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Some Economic Aspects of Energy Security*

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Abstract:

Energy security is becoming an increasingly important issue in the energy domain. However, from an economic point of view, many questions related to energy security are still unclear: from its definition and the costs associated to insecurity, to the design of policies intended to reduce it. In this paper we first illustrate why the security of energy supply is and will continue to be a major concern in the next few decades. We subsequently attempt, with a review of the limited literature on these matters, to provide an answer to some of the economic concepts associated to this issue and to the application of corrective public policies in the field.

Key Words: *Energy Security, Energy Demand, Price Elasticity, Externalities, Energy Costs, Energy Security Policies*

JEL Classification*: Q01, Q41, Q43, Q47, Q48*

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1. Introduction

Energy security is an increasingly popular concept: policy makers, entrepreneurs and academics usually claim to pursue it when proposing or implementing changes in the energy domain. Yet, this is an elusive issue as it is often not clear what the precise meaning of energy security is, especially when approaching it from an economic perspective. Although elusiveness may actually foster its growing use, as few would oppose actions against reducing energy insecurity in countries or regions, we feel that an excessive generalization may turn it into an empty and rather useless notion.

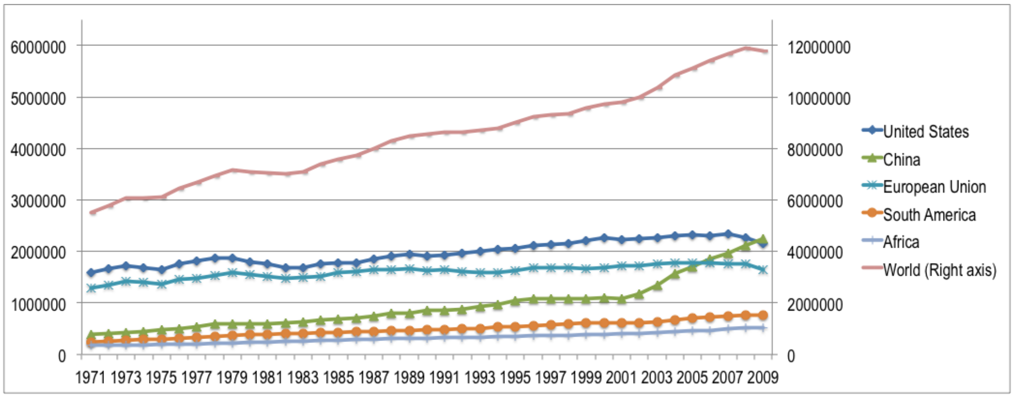
In this short and descriptive paper we intend to clarify both the meaning and economic importance of energy security and also, to discuss the strategies or alternatives to foster it. To do so, we first illustrate the importance of energy in contemporary economies and highlight how some of the particular characteristics of this area actually explain the increasing interest in this issue. After suggesting a specific definition of energy security, we provide some indications of the economic measurement and economic effects of energy security. The paper concludes with a description and discussion on the alternatives and public policies to control energy security.

2. The Evolving Role of Energy in the Economic System

Energy has always been crucial for the economic development of human societies, although its importance has expanded considerably after the industrial revolution, largely based on an intensive use of fossil fuels. Actually, the laws of thermodynamics imply that energy is necessary, at least, in a minimum quantity (even if ambitious and effective energy-efficiency strategies are carried out), for the material transformations that are related to most productive processes. Energy goods are also important both as intermediate inputs for production and transport and as final outputs that are often necessary for basic human welfare. Indeed, energy-related issues are highly relevant across the economic system through investment in durables (associated to different types and levels of energy consumption) and capital that usually reduces the capacity of agents to react in this area (see below). Thus, the first and basic fact behind this article is clear: a minimum supply of energy is essential for the functioning of economies (and societies).

In this sense, Figure 1 depicts the strategic importance of energy in contemporary societies. World energy consumption has seen an important growth during the last decades, which is largely explained by the emergence of developing countries, particularly China, since the late 1990s. Indeed, developed economies such as the United States (US) or the European Union (EU) have stabilized or even decreased their consumption in the last few years, whereas China has more than doubled its primary energy consumption in this decade, overcoming the EU and US and thereby becoming the biggest energy consumer in the world.

