the economy. If this is true, then RES deployment should be considered a fourth strategy to follow after (i) reducing energy intensity, (ii) turning to the EU Emissions Trading System, and (iii) gaining efficiency in sectors not covered by the EU ETS such as housing, agriculture, waste or transport.

In the second case, the competitiveness dimension of energy security could be a driver for RES deployment, but there are contradictory results for the GDP variable. The GDPpc variable becomes negative for the between estimation, positive for the within and not statistically significant for the Random Effects. We would expect that economies with less economic resources are reluctant towards RES deployment because of the great challenge in terms of financing; accordingly, the improvement in the economic situation increases their RES deployment. However, the GDP per capita is not statistically significant when the other dimensions are not represented in the model. On balance, compared with other dimensions, the GDP per capita variable may present a driver or a barrier to RES depending on the country (Al-Mulali, 2013). This can be because the GDP-RES nexus depends heavily on the type of RES technologies. For instance, Ohler and Fetters (Ohler & Fetters, 2014) report that increases in GDP decrease hydroelectric generation, but the reverse is true for waste generation. Therefore, to study the nexus, it may be necessary to differentiate between energy sources instead of taking all RES technologies as a whole.

Nevertheless, the competitiveness dimension remains significant in its second variable. More importantly, oil prices present one of the most consistent results. As expected, high oil prices are considered a signal of scarcity and risk of supply disruption by investors due to, among other things, demand increase, oil depletion or political instability in transit or producing countries. Therefore, oil price increases are one of the main factors affecting RES investment.

Conversely, a situation of local low economic growth in a country or region combined with low global energy demand may be a major threat to RES deployment, and the effect may be amplified by low gas and coal prices. Although gas and coal prices are not included in our regression, natural gas prices are directly linked to oil prices; thus, a shift from natural gas to coal in electricity generation is expected to be a major consequence of a possible increase in oil prices, in the absence of a stringent climate policy (Vielle & Viguier, 2007).[19] However, if coal prices increase together with oil and gas prices, and/or if climate policy is applied, the share of natural gas and renewable options is expected to increase, as happened in the last 20 years. The Nuclear energy sector's future is uncertain and will depend on the effects of the recent Fukushima disaster on public opinion and on the academic debate (Kiriyama & Kajikawa, 2014).

Finally, for the security of supply dimension, the results are ambiguous. The share of fossil fuels in electricity generation shows that the electricity mix is the main factor decelerating RES deployment. A higher share of gas and nuclear energy may reduce the deployment of RES more than a coal-based energy system. This effect is a consequence of the low price of nuclear energy[20] and the absence of GHG emissions in nuclear electricity generation. A share increase of nuclear electricity allows generating high quantities of electricity at low prices, but it requires a huge amount of previous investment. This restriction in the use of the cheapest electricity source is covered by gas and hydro power plants, dispatchable technologies at request with low levels of CO_2 emissions. Therefore, the use of these technologies, and most important, their combination, is a barrier to the introduction of RES. Moreover, in the case of natural gas, it could also be argued that because gas imports in the EU were until 2008 largely fulfilled by long-term contracts (Franza, 2014), their replacement by RES is even more difficult.

Moreover, import dependence is not the variable with more explanatory power within and between countries. One interpretation of this result is that import dependence is not a large driver of RES deployment because to date the displacement of energy imports by RES sources has not been significant. In the case of HHI, the results show that the diversification of energy sources fosters RES deployment. If we consider this result together with the share of fossil fuels and nuclear energy in electricity generation, the explanatory power of our regression increases. For instance, a minimally diversified energy system highly reliant in gas and nuclear sources may present a higher barrier to RES deployment than would a more pollutant coal-based and diversified one.

Finally, it is interesting to observe how the GasEco and GasPh are not as significant as other variables are, and their coefficients are different – positive for GasEco and negative

---

19 Despite the recent drop in oil prices, most studies forecast a price recovery in coming years. There are no estimations that retain 2015 oil prices in the medium and longer term (EIA, 2015a).

20 It must be kept in mind that low prices in nuclear power are possible because most externalities are not considered.

for GasPh. The negative coefficient of the ImpDep variable means that when countries become dependent on energy imports, the rate of RES deployment decreases. Additionally, more-dependent countries deploy fewer RES than do countries with lower levels of energy imports. By the same logic, an economy with higher natural gas levels of consumption per capita, represented by the GasPh variable, should present lower values of RES deployment than would economies with lower levels of gas consumption per capita because gas is considered a political weapon. The gas vulnerability is primarily associated with the political relationship of the EU with their suppliers, particularly Russia. Considering the stability of the energy relationship has existed for a long period in our sample, our variables may not fully reflect the effect of a possible political destabilization.

4.6 SUR model for the EU-15

In this section firstly, we assess the impact of different energy security indicators for the EU-15, using panel data disaggregated at the national level. Second, we analyse the individual slopes for each country separately. The accent is in exploring whether the energy security – renewable energy dynamics of the EU members differ. As the previous section show a predominance of energy supply security factors affecting RES deployment, we will concentrate the analysis in them. The main factors investigated here are policy-oriented proxies: energy dependence, diversification of primary energy sources and gas economic intensity. To put it simply, our main research questions are the following:

RQ 1: Are energy security policies a determinant for renewable energy deployment at the EU-15 level?

RQ 2: Which are the differences among EU-15 members?

4.6.1 Data and methodology

To answer the major research questions, three proxies of energy security and a set of control variables were chosen. These are the work hypothesis associated to each one of the proxies:

H1: Higher import dependence of energy sources lead to higher share of renewables.

Import dependency shows the extent to which a country relies upon imports to meet its energy needs. The theory suggests that higher reliance of a country on energy imports requires a higher level of RES deployment to improve that country's energy independence.

H2: Higher diversification of primary energy sources lead to higher share of renewables.

Diversification allows to minimize the risk of a supply disruption or price shock associated to one energy source. We expect less-diversified economies to increase the deployment of RES as a means of managing their dependence on other energy sources.

H3: Higher gas intensity lead to higher share of renewables.

Gas is highly politiced and its supply is dominated by three countries: Russia, Norway and Algeria. Therefore, gas carbon intensity implies increased vulnerability to changes in supply terms and a higher likelihood of facing negative consequences in terms of political pressures.

H4: Higher Oil prices lead to higher share of renewables.

We expect the increase in commodity prices to boost the adoption of RES technologies because an increase in oil prices makes the substitution of exhaustible energy sources with sustainable energy more profitable

Apart from the above hypothesis we are also interested in study the country specific effect of the following control variables in order to study the degree of heterogeneity: energy intensity, carbon intensity, share of coal/gas/nuclear on electricity generation and gdp per capita. For the gdp variable it is expected a high degree of heterogeneity. The share of fossil fuel sources on electricity generation is a proxy of the power of the brown lobby and is expected that they act as a barrier to RES deployment. Finally, for energy intensity and CO_2 emission it is expected a more homogeneous and positive causality as far as fitting climate change has been since late 80's a common policy goal.

Annual data for 15 EU countries (Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, The Netherlands, Norway, Portugal, Spain, Sweden and United Kingdom) were collected over the period 1990–2012. All variables were obtained from the Eurostat database with the exception of real GDP in constant prices and purchasing power parity (gdp) and population in millions were obtained from the World Bank. Since we want to measure the impact of changes in prices over time rather than the impact of price levels, the use of nominal prices seems to be reasonable. As previously, the Herman-Herifax Index (HHI) is employed as the indicator of concentration of primary energy sources.

The analysis begins with a logarithm transformation applied to address asymmetry with the Share of renewable in TEPS and GDP per capita. In a subsequent step, and to avoid problems of collinearity in the final model, a simple Ordinary Least Squares (OLS) regression is performed and checked for collinearity calculating the variance inflation factors (VIFs). Following Chajerte and Hadi (2006), all the variables included are not problematic as their VIF are below 10. Additionally, the correlation matrix shows a significant and high correlations between CO2pc and EnergyIntensity (0.734); GDPpc and CO2pc (0.693); and GDPc EnergyIntensity (0.770), we will address this issue in the estimation. Moreover, fixed panel and random panel regressions and a Hausman test for efficiency among the two estimators where performed, indicating that the Fixed Effects (FE) estimator is preferred. Therefore, accounting for country's FE, the linear econometric model becomes:

$$y_{it} = \propto + \gamma_1 ES_{it} + \theta_2 CON_{it} + \mu_i + \varepsilon_{it} \qquad \text{(eq. 2)}$$

where i = 1...N indexes countries and t = 1...T indexes time. ES is a vector of energy security variables; CON_{it} corresponds to the vector of control variables; μ_i is the country-specific effects; and ε_{it} corresponds to the error terms.

A part of the FE model we test for heterogeneity with a SUR model estimated with FGLS. The SUR comprises several individual relationships that are linked by the fact that their disturbances are correlated. Compared to FE the SUR estimator has several remarkable properties. First, constrained SUR estimates are more efficient than FE estimates (Zellner 1962) and it is possible to allow for slope heterogeneity across equations (countries) with more efficient estimates than simple equation-by-equation OLS estimates. We estimate both constrained and unconstrained (heterogeneous slopes) SUR and compare these results to the base FE estimates. For all SUR estimates, the Breusch–Pagan test of independence is reported.

4.6.2 Results and discussion

The results for the FE and constrained SUR are reported in table 6. As expected, coefficients of the constrained SUR estimates are similar to the FE estimates but with lower standard errors confirming the result of FE estimates. The four first coefficients are the coefficients of interest and present different effects on RES deployment. Surprisingly, in general terms Import dependence may not cause RES deployment and the effects of oil prices and gas intensity although significant are so small that they cannot enough to explain the displacement of fossil fuels in the energy mix. In the other hand, HHI the variable that represent the degree of concentration of primary energy show one of the highest coefficients indicating that more diversified energy systems are more prone to RES deployment. For the control variables seems notable the estimates for energy intensity and CO_2 emissions per capita, which are negative which means that in general terms, in the EU15 the use of more energy per capita and CO2 per capita have a negative effect on RES deployment. The same can be said for the coal share in electricity. Surprisingly gas share in electricity have a positive effect on renewables deployment, which contradicts in part the brown lobby hypothesis.

Table 7. Results for FE and constrained SUR

Variable/Model	FE	SUR	SUR
Import depenence	-0.029	-0.034***	-0.034***
	0.053	(0.009)	(0.009)
OilPrice	0.001***	0.001***	0.001***
	0.000	(0.000)	(0.000)
Concentration	-0.993***	-0.930***	-0.930***
	0.199	(0.052)	(0.052)
GasIntensty	0.000**	0.000***	0.000***
	0.000	(0.000)	(0.000)
GDPpc	0.005**	0.004***	0.004***
	0.002	(0.000)	(0.000)
CO2pc	-0.025***	-0.024***	-0.024***
	0.007	(0.002)	(0.002)
Energy consumptionpc	-0.048	-0.043***	-0.043***
	0.0352	(0.009)	(0.009)
ShareCoalElec	-0.106	-0.103	-0.103
	0.111	(0.024)	(0.024)
ShareGasElec	0.112	0.062**	0.062**
	0.074	(0.026)	(0.026)
ShareNuclearElec	-1.048***		-0.995***
	0.211		(0.048)
Constant	-0.561***		
	(0.121)		
Observations (NxT)	345	345	345
F test all u_i=0	182.98***		
Breusch-Pagan test of independence: chi2	477.189***	477.189***	

*, ** and *** signals significance on a 10%, 5% and 1% level respectively.

Table 8 display the results for the unconstrained SUR. As expected the EU members show a high degree of heterogeneity in certain variables and quite homogeneous behavior in others. Starting with the control variables, among the more homogeneous are the CO2 and energy intensity. In a second group could be categorized the coal gas and nuclear share in electricity generation, variables that although present same direction of causality, present big disparities in the coefficient magnitude, which is normal as different countries present lower shares of each technology in the electricity mix. Continuing the review of the results from the most homogenous to the more heterogeneous coefficients, the gdp should be the next. These hetereogeinty in the gdp were expected as previous studies have already reported (Smyth & Narayan 2015).

Focusing on the working hypothesis, the results show that higher import dependence of energy sources leads to lower share of renewables for all countries with the exception of Belgium that present not significant results. Which means that there is a common pattern at the EU-15. This is an interesting result since we expected the opposite effect. The explanation for this result is that although It is commonly accepted indigenous renewables reduce import dependency, but imports comprises mainly oil usage for transportation, so the deployment of renewables, which has been focused on electricity, has had little impact on transport. Moreover, natural gas, the other main component of energy imports complements volatile renewables, because modern gas-fired power stations can switch from idle to full output within minutes to compensate the intermittence of renewables.

Oil Prices do not confirm our hypothesis and show a high level of hetereogeneity across countries, but with very low coefficients which indicates that although significant the impact of oil prices in the displacement of fossil fuel sources from the energy mix is very marginal. These result is explained by the fact that renewables are incentivized by a series of policy instruments including Feed in Tariff and Quotas. These instruments have as aimed to ensure a reasonable return to the investors and the results show that these policies have been effective in protecting renewable from market competition for better or for worse. This means that increases (drops) in energy commodity prices does not incentive (discourages) the substitution of exhaustible energy sources for renewable sources.

This homogeneity in the results disappear for the third variable of interest, the concentration of primary energy. Results are positive for 5 countries, negative for 6 countries and not significant in 4 cases, but with the particularity that it shows the higher degree of variability between countries being the maximal positive effect in Luxembourg (5.694) and minimal in Denmark (-7.598). These means that although at the EU-15 level the diversification of energy sources as been promoted with the double purpose of increase energy security and incentive the use of renewables, the governments have developed different strategies and not always prioritizing the use of renewables. This result may be seen as an indicator of lack of coherence between energy security and environmental policy.

Finally, the results do not support the hypothesis that higher gas intensity lead to higher share of renewables. Gas intensity take positive values for 4 countries, negative for 3 and is not significant for the remaining 8. Moreover, the effect may be very marginal in all the cases as the coefficients are close to cero. The different results can be explained for two opposite effects. In one hand Gas is highly politicked, therefore, gas intensity implies increased vulnerability to changes in supply terms and a higher likelihood of facing negative consequences in terms of political pressures. In the other natural gas complements volatile renewables, because modern gas-fired power stations can switch from idle to full output within minutes to compensate the intermittence of renewables.

