Universidade de Aveiro Departamento de Economia, Gestão e Engenharia Industrial
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Ana Patrícia da Silva Martins

Impacto do Preço do CO_2 no Preço da Eletricidade: o caso do MIBEL

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Dissertação apresentada à Universidade de Aveiro para cumprimento dos requisitos necessários à obtenção do grau de Mestre em Economia, realizada sob a orientação científica da Doutora Marta Alexandra da Costa Ferreira Dias, Professora auxiliar do Departamento de Economia, Gestão e Engenharia Industrial da Universidade de Aveiro

Aos meus pais, Fernando e Marina.

o júri

presidente

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palavras-chave

Comércio de emissões, Preço das licenças de emissão de CO_2, Preço da Eletricidade, Custos de oportunidade, MIBEL

resumo

O custo das licenças de emissão de dióxido de carbono é um custo de oportunidade para as industrias afetadas, uma vez que essas licenças de emissão podem ser transacionadas no mercado. Particularmente no sector elétrico esta questão tem despertado a atenção do público, devido à possibilidade de incluir este custo de oportunidade no preço da eletricidade, gerando lucros adicionais para as centrais. Para avaliar a existência desta passagem de custos no recém criado Mercado Ibérico de Eletricidade, recolhemos dados sobre os preços das licenças de emissão de CO_2, do combustível e da eletricidade, e utilizamos o modelo do vetor autorregressivo (VAR). Concluímos que há evidencia de passagem de custos do CO_2 para o preço da eletricidade, sendo este ligeiramente mais elevado em Portugal do que em Espanha. A passagem de custos do CO_2 parece ser maior no pico da carga do que na carga base.

Keywords

Emissions Trading, CO_2 Allowances Prices, Electricity Prices, Opportunity Costs, MIBEL

abstract

The cost of carbon emission allowances is an opportunity cost for industries affected, since these allowances can be traded in the market. Particularly in the electrical sector this issue has triggered public attention, due to the possibility of including this opportunity cost in the electricity prices, generating windfall profits for utilities. To assess the existence of this pass-through in the newly created Iberian Electricity Market, we collect data on prices of electricity, fuel and CO_2 allowances, and we use a Vector Autoregressive (VAR) Model. We conclude that there is evidence of CO_2 cost pass-through to the electricity price, being a slightly higher in Portugal than in Spain. The CO_2 cost pass-through still seems to be higher at peak load than at base load.

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Abbreviations

CO_2 – Carbon dioxide

CRM – Conselho de Reguladores do MIBEL

EC – European Commission

EU ETS – European Emissions Trading Scheme

NAPs – National Allocation Plans

NGOs – Non-governamental Organizations

OMIE – Iberian Market Operator – Spanish pole

OMIP – Iberian Market Operator Power – Portuguese pole

UNICE – Union of Industrial and Employers Confederations of Europe

UNFCCC – United Nations Framework Convention on Climate Change

VAR – Vector Autoregressive model

I. Introduction

Climate change resulting from human activity is one of the most important questions of the XXI century. The first step towards reducing emissions of greenhouse gases happened with the entry into force of the Kyoto Protocol on 16 February 2005, where the European Union committed to reduce emissions of greenhouse gases to about 8% compared to levels registered in 1990, for the period 2008-2012. With the same objective, in December of 2002, the Emissions Trading Scheme was established. Was thus determined that most allowances would be given free of charge, however a small portion would be auctioned 5% and 10% respectively in the first (2005-2007) and second (2008-2012) phases. The allowances would be distributed by six key industries: energy, steel, cement, glass, bricks and paper/card. The allowances will be traded in the market so that power plants can supply deficits or sell excesses. The final environmental outcome is exactly the same as would occur in the case of both companies (buyer and seller) use the amount of allowances that was allocated for each, but with one significant difference, because both companies benefit of the flexibility offered by the trade. Therefore, the CO_2 allowances price represent, on one hand an additional cost for power plants that purchase allowances for supply deficits, on the other hand, also an opportunity cost for power plants, that received allowances for free, to use them and consequently are therefore impeded from selling them in the market.

The advantages of the EU ETS as a mechanism for reducing emissions are mainly flexibility, efficiency recorded at the level of costs and incentives for developing clean technologies. In fact, the EU ETS leads to reduction of pollution in a businesses and promote the development and diffusion of new technologies.

In 2008, approaching the end of the second phase, new talks started in order to decide the future of Kyoto Protocol, as well as the Emission Trading Scheme. With the creation of Directive 2009/29/EC, the electricity sector finds itself excluded from the free allocation of CO_2 allowances in the post-2012 period. This decision relates to the ability this sector seems to have, to pass the cost of CO_2 allowances to the cost of the final product, without incurring in loss of competitiveness. These transfers to consumers are known as “CO_2 cost pass through”, and are defined as the average increase in electricity price during a certain period of time, due to the increased cost of CO_2 allowances. It is, therefore, very important to infer the true on this het. Thus it becomes important to determine if this sector can really pass the additional cost of allowances to the electricity price. Therefore, the purpose of this dissertation is study the existence of that transfer, to infer if the additional costs of CO_2 allowances affect the price of electricity, i. e. determine if electricity sector can really pass the additional cost of allowances to the electricity price.

Thus, the main aim of this dissertation is an historical analysis of the existence of pass-through of costs of CO_2 to electricity price. As relevant market for our study, we consider the Iberian Electricity Market (MIBEL). This choice is not only due the lack of historical analysis on this market, but also because it is a market created recently.

One of the conclusions to be draw is that in fact there is evidence of pass-through of costs of CO_2 allowances to the electricity market, being a slightly higher in Portugal than in Spain. The CO_2 cost pass-through still seems to be higher at peak load than at base load.

With our results, we can have an idea about what will happen in the post-2012, after the implementation of free allocation of allowances. Despite the price of CO_2 allowances be reflected in the actual price of electricity, it may happen that these values become more relevant, and therefore may increase the price of electricity.

The dissertation is organized as follows. In the section II we present a literature review. In the section III we describe the origin and development of the European Trading Scheme. In the section IV we present the operation and the features of the electricity sector, focusing on the Iberian Electricity Market. In section V we present the model and the results. In section VI, we conclude and give suggestions for future research.

II. Literature Review

The fact that the price of CO_2 allowances represent an opportunity cost for the electric sector and the possibility this might be reflected in the final electricity prices has triggered several studies over the past years. These studies can be broadly divided into two types: those that perform analysis of possible scenarios, assigning multiple possible values to the price of allowances and considering different assumptions; and those who do their analysis based on historical values.

Initially we will focus on the first type. Within this type, we can divide the studies according to the countries to which they are applied. We leave for the end (of this type) those that are applied to the MIBEL or at one of the countries that constitute this market.

Several studies using computer models that simulating the operation of the electricity market, to study the problems mentioned. One is SIJM (2004) which was applied to the Netherlands. The author assume that the amount of additional costs derived from the trading of CO_2 emissions is fully included in the price of electricity, and concludes that the increase in electricity prices derived from emissions trading is determined by the factor of marginal production. Meanwhile, KARA et al. (2008), study the Finnish market and determine that the annual average electricity price increased by 0,74€/MWh for every 1€/ton CO_2.