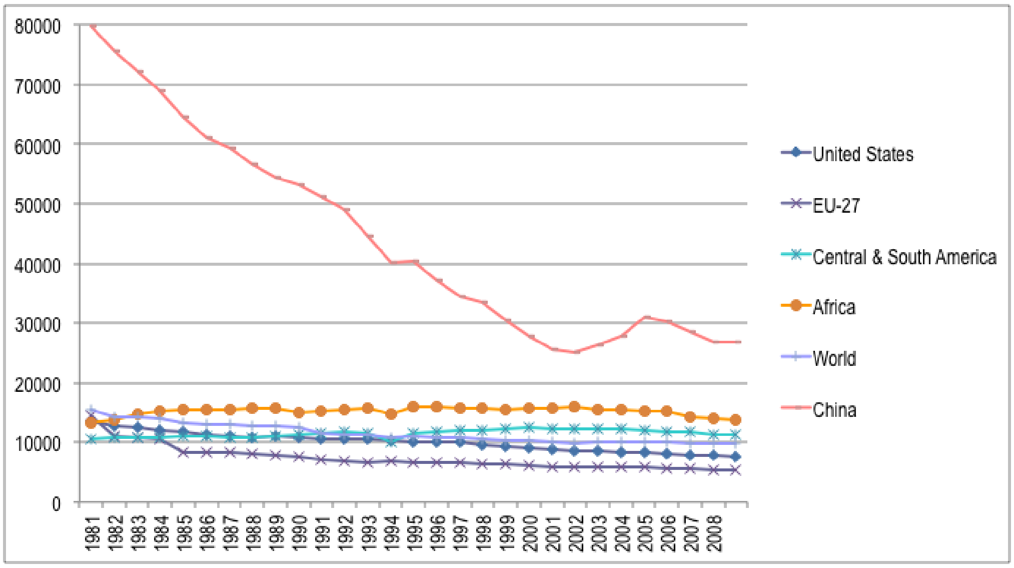
Figure 1. Total primary energy consumption (Kt of oil equivalent), 1970-2010



Source: World Bank (2012)

Although the preceding figure shows the continuous increase in energy consumption during the last thirty years, this is not the case with energy intensity (energy consumption per unit of GDP). Figure 2 depicts the evolution of energy intensity in the most important economies, reflecting that developed countries have been able to reduce significantly their ratios of energy consumption/GDP since the early 1970s. This is explained by the subsequent oil crises, which revealed the vulnerability of importing countries and by the increasing environmental concerns that, overall, led to decreases of energy intensities in the range of 50-60% in the US and the EU. China, however, is well above the energy intensity of developed countries, which is obviously worrying, given its current and future relevance in the overall energy consumption. Actually, China has shown an inconsistent evolution in the first decade of this century, with significant increases after a continuous decrease since the 1980s, which may help to understand its prevalence as a global energy consumer. However, even in developed countries there seems to be a halt in energy intensity improvements, as this variable has not shown significant changes since the last nineties.

Figure 2. Evolution of energy intensity (Btu per 2005 US$), 1980-2010



<u>Source:</u> US Energy Information Administration (2012)

The overall setting is therefore rather complex. On the one hand, a strong growth in global energy consumption is to be expected in the next decades due to the increasing demands from emerging economies. The size of this growth will be determined by the evolution of the energy intensities in those economies (and elsewhere): namely, by the degree of energy convergence of China and other emerging countries to the more developed world. Yet the capacity of societies to reduce their energy use below certain limits is limited, as already pointed out from Figure 2. Table 1 reinforces this view by reporting the rather low price elasticities of energy demand that report academic papers on the issue. This is obviously related to the above-mentioned coupling of energy use with the stock of existing specific capital and consumption of durable goods, which hampers the capacity of agents to react to price changes.

Table 1. Empirical evidence on price elasticities of energy demand in different countries