In fact, looking to the differences between the constrained models and the individual slopes, it is difficult to determine that a common pattern exist. Altogether, it is true that a common pattern regarding energy security may not exist but there are areas where the homogeneity of the results shows a common figure. By instance, the indicators related to climate change carbon intensity and energy intensity- with the Spanish exception- present a high level of uniformity. Regarding the security of supply policy, it seems that although energy dependence and increases on the oil price lead to renewable energy deployment, the lack of homogeneity in the diversification and gas intensity variable may indicate a room for improvement in energy security goals. By instance, the diversification of energy policies should take into account the possible negative effects over renewable energy deployment. This very important issue must be carefully tackled, given the current EU's energy security strategy based on the integration of energy markets and diversification of energy sources.

Something similar occurs with the economic variables. Our results show that economic growth does not always incentives the use of renewables raising doubts about the way in which sustainable development policies and priorities have been decided. For its part, oil prices, show a very low impact on renewable energy deployment that is a promising outcome of energy policies reform. Nevertheless, his last results may also open the door to the reconsideration of the internalization of externalities in order to reduce fossil fuels consumption. In that way, it may be possible to incentive transport fuels from renewables by taxing polluting resources in a sector with a very low renewable energy penetration.

Table 8. Results for unconstrained SUR

Variable/Country	Austria	Belgium	Denmark	France	Finland	Germany	Greece	Italy	Ireland	Luxembourg	Nederland	Portugal	Sweden	Spain	U. K.
Import Dependence	-1.131***	0.097	-0.272***	-0.783***	-0.535**	-0.835***	-0.975***	-0.570**	-0.917***	-2.049*	-0.567***	-1.022***	-1.321***	-0.754***	-0.285**
	(0.0430)	(0.381)	(0.0538)	(0.0570)	(0.272)	(0.237)	(0.0974)	(0.226)	(0.278)	(1.129)	(0.110)	(0.114)	(0.094)	(0.058)	(0.118)
OilPrice	0.000	0.002***	0.000	-0.000	0.000**	-0.001***	0.000	0.000	-0.000	0.003***	-0.000	-0.000*	0.000	0.000***	0.001
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Concentration	-0.346**	2.052***	-7.598***	-0.0869	-0.0941	-2.074***	0.788*	-3.524***	0.905	5.694**	-1.422***	0.339**	-0.321	-0.499***	2.692**
	(0.170)	(0.477)	(1.239)	(0.211)	(0.225)	(0.418)	(0.461)	(1.039)	(1.415)	(2.398)	(0.266)	(0.157)	(0.199)	(0.126)	(1.204)
GasIntensity	0.000	-0.000	-0.002***	-0.000	0.014	0.019***	0.002***	0.000	-0.008	0.001	-0.000	0.001	-0.081***	0.000***	0.0325**
	(0.000)	(0.007)	(0.000)	(0.002)	(0.0295)	(0.003)	(0.000)	(0.001)	(0.010)	(0.001)	(0.005)	(0.005)	(0.017)	(0.000)	(0.016)
GDPpc	0.002	-0.027***	-0.027***	0.003	-0.022***	0.028***	0.0119*	0.020***	0.022**	0.018**	-0.000	0.032***	-0.004	0.002***	0.008
	(0.001)	(0.009)	(0.005)	(0.002)	(0.004)	(0.004)	(0.007)	(0.005)	(0.009)	(0.007)	(0.006)	(0.005)	(0.006)	(0.000)	(0.009)
CO_2pc	-0.011	-0.082**	-0.069**	-0.013**	-0.106***	-0.053***	-0.0228	-0.061***	-0.288***	-0.0230	-0.111***	-0.106***	-0.069***	0.013**	-0.147***
	(0.007)	(0.032)	(0.027)	(0.006)	(0.016)	(0.017)	(0.017)	(0.021)	(0.040)	(0.021)	(0.017)	(0.014)	(0.011)	(0.006)	(0.032)
Energypc	0.031	0.058	0.431***	0.035***	0.181***	0.0428	-0.136	-0.046	0.661***	-0.016	0.0423	0.086*	0.123**	-0.050***	0.114
	(0.024)	(0.051)	(0.151)	(0.011)	(0.0326)	(0.072)	(0.106)	(0.098)	(0.191)	(0.085)	(0.042)	(0.050)	(0.048)	(0.010)	(0.126)
ShareCoalElec	-0.412***	-2.450**	-0.101	-0.663***	-0.574	-1.399***	-0.861***	-0.954***	0.505*	0.931***	-0.540	0.0454	-1.052***	0.0182	1.034
	(0.090)	(1.003)	(0.104)	(0.108)	(0.412)	(0.267)	(0.180)	(0.302)	(0.264)	(0.308)	(0.682)	(0.060)	(0.081)	(0.181)	(0.900)
ShareGasElec	-0.020	0.002	-0.466	-0.606***	-2.210***	0.741	0.046	-0.737***	-0.312*	-0.005	-1.084	-0.204***	-1.044***	1.213***	0.528
	(0.084)	(0.740)	(0.290)	(0.161)	(0.511)	(0.461)	(0.171)	(0.185)	(0.182)	(0.082)	(0.706)	(0.0538)	(0.069)	(0.273)	(0.799)
ShareNuclearElec	-	-2.658***	-	-1.199***	-2.088***	-1.405***	-	-	-	-	-3.818***	-	-2.509***	-0.751***	0.641
		(0.636)		(0.173)	(0.153)	(0.278)					(0.924)		(0.147)	(0.029)	(0.861)
Constant	0.132**	0.771	2.185***	0.232*	1.685***	0.104	-0.332	0.591***	-0.486	-2.736**	1.298**	0.0480	1.457***	0.162***	-2.730***
	(0.061)	(0.572)	(0.520)	(0.133)	(0.143)	(0.307)	(0.246)	(0.218)	(0.407)	(1.355)	(0.576)	(0.100)	(0.158)	(0.0470)	(0.698)
Breusch-Pagan test of independence: (chi2)	172.453***														
Observations	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23
R-squared	0.978	0.983	0.982	0.952	0.961	0.997	0.935	0.976	0.959	0.908	0.988	0.981	0.988	0.993	0.981

*, ** and *** signals significance on a 10%, 5% and 1% level respectively.

4.7. Long run and short run dynamics

This part of the study takes a closer look to the previous results of the PCSE and FGLS model. The Fixed Effects models allow to account for heterogeneity by including dummy variables for each one of the countries but they are still homogenous estimators. Recently, new developments on econometrics have provided new heterogeneous estimators that provide not only a solution for the presence of heterogeneity but are also a tool to explore causal dynamics between the long and short term. In this section, we will apply some of these estimators to explore the short and long-term dynamics of the security of supply indicators presented above. Moreover, we will also explore the granger-causality among the different indicators in order to understand the causality and possible endogeneity running from renewable energy deployment and our variables of interest.

As in the previous FGLS and PCSE models this part of the study employs EU annual data for 21 EU countries over the period 1990–2012: Austria, Belgium, the Czech Republic, Denmark, Estonia, Finland, France, Greece, Germany, Hungary, Ireland, Italy, Luxembourg, the Netherlands, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden and the United Kingdom. Here we focus on the variables related to the core aspects of energy security: Import dependence and diversification of primary energy sources. As previously, the share of renewable electricity (res) in TEPS, energy consumption per energy source and import dependence were obtained from the Eurostat database. The Herman-Herifax Index (HHI) is employed as the indicator of diversification classifying the different energy sources in five broad categories: nuclear, oil, gas, coal and renewables. As the long term causal relationship between GDP and renewable energy in EU countries is well stablished it is utilized as control variable. Real GDP in constant prices and purchasing power parity (gdp) and population in millions were obtained from the World Bank. GDP was divided by population to arrive at per capita measures. In the case of GDP and ren the variables are transformed to logarithms, the same procedure is not applied to HHI and IMPDEP.

4.7.1 ARDL Framework

In a ARLD framework it is necessary to first check for unit roots on the panels. Instead of conducting a unit root test for each series, we check for unit roots in using panel unit root test by conducting the Im et *al.* (2003) (IPS), Levin et *al.* (2002) (LCC) and the Fisher unit root test developed by Maddala and Wu (1999) to determine the order of integration of each variable in levels and first differences. The results of these tests are reported in Table 9. The variables, denoted in lower case letters, represent the natural logarithm of the variables. The results show that all data are integrated of order 1 but not of order 2, therefore a specification in first differences is appropriate to avoid spurious regression bias.

Table 9. Unit root statistics.

Unit root statistics variables in levels				Unit root statistics variables in first differences			
	LLC-test	IPS-Test	Fisher-test		LCC-Test	IPS-Test	Fisher-test
Variable	t-Star	W (t-bar)	Modified χ2	Variable	t-Star	W (t-bar)	χ2
Ren	-2.024**	1.389	4.591***	Δren	-2.426***	-4.986***	8.670***
HHI	1.26	1.800	-1.168	ΔHHI	3.184	-3.709***	6.343***
IMPDEP	1.524	2.558	-0.817	ΔIMPDEP	2.461	-3.893***	5.550***
Gdp		5.768	-2.160	Δgdp		-3.962***	5.256***

H0 is nonstationarity/unit root.
In all tests a trend and 2 lags are included.
*, ** and *** signals significance on a 10%, 5% and 1% level respectively.

To account for heterogeneity and long-run and short causality in panel data we will use Mean Group (MG) and Pooled Mean Group (PMG) estimators within the Autoregressive Distributed Lag (ARDL) specification developed by Pesaran et al. (1997, 1999). The MG estimator relies on averaging of cross-sections, and the PMG estimator relies on a combination of pooling and averaging of coefficients and therefore constrains the long-run elasticities to be equal across all panels. Following the ARLD approach we assume the following long-run function:

$$res_{it} = \propto_{it} + \delta_{it} + \theta_1 HHI_{it} + \theta_2 IMPDEP_{it} + \theta_3 gdp_{it} + \varepsilon_{it} \qquad \text{(eq.3)}$$

where I = 1;...;N for each country in the panel and t = 1;…;T refers to the time period. res_{it} is the log of share of renewables in TPES; HHI_{it} is the The Herman-Herifax Index and proxy for concentration of TPES; $IMPDEP_{it}$ is the energy import dependence; and gdp_{it} is the log of gdp per capita. Based on the unit root test, since in each country all of the series are individually nonstationary and if the series are cointegrated, these series pairs can be represented and estimated in a dynamic error correction model (ECM) based on the lagged residuals from Eq. (3) the ARDL(1,1,1,1) dynamic panel specification is:

$$res_{it} = \propto_{1i} + \delta_{10i} HHI_{it} + \delta_{11i} HHI_{i,t-1} + \delta_{20i} IMPDEP_{i,t} + \delta_{21i} IMPDEP_{i,t-1} + \delta_{31i} gdp_{i,t} + \delta_{32i} gdp_{i,t-1} + \lambda_i \, res_{i,t-j} + \varepsilon_{it} \qquad \text{(eq 4)}$$

And the error correction representation becomes:

$$\Delta res_{it} = \phi_1(res_{i,t-1} - \theta_{0i} - \theta_{1i}HHI_{it} - \theta_{2i}IMPDEP_{it} - \theta_{3i}gdp_{it}) + \delta_{11i}\Delta HHI_{it} + \delta_{21i}\Delta IMPDEP_{it} + \delta_{31i}\Delta gdp_{it} + \varepsilon_{it} \qquad \text{(eq. 5)}$$

Where $\phi_i = -(1-\lambda)$, $\theta_{0i} = \frac{\mu_i}{(1-\lambda_i)}$, $\theta_{1i} = \frac{\delta_{10i}+\delta_{11i}}{(1-\lambda_i)}$, $\theta_{2i} = \frac{\delta_{20i}+\delta_{21i}}{(1-\lambda_i)}$ and $\theta_{3i} = \frac{\delta_{30i}+\delta_{31i}}{(1-\lambda_i)}$

where the subscripts i and t denote country and the time period, respectively, Δ is the first difference operator; the parameter φi is the error-correcting speed of adjustment term; the coefficients, θ1i, θ2i and θ3i captures the long-run relationships between the variables; and $\delta_{11i}, \delta_{12i}$ and δ_{31i}captures the short-run relationships. We finally test for efficiency among the two estimators using a Hausman test, the results are reported in Table 10.

The Hausman test indicates that the PMG estimator outperforms the MG technique in all regressions and for a question of space we only comment the PMG regression. Table 4 indicates two different type of dynamics in the short and the long term. In the short term causality is determined by the statistical significance of the first differences using a Z-test. Results show a statistically significant result for ΔIMPDEP, which indicates that the concentration of primary energy sources (θ_{31} coefficient) has a negative short-run causal impact on the share of renewables in TEPS. Long-run term causality is determined by the statistical significance of the respective error correction term (ECM) using a Z-test. Results show that all coefficients are statistically significant being in both model specifications HHI the variable with a higher coefficient. The speed of adjustment measured by the ECT

The differences in the estimations can be due to different reasons. One is that the panel is likely to contain outliers as countries account with very different energy endogenous resources. Under such situation the PMG robust to the choice of lag order as well as to outliers (Pesaran et al., 1999). Moreover, that PMG estimator constrains the long-run elasticities to be equal across all panels. This “pooling” across countries yields efficient and consistent estimates when the restrictions are true. Often, however, the hypothesis of slope homogeneity is rejected empirically. If the true model is heterogeneous, the PMG estimates are inconsistent. Moreover, the time span for this study is 23 years, and the MG estimator may lack degrees of freedom.

Table 10. Panel ARDL estimations

Estimator	MG	PMG	MG	PMG
Long run coefficients				
HHI	-6.766**	-2.665***	-3.133	-1.386***
	(3.015)	(0.330)	(2.543)	(0.199)
IMPDEP	-3.637	-0.647***	-1.747	-0.352***
	(3.271)	(0.179)	(2.259)	(0.098)
Gdp	-5.469	0.323***	-0.161	0.339***
	(5.454)	(0.041)	(0 .337)	(0.0257)
Short run coefficients				
ECT	-0.488***	-0.205***	-0.606***	-0.276***
	(0.0865)	(0.0439)	(0.103)	(0.070)
Δ*HHI*	0.521	-0.211	1.028	-0.207
	(0.457)	(0.366)	(0.734)	(0.380)
Δ*IMPDEP*	-0.266	-0.748***	0.928	-0.961***
	(0.294)	(0.127)	(1.333)	(0.163)
Δ*gdp*	-0.0411	-0.161	-0.025	-0.196*
	(0.127)	(0.106)	(0.139)	(0 .100)
Δ*HHI(L1)*			0.977	0.050
			(0.561)*	(0.317)
Δ*IMPDEP(L1*			0.598	-0.079
			(0.522)	(0.154)
Δ*gdp(L1)*			-0.006	-0.132
			(0.204)	(0.181)
Constant	0.765	-0.182***	2.499	-0.385***
	(0.524)	(0.047)	(1.689)	(.106)
Wald test on ec=0	31.83***	21.75***		
Hausman statistic	0.78		1.64	

*, ** and *** signals significance on a 10%, 5% and 1% level respectively.