BERIZZI et al. (2009) consider two market structures, perfect competition and oligopoly, for the Italian Market, and conclude that the increase in electricity prices resulting from emission trading is significantly more higher in oligopoly than under perfect competition. In turn, WALS et al. (2003), in their study on Netherlands, Belgium, France and Germany, assign different values to the rising of CO_2 price, concluding that in all countries there is an increase in electricity prices. However, under oligopoly, an increase in marginal costs is not fully reflected in electricity prices, since the producers will partly reduce their mark ups. These authors also studied the relationship between the price of allowances and the amount of CO_2 emitted by verifying that an increase in the price of CO_2 to 5€/ton represents a 10% decrease in the amount of CO_2 emitted, for the four countries studied.

SIMSHAUSER et al. (2009) do a simulation for the Victoria region and determine that CO_2 pass through rate is 78%. In turn GENOESE et al. (2007) develop an agent-based analysis of the impact of CO_2 allowances price in electricity price, using spot prices for Germany. They conclude that approximately 75-100% of the CO_2 allowance price is passed through to the electricity price.

In their study applied to MIBEL, RENESES et al. (2008) formulate different scenarios for an inelastic demand, fuel costs and the availability of water in reservoirs, in the first phase, while in the second phase, they consider the water conditions as fixed and introduce scenarios for production using renewable. These authors conclude that an increase of 5€/ton in the price of CO_2 causes an increase of 3-3.5€/MWh in the price of electricity for the first phase and 2,5-2,8€/MWh in the second phase. In turn, SOUSA et al. (2005) also on the MIBEL, concluded that it can be expect an increase in electricity prices mainly when there is coal power generation, and during off-peak hours. Finally, LINARES et al. (2006), applied their study only to the Spanish electricity market, and using a model of oligopoly, found that prices have increased about 20% due to the trade in emission allowances, and that investments in clean energy sources should be encouraged.

Let us concentrate now in research whose analysis consider historical data. The first work that should be mentioned is FELL (2010), which is an application to the Nordic countries. He concludes that the response of electricity prices to changes in allowances price is generally significant and it will be dilute over time, at off-peak times. Furthermore, when the marginal production technology used is coal the transfer of costs is almost complete. In turn SIJM et al. (2006a) and SIJM et al. (2008) assume that all costs, excluding fuel or allowances, are constant, the market structure does not change, and the cost of fuel is fully reflected in electricity prices. SOLIER et al. (2011) with the same assumptions analyses this transfer for some European countries, including Spain, and conclude that this transfer is more relevant in the first phase of the EU ETS than in the second phase. Furthermore they find no evidence of cost pass-through in 2009 for all countries considered in their sample. The reason attributed to this result, was the financial crisis, and consequent instability of markets, volatility of prices and reduced demand for electricity. In order to verify to what extent the economic crisis will affect this transfer of costs, the authors conducted a further estimation using the forward prices and concluded that in this market there is evidence of cost pass-through. Although the year of 2009 had lower values comparing with others, confirming that the economic crisis may reduces the impact of CO_2 cost on electricity prices.

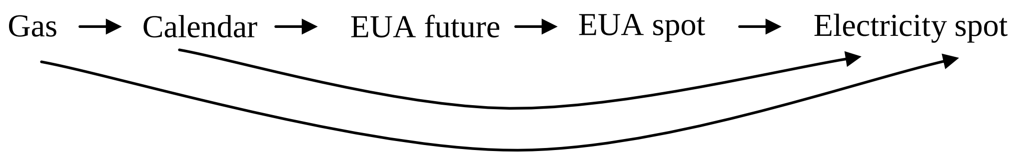
Recently presented at the 5th Atlantic Workshop on Energy and Environmental Economics, the unpublished work of FREITAS et al. (2012) study the CO_2 cost pass-through in Portugal, using a vector error-correction model (VECM), and conclude that the rate of CO_2 cost pass through is between 33-51%.

AHAMADA et al. (2012) study the economic impact of EU ETS on electricity prices, analysing futures prices in France and Germany, for the second phase (2008-2012). They identify a structural break in the series of carbon spot prices in October 2008, due to economic and financial crisis. They conclude that before October 2008, the impact of carbon prices is not significant in both countries. After October 2008 carbon prices strongly influences the price of electricity, an increase in the allowances price of 1% results in 0,19% to 0,21% and 0,13% to 0,14% higher electricity prices in France and Germany, respectively.

BUNN et al. (2007) conclude that one shock of 1% in carbon price causes on average one shock of 0.42% in electricity price on United Kigdom. In turn, ABADIE et al. (2011) study the relationship between the price of electricity, natural gas, coal and CO_2 allowances price, and determine that the electricity markets incorporate the price of CO_2 allowances. And finally, ZACHMANN et al. (2008) prove the existence of asymmetric CO_2 cost pass through in Germany, using forward prices.

Another way to determine the relationship between the CO_2 allowances price and electricity prices was presented by KEPPLER (2010), and KEPPLER et al. (2010) using the Granger causality test. These two studies concluded that in the first phase of the EU ETS there is a causal relationship between the forward price of CO_2 allowances and the future price of electricity (figure 1). This relationship is higher in base-load because the coal (typically used in base-load power production) is more intensive in carbon (KEPPLER et al., 2010). In the second phase of the EU ETS, KEPPLER et al. (2010) find a reversal in the causal relationship between the forward price of CO_2 allowances and forward prices of electricity, concluding that is the price of electricity that determine the price of CO_2 allowances.

Figure 1 – Causality relationship between the carbon, electricity and gas markets, after one period (one day)



Source: KEPPLER (2010)

A common result to all papers mentioned so far is that an increase in the CO_2 allowances price causes an increase in electricity prices. Therefore, one of the main questions is also the impact of CO_2 allowances prices on consumers. According to CHEN et al. (2008), the share of costs emission that is passed to consumers by increasing the price of electricity depends on the elasticity of demand, the price of allowances and also the market power.

BONACINA et al. (2007) focus their analysis on the effects that market structure has on the rate of cost pass-through concluding that the price of electricity on perfect competition internalise the marginal cost of opportunity of CO_2 allowances. In imperfect competition this internalization can be smaller or larger than in perfect competition, depending on several factors as: the degree of market concentration, the operated plant mix by each dominant firm or by the fringe, the price of CO_2 allowances and finally the capacity available. In particular, with the results obtained, this authors argue that under market power the impact of ETS is higher than in perfect competition only if there is excess capacity and the share of most polluting plants in the market is low enough. Moreover, without excess capacity, the impact on the market power is less than perfect competition and decreases significantly with market concentration. Additionally CHERNYASVS'KA et al. (2008) argue that the increase in the price of electricity due to emissions trading can also be higher or lower depending on the production capacity. PERRELS et al. (2006b, 2006a) reported that the spot price of electricity will naturally be less affected by increased CO_2 emissions allowances price if more capacity is installed.

III. Origins and Development of EU ETS

3.1 Theoretical and experimental foundations

The intellectual platform is perhaps the most important aspect in the origin of the EU ETS, since the development of theoretical and applied studies on emissions trading, allowed to give the EU ETS the status of policy instrument. As one of the precursors of the study of the problems of social cost, we find COASE (1960), which suggests that the allocation of property rights, provides the use of environmental endowments which in turn can be traded and negotiated so that the final result is economically efficient.

Years before PIGOU (1932) argued that the solution to correct externalities was the imposition of a tax applied on the activity causing the externality. This tax should be equal to the social damage caused by the last unit of damage created. A formalization of the ideas advocated by Pigou, was presented by BAUMOL (1972). The author demonstrates the veracity of the theoretical ideas presented by Pigou, however points out that there is still a long way to go before these ideas become operational, not only by the existing difficulty in calculating the marginal damage function, but also by the fact that can find more than one local maximum. Concluding BAUMOL (1972) says:

> "All in all, we are left with little reason for confidence in the applicability of the Pigouvian approach, literally interpreted. We do not know how to calculate the required taxes and subsidies and we do not know how to approximate them by trial and error."