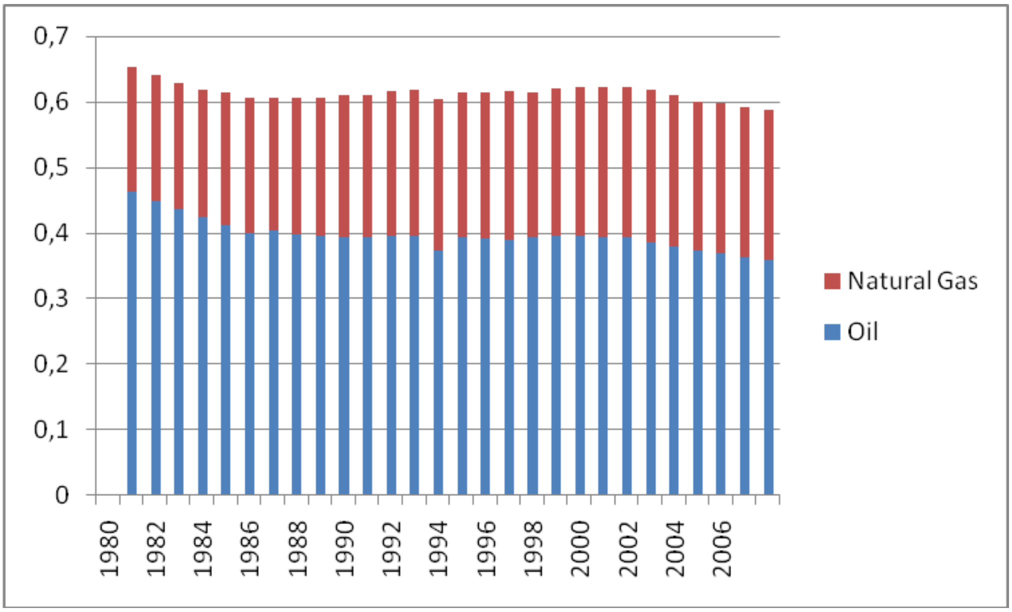
Bentzen and Engsted (1993)	Denmark	-0.13 (*st*), -0.46 (*lt*)
Dahl (1994)	50 developing countries	-0,33
Rothman et al. (1994)	53 countries	[-0.78, -0.69]
Hunt and Witt (1995)	United Kingdom	-0.29
Pesaran et al. (1998)	12 Asian countries	[-1.16, 0.06]
Koopmans and te Velde (2001)	The Netherlands	-0.29
Hunt et al. (2003)	United Kingdom	-0.18
Galindo (2005)	Mexico	-0.20
De Vita et al. (2006)	Namibia	-0.34
Bernard (2008)	United States	[-0.30,-0.21]
Kilian (2008)	United States	-0.45
Webster et al. (2008)	United States	[-0.24,-0.22]
Agnolucci (2009)	United Kingdom and Germany	-0.64
van Benthem and Romani (2009)	24 non-OECD countries	[-0.55, -0.18]
Iimi (2010)	7 Balkan countries	[-0.40, -0.37]
Filippini and Hunt (2011)	29 OECD countries	-0.45
Sa'ad (2011)	South Korea Indonesia	-0.11 -0.45

Note: st and lt respectively mean short term and long term

Therefore, energy security is and will continue to be an issue because of the ongoing relevance and inertias associated to energy in contemporary economies. Furthermore, energy security is likely to keep on playing a significant role in energy policy agendas because of the ongoing importance of fossil fuels, particularly hydrocarbons. In this sense, Figure 3 shows that global consumption of oil and natural gas has been around 60% of total energy demand since the 1980s. The preceding figure shows that that oil has lost, in comparative terms, against natural gas in the last few decades, but its importance in the transport sector guarantees a significant share of consumption in the medium and long terms.

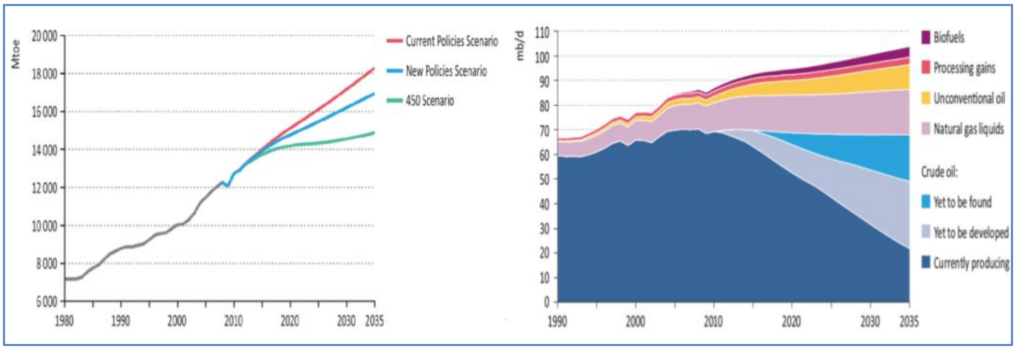
The future relevance of oil is actually depicted in Figure 4, taken from the 2011 World Energy Outlook (WEO) of the International Energy Agency (IEA). Note that in all cases, even in the ambitious '450 ppm' scenario, energy demand shows a remarkable increase in the next 25 years. In the intermediate 'new policies' scenario, still quite ambitious, this means that liquid fuels show a relevant increase until 2035. Probably this has to do with the constraints to the deployment of different energy sources in certain areas such as transport, which justifies our previous assertions. It is true that Figure 4 indicates a certain amount of substitution of conventional crude oil, which remains quite stable in any case, by unconventional oils, liquid natural gas or biofuels, but liquid fossil fuels are likely to maintain their importance in the near future. This clearly contradicts previous pessimistic approaches on the likely depletion of oil and natural gas reserves in the short term, although this phenomenon does not necessarily reduce the relevance of energy security, as we will show next.