Regarding the log-term and short term causality estimates three mayor hypotheses are tested, which have important policy implications. These are (a) diversification of primary energy sources cause renewable energy deployment; (b) Import dependence cause renewable energy deployment; (c) GDP growth cause renewable energy deployment. All the estimations return significantly negative error-correction coefficients, providing strong support for the hypothesis that the three variables share a significant long-run relation. For the long term relation, we can say that all variables have a long run causality with renewables being the diversification of energy sources the one with a higher impact. This can be due to the fact that increases in energy dependence or GDP growth are more difficult to sustain in the long run compared to diversification. In the other hand, the import dependence short-run coefficients seems to be more relevant than the others. Our explanation is that energy dependence is commonly regarded as a proxy of energy security and therefore governments may be more inclined to implement policies to reduce energy import by instance by taxing energy consumption of certain sources and implementing energy efficient measures. Nevertheless, the gains in the long term are lower as long as energy needs continues to increase for this specific non endogenous energy sources. This explanation may be in line with the rebound effect or Jevons's paradox, the process which explains the reductions in gains from energy efficiency of resource use because of behavioral responses (Herring, 1999; Freire-González & Puig-Ventosa 2015)

4.7.2 Granger Causality Framework

Granger-causality is a different notion of causality of the one commonly used and applied to time series analysis. The idea is that a variable X Granger-causes Y if X can better predict Y using both X and Y than it can using Y alone. In a Granger causality framework, it is necessary to establish the existence of stationarity between different variables included in the analysis. In order to check for stationarity, the Pedroni's (1999, 2004) panel cointegration test is applied. The test account for heterogeneous panels and is based on an examination for a unit root process in the residuals. If the variables are cointegrated then the residuals should be I(0). The following a priori cointegration equation is consider:

$$res_{it} = \propto_{it} + \delta_{it} + \beta_1 HHI_{it} + \beta_2 IMPDEP_{it} + \beta_1 gdp_{it} + \varepsilon_{it} \qquad \text{(eq. 7)}$$

Which is the same a (eq. 3). The results of table 11 shows that 4 out of 7 test reject the null hypothesis of no cointegration. We also assumed all 36 combinations possible a priori cointegration equations with gdp, HHI and IMPDEP as dependent variable, but in all cases only 2 out of 7 cointegration reported the existence of cointegration.

Table 11. Panel cointegration tests

Panel test statistics: *(Within dimension)*		Group mean panel test statistics: *(Between dimension)*	
Panel v-stat	1.649**	Group rho-stat	1.179
Panel rho-stat	0.04492	Group pp-stat	-5.162***
Panel pp-stat	-4.865***	Group adf-stat	-3.059***
Panel adf-stat	-3.202***		

*, ** and *** signals significance on a 10%, 5% and 1% level respectively.

To examine the parameters of the long-run relationship between renewable generation and economic growth, we estimate Eq. (7) using Kao and Chiang (2000) Dynamic Ordinary Least Squares (DOLS) for cointegrated panel data to reduce the bias from endogeneity and serial correlation of OLS estimations. Results are displayed in Table 12. All coefficients are statistically significant which means that security factors are a source of renewable energy expansion and vice versa. As expected, the negative sign in the HHI variable indicate that an increase in concentration of energy sources reduce the expansion of renewables. In the case of the Import IMPDEP the variable indicates that for our sample dependence to external energy sources causes the increase of the share of renewables in TPES.

Table 12. Dynamic OLS long-run estimates.

	DOLS
ΔHHI	-0.503**
	(0. 21068)
ΔIMPDEP	-0.3170***
	(0 .0586)
Δgdp	-0.2439***
	(0.0553)
Wald chi^2	8.79

*, ** and *** signals significance on a 10%, 5% and 1% level respectively.

Since we are working with panel data and in each country all of the series are individually nonstationary, but the series pairs together are cointegrated, these series pairs can be represented and estimated in a dynamic Error Correction Model (ECM) based on the lagged residuals from Eq. (7). To account for stationarity variables are first-differenced and for each equation one lag-length is utilized, such that the model becomes:

$$\Delta res_{it} = \propto_{1i} + \beta_{11i}\Delta res_{it-1} + \beta_{12i}\Delta HHI_{it-1} + \beta_{13i}\Delta IMPDEP_{it-1} + \beta_{14i}\Delta gdp_{it-1} + \lambda_{1i}\,\varepsilon_{1it-1} + \mu_{it} \quad (7.a)$$

$$\Delta HHI_{it} = \propto_{1i} + \beta_{11i}\Delta HHI_{it-1} + \beta_{12i}\Delta res_{it-1} + \beta_{13i}\Delta IMPDEP_{it-1} + \beta_{14i}\Delta gdp_{it-1} + \lambda_{1i}\,\varepsilon_{1it-1} + \mu_{it} \quad (7.b)$$

$$\Delta gdp_{it} = \propto_{1i} + \beta_{11i}\Delta gdp_{it-1} + \beta_{12i}\Delta HHI_{it-1} + \beta_{13i}\Delta IMPDEP_{it-1} + \beta_{14i}\Delta res_{it-1} + \lambda_{1i}\,\varepsilon_{1it-1} + \mu_{it} \quad (7.c)$$

$$\Delta IMPDEP_{it} = \propto_{1i} + \beta_{11i}\Delta IMPDEP_{it-1} + \beta_{12i}\Delta HHI_{it-1} + \beta_{13i}\Delta res_{it-1} + \beta_{14i}\Delta gdp_{it-1} + \lambda_{1i}\,\varepsilon_{1it-1} + \mu_{it} \quad (7.d)$$

where the subscripts i and t denote country and the time period, respectively, Δ is the first difference operator, and ε_{1it-1} is the one period lag of the residuals from the long-run cointegrated relationship. Based on our previous result, the equation which results in stationary error term is only the equation with res as dependent variable. Hence, we estimate a long-run relationship only from this equation. Equations 7.a-d are estimated using Group Mean (GM), Pooled Mean Group (PMG) and Dynamic Fixed Effets (DFE) estimators. We test for efficiency among the three estimators using a Hausman test, which indicates the PMG estimator is preferred. The results for PMG are reported in Table 13.

Regarding the granger causality four competing hypotheses are tested, which have important policy implications. These are (a) unidirectional Granger causality running from energy security to renewable energy; (b) unidirectional Granger causality running from renewable energy to energy security; (c) bilateral Granger causality; and (d) independence.

Table 13. Panel Granger causality tests

	Sources of causation				
	Short run				Long run
	Δres	ΔHHI	ΔIMPDEP	Δgdp	ECT
Δres		46.79[0.097] (0.000)	21.40[0.322][a] (0.000)	61.01[-0.274][b] (0.000)	-0.212[b] (-2.57)
ΔHHI	84.41[-0.002] (0.000)		36.70[-0.002] (0.000)	158.38[0.020] (0.000)	0.0174[a]
ΔIMPDEP	48.33[-0.098][a] (0.000)	57.54[-0.919] (0.000)		61.93[0.188][b] (0.000)	0.127[a] (2.76)
Δgdp	26.04[-0.039] (0.000)	22.32[-0.313] (0.000)	18.17[-0.091][c] (0.000)		-0.067[a] (-4.41)

This table reports the partial F-statistics with respect to short-run changes in the independent variables from a likelihood ratio test. The lag length is one and the coefficients are reported in parenthesis. p-Values are reported in brackets for the likelihood ratio test. For the ECT, we report the s.e. test in parenthesis.
[a], , [b] und [c] signals significance on a 10%, 5% and 1% level respectively.

Table 13 displays the results from the panel error correction model. Short-run term elasticity is determined by the statistical significance of the corresponding right-hand side variables in each equation using a Likelihood-ratio test. The results show that the causal dynamics among the variables is very poor. As in the previous model RES is affected on the short term by the level of dependence and negatively by the increase on GDP. Which make sense as far as increases in gdp per capita may be associated with more energy consumption, which in the short term cannot be provided by RES for a question of availability. In the case of IMPDEP we observe that the variable is affected negatively by res, which may mean that the deployment of renewable energy actually decreases the import dependence. Nevertheless, the effect is so small that represent one half of the positive effect that gdp have on IMPDEP.

Regarding the Granger Causality results. The analysis show that all the variables are associated and granger causes each other. Nevertheless, the error correction terms in each of the equations are statistically significant but with different signs, which implies different rates of adjustments in the long term, but may also indicate in conjunction to the low coefficients that the process it not converging in the long run.

4.7.3 Discussion

The main motivation for testing for a unit root is to determine whether shocks have permanent or temporary effects. This result has an important policy relevance. As the proxy for primary energy concentration (HHI) and import dependence (IMPDEP) contain a unit root, its fluctuations will be permanent and policies designed to increase the energy supply diversification and decrease energy dependence will be effective in the long term because the shock induced by the policy change will be persistent.

The ARLD framework has proved again the importance of security of supply policies on renewable energy deployment at the EU-21 level in both short and long term. In the other hand, the fact that the MG and PMG result are diverse may reveal a high degree of heterogeneity among the studied countries. In this regard our panel data model may not be appropriate if the research question, and resulting policy implications, focus on results for individual European countries. On the other hand, as the aim of this study is to explore the driving factors at the EU level, the fact that our model does not reveal anything about the causality relationship for individual countries is not an issue. Nevertheless, the policy implications of a high degree of heterogeneity may be a fruitful avenue of future research.

Nevertheless, the second part of this section, the panel Granger causality framework, does not reveal a common short-run granger causality relation among the two energy security indicators and the share of renewable energy in the TPES. Indeed, the analysis reveal the existence of causal dynamics for the import dependence, gdp and renewable energy deployment inn some directions. In fact, it reveals that the long-run model of cointegration is problematic. The results show that at the EU level the relationship between energy security and renewables may be bidirectional but due to, by instance, the presence of structural breaks, the process it not converging in the long run. Moreover, as we have seen in previous section, in a Granger causality framework, it is necessary to establish the existence of stationarity between different variables included in the analysis. Nevertheless, panel cointegration tests can lead to potentially misleading results if some of the series are stationary. These may explain why the process it not converging in the long run and the results of the panel cointegration tests. Despite to these results, the analysis may open the door to new studies on the causal dynamics among energy security, economic and environmental policies that increase our understanding of the coherence and consistence among policy targets.

4.8 Conclusions

It is commonly assumed that environmental sustainability is the primary driver behind RES deployment, although RES contribution to energy security through domestic electricity generation is widely recognized. However, the relationship between RES deployment and energy security merits proper assessment. The purpose of this article is, specifically, to analyse the relationship between RES deployment and the supply security dimension of the European energy policy. To do so, we employ a set of indicators to assess factors influencing RES' share of TEPS. Our study focussed on barriers and drivers concerning energy security and sustainability and competitiveness, the other two pillars of European energy policy. Using data from 21 EU Countries from 1990 to 2013, we implement several panel data models. Unlike previous studies, we report a long-term relationship between energy security and renewable deployment.

The results presented here imply that energy security issues have a significant role in RES deployment. Our findings suggest that the relationship between energy security policies and RES deployment is far from straightforward and depends on the chosen energy security strategy, usually linked to the different energy security conceptualizations presented in section 3. Hence, this study contributes to the ongoing debate about the relationship between energy security and RES deployment with four main conclusions.

The most obvious one is that the introduction of a wide range of indicators of energy security appears to be not only relevant to assess the role of the energy security dimension in RES deployment but also necessary in the formulation of a coherent EU energy policy. The complex relationships between different energy security dimensions cannot be covered with only one indicator, as has traditionally been performed with energy dependence.

More importantly, our second and perhaps main conclusion is that variables related to energy security play a significant role in the development of renewable energy in the EU. This finding partially contradicts almost all earlier empirical findings [6,7,9] because the energy security dimension of the variables included in their models is omitted – except for the energy dependence variable. Moreover, the results of our analysis show that environmental policies such as the reduction of CO_2 emissions and energy intensity are not the main driver of RES deployment. In our view, although the pursuit of environmental targets may be theoretically one of the drivers of RES deployment, the EU environmental policy does not in fact really discourage the use of fossil fuels. In other words, despite the common opinion that renewable energy deployment is solely driven by the aim to reduce CO_2 emissions, our results suggest that this development is an intended consequence of the EU energy security strategy. Thus the main finding of this article contradicts a deeply rooted idea among policymakers, experts or the public opinion: the main driver behind RES deployment is energy security rather than environmental concerns and sustainability policies. This fact would imply the need to reassess the European energy policy approach to both energy security and renewable energies.

The third and fourth conclusions belong to the debate on the definition of energy security and its objectives. From a narrow perspective on energy security, accessibility to energy resources would be represented primarily by import dependence indicators, which our results show do not constitute the main security driver in RES deployment. Therefore, the non-inclusion of other factors may distort significantly the results and lead to biased conclusions. This result accords more with a modern approach to energy security without a prejudice against energy dependence (Guivarch & Monjon, 2015; Brown & Huntington, 2008). Finally, our fourth conclusion is that an energy security definition primarily based on the disruption of energy supplies due to physical interruptions (accessibility dimension) constitutes a reductionism and implies a lack of coherence among the different EU's energy policy dimensions.

Although our indicators list was formed with the inclusion of variables from three different sources, the final assessment of the barriers does not cover all the indicators proposed in the energy security literature. Nevertheless, in a follow-up study of the coherence between energy policy dimensions, it would be informative to introduce a wider set of variables. Moreover, future research may need to consider the different characteristics of RES technologies. Considering their differences would allow to identify whether the effect of energy security issues depends on the level of maturity of each technology or on any other feature of different RES.

Conclusions

The rapidly energy consumption is one of the primary challenges facing the world in recent decades. Both the public and private sectors have hastened to respond to the emerging energy needs of the economies resulting in a securitization of energy policies. Energy security is a sub-field of energy economics and has attracted the attention of researchers for more than half a century. Currently, energy security has drawn increasing interest until becoming transcendent in national governments and international organizations. This thesis explores the implications of energy security issues on energy policy from three main angles: i) the nature of the energy security concerns and narratives behind the adoption of specific risk mitigation policies; ii) energy policy evaluation with a focus on the impact of energy security issues and; iii) Global Energy Governance.

The multidimensionality of the notion of energy security make its study interdisciplinary in nature. For that reason, the first and second chapters of this thesis explores the intersection between areas of study as International Political Economy and Economic Geography. They investigate the institutional framework assessing wherever global energy governance have the capacity to reduce energy risk and generate a coordinated response to energy related challenges. From an International Political Economy perspective, the study reveals that although during last years new institutions have achieved to extend the publicness of consuming, benefits and decision-making, currently, energy security is not more than a Public Transnational Good and it will be a Global Public Good by decision of the actors involved in its governance. In order for this to happen, it will be necessary the expansion of the publicness of the material capacities to the current institutional arrangements and not necessary the inclusion of new actors.