This theoretical framework has gained more notoriety and expressiveness, as a way of creating the system of emissions trading, with the works of DALES (2002) and TIETENBERG (2006). DALES (2002) says that the solution to minimize this problem could pass by setting allocated quotas, expressed in equivalent tons of discharges, and these same quotas would be likely to exceed the total quota allocated to the region. However, these quotas could be traded in the market, and the outcome of the matching of aggregated offer and demand would set the price, and its signal would be a continued drive for innovation and efficiency. More recently, TIETENBERG (2006) summarizes the experience of the U. S., whose essence is on "learning by doing". Indeed, it is often the search for solutions to the problems that give rise to the innovation. The emissions trading encourages both emissions-reducing innovation and the adoption of new emissions-reducing technologies.

3.2 The role of the Kyoto Protocol

Most of the Member States, institutions, green groups and industries of the EU were sceptical about the idea of emissions trading (SKJAERSETH et al., 2008). However, despite this initial scepticism, the European Union was one of the earliest supporters of reducing the emissions of greenhouse gases. The first signal of this shift has emerged in the spring of 1998, through communication of the EU Strategy for the post-2012, which determined the existence of an internal pilot phase for emissions trading, and reinforced the need for the EU to show improvements in climate policy during the year of 2005, in accordance with the provisions of the Kyoto Protocol (EC, 1998). In May 1999, with the publication of the document "Preparing for Implementation of the Kyoto Protocol", the discussion of the possible creation of a domestic system of emissions trading has intensified. Initially, this system should be applied only to a few key sectors, and include only the CO_2 emissions (gas easier to measure) and later would be gradually extend to other types of emissions (EC, 1999).

Issues such as the harmonization and the degree of centralized power, hitherto treated surface, subsequently receive more attention in the publication of EU ETS Green Paper (EC, 2000). This document alert to the need for a more centralized and harmonized market in order to encourage the ambition on the part of Member States in reducing CO_2 emissions.

There are several reasons for the change of position by the European Commission in relation to emissions trading (SKJAERSETH et al., 2009). The main ones are: EU perseverance in defending binding numerical targets for reducing emissions; the commitments imposed by the Kyoto Protocol and the provisions for international emissions trading; the attractiveness of the idea of emissions trading; and the entrepreneurial behaviour demonstrated by the European Commission. The imposition of numerical targets required that the EU itself had a particular obligation to fulfil the goals it set itself. The entrepreneurial behaviour demonstrated by the EU was caused by the change of staff, which has consisted mostly of economists, who were receptive or supporters of the idea of emissions trading, and that worked to foster the rapid development of the EU ETS. Other reasons for change of mentality of EU are: the United States decision in vetoing the Kyoto Protocol, which fuelled a movement in support of Kyoto, credible for most industrial emitters, and the growing recognition that the new climate policy instruments would be needed to achieve the Kyoto targets.

However, the Kyoto Protocol is identified as the key factor. This agreement adapted the effort and turned it into real action as: the creation of a target of 8% reduction in emissions recorded in 1990; the introduction of flexible mechanisms, among which was the trade of allowances, as aids in meeting the goals; and finally the impetus for the creation of a burden sharing Agreement, which took place in June 1998 and which was attributed to each of the 15 Member States a legally binding order (CONVERY, 2009). The Protocol give to the EU a special impetus towards the adoption of emissions trading, also by the great economic opportunity that it represented, but in particular because it can lead to reduced costs of compliance with Kyoto targets (SKJAERSETH et al., 2009). However, although the EU ETS has been clearly linked with the ratification of the Kyoto Protocol, he was included in EU law so that its creation was independent of the Kyoto Protocol (ELLERMAN et al., 2007).

3.3 Success in implementing the EU ETS

The successful creation of the European emissions trading scheme was not predetermined. In fact, countries that were regarded as less complex and more cohesive than the European countries, like Canada or Japan, in both institutional and cultural contexts, failed. The success of European ETS is due to several reasons, including (CONVERY, 2009): the opposition to the proposed carbon energy tax, in the 90s; easy acceptance of emissions trading by the industry; creating their own systems by the United Kingdom and Denmark. The failure of the struggle against the inclusion of trade in emissions allowances as a flexible tool in the Kyoto protocol in 1997, and the existence of a single market, characteristic of extreme importance to the environment are others important reasons for the success of the EU ETS.

Opposition to the proposed carbon energy tax emerged from two core elements. Several countries consider their autonomy with regard to taxation as a core value, which should not be called into question, even if the argument is the benefit of environment. Although the carbon energy tax have been presented as a special case, countries feared that the same happen in other tax initiatives and gradually the fiscal autonomy would be diluted. The chief representative of the industry at EU level, UNICE, was also against the carbon energy tax. The skill and persistence of the opposition allowed him to be strong enough to remove the proposed carbon energy tax in 1997. And in 1998 the Commission published “Climate Change – Towards a strategy for the EU post-Kyoto” advocating that itself could establish its own system of internal trade in 2005 (EC, 1998).

The creation of a single market also reinforced the urgency of addressing the environmental challenges that transcend national boundaries. The polluter pays principle has also received much attention, like the obligation to perform an analysis of costs and benefits of environment measures (DELBEKE, 2006). This created the legal basis for mobilizing the market in the direction of finding solutions to combat climate change.

Finally, emissions trading has been welcomed by industry due to the great effort of the EC to highlight different aspects of emissions trading among different stakeholders. In the case of the industry the argument used was the cost efficiency. Such efficiency could create economic opportunities because firms reduce emissions and thus can sell allowances.

3.4 The difficulties that arose

The main difficulties encountered during implementation of the EU ETS were mainly the decentralized approach that was implemented with the system of emissions trading (SKJAERSETH et al., 2009) and the lack of data at the emission installations (BUCHNER et al., 2006, ELLERMAN et al., 2007, MULLINS, 2005).

One of the main features of the EU ETS, has been the decentralization with respect to the establishment of limits on the amount of allocated allowances and therefore the setting of emissions limit. This decentralized approach was the result of power sharing and the attempt of agreement between the European Commission and Member States. Thus, the final proposal was in fact more detailed about the decentralized setting limits on the amount of emissions, according to the proposal from the European Commission (Article 9 of the ET Directive). Therefore the allowances allocation was being done at the Member State level. A decentralized system can easily lead to over-allocation and consequently reduce the ambition to the mitigation of emissions. Thus, the key element for the creation of the EU ETS was the development of national allocation plans (NAPs). Each Member State is responsible for the preparation of his own, under the ET Directive. The European Commission here has played a less prominent role, particularly at the decision phase. But continued to play a central role, being very active behind the scenes of negotiations of the Council and working as a conciliatory party. Thus the EU assessing national allocation plans and excluding any meeting that did not agree with the way forward to achieve the Kyoto targets in 2005-2007 and/ or were not in agreement with the proposed goals for 2008-2012.

Another problem that arose in the implementation of the EU ETS was the lack of data level of CO_2 emitting facilities. It was with great surprise that most people realized the existence of this problem, because many countries had created reasonable inventory data for CO_2 emissions. This problem was caused by two distinct situations. The first derives from the fact that the directive on emissions trading requires the free allocation of at least 95% of allowances. While the second is because the existing data on CO_2 emissions were based on aggregate energy use and were not segregated by facility. In fact countries like Sweden and Germany, which had already recorded data at the level of facilities to suit their aims, they found unacceptable flaws in their data (ELLERMAN et al., 2007). In fact only Denmark, did not suffer the problems of lack of data, since their data was already collected at the level of facilities to cope with their own system of emissions trading.