Figure 3. Share of oil and natural gas in total energy consumption, 1980-2008



Source: U.S. Energy Information Administration (2012)

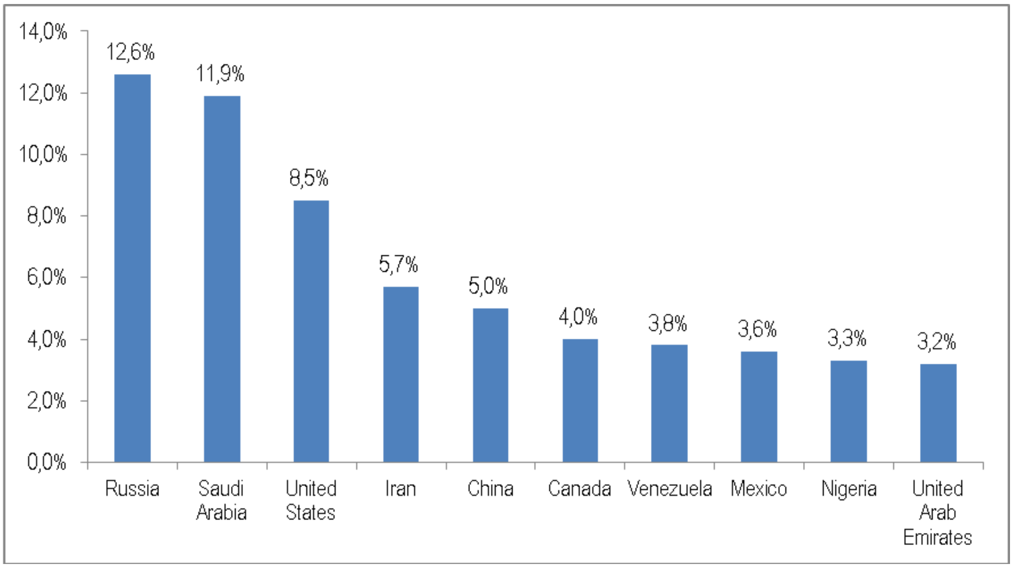
Figure 4. Demand of primary energy and liquid fuels (new policies) in the WEO, 1990-2035



Source: IEA (2011)

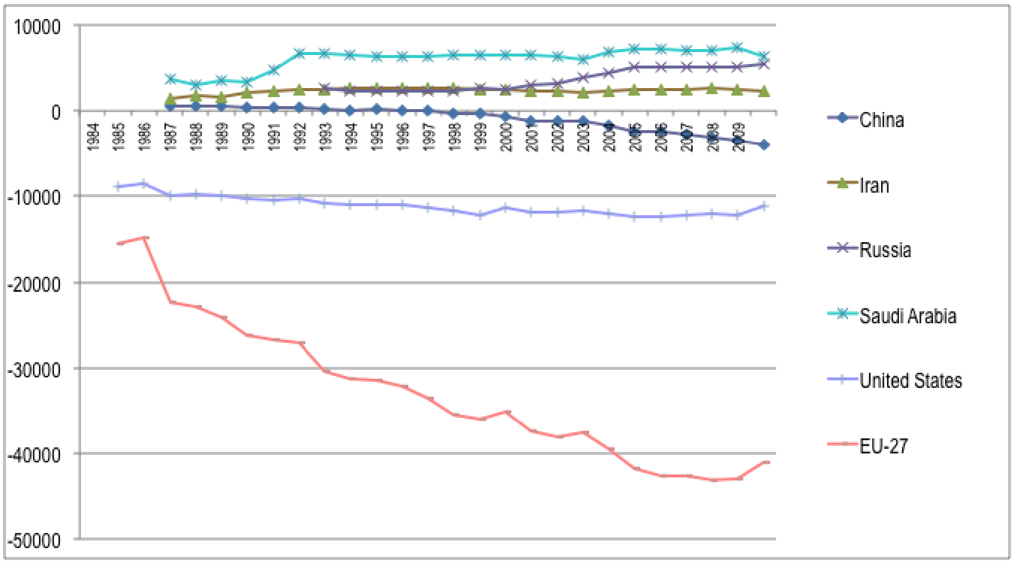
Indeed, a major problem associated to hydrocarbons is the one related to their heterogeneous distribution across the planet. Figure 5 indicates that in 2010 only eight countries, especially Russia, Saudi Arabia and the US, were responsible for the production of more than 50% of crude oil. And although new oil discoveries are assumed to take place in the next decades (see Figure 4), it is probable that their size and geographical concentration will not alter the current situation in a significant manner.