The analysis shows that one potential consequence of a new turn to a less cooperative governance is that energy security would be consolidated as a transnational public good and, therefore, available to only a very few actors. In order for this not to happen, the effects over the global energy offer and demand will be important for the transition to an energy model less based on hydrocarbons. The challenge for the members of the IAE and the OPEC will be their capacity to lead a change that will encourage international cooperation in the transition to an energy security increasingly more public in its three aspects, consume, benefits and decision-making on the most harmonious possible way.

The second essay continues the institutional framework analysis by exploring the recent development in energy security strategies of key actors on the oil markets. The analysis exposes in what extent geopolitical approaches find a niche in the gaps left by the increasing complexities of global energy governance. In this regard, energy geopolitics may be thought of as 'governance by other means', an alternative to failed external energy governance solutions. Moreover, the study complements the first essay presenting key policy implications related to the main characteristics that determine the current failure of cooperative energy governance.

The main policy implication is that global energy governance must be approached as the management of interdependence in a context of accelerated redistribution of global energy hegemony through horizontal and vertical power shifts. This article argues that it is precisely in these global governance gaps where geopolitical approaches are being used as second-best options. The oil market shows that there have been several proposals to establish cooperative mechanisms to curb volatility, from price bands to using strategic reserves, extending long-term and take-or-pay contracts to oil or even vertical integration. Nevertheless, none of these proposals has ever been seriously considered, and oil price volatility continues to cause economic power shifts and geopolitical volatility. The challenge that lies ahead is to promote international cooperation to fill the gaps in global energy governance, fostering a harmonious transition from oil geopolitics to governance arrangements and preventing the re-securitization of energy policies.

The first and second chapter of this thesis analyzed how in the process of securitization the focus have shifted from reducing the risk of energy disruption to issues as the impact of biofuel development on agriculture, the unsustainable use of water sources and access to modern fuels. But in this re-securitization process the notion of energy security is also being used as a rationale for justifying a variety of objectives ranging from military action to massive intervention into energy markets to increase domestic renewable energy production and reduce CO2 emissions. The third chapter of this thesis explains how these decisions rely not only on personal beliefs or on political interests but most importantly on theoretically objective judgements that determine the definition of energy security instrumentalized as well as the set of tools constructed to evaluate the risks and challenges of energy systems.

The analysis of the indicators demonstrates how decision-making processes involve several (potentially) conflicting points of view (criteria) that should be taken into account conjointly, in order to evaluate the situation and arrive at a reasonable decision. These decisions have large effects on the development of energy policy determining among other energy subsidies/taxes, renewable energy deployment trajectories or carbon dioxide emissions over time, altering the social, technological, political and economic system structure. This is the case of the European Union (EU), which has developed its Energy Union Package to deliver energy security to their member states and expect to export its energy governance model to its neighborhoods. Therefore, understanding how these decisions are taken as well as their consequences requires paying attention to the criteria involved in policy design.

Usually, in the energy economics literature data is expressed in units or percentages but it is less common to find studies containing numerical (discrete and continuous), categorical, and ordinal data. This is not case in the ecological economics literature due to the rising concerns on the anthropogenic impact on the environment a well number of studies have developed composite indicators designed to measure such impacts from a multidimensional perspective. Our study is based on this research to address the shortcomings of the current state of the art on multidimensional energy indicators for ES. The conclusions of this study prove the high level of arbitrariness in the methodological choices and the lack of consistency between such choices and the argued energy policy targets. Furthermore, the study notes the absolute necessity to develop a more consistent approach signaling the main drawbacks of the indicators review.

But this is not the only issue regarding the aggregation procedure. None of the studies reviewed above do use an aggregation procedure that fulfil the requirements of meaningfulness presented. All the indicators above involve RNC variables, which means that the geometrical mean is the only meaningful aggregation procedure. Moreover, in many of the cases mentioned above, namely those involving strictly positive RNC variables could be obtained by computing the geometric mean of the normalized or raw indicators. In this regard, if the objective was to generate a value between (0,1) the normalization could be instead applied to the aggregated metric. This would reduce the influence of the normalization procedure in the final metric and would allow identifying more easily such influence.

What explains cross-national variation in energy policy? Although renewable energy is widely acknowledged as a central element of energy security and international efforts to mitigate climate change, the domestic politics of energy security are not well understood. The final chapter implements a panel approach to investigate the empirical relevance of energy security policy on sustainable energy transitions, making a number of contributions to the literature. We argue that variation in renewable energy deployment can be explained by energy security concerns.

Overall, the analysis carried reinforce the notion that the energy security represents an important constraint for sustainable energy transitions and give remarkable support to the lock-in hypothesis. This result have important policy implications for EU and national policy makers and stakeholders concerned with energy governance. It underlines the need for comprehensive energy policies targeting energy security and renewable energy deployment as well as market integration. The results stress the need for enhanced coordination and balanced development of renewable energy and security of supply policies across all EU economies as essential for achieving climate change goals and a genuine low-carbon energy transition.

The results of the regressions confirm that energy security policies are a key driver of the displacement of fossil fuels from the energy mix, but their impact is very heterogeneous at the EU15 level. In fact, these results question any results based on estimators that do not account for panel heterogeneity, as they may lead to non- meaningful policy prescriptions. Building on a panel data approach a FE, RE, SURE, MG and PMG estimation methods, we use annual data over the 1990–2012 period for a panel of 21 EU countries to estimate the energy dependence effect on the short term and find that it is statistically different from the average long run effect in the period.

This result is supported by country-specific estimations too and provides significant support for the dependence hypothesis, indicating that exogenous shocks associated to energy dependence affect negatively renewable energy trajectories. Besides, we also explore empirically the hypothesis that diversification must facilitate "unlock" the energy sector from the traditional fossil fuels technologies and other non-renewable energy resources. We estimate the impact of primary energy supply diversification for the countries in our panel dataset and find that the panel estimate is very different to the country-specific estimations and provides significant support for the lock-in hypothesis, indicating that exogenous shocks associated to energy dependence affect differently renewable energy trajectories.

Together with the evidence indicating that energy dependence affect renewable energy deployment in the long run, our results strongly suggests that energy security policy in the EU may be a driver or a barrier to renewable energy deployment depending on the strategic trajectories choices of governments. This is in line with the argument proposed in our research hypothesis and is consistent with a scenario in which the direction of causality runs from energy security indicators to RES and vice versa. In order to gain further insights into this process and check the robustness of the results, we first propose and implement a panel Granger causality method, to explore the direction of causality among our variables.

In fact, examining the constrained and individual slopes models, it is difficult to determine that a common pattern exists in energy security policy. Nevertheless, even if it is true that a common pattern in energy security may not exist, there are areas where the homogeneity of the results shows commonalities. For instance, the indicators related to climate change –carbon and energy intensity – present a high level of uniformity in the results. Regarding the security of supply policy, it seems that although energy independence and increases in oil prices lead to renewable energy deployment, the lack of homogeneity in the diversification and gas intensity variables may indicate room for improvement in energy security goals. For instance, our results reveal that energy policies should take into account the possible negative effects of diversification on renewable energy deployment. This very important issue must be carefully tackled, given the current EU's energy security strategy, which is based on the integration of energy markets.

Finally, our results show that economic growth does not always incentivize the use of renewables, raising doubts about the way in which sustainable development policies and priorities have been decided. For their part, oil prices show a very low impact on renewable energy deployment, which is a promising outcome of energy policy reform and opens the door to the reconsideration of the internalization of externalities in order to reduce fossil fuel consumption.

The avenues for future research can be summarized in three lines. The two first chapters on energy governance have proven to be a promising line of research that allow to find synergies between disciplines providing fresh new point of view to the limitations to cooperation on energy security governance. Following this line of research I expect to answer important unsolved question as "What drove energy cooperation in last years?" "How can be these barriers overcome?". To answer these questions it is necessary to give more attention to the narratives of price formation and scarcity. Answering this questions will allow to anticipate future challenges and needs for international cooperation. A first step on this direction would be to create a review of the literature that include perspectives from different disciplines in order to a part of critically present the current state-of-the-art we include opposing viewpoints, and identify challenges and opportunities.

The second line of research on energy policy evaluation will quantitatively address the study of policies that facilitate "unlock" the energy sector from the traditional fossil fuels technologies and other non-renewable energy resources. The approach presented in this thesis only deals with the impact of energy security on renewable energy. Further studies have to address the impact of security issues on other proxies for environmental innovation. To do that, one of the first challenges will be find new and better proxies to energy security and for innovation. Candidates to measure environmental innovation are: environmental patents, R&D expenditures and publication of research articles. Once this challenge is overcome the project will apply a Synthetic Control Method approach for policy evaluation. The synthetic control method was designed for the purposes of estimating causal effects in comparative case studies where only a single unit was treated

The third line of research focused on the nature of the energy security concerns and narratives behind the risk mitigation policies will serve to generate scenarios to translate factors related to energy policy that are considered relevant for the future into storylines. The research will integrate energy concerns and a number of energy indicators on a model with two dimensions of government policy uncertainty is used. One of the dimensions will indicate whether the world is heading towards increased multilateralism or more towards bilateralism and nationalism outside global governance institutions. The other dimension will indicate whether the world is characterized by governments engaging in a more state-driven orientation of actors, or in one driven by an economic efficiency orientation of actors. The model are expected to be applied to two case studies the EU and USA. These case studies will also incorporate an analysis of the narratives behind their policy preference. The expected outcome is the translation of the significant uncertainties identified in terms of risks, indicating possible events, trends and patterns.

Annex A

Study	Scope	ES definition	Normalization	Weight	Agggregation	Data
Oinamics 2005	Central and south European countries	"The ability of a country to protect itself from, or quickly recover from, sudden or prolonged shocks to the country's energy supply or infrastructure"	Distance to the leader	Equal for all least 1 indicators having the double	Linear aggregation	INC
Gnansounou 2008	37 industrialized countries on 2003	energy vulnerability instead of energy security with a very general definition	Min-Max	Equal	Root mean square	RNC
Sovaoool and Brown 2010	OCDE 1970-2007	"Energy security should be based on the interconnected factors of availability, affordability, efficiency, and environmental stewardship"	Directional changes or z-scores	Equal	Linear aggregation	RNC
Vivoda 2010	Global 2009	Reference to the work of von Hipel (2008)	Range fom low-medium-high	Equal	No	RNC
Augutis *et al.* 2011 and Augustis et al 2012	Ignalina Nuclear Power Plant in Lithuania 2007-2010	No clear definition	range from 1 to 15	Mixed: Equal weights between dimensions and weights as energy share	Linear aggregation	RNC
Sovacool et al. (2011) and Sovacool (2013a and 2013b)	18 countries for the period 1990 to 2010	"How to equitably provide available, affordable, reliable, efficient, environmentally benign, proactively governed and socially acceptable energy services to end-users"	Min-Max	Equal	Arithmetic mean and linear aggregation	RNC
The Institute for 21st Century Energy 2012, 2013 and 2015	25 countries, mostly industrialized 2012-2015	No clear definition	Distance from the mean in 1980	Analysis and expert judgment	Linear aggregation	RNC
Sheinbaum and Pardo 2012	Mexico 1990-2008	Concept of sustainability developed by the OLADE, CEPAL and GDF (2000)	Different normalization methods	Equal	Weight average	RNC
The Energy Architecture Performance Index	Global 2012-2015	Defined across each side of the energy triangle: economic growth and development, environmental sustainability, and energy access and security	Min-Max, and percentile rankings	Equal across baskets different within	Linear aggregation	RNC
Selvakkumaran and Limmeechokchai (2013)	Sri Lanka, Thailand and Vietnam 1990-2010	"Ability of an economy to guarantee the availability of energy resource supply in a sustainable and timely manner, with the energy price being at a level that will not adversely affect the economic performance of the economy" APERC (2007)	Scaling minimum value is set to 0 and maximum to 1	Equal	Arithmetic mean	RNC
Kamsamrong and Sorapipatana (2014)	Thailand 2010-2030	"Ability of an economy to guarantee the availability of energy resource supply in a sustainable and timely manner, with the energy price being at a level that will not adversely affect the economic performance of the economy" APERC (2007)	Min-Max	Mixed: Equal weights between dimensions and weights as energy share	The root mean square	RNC
Sharifuddin (2014)	Indonesia, Malaysia, Philipines, Thailand and Vietman 2002-2008	"Energy security is conceptualized for this study as having at least five core aspects: availability, stability, affordability, consumption efficiency and environmental impact"	Z scores and then standard normal distribution (0,1)	Mixed: Equal weights between dimensions and weights as energy share	Weight average	RNC
Yao and Chang (2014)	China 1980-2010	"An 'energy secure' nation is a nation that has affordable energy resources with an adequate amount of fossil fuels, nuclear energy, and Renewable resources, technologies applicable to energy harnessing and utilization, and, at the same time, addresses social and environmental concerns"	Scoring scale from 1 to 10	Equal weights	Arithmetic mean	RNC

Bibliography

CHAPTER 1

Andrews-Speed, P. (2011). Energy market integration in east asia : a Regional Public Goods approach. Discussion Paper ERIA-DP-2011-06, Chantam House, UK.

Abbott, K. W. (2012). The transnational regime complex for climate change. *Environment and Planning C: Government and Policy* 30(4), 571 – 590.

Alhajji, A. F., & Huettner, D. (2000). OPEC and other commodity cartels: A comparison. *Energy Policy* 28, 1151–64.

Altvater, E. (2007). Public goods for human security. *Papeles del Este* 14, 1–19.

Ang, B.W., Choong, W.L., & Ng T.S. (2015). Energy security: definitions, dimensions and indexes. *Renewable and Sustainable Energy Review* 42, 1077–93.

Anthoff, D., & Hahn, R. (2010). Government failure and market failure: on the inefficiency of environmental and energy policy. *Oxford Review of Economic Policy 26*(2), 197-224.

Avalos, F. (2014). Do oil prices drive food prices? The tale of a structural break. *Journal of International Money and Finance* 42, 253–71.

Baccini, L., Lenzi, V., & Thurner, P. W. (2013). Global energy governance: trade, infrastructure, and the diffusion of international organizations. *International Interactions 39*(2), 192-216.

Baker, K., & Stoker, G. (2013). Governance and nuclear power: why governing is easier said than done. *Political Studies* 61(3), 580 – 598.

Bamberger, C. S. (2004). IEA, the first thirty years: the history of the International Energy Agency, 1974–2004. Paris: IEA/OECD.