The problem was compounded due to the lower limit – 20MW thermal rating – to include combustion installations in the EU ETS, to the difficulty in identifying all these facilities, especially in large countries with many facilities such as Germany (MULLINS, 2005). Although the lower limit will minimize the distortion of competition between the power plants, intensifies the problem of data, because more facilities are included. BUCHNER et al. (2006) even state that in the short term, "...the inclusion of small installations was not worth it" however in the long run these facilities must be included in the EU ETS. In fact the inclusion of small installations in the EU ETS causes two problems: the data for each installation are specific to that facility and the submission and verification of the data implies costs for small facilities that are very high in view of their low emissions and low potential of abatement.

The unavailability of data at the installations level had consequences. One of these consequences was the lack of legal authority to collect relevant data. The collection of data directly from the installation combined with the reduced time limits for submission of NAPs, put the governments of Member States in a position of strong dependence on the voluntary submission of data by industry (BUCHNER et al., 2006). However, the affected companies cooperated as best as possible, which allowed this problem to be minimized. Another consequence was that some alternatives for the allowances allocation that could be preferable, could not be used because they were simply impractical (MULLINS, 2005). The lack of data has led some countries to prefer to base the allocation on historical emissions. In fact some countries with greater availability of data selected years or base periods between 1998 and 2002, including the United Kingdom, Germany and Sweden. While for most member states the baseline or reference period covers only some of the more recent years, in which data at the installation are available (BUCHNER et al., 2006, MULLINS, 2005). Despite the lack of data at the level of facilities have restricted the choices of allocation, the need to collect data on allocation and verified emissions of CO_2 resulted in significant improvement of data quality emissions and energy use. However, in contrast to other issues linked to the allowances allocation, the lack of data has been largely overcome.

3.5 Allowances allocation

One of the most important political aspects of emissions trading was the allocation, particularly in the first time it was performed. The allocation, is the distribution of the total amount of emissions under the European Trading Scheme in the form of rights, licenses or permits. The method of allocation, by itself, has no implications on the functioning of the Emissions Trading Scheme, however the assignment determines who receives the economic value of patents (LEFEVERE, 2005). Two main different allocation options were on the table, including auctioning and grandfathering, and it was necessary to choose between them.

The auction was clearly the favourite of economists and also environmental NGOs, or by their effectiveness or the ease with which would be applied. However, this method was not the allocation method chosen due to industry opposition. According to LEFEVERE (2005), “this opposition can be explained by the fact that use of the resource which as previously free of charge must now be paid for through an auction, often at prices unknown at the time of the design of the scheme”. To offset the costs that the auction could impose on the industry was provided the recycling of revenues, or its neutralization with the imposition of fees, however this method was difficult to implement in practice due to the reluctance of Member States (VIS, 2006). The opposition of the industry, the pressure within the limited time available, the dependence of firms in relation to emissions data that were not collected so far, or the requirement that 95% of allowances were allocated free of charge during the first phase of the EU ETS, dictated that only four European countries chose the auction[1] (ELLERMAN et al., 2007).

As for the free allocation of allowances that can be based in three types (VIS, 2006): historical emissions in a given base year(s); benchmarked emissions during a given base year(s); benchmarked emissions in a future year(s).

Free allocation is generally preferred by the industry (LEFEVERE, 2005). This implies that sources less often incur extra costs to the allocation and provides a valuable asset that can be used or sold. It is, however, the most difficult method to implement since it requires that the various interests are matched, not to put themselves at disadvantage plants that have already reduced their emissions in the past, or at advantage those who did not. Once the allowances have value, each of the power plants seek to maximize the amount of allowances allocated to it, trying to ensure they have the necessary amount of allowances to cover their emissions. This allocation method may have significant implications for the rules on state aid to EU, since valuable assets are allocated for free to the industry.

In turn, the benchmarking is a method that permits assigned as the value of the output produced, i. e., gives a number of CO_2 allowances per ton of output produced in a given period. Thus indices are calculated from historical activity or capacity which is then multiplied by an standard and uniform emission rate for determining the amount of allowances allocated each power plant (ELLERMAN et al., 2007). The benchmarking is not an easy option because it needs more information than other methods, including the verified emissions data and output produced. This data should be reported, at least to the regulator (VIS, 2006). Benchmarking have most decisive effects, is less effective in reducing emissions at lower cost and therefore is unlikely to produce a strong incentive in favour of renewal investment. In short, the idea behind benchmarking is that two plants with identical characteristics, differing only in emissions levels recorded, should be treated equally, i.e., should receive the same amount of allowances (LEFEVERE, 2005). However the existing facilities have specific characteristics that require the establishment of different benchmarks for different production processes. This requirement together with the problem of lack of existing data make this process of allocation too complex. Thus, despite the strong support existing in his favour, benchmarking was not the general

[1] Including Denmark, Hungary, Lithuania and Ireland, to 5, 2,5, 1,5 and 0,75% of its total.

principle chosen for the assignment in the EU ETS. But yet there are some exceptions, notably with regard to new entrants in the market, who do not have a track record of emissions, and Spain, where many industries were benchmarked allocations, including some power plants (ELLERMAN et al., 2007).

The method chosen for allocation allowances includes free allocating based on historical values and the auction. Thus, in the first period of the EU ETS (2005-2007), were allocated 95% of allowances by free of charge and auctioned the remaining 5%, in the second phase (2008-2012), 90% of allowances were free allocated and the remaining auctioned. With regard to the amount that each individual Member State must reduce its total emissions ET directive does not provide any information. Even about the goal that all member states should seek to achieve there is no mention. In fact, when the policy was drafted, existing information was still very low, especially with respect to which facilities would be covered by the scheme and its potential to reduce emissions (LEFEVERE, 2005). But the overall goal of reducing emissions of greenhouse gases has already been set in the Kyoto Protocol by 8% for the EU as a whole. Later the EU Burden-sharing Agreement distributed this aim among the various member states, setting a reduction target for each of them in percentage of 1990 emissions (for Portugal +27 and for Spain +15)(MULLINS, 2005).

IV. MIBEL

Due to increasing liberalization and high degree of complementarily between the electrical systems of Portugal and Spain, the actors in the electricity sector in both countries felt the need to create an organized market that allowed the short-term transactions and therefore minimize the associated costs (SILVA, 2007). Since electricity is a homogeneous good, standardized contracts can be traded, therefore soon the main conditions for the creation of the Iberian Electricity Market were filled.

The idea begins to take shape in 1998, in which Portugal and Spain began studies and talks with the goal of gradually eliminating obstacles. However, due to great hesitation that characterized the start of MIBEL, MIBEL only became operational in June 2007.

4.1 Characterization of Iberian Electricity Market

In this sub-section we present some statistics for the two countries, Portugal and Spain. These data will allow us to know a little better the Iberian market and have an idea about the final results of our study. Indeed as we saw before, BONACINA et al. (2007) report that the CO_2 cost pass-through depends of the factors such as the degree of market concentration, the electricity generation mix, the price of allowances and the available capacity in the market. Statistics are presented together for Spain and Portugal, so that we can make a comparison between the two countries.