Figure 5. Main oil producers in 2010



Source: IEA (2011b)

Figure 6. Net exports of crude oil (1000 barrels/day) 1995-2011



Source: U.S. Energy Information Administration (2012)

Of course, such geographical concentration of hydrocarbons has effects on the balances of payments of countries. Figure 6 provides information on this, showing that the EU needs to import almost all the oil used in the energy domain, thus clearly affecting its balance of payments. Despite being one of the major oil producers (see Figure 5), the US is also a net importer of oil, with obvious negative effects on the balance of payments. On the contrary, countries such as Saudi Arabia or Russia show levels of oil production that are well over their consumption.

All the preceding facts and information indicate the relevance of energy security. Growing energy demands, the significant (both current and expected) share of fossil fuels in energy systems, and the significant geographical concentration of hydrocarbons, all reinforce the concerns on energy dependence. Energy security, as a tool to tackle the preceding problems and challenges, has thus become one of the priorities and guiding objectives, together with the environmental and wide economic effects associated to energy, of energy policies across the globe. Therefore, it is crucial to have a precise definition of energy security.

3. The Meaning of Energy Security

The most extended meaning of energy security refers to the availability of sufficient energy supplies at affordable prices, thus focusing on the supply-side of the energy domain. It is clear that this is an elusive concept because several parts of the definition are rather unclear: whether this availability should be continuous, if sufficiency takes into account the heterogeneity of energy sources and, above all, how affordability can be defined.

As indicated before, energy security has become an important objective of energy policy in many countries: in the EU, for example, energy security is one of the three pillars of energy policies, together with efficiency and sustainability (European Commission, 2008). Concerns about energy security first arose in the early 1970s in Europe, Japan and the United States, when the first oil crisis revealed the vulnerability of developed economies to oil price shocks. This actually explains the creation of the International Energy Agency (IEA) within the OECD, whose reports are widely cited in the literature on this issue and thus in this paper. The IEA aims to promote energy security among its member countries through collective response to physical disruptions of energy supplies, for instance holding stocks of at least 90 days of oil net imports. Indeed, one of the first definitions of energy security was given by the IEA. As soon as in 1985, the IEA referred to energy security in a rather simple manner as an “adequate supply of energy at a reasonable cost”. The IEA has restated the definition through the years to characterize energy security as adequate, affordable and reliable supply of energy.

As indicated above, security of energy supply has been a key priority in the EU agenda and thus the European Commission has also employed and provided a definition on this issue. Indeed, a 2000 green paper referred to energy supply security as “the uninterrupted physical availability of energy products on the market, at a price that is affordable for all (private and industrial) consumers, while respecting environmental concerns and looking towards sustainable development" (European Commission, 2000). This involves an obvious extension of the IEA definition, with the inclusion of environmental and sustainability issues that may introduce additional and sometimes disparate constraints. In this context, the Commission's green paper identifies several sources of risk in the energy arena:

- Physical risks, distinguishing between permanent disruption (due to stoppages in energy production or to exhaustion of energy resources) and temporary disruptions (due to geopolitical crisis or natural disasters).
- Economic risks, caused by volatility in energy prices after imbalances between demand and supply.
- Political risks, brought about by energy exporting countries that intend to employ energy deliveries as a political weapon.
- Regulatory risks, due to poor regulations in the domestic markets and regulatory variability in exporting countries (both in terms of security of energy investments and of security of supply contracts).
- Social risks, due to social conflicts that are linked to continuous increases in energy prices.
- Environmental risks that are related to the energy sector (oil spills, nuclear accidents, etc.) and may cause significant environmental damages.