Barrett, M., Bradshaw, M., Froggatt A, Mitchell C, Parag Y, Stirling A, et al. (2010). Energy security in a multi-polar world. Exeter Working Paper.

Barros, C. P., Gil-Alana, L. A., & Payne, J. E. (2011). An analysis of oil production by OPEC countries: persistence, breaks, and outliers. *Energy Policy* 39(1), 442-453.

Bielecki, J. (2002). Energy security: is the wolf at the door?. *Quarterly Review of Economics and Finance* 42, 235-50.

Bradshaw, M. J. (2009). The geopolitics of global energy security. *Geography Compass*, *3*(5), 1920-37.

Brémond, V, Hache, E., & Mignon, V. (2012). Does OPEC still exist as a cartel? An empirical investigation. *Energy Econonomics* 34, 125–31.

Bosse, G., & Schmidt-Felzmann, A. (2011). The geopolitics of energy supply in the "Wider Europe.". *Geopolitics* 16, 479–85.

Bridge, G. (2015). Energy (in) security: world-making in an age of scarcity. *The Geographical Journal* 181(4), 328–339.

Carbonnier, G. (2011). The global and local governance of extractive resources. *Global Governance* 17 (2), 135–147.

Cherp, A., Jewell, J., & Goldthau, A. (2011). Governing global energy: systems, transitions, complexity. *Global Policy* (2)1, 75–88.

Cherp, A., & Jewell, J. (2011). The three perspectives on energy security: intellectual history, disciplinary roots and the potential for integration. *Current Opinion on Environment and Sustainability* 3, 202–12.

Cherp, A., & Jewell J. (2014). The concept of energy security: beyond the four As. *Energy Policy* 75, 415–21.

Clifton, J., & Díaz-Fuentes, D. (2011). The OECD and phases in the international political economy, 1961-2011. *Review of International Political Economy* 18(5), 552-69.

Colgan, J. D. (2014). The emperor has no clothes: the limits of OPEC in the global oil market. *International Organization* 68(3), 599-32

Colgan, J.D., Keohane, R.O., & van de Graaf, T. (2012). Punctuated equilibrium in the energy regime complex. *Review of International Organisations* 7(2), 117–43.

Escribano, G. (2015). Fragmented energy governance and the provision of Global Public Goods. *Global Policy* 6(2), 97-106

Dike, J.C. (2013). Measuring the security of energy exports demand in OPEC economies. *Energy Policy* 60, 594–600.

Dubash, N. K., & Florini, A. (2011). Mapping global energy governance. *Global Policy*, Special Issue on Global Energy Governance 2(S1), 6–18.

Falkner, R. (2014). Global environmental politics and energy: mapping the research agenda. *Energy Research & Social Science* 1(1), 188-97

Fattouh, B. (2014). The US tight oil revolution and its impact on the Gulf Cooperation Council countries: beyond the supply shock. OIES Paper: WPM 54, Oxford Institute for Energy Studies.

Fattouh, B., & Van Der Linde, C. (2011). The international energy forum: twenty years of producer-consumer dialogue in a changing world. In *Riyadh International Energy Forum*.

Florini, A., & Dubash, N. K. (2011). Introduction to the special issue: governing energy in a fragmented world. *Global Policy* 2(S1), 1–5.

Florini, A., & Sovacool, B.K. (2009). Who governs energy? the challenges facing global energy governance. *Energy Policy* 37, 5239–5248.

Goldthau, A. (Ed.). (2013). *The handbook of global energy policy*. John Wiley & Sons.

Goldthau, A., (2012), A public policy perspective on global energy security. *International Studies Perspectives* 12(4), 65-84.

Goldthau, A., & Sovacool, B. K. (2012). The uniqueness of the energy security, justice, and governance problem. *Energy Policy* 41, 232–240

Goldthau, A., & Witte, J. M. (2009). Back to the future or forward to the past? Strengthening markets and rules for effective global energy governance. *International Affairs* 85(2), 373–390.

Goldthau A., & Witte, J.M. (eds) (2010). *Global energy governance: the new rules of the game.* Brookings Institution Press: Washington DC.

Goldthau, A., & Witte J.M. (2011). Assessing OPEC's performance in global energy. *Global Policy*, Special Issue on Global Energy Governance 2(S1), 31–39.

Hardin, G. (1968). The tragedy of commons. *Science* 162, 1243-1248

Hancock, K. J., & Vivoda, V. (2014). International political economy: a field born of the

OPEC crisis returns to its energy roots. *Energy Research & Social Science 1*, 206-216.

Harks, E. (2010). ‘The international energy forum and the mitigation of oil market risks’, in Goldthau, A. & Witte J.M. (eds), *Global energy governance: the new rules of the game*. Washington, DC: Brookings Press, 247–268.

Henriques, I., & Sadorsky, P. (2008). Oil prices and the stock prices of alternative energy companies. *Energy Economics* 30, 998–1010.

Hughes, L., & Long, A. (2014). Is there an oil weapon? Security implications of changes in the structure of the international oil market. *International Security* 39(3), 152-89.

Karlsson-Vinkhuyzen, S.I. (2010). The United Nations and global energy governance: past challenges, future choices. *Global Change, Peace and Security* 22, 175–95.

Karlsson-Vinkhuyzen, S. I., Jollands, N., & Staudt, L. (2012). Global governance for sustainable energy: the contribution of a global public goods approach. *Ecological Economics*, *83*, 11-18.

Kaul, I. (2012). Rethinking public goods and global public goods. In: E., Brousseau, T. Dedeurwaerdere, & B. Siebenhüner, (eds). (2012). *Reflexive governance for global public goods.* Cambridge, MA: MIT Press, 37-53

Kaul, I., & Mendoza, R. U. (2003). Advancing the concept of public goods. In: Kaul, I., Conceicao, P., Le Goulven, K., & Mendoza, R. U. (2003). *Providing global public goods: managing globalization*. Oxford University Press, 78-111.

Keohane, R. O (1984). *After hegemony: cooperation and discord in the world political economy*. Princeton University Press, 1984.

Krause, L.B., & Nye J. S. (1975), Reflections on the economics and politics of international economic organizations. World Politics and International Economics, Washington D.C.: The Brookings Institution

Lardic, S. & Mignon, V. (2008). Oil prices and economic activity: an asymmetric cointegration approach. *Energy Economics* 30(3), 847–55.

Le Billon, P., & El Khatib, F. (2004). From free oil to ‘freedom oil’: terrorism, war and US geopolitics in the Persian Gulf. *Geopolitics*, *9*(1), 109-37.

Lesage, D., Van de Graaf, T., & Westphal, K. (2010). G8+5 collaboration on energy efficiency and IPEEC: shortcut to a sustainable future?. *Energy Policy* 38(11) 6419 – 6427.

Luciani, G. (2011) The functioning of the international oil markets and its security implications. CEPS Working Document 351 (Brussels: Centre for European Policy Studies [CEPS] May 2011).

Luciani, G. (2010). Geopolitical threats to oil and the functioning of the international oil market. CEPS Policy Brief 221 (Brussels: Centre for European Policy Studies [CEPS] November 2010).

Luciani, G. (2005). “Oil and political economy in the international relations of the Middle East”, in Halliday, F. (ed.) *The Middle East in international relations: power, politics and ideology*. Cambridge University Press, 81–103.

Malkin, J., & Wildavsky, A. (1991). Why the traditional distinction between public and private goods must be abandoned. *Journal of theoretical Politics,* 3(4)*,* 355-378.

Maugeri, L. (2012). The geopolitics of energy project. Oil: the next revolution. Discussion Paper 2012-10, Belfer Center for Science and International Affairs.

Miller, R. G. (2011). Future oil supply: the changing stance of the International Energy Agency. *Energy Policy* 39(3), 1569-1574.

Narayan, P.K., Sharma, S., Poon W.C., & Westerlund, J. (2014). Do oil prices predict economic growth? New global evidence. *Energy Economics* 41, 137–46.

Narula, K., & Reddy, B.S. (2015). Three blind men and an elephant: The case of energy indices to measure energy security and energy sustainability. *Energy* 80, 148–58.

Nordhaus, W. D. (2009). The economics of an integrated world oil market. Paper presented at the International Energy Workshop, June 2009, Venice, Italy

North, D. (1990), *Institutions, institutional change and economic performance*. Cambridge: Cambridge University Press.

Raustiala, K., & Victor, D. G. (2004). The regime complex for plant genetic resources. *International organization 58*(2), 277-309.

Ravenhill, J. (2013). Resource insecurity and international institutions in the Asia-Pacific region. *The Pacific Review* 26(1), 39-64.

Reboredo, J.C. (2015). Is there dependence and systemic risk between oil and renewable energy stock prices?. *Energy Economics* 48, 32–45.

Olson, M. (1971) [1965]. *The logic of collective action: public goods and the theory of groups* (Revised ed.). Harvard University Press.

Samuelson, P. (1954). The pure theory of public expenditure. *Review of Economics and Statistics* 36(4), 387-389.

Sovacool, B. K., & Brown, M. A. (2010). Competing dimensions of energy security: an international perspective. *Annual Review of Environment and Resources 35*, 77-108.

Strange, S. (1994). Wake up, Krasner! The world has changed. *Review of International Political Economy* 1(2), 209-219.

Stretton, H., & Orchard, L. (1994). *Public goods; public enterprise, public choice: theoretical foundations of the contemporary attack on government*. Palgrave Macmillan.

Turton, H., & Barreto, L. (2006). Long-term security of energy supply and climate change. *Energy Policy* 34, 2232–50.

Van de Graaf, T., & Lesage, D. (2009). The International Energy Agency after 35 years: reform needs and institutional adaptability. *Review of International Organizations* 4(3), 293–317.

Van de Graaf, T. (2012). Obsolete or resurgent? The International Energy Agency in a changing global landscape. *Energy Policy* 48, 233–241

Van de Graaf, T. (2013). Fragmentation in global energy governance: explaining the creation of IRENA. *Global Environmental Politics* 13(3), 14-33.

Van de Graaf, T., & Colgan, J. (2016). Global energy governance: a review and research agenda. *Palgrave Communications*, *2*.

Van de Graaf, T., & Westphal, K. (2011). The G8 and G20 as global steering committees for energy: Opportunities and constraints. *Global Policy* 2(S1), 19–30.

Wilson, J. (2015). Multilateral organisations and the limits to international energy cooperation. *New Political Economy* 20(1), 85-106.

Winzer, C. (2012). Conceptualizing energy security. *Energy Policy* 46, 36–48.

Wirl, F. (2009). OPEC as a political and economical entity. *European Journal of Political Economy* 25, 399–408.

Woodward, R. (2009). *The Organization for Economic Co-operation and Development*. UK: Routledge.

Wuyts, M. (1992). '*Deprivation and public need'*, in Macintosh, M. & Wuyts, M. *Development policy and public action*. Milton Keynes: Open University Press.

Yergin, D. (2006). Ensuring energy security. *Foreign Affairs* 85(2), 69- 82

CHAPTER 2

Abbott, K. W. (2011). The transnational regime complex for climate change. *Environment & Planning C: Government & Policy* 30/4, 571-90

Adams, C. (2015). Volatile climate in the energy sector puts billions at risk. *Financial Times* (April 20) available at <http://www.ft.com/intl/cms/s/0/daf313fa-d927-11e4-b90700144feab7de.html#axzz3YF7pteHI>.

Alberta Energy (2016). *Facts and statistics*, available at <http://www.energy.alberta.ca/oilsands/791.asp>.

Baffes, J. A. Kose, F. Ohnsorge, & Stocker, M. (2015). The great plunge in oil prices: causes, consequences, and policy responses. WB Policy Research Note, World Bank, Washington, DC, 22-37.

Baker, K., & Stoker, G. (2013). Governance and nuclear power: why governing is easier said than done. *Political Studies* 61(3), 580-98.

Barysch, K. (ed.), (2008). Pipelines, politics and power: the future of EU-Russia energy relations. London: Centre for European Reform.

Bamberger, C. S. (2004). History of the IEA: the first 30 years. International Energy Agency (IEA), Paris.

Bank of Canada, (2015). Monetary policy report January 2015, available at <http://www.bankofcanada.ca/wp-content/uploads/2014/07/mpr-2015-01-21.pdf>

Blank, S., & Levitzky, E. (2015). Geostrategic aims of the Russian arms trade in East Asia and the Middle East. *Defence Studies* 15(1), 63-80.

Bradshaw, M. J. (2009). The geopolitics of global energy security. Geography Compass 3(5), 1920-37.

Bradshaw, M. J. (2010). Global energy dilemmas: a geographical perspective. The Geographical Journal 176(4), 275-90.

Bressand, A. (2010). "The future of producer-consumer cooperation: a policy perspective", in A. Goldthau and J. Martin (eds.), Global energy governance, the new rules of the game, Washington, DC: Brookings Institution Press, 269-87.

Bridge, G., (2015). Energy (in) security: world-making in an age of scarcity. *The Geographical Journal* 181(4), 328–39.

Bruun, J. M., & Medby, I. A. (2014). Theorising the thaw: geopolitics in a changing arctic. *Geography Compass* 8(12), 915-29.

Burgos Cáceres, S., & Ear, S. (2012). The geopolitics of China's global resources quest.

Geopolitics 17(1), 47-79.

Carbonnier, G. (2011). The global and local governance of extractive resources. *Global Governance* 17(2), 135-47.

Casier, T. (2011). The rise of energy to the top of the EU-Russia agenda: from interdependence to dependence?. *Geopolitics* 16(3), 536-52.

Cherp, A., Jewell, J., & Goldthau, A. (2011). Governing global energy: systems, transitions, complexity. *Global Policy* 2(1), 75-88

Colgan, J. D. (2014). The emperor has no clothes: the limits of OPEC in the global oil market. *International Organization* 68(3), 599-632.

Cox, R. W. (1996). *Approaches to world order*. Cambridge: Cambridge University Press.

Del Sarto, R. A. (2010). "Borderlands: the Middle East and North Africa as the EU's southern buffer zone" in Bechev, D., & Nicolaidis, K. (eds.). *Mediterranean Frontiers: borders, conflicts and memory in a transnational world.* London: IB Tauris, 149-65.

Del Sarto, R. A. (2015). Normative empire Europe: the European Union, its borderlands, and the 'Arab Spring'. *Journal of Common Market Studies* 54(2), 215-32

Denise, N. (2015). The Kurdish quasi-state: leveraging political limbo. *The Washington Quarterly* 38(2), 145-64.

Dibooglu, S., & Al-Gudhea, S. N. (2007). All time cheaters versus cheaters in distress: an examination of cheating and oil prices in OPEC. *Economic Systems* 31(3), 292-310.