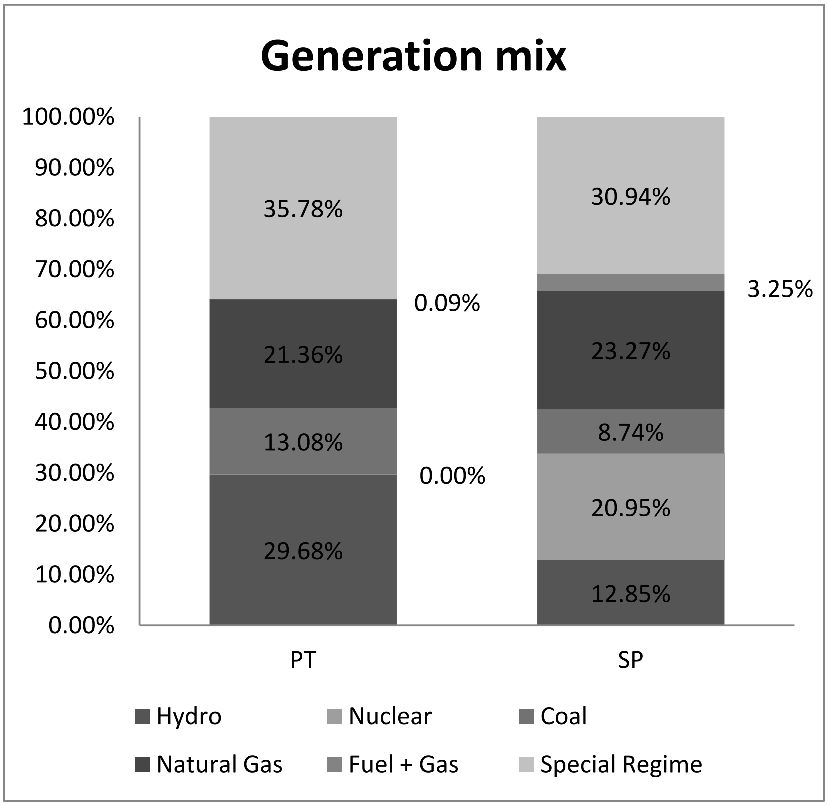
4.1.1 Generation mix

The electricity generation mix influences the CO_2 cost pass-through, according to their greater or lesser content of fossil fuels. Indeed, how much higher is the use of fossil fuels, especially those rich in carbon such as coal, more higher will be the CO_2 cost pass-through.

In Graph 1 we shows respectively the production mix of Portugal (PT) and Spain (SP). As we can see, in both countries, much of the electricity was produced, using carbon free sources. In Spain this portion equals about 64.74%, and Portugal at about 65.46%. This means that more than half of generated electricity is produced without CO_2 emissions. So we can expect a smaller impact of the price of CO_2 allowances in the electricity price.

As regard the use of fossil fuels, the most used are gas and coal. In Portugal coal has more impact on the production mix than in Spain, accounting for 13.08% of production while in Spain represents only 8.74% of production. Thus we can expect that the CO_2 cost pass through is slightly smaller in Spain. Regarding the use of natural gas, is Spain which has higher share of use of 23.27% while Portugal is 21.36%.

Figure 2 - Electricity generation mix in Portugal and Spain[2]. Data of 2010.



Sources: REN, Technical data 2010; CNE, Spanish Regulator's Report to the European Commission 2011

4.1.2 Degree of Market Concentration

The degree of market concentration has a positive impact on the CO_2 cost pass-through. Indeed, how much more concentrated is the market, more the firms with the largest market share are able to fix the prices. Thus, it becomes easier to include the price of CO_2 allowances in the electricity price.

Table 1 shows the production market shares, for the largest firms that compete in each market. In Portugal, the degree of market concentration is higher, with EDP to

[2] By Special Regime means all renewable.

produce more than half of the total energy produced in the country. The Spanish market is less concentrated, with the two main firms, Endesa and Iberdrola, presenting market shares of 24.3% and 19.6% of total production, respectively. According to this data, it is then likely that the CO_2 cost pass-through is higher in Portugal than in Spain.

Table 1 - Market share in production verified in Portugal and Spain. Data of 2010.

Production - Market Share	Portugal	Spain
EDP	54.3%*	
REN Trading	13.9%*	
Endesa	1.3%*	19.6%
Iberdrola	0.9%*	24.3%
Others	29.6%*	
Gas Natural Fenosa		15%
EDP-Hidrocantabrio		5.3%
E.ON		3.5%
Others (Ordinary Regime)		4.5%
Others(Special Regime)		25.9%

* approximated values

Sources: ERSE, Annual Report to the European Commission 2011; CNE, Spanish Regulator's Report to the European Commission 2011

4.1.3 Available Capacity in the Market

The installed capacity has a negative impact on CO_2 cost pass-through. In fact how much greater is the capacity, more electricity can be produced by renewable or less carbon intensive fuels and therefore lower will be the impact of CO_2 allowances in the electricity price.

Table 2 shows the installed capacity in Portugal and Spain. Spain has more installed capacity, which would be expected since it is a country larger in size compared to Portugal. Thus, we may have more CO_2 cost pass-through in Portugal than in Spain.

As regards the relative dimensions of each source, the production capacity is more higher for special regime followed by hydropower, both being renewable. Within the fossil fuels who have more installed capacity is natural gas, presenting 25.235MW and 3829MW in Spain and Portugal, respectively.

Table 2 - Available capacity in Portugal and Spain. Data of 2010.

Technology\Generation capacity (MW)	Spain	Portugal
Fuel+Gas (conventional)	2.860	1657
Coal	11.380	1756

Nuclear	7.777	
Diesel		165
Natural Gas	25.235	3829
Hydraulic	17.561	4578
Special Regime	34.230	5935
TOTAL	99.043	17920

Sources: REN, Technical data 2010; CNE, Spanish Regulator's Report to the European Commission 2011

4.2 Functioning of spot market (daily and intraday market)

The structural organization of the market comprises a vertical chain of activities that can be characterized in three fundamental points: energy production, transport and distribution, and finally supply. The activities of transport and distribution of electricity are based on the energy network leading from the place where it is produced to the point where it is consumed, requiring large initial investments. Therefore, from the economic point of view is more efficient to keep the monopolistic structure in such activities. Natural monopolies inherent in such activities are regulated, and there is a principle of free access by third parties with the payment of regulated tariffs. Recently, aiming at increasing integration and liberalization of the Portuguese and Spanish power market, it was published in Portugal the Decree-Law 75/2012, which proposes the abolition of regulated tariffs for all customers by early 2013. Thus more power companies can compete in the supply even if they do not have distribution networks, and it may lead to reduction on the price of electricity.

4.2.1 Daily market

In operation since the 1st January 1998, for the Spanish system, and since the 1st July 2007, for the Portuguese system, the daily market is a platform that allows trade of electricity in order to be delivered on the next day. The functioning of this market stems from the cross between the bids and offers for sale, conducted by the various agents[3] on the market. Each offering referred to the day and time that corresponds, as well as the price and amount of energy required. Buyers in this market are usually distributors, qualified consumers, suppliers and external agents with authorization. Traders are in the market to sell energy to qualified consumers, or in the case of the last resort traders, they may also

[3] For market agents we mean the individuals or entities involved in economic transactions that take place in electricity market.

use the market to buy the electricity to meet consumer demand. In turn direct consumers purchase electricity directly in the organized market, through a retailer.

Is fixed one price for each hour of the day and every day of the year.

Supply curve of daily market

The supply curve for electricity in the daily market, for each hour of the day are of the various offers made by sales agents sorted in ascending price. In the lower part of the curve usually are the offers made by nuclear power plants and special regime (in the case of Spain) since the opportunity cost of these technologies is very low. In Portugal, in turn, the special regime does not participate in the production market (CRM, 2009). However, special regime production is purchased by the traders of last resort, and this electricity is integrated into its takeover bids. In the same area of the supply curve is also usually a price taker offer of sellers in the first eight CESUR auctions[4], corresponding to their obligations, and also the hydro plants of run-of-water[5].