Also with further extensions to the original IEA definition, the Asia Pacific Energy Research Centre (APERC, 2007) emphasizes the 'four A approach' of Availability, Accessibility, Affordability and Acceptability, when dealing with this question. APERC defines energy security as "the ability of an economy to guarantee the availability of the supply of energy resources 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". According to that view, security of energy supply is affected by factors such as the (physical) availability and the (geopolitical) accessibility of energy sources, the (price and cost of infrastructures) affordability of energy as well as the (environmental) acceptability.

From an economic perspective, Bohi and Toman (1996) define energy insecurity as the loss of welfare resulting from a change in the price or physical availability of energy. Some authors also define energy security as an externality. In this sense, Bohi and Toman (1993) discuss the costs of energy security, considering two potential externalities: those related to changes in the volume of oil imports, and those related to price volatility. The externalities related to oil imports arise from the market power of exporters because organizations such as the OPEC may be able to keep the market price of oil above the competitive level. As far as energy-exporting countries have non-competitive market behaviour, importer countries would face a market failure that provides them with reasons to recapture rents. Thus, a non-competitive market structure would affect the affordability of energy, one of the main elements of energy security that can be found throughout all definitions.

A second set of energy-related externalities is linked to the effects of fluctuations in energy costs on the economy. A slow adjustment in the factor and product markets may lead to higher economic costs: in the labour market, for instance, a rise in energy prices can increase unemployment because of wage rigidities. Similarly, a rise in energy prices can affect capital markets through an increase of obsolescence of productive capital, particularly of energy-intensive capital (Markandya and Hunt, 2004).

The literature, mostly responding to the concerns of countries heavily dependent on foreign energy stocks, has focused on a supply-side view of energy security. However, energy insecurity may be also caused from the demand side: when importer countries promote the reduction in energy imports (through subsidies for investment in alternative energy sources, energy efficiency measures, etc.) they certainly affect energy producers. In this sense, OPEC officials have emphasized that energy security must be considered from a global perspective, as a reciprocal concept among energy exporters and importers. In a 2008 statement, the OPEC Secretary General claimed that energy security it is not just about high 'unaffordable' price levels, but also about price volatility which affects not only firms and consumers in importing countries, but also to energy producing countries because energy demand becomes more unpredictable and thus increases uncertainties for investment. Actually, Van der Ploeg and Poelhekke (2009) reinforced this view by showing the negative effects on growth brought about by the usually positive correlation between degree of dependence on natural resources and macroeconomic volatility.

4. Measuring energy security and its costs

At this point it should be clear that the measurement of energy security is not straightforward. Those difficulties arise from its very definition, which mixes elements that are highly context-dependent. The simplest definition of energy security (adequate supply of energy at a reasonable cost) illustrates how complex any attempt of measurement would be: from the assessment of the “adequate” level of supply to the “reasonable” price level of the energy mix. Those difficulties are reflected in the limited existing literature, which is related to the usually limited theoretical background in these matters.

4.1. Quantifying Energy Security

The papers on the measurement of energy security have addressed the issue with either an indirect approach through a pure geopolitical analysis (see e.g. Keppler, 2007) or, mostly, through indicators of security of supply. One of the few exceptions to both approximations, Markandya and Pemberton (2010), addresses the issue in a theoretical economic model. Although these authors use a partial equilibrium model to deal with an issue with obvious wider implications, the paper establishes the key factors for understanding and assessing the main economic dimensions of energy security: risk aversion, probability of disruption, demand elasticity and cost of disruption.