Dubash N. K., & Florini, A. (2011). Mapping global energy governance. *Global Policy Special Issue on Global Energy Governance* 2(S1), 6-18

Ebrahim, Z., Inderwildi, O. R., & King, D. A. (2014). Macroeconomic impacts of oil price volatility: mitigation and resilience. *Frontiers in Energy* 8(1), 9-24.

Energy Information Administration (EIA), (2014). International energy outlook 2014: world petroleum and other liquid fuels, with projections to 2040. Washington, DC: EIA.

Energy Information Administration (EIA), (2015a). Canadian oil production expected to increase despite lower prices Washington, DC: EIA, June, available at <http://www.eia.gov/todayinenergy/detail.cfm?id=25112> .

Energy Information Administration (EIA), (2015b). Oil and natural gas production job declines tend to lag oil price declines. Washington, DC: EIA, June.

Ericson, R. E. (2009). Eurasian natural gas pipelines: the political economy of network interdependence. *Eurasian Geography and Economics* 50(1), 28-57.

Escribano, G., (2013). Ecuador's energy policy mix: development versus conservation and nationalism with Chinese loans. *Energy Policy* 57, 152-159.

Escribano, G. (2015). Fragmented energy governance and the provision of global public goods. *Global Policy* 6(2) (2015), 97-106

Escribano, G. Pathways towards a global standard for transparency in the governance of energy resources. *Global Governance*, Forthcoming.

Escribano, G., Marín-Quemada, J.M., & González, E.S.M. (2013). RES and risk: renewable energy's contribution to energy security. a portfolio-based approach. *Renewable and Sustainable Energy Reviews* 26, 549-59.

Escribano G., & García-Verdugo, J. (2012). “Energy security, energy corridors and the geopolitical context: a conceptual approach”, in Marin-Quemada, J. M., García-Verdugo, J., & Escribano, G. (Eds.) *Energy security for the EU in the 21st century: markets, geopolitics and corridors* (Routledge, Taylor & Francis Group), 26-36.

Far, S., & Youngs, R. (2015). Energy Union and EU global strategy. SIEPS Report Nº 5 Stockholm: Swedish Institute for European Policy Studies, available at <http://www.sieps.se/sites/default/files/sieps_%202015_5_rapp.pdf>

Fattouh, B. (2006). OPEC pricing power. Oxford Institute for Energy Studies Working Paper 31, Oxford: Oxford Institute for Energy Studies.

Fattouh, B., & Allsopp, C. (2009). The price band and oil price dynamics. Oxford Energy Comment, Oxford: Oxford Institute for Energy Economics, July.

Findlay, P.J. (2016). The future of the Canadian Oil Sands: growth potential of a unique resource amidst regulation, egress, cost, and price uncertainty. OIES paper: wpm 64, available at <https://www.oxfordenergy.org/wpcms/wp-content/uploads/2016/02/The-Future-of-the-Canadian-Oil-Sands-WPM-64.pdf >.

Florini, A. & Sovacool, B. K. (2009). Who governs energy? the challenges facing global energy governance. *Energy Policy* 37, 5239-48

Fondazione Eni Enrico Mattei (FEEM). (2008). A report on final recommendations about technical and regulatory measures. SECURE project, Deliverable 6.3, available at <http://www.feem-project.net/secure/plastore/Deliverables/SECURE_D6-3.pdf>.

Gil-Alana, L. A., & Barros, C. P. (2011). An analysis of oil production by OPEC countries: persistence, breaks, and outliers. *Energy Policy* 39(1), 442-53.

Gause III, F. G. (2015). Sultans of swing? the geopolitics of falling oil prices. Brookings Policy Briefing in Foreign Policy. Washington, DC: Brookings Doha Center.

Gilpin, R. (1987). *The political economy of international relations*. Princeton, NJ: Princeton University Press.

Goldman Sachs. (2015). The low carbon economy, equity research. available at <http://www.goldmansachs.com/our-thinking/pages/new-energy-landscape-folder/report-the-low-carbon-economy/report.pdf>.

Goldthau, A., (2012) A Public policy perspective on global energy security. *International Studies Perspectives* 13(1), 65-84.

Goldthau, A., (2014) Rethinking the governance of energy infrastructure: scale, decentralization and polycentrism. *Energy Research & Social Science* 1, 134-40.

Goldthau, A., & Sitter, N. (2015) Soft power with a hard edge: EU policy tools and energy security. *Review of International Political Economy* 22(5), 941-65.

Goldthau, A., & Sovacool, B. K. (2012). The uniqueness of the energy security, justice, and governance problem. *Energy Policy* 41, 232-40.

Goldthau, A., & Witte, J. M. (2009). Back to the future or forward to the past? strengthening markets and rules for effective global energy governance. *International Affairs* 85(2), 373-90.

Goldthau, A., & Witte, J. M. (2011). Assessing OPEC’s performance in global energy. *Global Policy Special Issue on Global Energy Governance* 2(S1), 31–9.

Grevi, G. (2009). The interpolar world: a new scenario. EUISS Occasional paper. Paris: European Union Institute for Security Studies (EUISS).

Gunes, C. & Lowe, R. (2015). The impact of the Syrian War on Kurdish politics across the Middle East. Middle East and North Africa Programme Working Paper, London: Chatham House.

Harks, E. (2010) "The International Energy Forum and the mitigation of oil market risks", in Goldthau, A., & Martin, J. (eds.), *Global energy governance. the new rules of the game*. Washington, DC: Brookings Institution Press, 247–67.

Hartemi, P., & Wedeman, A. (2007). Oil and conflict in Sino-American relations. *China Security* 3(3), 95–118.

Haukkala, H. (2010). *The EU-Russia strategic partnership the limits of post-sovereignty in international relations.* London: Routledge.

Heinrich, A. (2008). Under the Kremlin's thumb: does increased state control in the Russian gas sector endanger European energy security?. *Europe-Asia Studies* 60(9), 1539-74.

Huber, M.T. (2011). Enforcing scarcity: oil, violence, and the making of the market. *Annals of the Association of American Geographers* 101(4), 816-26.

International Crisis Group (ICG), (2015). The prize: fighting for Libya's energy wealth. Middle East and North Africa Report 165, Brussels: ICG.

International Energy Agency (IEA), (2014). 2014 World Energy Outlook, Paris: IEA.

International Energy Agency (IEA), (2015a). Medium term oil market report, Paris: IEA.

International Energy Agency (IEA), (2015b). Oil market report, 12 August, Paris: IEA.

International Energy Agency (IEA), (2015c). Oil market report, 11 September, Paris: IEA.

International Monetary Fund (IMF), (2015) Global prospects and policy challenges. G-20 Finance Ministers and Central Bank Governors Meeting, Istanbul: IMF, available at <https://www.imf.org/external/np/g20/pdf/2015/090415.pdf>.

International Monetary Fund, (IMF) (2015). Learning to live with cheaper oil amid weaker demand. Regional Economic Outlook Update, Washington DC: International Monetary Fund. 21 Jan 2015, available at <http://www.imf.org/external/pubs/ft/weo/2015/01/pdf/c1.pdf>

Karlsson-Vinkhuyzen, S.I. (2010). The United Nations and global energy governance: past challenges, future choices. *Global Change, Peace and Security* 22, 175-95.

Kennedy, E. (2014). From petro-states to "new realities": perspectives on the geographies of oil. *Geography Compass* 8(4), 262-76.

Keohane, R. O. (1984). *Cooperation and discord in the world political economy.* Princeton, NJ: Princeton University Press.

Krasner, S. D. (ed.),(1983). *International regimes*. Ithaca, NY: Cornell University Press.

Kropatcheva, E. (2011). Playing both ends against the middle: Russia's geopolitical energy games with the EU and Ukraine. *Geopolitics* 16(3), 553-73

Kupchan, C. A. (2014). The normative foundations of hegemony and the coming challenge to Pax Americana. *Security Studies* 23(2), 219-57.

Labban, M. (2010). Oil in parallax: scarcity, markets, and the financialization of accumulation. *Geoforum* 41(4), 541-52.

Le Billon, P. & Cervantes, A. (2009). Oil prices, scarcity, and geographies of war. *Annals of the Association of American Geographers* 99(5), 836-44.

Lesage, D., Van de Graaf, T., & Westphal, K. (2010a). G8+5 collaboration on energy efficiency and IPEEC: shortcut to a sustainable future?, *Energy Policy* 38/11, 6419-27.

Lesage, D., Van de Graaf T., & Westphal, K. (2010b). *Global energy governance in a multipolar world*. Burlington: Ashgate.

Luciani, G. (2011). The functioning of the international oil markets and its security implications. CEPS Working Document 351, Brussels: Centre for European Policy Studies (CEPS) May.

Luciani, G., & Henry, F.-L. (2011). Strategic oil stocks and security of supply. CEPS Working Document 353, Brussels: Centre for European Policy Studies (CEPS) June.

MacDonald, J. (2016). Electric vehicles to be 35% of global new car sales by 2040, *Bloomberg New Energy Finance*, Bloomberg (Feb, 25) available at http://www.bbhub.io/bnef/sites/4/2016/02/BNEF_EV-Forecast_2016_FINAL.pdf.

Malkin, E. (2015). 'In Mexico oil market, mood moves from excited to anxious'. *The New York Times* (March 13), available at <http://www.nytimes.com/2015/03/14/business/energy-environment/pemexseeks-private-investment-as-mexico-oil-industry-falters.html?_r=1 >.

Mamadouh, V., & Dijkink, G. (2006). Geopolitics, international relations and political geography: the politics of geopolitical discourse. *Geopolitics* 11(3), 349-66.

Mann, Y. (2012). Saudi Arabia's policy toward non-OPEC countries. *Diplomacy and Statecraft* 23(2), 381-91.

Meyer, J. W., & Rowan, B. (1977). Institutionalized organizations: formal structure as myth and ceremony. *American Journal of Sociology* 83(2), 340-63.

Mohseni, P. (ed.), (2015). Disrupting the chessboard perspectives on the Russian intervention in Syria. Belfer Center for Science and International Affairs, Cambridge, MA: Harvard Kennedy School.

Miller, R. (2011). Future Oil Supply: The changing stance of the International Energy Agency. *Energy Policy* 39(3), 1569-74.

Millne, R., Adams, C., & Crooks, E. (2015). Oil companies put Arctic projects into deep freeze. *Financial Times* (5 Feb.) available at <http://www.ft.com/intl/cms/s/0/ae302d22-ad1b-11e4-a5c100144feab7de.html#slide0>.

Myers, G.A. (2014). Toward expanding links between political geography and African studies. *Geography Compass* 8(2), 125-36.

Nye, J. S. (1990). Soft power, *Foreign Policy* 80, 153–71.

Nye, J. S. (2004). *Soft power: the means to success in world Politics*. New York: Public Affairs.

Observatoire Méditerranéen de l'Energie (OME), (2008). A report on final policy recommendations. SECURE project Deliverable 6.4, available at <http://www.feem-project.net/secure/plastore/Deliverables/SECURE_D6-4.pdf >.

Oye, K. A. (1986). *Cooperation under anarchy*. Princeton, NJ: Princeton University Press.

Randall, T. (2016). Here's how electric cars will cause the next oil crisis. *Bloomberg New Energy Finance,* Bloomberg (February 25), available at <http://www.bloomberg.com/features/2016-ev-oil-crisis/>.

ScotiaBank Economics. (2014). Commodity price index September 2014. ScotiaBank.

Sinn, H. W. (2012). *The green paradox: a supply-side approach to global warming*. Cambridge, MA: MIT Press.

Strange, S. (1994). *States and markets*. London: Continuum.

Strange, S. (1995). The defective state. *Daedalus* 124(2), 55-74.

Stulberg, A. (2015). Out of gas? Russia, Ukraine, Europe, and the changing geopolitics of natural Gas. *Problems of Post-Communism* 62(2) 112-30.

Tocci, N. (ed.), (2008). Who is a normative foreign policy actor? The EU and its global partners.

CEPS Paperbacks, Brussels: Center for European Policy Studies (CEPS).

Van der Graaf, T. (2012). Obsolete or resurgent? The International Energy Agency in a changing global landscape. *Energy Policy* 48, 233–41.

Van Loon, J. (2016). Near-record cash “comfort” for Canada oil firms amid price rout. *Bloomberg* (March 15), available at <http://www.bloomberg.com/news/articles/2016-03-15/near-record-cash-comfort-for-canada-oil-firms-amid-price-rout>.

Verbruggen, A., & Van de Graaf, T. (2015). The geopolitics of oil in a carbon-constrained world. *IAEE Energy Forum* 2, 21-4.

Wirl, F. (2012). OPEC as a political and economical entity. *European Journal of Political Economy* 25(4), 399-408.

World Bank (WB), (2015). Global economic prospects, January 2015: having fiscal space and using it. Washington, DC: WB.

Youngs, R. (2009). *Energy security: Europe’s new foreign policy challenge*. London: Routledge.

Zalik, A. (2010). Oil “futures”: Shell scenarios and the social construction of the global oil market. *Geoforum* 41, 553-64.

Zielonka, J. (2008). Europe as a global actor: empire by example. *International Affairs* 84(3), 471-84.

CHAPTER 3

Alhaji A.F. (2008a). What is energy security? Definitions and concepts part (3/5). *Middle East Economic Survey* 45.

Alhaji A.F. (2008b). What is energy security? Definitions and concepts part (4/5). *Middle East Economic Survey* 45.

Ang, B. W., Choong, W. L., & Ng, T. S. (2015). Energy security: definitions, dimensions and indexes. *Renewable and Sustainable Energy Review 42*, 1077-1093.

APERC (2007). A quest for energy security in the 21st century. Institute of Energy Economics. Asia Pacific Energy Research Centre, Tokyo.

Augutis, J., Krikštolaitis, R., Matuzien, V., & Peiulyt, S. (2009). Assessment of Lithuanian power supply security depending on nuclear energy. *Safety and Security Engineering III, 235-247.*

Augutis, J., Krikštolaitis, R., Pečiulytė, S., & Konstantinavičiūtė, I. (2011). Sustainable development and energy security level after Ignalina NPP shutdown. *Technological and economic development of economy* 17, 5-21.

Augutis, J., Krikstolaitis, R., Martisauskas, L., & Peciulyte, S. (2012). Energy security level assessment technology. *Applied Energy 97*, 143-149.

Barbier, E.B., & Markandya, A. (1990). The conditions for achieving environmentally sustainable growth. *European Economic Review* 34, 659 – 669.

Böhringer, C., & Jochem, P. E. (2007). Measuring the immeasurable—A survey of sustainability indices. *Ecological Economics 63*, 1-8.