In the intermediate zone of the supply curve lies usually the offer of the coal-fired power plants and natural gas combined cycle, following a certain order depending on their income and their fuel supply contracts.

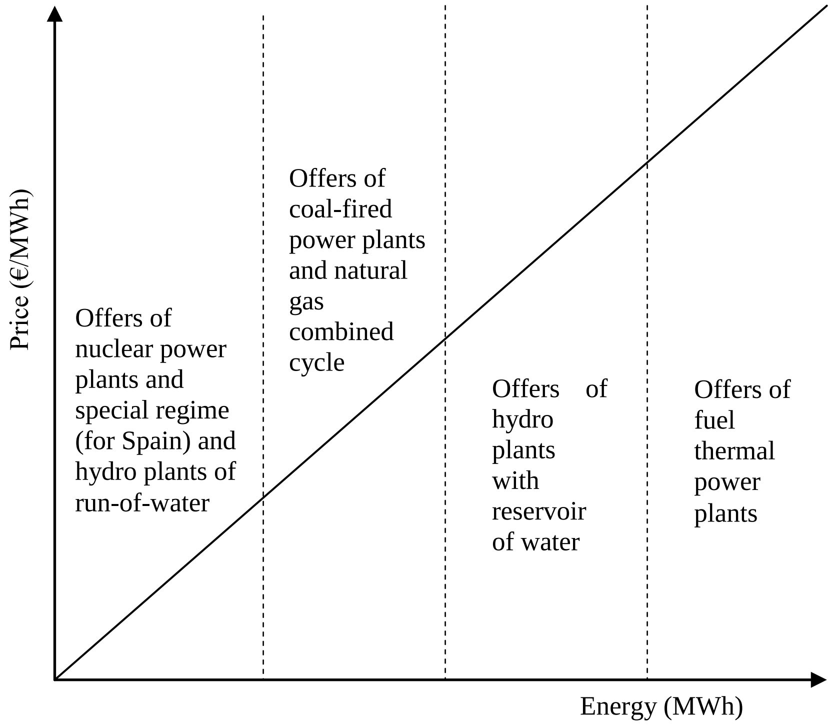
In the upper curve are usually the hydro plants with reservoir of water, because their opportunity cost is dependent on the expectation of future price or depending the technology that it replaces. Finally, in the highest part of the curve, there are the fuel thermal power plants. For Portugal the fuel thermal plants are very important, bridging the limited reserves of hydro power, in extreme times of the year.

The daily market include also open positions in the futures market conducted by the OMIP, the actions of emissions of primary energy, in the extent to which recur to the daily market to buy or sell energy compromised in certain auctions, and finally the distribution auctions by producers who come to the market daily to buy power for so they can ensure compliance with the derivative contracts of certain auctions.

[4] The CESUR auctions are auctions of Iberian context, which sets physical bilateral contracts for the purchase or sale of energy between agents. In these contracts buyers are required to acquire the indicated amounts of energy in specific orders issued by authorities of respective countries. The electricity purchased at CESUR auctions is delivered in the Spanish zone of the Iberian Market (EDP, 2009).

[5] As it has no capacity to store water to other times.

Figure 3 - Supply curve of daily market



Source: Own elaboration

Demand curve of daily market

The demand curve is constituted by the set of offers to purchase electricity, sorted in descending order of price. Thus, in the highest part of this curve, there is demand on the regulated supply, using the instrument price (180,03€/MWh)[6], at the middle and lower, are generally hydro plants with the pumping system and the traders who buy electricity to sell on the open market.

The physical deliveries of electricity to come from procurement of energy in OMIP are considered as simple offers purchase at instrumental price (CRM, 2009).

In the first eight auctions CESUR, sellers are required to launch a purchase bid, corresponding to their commitments in the same auctions. The price on the bid should equal the instrumental price in the daily market. In the first five virtual capacity auctions, participants can also use the daily market to meet its commitments.

[6] For instrument price we means the maximum price at which whether make offers to purchase on the daily market.

Market price and market separation

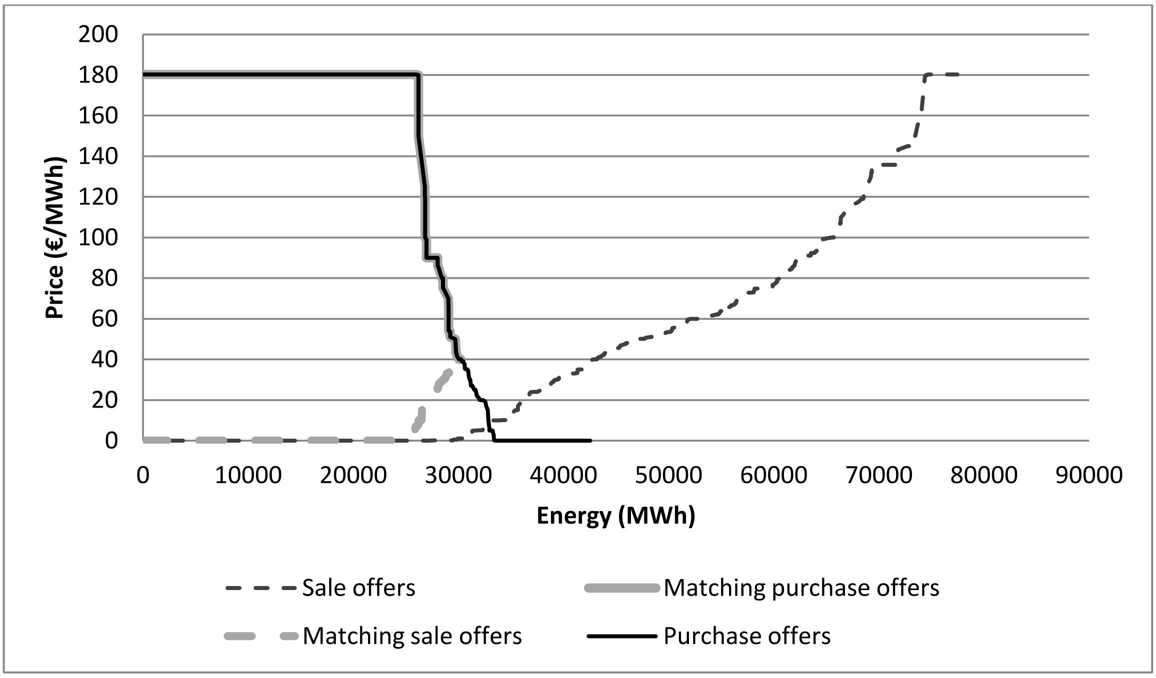
The purchase and sale offers matching is conducted by the market operator through the process of simple or complex matching as they have been made simple or complex[7] offers. The simple matching method is a method to determine in isolation the marginal price, and the accepted amount of electricity in each unit of production or acquisition for each time period. In turn, the complex matching method determines the outcome of the matching from the simple matching method, which is added the indivisibility and graduate load conditions, resulting in the simple conditional matching. The various simple conditional matching are carried out through repeated processes until the units of matching offers satisfy the complex conditions stated. The result is the first provisional final solution. Later, the first final solution is reach also through an iterative process considering the maximum capacity of international interconnection including the offers made in the daily market, and the executions of physical bilateral contracts with affectation to express external interconnections to the Iberian market.