The literature on indicators of energy security is quite extensive. In a survey that oversees this field, Kruyt et al. (2009) state that there is no ideal indicator and therefore, it is needed the application of several indicators for a broader assessment and understanding of energy security. Scheepers et al. (2007) propose two quantitative indicators that can be used to in EU security of supply: the Supply/Demand Index based on objective information contained in energy balances and the Crisis Capability Index, which measures the ability of countries to manage short-term supply interruptions. Gupta (2008) explores the relative oil vulnerability of 26 net oil-importing countries combining different indicators into a composite index whose purpose is to capture the sensitivity of the economies to factors such as the geopolitical oil market concentration, the diversification of supply sources, the political risk in oil-producing countries, or market liquidity. In another relevant paper, Roupas et al. (2009) compare the security of oil supply of the 27 countries of the European Union by measuring past episodes of oil vulnerability. The methodology uses principal-component analysis to set up a synthetic index that intends to reflect the core of vulnerability and security of supply. Furthermore, Le Coq and Paltseva (2009) put up a set of indexes for different primary energy types for the EU, showing that supply risk differs not only among countries, but also among energy sources. The results suggest that preferences of countries over supra-national energy policies could thus differ considerably.

From a different perspective, but also employing an index-based methodology, Marín-Quemada and Muñoz-Delgado (2011) explore the relationship between the EU and other countries in terms of competition (rivalry) or complementarities (affinity) regarding energy import and export flows. The authors propose an Energy Affinity Index to analyse the EU-27's energy relations with third countries.

Finally, the International Energy Agency has very recently developed a Model of Short-Term Energy Security (MOSES) to evaluate short-term security of energy supply in IEA countries (IEA, 2011a). The model is based on a set of quantitative indicators that measures both the risk of disruptions in energy supply and the ability of the energy system to deal with those eventual disruptions. MOSES takes energy systems, from energy supply to end-use energy services, as the approach to study energy security and includes indicators of both domestic and external risks and resilience.

4.2 Costs of Energy Insecurity

As indicated in the introduction, many countries have energy security as a major priority in their energy policies. Yet, is this a really important issue from an economic point of view? Again, few studies have attempted to estimate the cost of energy insecurity. Probably, the above-mentioned difficulties to define and measure energy security make the estimation of energy insecurity costs rather complex. However, given their potential importance, many researchers have approached the economic cost of energy insecurity for a number of countries or economic spaces.

A first negative economic consequence of energy insecurity is related to price shocks, and several authors have tried to quantify their economic effects. In a summary of knowledge on this issue, Hamilton (2005) points out that nine of the last ten recessions since World War II have been preceded by an increase in oil prices. Hamilton (1983), Burbidge and Harrison (1984), Gisser and Goodwin (1986), Raymond and Rich (1997), and Hamilton (2003) actually found a negative relation between oil price and economic activity. However, it is not obvious how the price of oil does affect economic activity. The standard approach to modeling energy price shocks has been to consider imported oil as an input in the production function, followed by Kim and Loungani (1992), Rotemberg and Woodford (1996) and Finn (2000) to study the effects of energy price shocks in real business cycle models. However, there are problems in explaining economic declines based on this intermediate input cost because the share of oil in GDP is relatively small, less than 5% in a developed economy such as the US. Consequently, there is no reason to expect large effects on the economy due to higher production costs (Kilian, 2007).

Another branch of the literature has focused on the demand side of the economy to explain the effects of oil shocks. Bernanke (2006) stated that an increase in energy prices would primarily slow economic growth through its effects on consumers' expenditure. Changing prices may create uncertainty about the future and, therefore, consumers would respond by increasing their precautionary savings and postponing purchases of energy-intensive durable goods such as automobiles. Indeed, Hamilton (2005) stressed that higher uncertainty about future energy prices is the main mechanism through which energy shocks affect the economy. In this sense, Henriques and Sadorsky (2011) and Ferderer (1996) showed that oil price volatility negatively affect investment and, consequently, economic activity.

As already indicated, energy security is not just related to price shocks but also to physical availability of energy. Prices are not always able to adjust energy demand and supply and, therefore, supply interruptions may occur. In the academic literature several studies have analyzed the cost of electricity interruptions. In particular, Targosz and Manson (2007) conducted a survey to estimate the cost of inadequate power quality within the EU-25, which they quantified over 150.000 million Euros (90% arising in the industrial sector). Another relevant study, LaCommare and Eto (2006), developed a bottom-up approach to estimate the cost to US consumers related to power quality problems (interruptions and other quality events), finding out that the annual costs amounted 79.000 million US$ with 70% arising in the commercial sector.