Cabalu, H. (2010). Indicators of security of natural gas supply in Asia. *Energy Policy 38*, 218-225.

Cherp, A., & Jewell, J. (2011). The three perspectives on energy security: intellectual history, disciplinary roots and the potential for integration. *Current Opinion on Environmental Sustainability* 3, 202-212.

Cherp, A. (2012). Defining energy security takes more than asking around. *Energy Policy 48*, 841-842.

Cherp, A., & Jewell, J. (2013). Energy security assessment framework and three case studies, in: Dyer, H., & Trombetta, M.J. (Eds.) *International Handbook of Energy Security*. Edward Elgar Pub., 146-173.

Chester, L. (2010). Conceptualising energy security and making explicit its polysemic nature. *Energy policy 38*, 887-895.

Chuang, M. C., & Ma, H. W. (2013). An assessment of Taiwan's energy policy using multi-dimensional energy security indicators. *Renewable and Sustainable Energy Review 17*, 301-311.

Cohen, G., Joutz, F., & Loungani, P. (2011). Measuring energy security: Trends in the diversification of oil and natural gas supplies. *Energy Policy 39*, 4860-4869.

Decancq, K., & Lugo, M. A. (2013). Weights in multidimensional indices of wellbeing: An overview. *Econometric Review 32*, 7-34.

Ebert, U., & Welsch, H., (2004). Meaningful environmental indices: a social choice approach. *Journal of Environmental Economic Management. 47*, 270-283.

Ediger, V. Ş., & Berk, I. (2011). Crude oil import policy of Turkey: Historical analysis of determinants and implications since 1968. *Energy Policy 39*, 2132-2142.

Freudenberg, M., (2003). Composite indicators of country performance: a critical assessment. STI Working Paper 2003/16. Paris: OECD.

Gómez-Limón, J. A., & Sanchez-Fernandez, G. (2010). Empirical evaluation of agricultural sustainability using composite indicators. *Ecological Economics 69*, 1062-1075.

IEA, International Energy Agency (2014), Energy Supply Security 2014: Emergency Response of IEA Countries, Paris: IEA.

Institute for 21st Century Energy (2012). Index of U.S. energy security risk. Chamber of Commerce, Washington, DC.

Institute for 21st Century Energy (2013). Index of U.S. energy security risk. Chamber of Commerce, Washington, DC.

Institute for 21st Century Energy (2015). Index of U.S. energy security risk. Chamber of Commerce, Washington, DC.

Jansen, J. C., Van Arkel, W. G., & Boots, M. G. (2004). Designing indicators of long-term energy supply security. Working Paper ECN-C--04-007, Energy research Centre of the Netherlands.

Kamsamrong, J., & Sorapipatana, C. (2014). An assessment of energy security in Thailand's power generation. *Sustainable Energy Technologies and Assessment 7*, 45-54.

Luzzati, T., & Gucciardi, G. (2015). A non-simplistic approach to composite indicators and rankings: an illustration by comparing the sustainability of the EU Countries. *Ecological Economics 113*, 25-38.

Marozzi, M. (2014). Construction, dimension reduction and uncertainty analysis of an index of trust in public institutions. *Quality and Quantity* 48, 939–953.

Marozzi, M. (2015). Construction, robustness assessment and application of an index of perceived level of socio-economic threat from immigrants: a study of 47 European Countries and Regions. *Social Indicators Research 128*, 1-25.

Martchamadol, J., & Kumar, S. (2012). Thailand's energy security indicators. *Renewable and Sustainable Energy Review 16*, 6103-6122.

Martinez-Alier, J., Munda, G., & O'Neill, J. (1998). Weak comparability of values as a foundation for ecological economics. *Ecological Economics. 26*, 277-286.

Munda, G. (1997). Environmental economics, ecological economics and the concept of sustainable development. *Environmental Value.* 6, 213 – 233.

Narula, K., & Reddy, B. S. (2015). Three blind men and an elephant: The case of energy indices to measure energy security and energy sustainability. *Energy 80*, 148-158.

Nardo, M., Saisana, M., Saltelli, A., Tarantola, S., Hoffman, A., & Giovannini, E. (2005). *Handbook on constructing composite indicators*. Paris: OECD.

Oinamics (2005). Energy security index. Central and Eastern Europe. Oinamics Global Risk Consulting. Washington, DC.

OLADE, CEPAL & GTZ (2000). Energía y desarrollo sustentable en América Latina y el Caribe: Guía para la formulación de políticas energéticas. OLADE, Quito.

Patlitzianas, K. D., Doukas, H., Kagiannas, A. G., & Psarras, J. (2008). Sustainable energy policy indicators: Review and recommendations. *Renewable Energy 33*, 966-973.

Portugal-Pereira, J., & Esteban, M. (2014). Implications of paradigm shift in Japan's electricity security of supply: a multi-dimensional indicator assessment. *Applied Energy 123*, 424-434.

Ren, J., & Sovacool, B. K. (2014). Quantifying, measuring, and strategizing energy security: Determining the most meaningful dimensions and metrics. *Energy 76*, 838-849.

Saisana, M., Saltelli, A., & Tarantola S. (2005). Uncertainty and sensitivity techniques as tools for the analysis and validation of composite indicators *Journal of the Royal Statistical Society A* 168, 307-323.

Saisana, M., & Saltelli, A. (2011). Rankings and ratings: instructions for use. *Hague Journal on the Rule of Law 3*, 247-268.

Selvakkumaran, S., & Limmeechokchai, B. (2013). Energy security and co-benefits of energy efficiency improvement in three Asian countries. *Renewable and Sustainable Energy Review 20*, 491-503.

Sharifuddin, S. (2014). Methodology for quantitatively assessing the energy security of Malaysia and other southeast Asian countries. *Energy Policy 65*, 574-582.

Sheinbaum-Pardo, C., Ruiz-Mendoza, B. J., & Rodríguez-Padilla, V. (2012). Mexican energy policy and sustainability indicators. *Energy Policy 46*, 278-283.

Singh, R. K., Murty, H. R., Gupta, S. K., & Dikshit, A. K. (2009). An overview of sustainability assessment methodologies. *Ecological Indicators 9*, 189-212.

Sovacool, B. K., & Brown, M. A. (2010). Competing dimensions of energy security: an international perspective. *Annual Review of Environmental Resources 35*, 77-108.

Sovacool, B.K., & Mukherjee, I. (2011). Conceptualizing and measuring energy security: a synthesized approach. *Energy* 36, 5343–5355. August, 2011.

Sovacool, B. K. (2012). The methodological challenges of creating a comprehensive energy security index. *Energy Policy 48*, 835-840.

Sovacool, B. K., Mukherjee, I., Drupady, I. M., & D'Agostino, A. L. (2011). Evaluating energy security performance from 1990 to 2010 for eighteen countries. *Energy 36*, 5846-5853.

Sovacool, B. K. (2013a). Assessing energy security performance in the Asia Pacific, 1990–2010. *Renewable and Sustainable Energy Review 17*, 228-247.

Sovacool, B. K. (2013b). An international assessment of energy security performance. *Ecological Economics 88*, 148-158.

Streimikiene, D., Ciegis, R., & Grundey, D. (2007). Energy indicators for sustainable development in Baltic States. *Renewable and Sustainable Energy Review 11*, 877-893.

Vera, I., & Langlois, L. (2007). Energy indicators for sustainable development. *Energy 32*, 875-882.

Vivoda, V. (2010). Evaluating energy security in the Asia-Pacific region: A novel methodological approach. *Energy Policy 38*, 5258-5263.

WEF (2015). The global energy architecture performance index report 2015. World Economic Forum. Geneva, Switzerland.

Winzer, C. (2012). Conceptualizing energy security. *Energy policy 46*, 36-48.

Yao, L., & Chang, Y. (2014). Energy security in China: a quantitative analysis and policy implications. *Energy Policy 67*, 595-604.

Zhang, H. Y., Ji, Q., & Fan, Y. (2013). An evaluation framework for oil import security based on the supply chain with a case study focused on China. *Energy Economics 38*, 87-95.

CHAPTER 4

Abolhosseini, S., & Heshmati, A. (2014). The main support mechanisms to finance renewable energy development. *Renewable and Sustainable Energy Review* 40, 876–85.

Aguirre, M., & Ibikunle, G. (2014). Determinants of renewable energy growth: A global sample analysis. *Energy Policy* 69, 374–84.

Al-Mulali, U. Fereidouni, H.G., Lee, J.Y., & Che Sab, N.B.C. (2013). Examining the bi-directional long run relationship between renewable energy consumption and GDP growth. *Renewable and Sustainable Energy Review* 22, 209–22.

Ang, B.W., Choong, W.L., & Ng, T.S. (2015). Energy security: definitions, dimensions and indexes. *Renewable and Sustainable Energy Review* 42:1077–93.

Awerbuch, S., & Yang, S. (2007). Efficient electricity generating portfolios for Europe: Maximising energy security and climate change mitigation. EIB Papers 7/2007, European Investment Bank, Economics Department.

Baltagi, B.H., & Wu, P.X. (1999). Unequally spaced panel data regressions with AR(1) disturbances. *Economic Theory* 15, 814–823.

Bauen, A. (2006) Future energy sources and systems. Acting on climate change and energy security. *Journal of Power Sources* 157, 893–901.

Bazilian. M, Nakhooda, S., & Van de Graaf, T. (2014). Energy governance and poverty. *Energy Research and Social Science* 1, 217–25.

Beck, N., & Katz, J.N. (1995). What to do (and not to do) with time-series cross-section data. *American Political Science Review* 189, 634–47.

Bigano, A., Ortiz, R.A., Markandya, A., Menichetti, E., & Pierfederici, R (2010). The linkages between energy efficiency and security of energy supply in Europe. Milan: Fondazione Eni Enrico Mattei Available at http://ageconsearch.umn.edu/bitstream/90950/2/NDL2010-064.pdf

Bird, L., Bolinger, M., Gagliano, T., Wiser, R., Brown, M., & Parsons, B. (2005). Policies and market factors driving wind power development in the United States. *Energy Policy* 33, 1397–407.

Böhringer, C., & Keller, A. (2011). Energy Security: An impact assessment of the EU climate and energy package climate. Inst. für Volkswirtschaftslehre, University of Oldenburg.

Böhringer, C., & Bortolamedi, M. (2015). Sense and no (n)-sense of energy security indicators. *Ecological Economics* 119, 359–371.

Brown, S.P.A., & Huntington, H.G. (2008). Energy security and climate change protection: Complementarity or tradeoff? *Energy Policy* 36, 3510–3.

Carley, S. (2009). State renewable energy electricity policies: An empirical evaluation of effectiveness. *Energy Policy* 37, 3071–81.

Chatterjee, S., & Hadi, A.S. (2006). *Regression analysis by example*. John Wiley & Sons.

Cherp, A., & Jewell, J. (2011). The three perspectives on energy security: intellectual history, disciplinary roots and the potential for integration. *Current Opinion on Environmental Sustainability* 3, 202–12.

Chester, L. (2010). Conceptualising energy security and making explicit its polysemic nature. *Energy Policy* 38, 887–95.

Chien, T., & Hu, J. (2008). Renewable energy: An efficient mechanism to improve GDP. *Energy Policy* 36, 3035–42.

Correljé, A., & van der Linde, C. (2006). Energy supply security and geopolitics: a European perspective. *Energy Policy* 34, 532–43.

Costantini, V., Gracceva, F., Markandya, A., & Vicini, G. (2007). Security of energy supply: comparing scenarios from a European perspective. *Energy Policy* 35, 210–26.

Darmani, A., Arvidsson, N., Hidalgo, A., & Albors, J. (2014). What drives the development of renewable energy technologies? Toward a typology for the systemic drivers. *Renewable and Sustainable Energy Review* 38, 834–47.

DECC, Department of Energy & Climate Change, (2009). Energy markets outlook. Available at http://www.official-documents.gov.uk/document/hc0910/hc01/0176/0176.pdf

EC, European Commission. (2014). Communication from the Commission to the Council and the European Parliament: European energy security strategy “In-depth study of European energy security”, Commission Staff Working Document, SWD(2014) 330 final/3. Brussels.

EC, European Commission. (2013). Member States’ energy dependence: an indicator-based assessment. Brussels: 2013.

EIA, Energy Information Administration. (2015). Annual Energy Outlook, 2015. U.S. Energy Information Administration. April DOE/EIA-0383(2015).

Eleftheriadis, I.M., & Anagnostopoulou, E.G. (2015). Identifying barriers in the diffusion of renewable energy sources. *Energy Policy* 80, 153–64.

Escribano Francés, G., Marín-Quemada, J.M., & San Martín González, E. (2013). RES and risk: Renewable energy’s contribution to energy security. A portfolio-based approach. *Renewable and Sustainable Energy Review* 26, 549–59.

Franza, L. (2014) Long-term import contracts in Europe. The evolution in pricing mechanism. CIEP Working Paper. The Hague, The Netherlands.

Frees, E.W. (1995). Assessing cross-sectional correlation in panel data. *Journal of Econometrics* 69, 393–414.

Freire-González, J. & Puig-Ventosa, I. (2015). Energy Efficiency Policies and the Jevons Paradox. *International Journal of Energy Economics and Policy* 5(1), 69–79.

Friedman, M. (1937). The use of ranks to avoid the assumption of normality implicit in the analysis of variance. *Journal of the American Statistical Association* 32, 675–701.

Gan, L., Eskeland, G.S., & Kolshus, H.H. (2007). Green electricity market development: Lessons from Europe and the US. *Energy Policy* 35, 144–55.

González-Eguino, M. (2015). Energy poverty: an overview. *Renewable and Sustainable Energy Review* 47, 377–85.

Gracceva, F., & Zeniewski, P. (2014). A systemic approach to assessing energy security in a low-carbon EU energy system. *Applied Energy* 123:335–48.

Grubb, M., Butler, L., & Twomey, P. (2005). Diversity and security in UK electricity generation: the influence of low carbon objectives. *Energy Policy* 34, 4050–62.

Guivarch, C., & Monjon, S. (2015). Would climate policy improve the European energy security? *Climate Change Economics* 06, 1550008.

Herring, H. (1999). Does energy efficiency save energy? The debate and its consequences. *Applied Energy* 63 (3), 209–226.

Huang, M.Y., Alavalapati, J.R.R., Carter, D.R., & Langholtz, M.H. (2007). Is the choice of renewable portfolio standards random? *Energy Policy* 35, 5571–5.

IEA, International Energy Agency (2001). Toward a sustainable energy future. Paris: IEA.

IEA, International Energy Agency (2008). Energy Outlook. International Energy Agency, Paris.