As the result, the market operator reaches the outcome of the matching, which is given by the schedule entry defined by the network operator through offers of cooperation in which on gets the amount of electricity to ensure which production satisfy the demand in each time period of the same day.

Graphically as we can see on figure 4, the market price is determined by the intersection of the supply curve (dashed dark gray curve) and the demand curve (black curve), for the same hour. The equilibrium price corresponds to the lowest price that ensures that supply meets demand. When the complex conditions are present in unit sales some units are removed from the encounter process, causing a displacement of the equilibrium final price for the crossing the light gray line and the black line. The functioning of this market is organized so that all buyers pay the same price and all sellers receive the same value, (model of marginal price).

[7] Complex offers including complex conditions as: Indivisibility, Load Gradients, Minimum income, and Schedule stop (for more information see http://www.omie.es/en/home/markets-and-products/electricity-market/daily-and-intradaily/daily-market/daily-market).

Figure 4 – Aggregate supply and demand in the daily market of MIBEL, 26/04/12, 16:00h



Source: OMIE

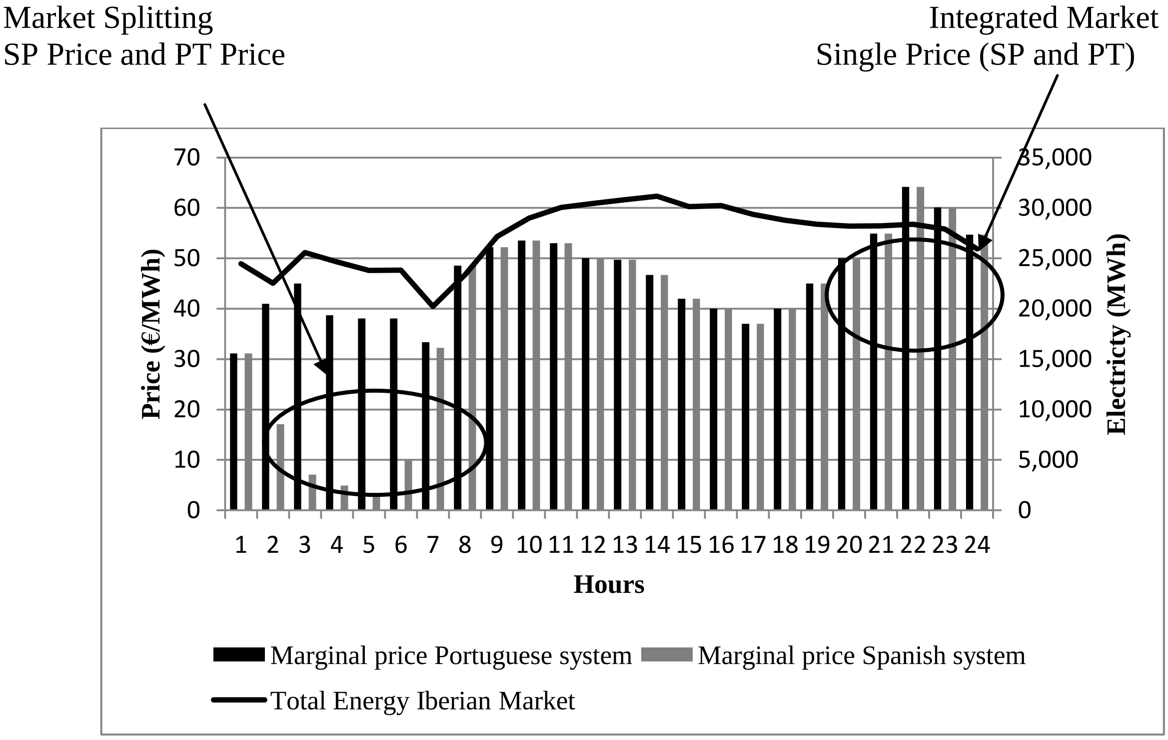
Since the daily market includes both Iberian countries it is important to determine in which situations the interconnection capabilities available between them, is enough to allow to support cross-border flows of energy required and determined in the market.

Where this happens, if the interconnection capacity is not enough, described above is repeated, separating the two geographic areas and obtaining a market price specific to each one. This mechanism is called market splitting (see figure 5).

When the prices for the two parts of the market are not the same it is said that there is a “spread price” between them. The separation of markets, and corresponding spreads prices are likely to be caused by a variety of factors. These include the structural organization of production in each area, the lack of interconnection capacity or the behaviour of agents. The supervision acts to minimize the situations of separation of the market, in particular preventing them to lead to anti-competitive behaviour of the agents.

The price determined for each hour of each session on the daily market is equal to the price of the final set of sell offer on last unit of production whose acceptance is necessary to meet the demand. In this case there is no separation of the markets. However when there is separation of markets, the price of the exporting country will be equal to the price of the last offer, held within its borders, and the price of the importing country will be equal to the maximum price from the ones set in the two meetings of offers corresponding to both countries.

Figure 5 – Daily market hourly price, MIBEL, 26/04/12



Source: OMIE

The daily market closes at 10 hours of the previous day of the date of delivery and the outcome of the matching are published one hour later. The matching process involves: the transfer of open positions of the daily market, where physical delivery is requested; the information on the execution of regulated auctions, whenever it arises by physical delivery, and also the results of the capacity auctions on interconnections.

4.2.2 Intraday market

The intraday market is a platform that complements the daily market, where is traded the electricity to adjust the quantities traded in the daily market, through the submission of offers for sale and purchase electricity. The intraday market includes six daily sessions of trading, each of them leads to a price for each of the hours on trading. As the daily market, the intraday market also includes all hours of the day and every day of the year, and runs through the intersection of offers to purchase and sale of electricity, conducted by various agents able to transact in the daily market.

Supply curve

The supply curve includes sell offers of electricity held by two type of agents. Firstly, agents able to submit in the daily market and who have participated in the session of the respective daily market or have performed a bilateral contract or who did not participate because a temporary unavailability. Secondly agents, who able to submit the purchase bids in the daily market, have participated in the respective session of the daily market, from which opens the session of the intraday market, or run a physical bilateral contract. These agents are only allowed to participate in sessions of the intraday market for the time frame corresponding to the programming included in the daily market sessions.

The final program resulting from the complete acceptance of the offer plus the previous program of the unit of production or acquisition must fulfill the restrictions declared by the operator of the system for the time of the programming, or if do not meet before the deal be completed, it is very close to their fulfillment.

Demand Curve

The demand curve aggregates the purchase bids of electricity made by all agents able to submit in the daily market and also for all agents able to present purchase offers in the daily market, they participated in the session on the daily market on which was open to intraday market session or have performed a physical bilateral contract. Holders of purchase bids in the daily market can only participate in the program schedules included in the intraday market sessions corresponding to those included in the intraday market session in which they will participate.

Again, the final program obtained the complete acceptance of the offer plus the previous program, the production unit must comply with the restrictions laid down by the operator of the system for the scheduling horizon, or in fail to comply case, be near to fulfill them. So the purchase bids in each intraday market sessions shall be such as to enable compliance with this programs.

Market price

The process is the same of the daily market until determine the first provisional final solution. Subsequently, also through an iterative process attains the final and binding first solution that takes into account the maximum international interconnection capacity.

In both matching methods, its ensure that any offer that not comply with the restrictions imposed by the operator of the system or cannot meet these restrictions (still that the matching offers allow him to approaching the fulfillment) will be matching, for safety.

The price determined for each hour of each session of the intraday market is equal to the price of last block of the sell offer of the last production unit whose acceptance is necessary to meet some or all purchase offers at equal or higher price than the marginal price.