5. Energy Security Policies

If the costs of energy insecurity are high and, as indicated in Section 3, take the form of a negative externality, there is a clear reason for public intervention. Plenty of papers have approached this issue informally, though, with three basic questions being usually omitted. The first question is related to the cost-benefit analysis of energy security: Energy security should not be an end in itself, or a general argument for energy policy intervention, but rather a concept that allows societies to protect their welfare in a proper and balanced manner. Hederus et al. (2010), for instance, suggest that four energy security policies aimed at substituting oil imports in the EU (use of imported or domestic ethanol, more efficient vehicles or use of pellets) would not pass a cost-benefit assessment unless other additional effects (e.g. GHG reductions) are included. Of course, to establish whether a policy to diminish energy insecurity is recommendable it would be necessary to have full information on the economic costs of such policies and on the benefits of energy security that, as shown across the whole article, is not an easy and straightforward task. A second matter would be linked to the operational definition of energy security policies through appropriate and cost-effective mechanisms (see e.g. Bohi and Toman, 1993). The third issue, which is somehow related to the two preceding questions, reflects the often-neglected synergies and interactions between energy-security endeavors and other energy-related policies that aim environmental protection or revenue raising objectives.

There is quite poor academic literature on energy security policies, which probably reflects the now well-known problems for definition and assessment of energy security. Several commentators have classified these policies in two groups: those acting on the supply side of the energy system, and those devised for the demand side. Among the former, a number of strategies and tools such as increased interconnections, a bigger share of renewables or non-dependent energy technologies (such as nuclear or coal, when the country has this endowment), a bigger amount of strategic reserves of fossil fuels, a diversified purchasing portfolio of oil and gas, etc. Among the latter, a reduced use of energy through energy efficiency and conservation. Alternative classifications include the proposed by Correljé and van der Linde (2006), who distinguish between instruments devoted to prevention, dissuasion, contention and management of energy crises.

Often, some of the above-mentioned strategies can be aligned with the general environmental prescriptions on energy systems (more renewables, more energy efficiency), but this is not always the case (more coal). Therefore, it is important to specify the share of current energy policies that actually respond to these concerns rather than provide a general reinforcement for other policies due to non-specified energy security issues. Of course, this needs a level of quantification and precision that, unfortunately, is not yet available in this area. Moreover, conflicting interests between energy security and other policy objectives, such as those mentioned above, should not be hidden but also quantified and solved. Several papers, including Turton and Barreto (2006) and Bollen et al. (2010), have dealt with these questions showing that trade-offs and synergies are likely to vary due to different circumstances and strategies of different countries, for instance in cost-benefit terms. Moreover, synergies (Froggatt and Levi, 2009) may be due to the simultaneous action of firms and governments in this area.

Finally, some reflections on the use of specific instruments to attain energy security may be necessary. Economists have usually advocated the use of market approaches in energy policies, namely prices. They contrast with conventional regulations that may not be cost-effective, such as mandatory energy restrictions on consumers or producers. Higher energy prices, for instance brought about by energy taxes, may attain higher energy efficiency and conservation and thus, they contribute to a reduction of energy insecurity. However, they may come into conflict with the "affordable costs" approach of most definitions of energy security. In sum, yet another reason for a proper quantification of effects, for the employment of a proper definition and, probably, for the use of a rich set of coordinated policy instruments in the energy security arena.

6. Conclusions

In this paper we have addressed some economic aspects associated to energy security. First of all, we showed the importance of energy for contemporary economies and how exhaustible and geographically concentrated resources are playing, and are likely to play in the future, a very important role within energy systems. We also dealt with the elusiveness of the notion of energy security, whose many definitions often include subjective questions that are difficult to understand. We then focused on the measurement of energy security, highlighting again the difficulties to provide a meaningful quantification of this concept. Yet, we provided some indications on the negative economic effects from both energy price volatility and supply disruptions, which claim the implementation of public policies in this area. The article thus concluded with a reflection on the design of energy security policies, both taking into account their overall costs and benefits, their efficient application through appropriate policy instruments and the likely interactions that may occur with other energy and environmental policies.

The paper tried to explain how popular and apparently important issues, such as energy security, might be associated to a number of shortcomings that may prevent its practical implementation. In the case of energy security, there is a risk of reducing this matter into an empty, too general, and difficult to address question. Therefore, fostering research on the economic impacts of energy insecurity may provide clues to the real assessment of this problem and to define proper responses, through public and private policies and strategies, to the challenges brought about by the security of energy supply at reasonable prices.

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