Im, K.S., Pesaran, M.H., Shin, Y. (2003). Testing for unit roots in heterogeneous panels. *Journal of Econometrics* (115), 53–74.

Jaforullah, M., & King, A. (2015). Does the use of renewable energy sources mitigate CO2 emissions? A reassessment of the US evidence. *Energy Economics* 49, 711–7.

Jansen, J.C., & Seebregts, A.J. (2010). Long-term energy services security: What is it and how can it be measured and valued? *Energy Policy* 38, 1654–64.

Jewell, J., Cherp, A., & Riahi, K. (2014). Energy security under de-carbonization scenarios: An assessment framework and evaluation under different technology and policy choices. *Energy Policy* 65, 743–60.

Johansson B. (2013). A broadened typology on energy and security. *Energy* 53, 199–205.

Johansson, B. (2013). Security aspects of future renewable energy systems-A short overview. *Energy* 61, 598–605.

Johnstone, N., Haščič, I., & Popp, D. (2010). Renewable energy policies and technological innovation: Evidence based on patent counts. *Environmental and Resource Economics* 45, 133–55.

Kao, C., Chiang, M.H. (2001). On the estimation and inference of a cointegrated regression in panel data. *Advances in Econometrics* 15, 179-222.

Karakosta, C., Pappas, C., Marinakis, V., & Psarras, J. (2013). Renewable energy and nuclear power towards sustainable development: characteristics and prospects. *Renewable and Sustainable Energy Review* 22, 187–97.

Kilinc-Ata, N. (2016). The evaluation of renewable energy policies across EU countries and US states: An econometric approach. *Energy and Sustainable Development* 31, 83–90.

Kiriyama, E., & Kajikawa, Y. (2014). A multilayered analysis of energy security research and the energy supply process. *Applied Energy* 123, 415–23.

Kruyt, B., van Vuuren, D.P., de Vries, H.J.M., & Groenenberg, H. (2009). Indicators for energy security. *Energy Policy* 37, 2166–81.

Lefevre, N. (2007). Energy security and climate policy assessing interactions. International Energy Agency, Paris: OECD/IEA.

Levin, A., Lin, C.F., Chu, C.S.J. (2002). Unit root tests in panel data: asymptotic and finite sample properties. Journal of Economics 108, 1–24.

Lima, F., & Portugal-Pereira, J. (2015). Analysis of energy security and sustainability in future low carbon scenarios for Brazil. *Natural Resources Forum* 39, 175-190

Mabro, R. (2008). On the security of oil supplies, oil weapons, oil nationalism and all that. *OPEC Energy Review* 32, 1–13.

Maddala, G.S., Wu, S., (1999). A comparative study of unit root tests with panel data and a new simple test. *Oxford Bulletin of Economics and Statistics*. 61, 631–652.

Månsson, A., Johansson, B., & Nilsson, L.J. (2014). Assessing energy security: an overview of commonly used methodologies. *Energy* 73, 1–14.

Marques, A.C., Fuinhas, J.A. & Pires Manso, J.R. (2010). Motivations driving renewable energy in European countries: A panel data approach. *Energy Policy* 38, 6877–85.

Marques, A.C., & Fuinhas, J.A. (2015). Drivers promoting renewable energy: A dynamic panel approach. *Renewable and Sustainable Energy Review* 15, 1601–8.

Marques, A.C., & Fuinhas, J.A. (2012). Are public policies towards renewables successful? Evidence from European countries. *Renewable Energy* 44, 109–18.

Martínez, S., Koberle, A., & Rochedo, P. (2015). Possible energy futures for Brazil and Latin America in conservative and stringent mitigation pathways up to 2050. *Technological Forecasting and Social Change* 98, 186–210.

McCollum, D., Bauer, N., Calvin, K., Kitous, A., & Riahi, K. (2013). Fossil resource and energy security dynamics in conventional and carbon-constrained worlds. *Climate Change* 123, 413–26.

Meade, N., & Islam, T. (2015). Modelling European usage of renewable energy technologies for electricity generation. *Technological Forecasting and Social Change* 90, 497–509.

Milov, V. (2005). Global energy agenda. *Russia in Global Affairs* 4. Available online at http://eng.globalaffairs.ru/number/n_5847

Narula, K., & Reddy, B.S. (2015). Three blind men and an elephant: The case of energy indices to measure energy security and energy sustainability. *Energy* 80, 148–58.

Natorski, M., & Surrallés, A.H. (2008). Securitizing moves to nowhere? The framing of the European Union's energy policy. *Journal of Contemporary European Research* 4(2), 71-89.

Neff, T.L. (1997). Improving Energy Security in Pacific Asia: Diversification and Risk Reduction for Fossil and Nuclear Fuels. Pacific Asia Regional Energy Security Project, December.

Nesta, L., Vona, F., & Nicolli, F. (2014). Environmental policies, competition and innovation in renewable energy. *Journal of Environmental Economic Management* 67, 396–411.

Nooij de, M., Koopmans, C., & Bijvoet, C. (2007). The value of supply security. The costs of power interruptions: Economic input for damage reduction and investment in networks. *Energy Econonmics* 29, 277–95.

Novacheck, J., & Johnson, J.X. (2015). The environmental and cost implications of solar energy preferences in Renewable Portfolio Standards. *Energy Policy* 86, 250–61.

Ohler, A, & Fetters, I. (2014). The causal relationship between renewable electricity generation and GDP growth: a study of energy sources. *Energy Economics* 43, 125–39.

Pedroni, P. (1999). Critical values for cointegration tests in heterogeneous panels with multiple regressors. *Oxford Bulletin of Economics and Statistics* 61(S1), 653–670.

Pedroni, P. (1999). Panel cointegration: asymptotic and finite sample properties of pooled time series tests with an application to the PPP hypothesis. *Econometric Theory* 20, 597–625.

Percebois, J. (2006). Dependance et vulnerabilite: deux façons connexes mais differentes d'aborder les risques energetiques. *Revue de l'ISMEA*, Série EN 10, Montpellier.

Pesaran, M.H., Shin, Y., Smith, R.P. (1999). Pooled mean group estimation of dynamic heterogeneous panels. *Journal of the American Statistical Association* 94, 621–634.

Pesaran, M.H. (2004). General diagnostic tests for cross section dependence in panels. Cambridge Working Papers in Economics 0435, Faculty of Economics, University of Cambridge.

Popp, D. (2002). Induced innovation and energy prices. *American Economic Review* 92, 160–80.

Popp, D., Hascic, I., & Medhi, N. (2011). Technology and the diffusion of renewable energy. *Energy Economics* 33, 648–62.

Reed, W. R., & Ye, H. (2011). Which panel data estimator should I use?. *Applied Economics 43*(8), 985-1000.

Ren, J., & Sovacool, B.K. (2014). Quantifying, measuring, and strategizing energy security: Determining the most meaningful dimensions and metrics. *Energy* 76, 838–49.

Röpke, L. (2013). The development of renewable energies and supply security: A trade-off analysis. *Energy Policy* 61, 1011–21.

Sanyal, P., & Ghosh, S. (2013). Product market competition and upstream innovation: evidence from the us electricity market deregulation. *Review of Economics and Statistics* 95, 237–54.

Smyth, R., & Narayan, P. K. (2015). Applied econometrics and implications for energy economics research. *Energy Economics* 50, 351-358.

Scholten, D., & Bosman, R. (2016). The geopolitics of renewables; exploring the political implications of renewable energy systems. *Technological Forecasting and Social Change* 103, 273–83.

Sovacool, B.K. (2009). Rejecting renewables: the socio-technical impediments to renewable electricity in the United States. *Energy Policy* 37, 4500–13.

Sovacool, B.K., & Saunders, H. (2014). Competing policy packages and the complexity of energy security. *Energy* 67, 641–51.

Sovacool, B.K., & Dworkin, M.H. (2015). Energy justice: conceptual insights and practical applications. *Applied Energy* 142, 435–44.

Strambo, C., Nilsson, M., & Månsson, A. (2015). Coherent or inconsistent? Assessing energy security and climate policy interaction within the European Union. *Energy Research and Social Science* 8, 1–12.

Tishler, A., Newman, J., Spekterman, I., & Woo, C.K. (2006). Cost-benefit analysis of reforming Israel's electricity industry. *Energy Policy* 34, 2442–54.

UNDP, United Nations Development Program. (2004). World energy assessment: overview, 2004 update. United Nations Development Program. New York.

Vielle, M., & Viguier, L. (2007). On the climate change effects of high oil prices. *Energy Policy* 35, 844–9.

Winzer, C. (2012). Conceptualizing energy security. *Energy Policy* 46, 36–48.

Wooldridge, J.M. (2002). *Econometric analysis of cross section and panel data*. MIT press.

Yergin, D. (2006). Ensuring energy security. *Foreign Affairs* 85, 69-82.

Zellner, A. (1962). An efficient method of estimating seemingly unrelated regressions and tests for aggregation bias. *Journal of the American Statistical Association* 57, 348-368.

Zhao, Y., Tang, K.K., & Wang, L. (2013). Do renewable electricity policies promote renewable electricity generation? Evidence from panel data. *Energy Policy* 62, 887–97.

UNIVERSITÀ DEGLI STUDI DI FERRARA
EX LABORE FRUCTUS

Sezioni

Dottorati di ricerca

Dichiarazione di conformità

AL MAGNIFICO RETTORE

UNIVERSITÀ DEGLI STUDI DI FERRARA
UFFICIO DOTTORATO
Via delle Scienze, n. 41/B – 44121 Ferrara
Tel. 0532/455284 - Fax 0532/455262
e-mail dottorato@unife.it

ATTENZIONE: il presente modulo è da stampare, firmare e inserire come parte integrante della tesi in formato cartaceo; va inoltre inserito all'interno dei DVD o CD-ROM della tesi come file formato pdf.

Il tuo indirizzo e-mail Inserisci qui l'e-mail che ti ha fornito l'Università

vldjrn@unife.it

Oggetto: Indicare qui: "Dichiarazione di conformità della tesi di Dottorato"

Dichiarazione di conformità della t

Io sottoscritto Dott. (Cognome e Nome)

Javier Noel Valdés Lucas

Nato a: Indicare il Comune di nascita

Santo Domingo

Provincia: Scrivere per esteso la provincia di nascita oppure lo Stato (se nato all'estero)

Rep. Dominicana

Il giorno: Trascrivere la data di nascita

23/08/1986

Avendo frequentato il Dottorato di Ricerca in: Specificare il nome del corso

Economics and management of innovation

Ciclo di Dottorato Scrivere in cifre (es. 26)

29

Titolo della tesi: Attenzione: deve essere lo stesso riportato sulla tesi cartacea

Essays on Energy Economics

Titolo della tesi (traduzione): Se la stesura della tesi è autorizzata dal Collegio dei docenti in una lingua diversa dall'italiano, è obbligatorio compilare il campo secondo queste modalità: - Tesi in inglese: traduzione in lingua italiana - - Tesi in francese, spagnolo, tedesco etc.: traduzione del titolo sia in italiano che in inglese

Saggi su economia dell'energia

Tutore: Prof. (Cognome e Nome)

Massimilaino Mazzanti

Settore Scientifico Disciplinare (S.S.D.) Indicare il settore della tesi. Ad esempio, BIO/01

SECS-P/06

Parole chiave della tesi (max 10): In Italiano, Inglese ed eventuale terza lingua

Energy economics, energy policy, energy

Consapevole, dichiara Selezionare con un click

◉ CONSAPEVOLE: (1) del fatto che in caso di dichiarazioni mendaci, oltre alle sanzioni previste dal codice penale e dalle Leggi speciali per l'ipotesi di falsità in atti ed uso di atti falsi, decade fin dall'inizio e senza necessità di alcuna formalità dai benefici conseguenti al provvedimento emanato sulla base di tali dichiarazioni; (2) dell'obbligo per l'Università di provvedere al deposito di legge delle tesi di dottorato al fine di assicurarne la conservazione e la consultabilità da parte di terzi; (3) della procedura adottata dall'Università di Ferrara ove si richiede che la tesi sia consegnata dal dottorando in 2 copie di cui una in formato cartaceo e una in formato pdf non modificabile su idonei supporti (CD-ROM, DVD) secondo le istruzioni pubblicate sul sito: http://www.unife.it/studenti/dottorato alla voce ESAME FINALE – disposizioni e modulistica; (4) del fatto che l'Università, sulla base dei dati forniti, archivierà e renderà consultabile in rete il testo completo della tesi di dottorato di cui alla presente dichiarazione attraverso l'Archivio istituzionale ad accesso aperto "EPRINTS.unife.it" oltre che attraverso i Cataloghi delle Biblioteche Nazionali Centrali di Roma e Firenze; DICHIARO SOTTO LA MIA RESPONSABILITA': (1) che la copia della tesi depositata presso l'Università di Ferrara in formato cartaceo è del tutto identica a quella presentata in formato elettronico (CD-ROM, DVD), a quelle da inviare ai Commissari di esame finale e alla copia che produrrò in seduta d'esame finale. Di conseguenza va esclusa qualsiasi responsabilità dell'Ateneo stesso per quanto riguarda eventuali errori, imprecisioni o omissioni nei contenuti della tesi; (2) di prendere atto che la tesi in formato cartaceo è l'unica alla quale farà riferimento l'Università per rilasciare, a mia richiesta, la dichiarazione di conformità di eventuali copie; (3) che il contenuto e l'organizzazione della tesi è opera originale da me realizzata e non compromette in alcun modo i diritti di terzi, ivi compresi quelli relativi alla sicurezza dei dati personali; che pertanto l'Università è in ogni caso esente da responsabilità di qualsivoglia natura civile, amministrativa o penale e sarà da me tenuta indenne da qualsiasi richiesta o rivendicazione da parte di terzi; (4) che la tesi di dottorato non è il risultato di attività rientranti nella normativa sulla proprietà industriale, non è stata prodotta nell'ambito di progetti finanziati da soggetti pubblici o privati con vincoli alla divulgazione dei risultati, non è oggetto di eventuali registrazioni di tipo brevettale o di tutela. PER ACCETTAZIONE DI QUANTO SOPRA RIPORTATO

Firma del dottorando

Ferrara, li 20/03/2017 (data)

Firma del Tutore

Visto: Il Tutore
Si approva
Firma del Tutore

Selezionando il tasto "**INVIA**" in fondo alla pagina, la dichiarazione di conformità viene spedita automaticamente alla posta elettronica dell'Ufficio Dottorato. Per ottenerne una copia in **FORMATO PDF**, fare click sull'icona della stampante del proprio browser (Internet Explorer, Firefox, Google Chrome etc.), quindi selezionare l'opzione Pdf Creator o simili (a seconda del programma in uso).