4.3 CO_2 Allowances

Here we will give an overview of the trading of allowances. We present the foreign and domestic trade of allowances recorded in Spain and in Portugal, and we provide the legislation for the post-2012 period.

As we can observe (on table 3) Spain is the country that purchases more allowances to and from foreign countries, presenting average values around 54 million for exports and 44 million for imports. The two main buyers and seller countries are Great Britain and France (see appendix C). In turn Portugal export and import fewer allowances with foreign countries, however the imported allowances is in the average 12 million and the exported allowances is in the average 16 millions. The three countries with more trading relationships with Portugal are France, Spain and Denmark. In general both countries export more allowances than they import.

Table 3- Foreign trade of emission allowances.

Foreign Trade	2008	2009	2010
Portugal			
import	3.503.501	28.019.395	6.349.425
export	7.917.857	27.039.815	13.067.978
Spain			
import	22.964.972	67.678.802	42.142.441
export	32.794.766	69.848.446	60.603.307

Source: United Nations, Framework Convention on Climate Change.

For the domestic trade, considering only the transactions carried out by electricity generators. For this purpose we collect data on the number of allowances allocated to each power plant and the ones used by each power plant. The difference between the two values is the number of CO_2 allowances purchased or sold by each generator. These results aggregation are tables 4 and 5. In Portugal (table 4) we can see that the number of allowances purchased exceeds the value of sold allowances, being the sales are in average 600.000 and the purchases are in average 24 million.

Table 4- Electricity market transactions of CO_2 allowances in Portugal.

Allowances PT	2005	2006	2007	2008	2009	2010	2011
Purchased	1.536.301	22.372.179	41.728.836	2.930.969	20.278.136	33.082.163	46.834.785
Sold	849.934	0	0	1.446.863	711.586	630.932	619.452

Source: Own calculations; European Commission, Climate Action[8]

In Spain (table 5) the situation is the same, the number of allowances purchased exceeds the number of allowances sold, and the purchases are in average 150 million while the sales are in average 5 millions.

Table 5- Electricity market transactions of CO_2 allowances in Spain.

Allowances SP	2005	2006	2007	2008	2009	2010	2011
Purchased	33.596.078	149.746.021	272.726.477	31.465.753	110.353.870	174.119.730	252.588.794
Sold	14.807.751	9.760.335	8.337.286	6.576.700	1.050.943	179.453	163.142

Source: Own calculations; European Commission, Climate Action[9]

Regarding CO_2 allowances, for the post-2012 period, CRM (2009) says that:

> "The solution found in the scope of MIBEL for treatment of allowances of carbon dioxide linked to the production of electricity should be in line with the new Directive 2009/29/EC (…). The same happens with legal regime applicable to the ongoing period (2008-2012), i.e., any solution to

[8] ,[8]available in http://ec.europa.eu/environment/ets/allocationComplianceMgt.do;EUROPA_JSESSIONID=VKW4QJFKbGMW798LjGv5GWFrtPVCMPTrg6yk123RQngstlzGXnns!-405364425?languageCode=en

> the MIBEL in this period must be in accordance with national laws, but also with the European Directive, being important to remember that national allocation plants were approved by the European Commission."

One of the most important aspects of the directive 2009/29/EC is the exclusion of the electric sector of the free allocation of allowances in the post-2012 period. Therefore, the CO_2 allowances should be acquired in full by auction. This decision is based on the ability of the electric sector has to include the cost of allowances in electricity price without loss of competitiveness against possible competitors from outside (19º considering policy 2009/29/EC). Only on very strict conditions (not applicable to MIBEL) is that it will allow the gradual introduction of auctions from a free allocation system (Article 10º - C Directive 2009/29/EC).

The directive further provides that at least 50% of revenues from sales of CO_2 emission allowances by auction should be used to reduce emissions of greenhouse gases. These reductions will be achieved through the development of renewable, measures to avoid deforestation and increase forestation, capture and geological storage of CO_2 in a safe environment, funding equity research and developments in the fields of energy efficiency and clean technologies (article 10º, point 3).

V. Methodology, data and results

Own aim is to estimate the impact of the price of CO_2 allowances in the price of electricity. For this we estimate a vector autoregressive model (VAR). In fact, taking in to account the empirical studies analyzed, the VAR methodology was that seemed most appropriate. The VAR (SIMS, 1980) includes as explanatory variables one or more lags of dependent variable. These models are often used because provide better estimates than other more complex models, considers all variables as endogenous and allows simple estimation OLS generating consistent estimators (GUJARATI, 2003).

As a starting point we take the model and assumptions made by SIJM et al. (2006a). However, instead of using forward prices, we use spot prices, as FELL (2010) and SOLIER et al. (2011). This decision was made due to the unavailability of data on the future price of electricity, segregated by country and load periods, and mainly because we want to assess the impact of CO_2 in the current price of electricity.

We do not consider that the price of fuel used to produce electricity is fully included in the price of electricity. In fact SIJM et al. (2006a), justify the use of this assumption by the high correlation between the price of fuel and the price of CO_2 allowances. This does not seems to happen in our case. This hypothesis was even discarded in SIJM et al. (2006b).

According SIJM et al. (2006a) we assume that all costs other than those taken with fuel and CO_2 allowances are constant and the market structure does not change. The use of these assumptions is justified by the lack of data.

The basic equation used is the relationship between the price of electricity at time t and at time t-1, the cost of fuel, the cost of CO_2 allowances and the temperature.

$$P_{l,t}^{Electricity} = \alpha + \beta_1 P_{l,t-1}^{Electricity} + \beta_2 CO_{2\,t}^{\,o,c} + \beta_3 P_{l,t}^{Fuel\ o,c} + \beta_4 T + \beta_5 T^2 + \varepsilon_t \qquad (1)$$

Where $P^{Electricity}$ represents the spot electricity price, CO_2 is the spot price of CO_2 allowances, P^{Fuel} is the spot price of fuel used in power generation, T represents the temperature, and ε_t is the error term. The underscripts l and t represents the load duration period (base load and peak load) and the time of the observation, respectively. The overscripts o and c represent the marginal technology used during the considering load period (oil and coal respectively).

We introduce two additional variables to the initial model of SIJM et al. (2006a), the temperature and the price of electricity at time t-1, the variables are used by AHAMADA et al. (2012), referred as crucial in determining the day-ahead price of electricity. Considering the fact that the non-linearity of the relationship between the demand for electricity and the temperature, we use as the authors mentioned above, the temperature (T) and its square (T^2). Indeed, ENGLE et al. (1986) determine that the relationship between electricity demand and the temperature is V-shaped, i. e. The demand for electricity is higher during periods were the temperature are extreme.

We define a single marginal technology for each country and load period, as SIJM et al. (2008). For Spain, we consider that the price of electricity in base load is set by coal, while in peak load is determined by oil, following SOLIER et al. (2011). For Portugal, given that at the best of our knowledge, there are no studies about these information. We decided to set coal for the base load price, since it is one of the most used fuels in power generation, and oil for peak load. This assumption is justified by BONACINA et al. (2007) that argue that gas and coal are not peak technologies.

The period of our analysis starts on February 26th of 2008 and end on December 31st of 2011, thus covering only the second phase of the EU ETS. The reason for this choice lies in the lack of more recent data and the break in the price of CO_2 allowances price in the end of 2007.

The sample data were collected from several sources, as we can see in the following table.

Table 6 - Sumary of variables

Variable	Description	Source	Unit
Price of electricity	Electricity spot price segregated by load: base and peak load	Iberian market Operator – Portuguese polo (OMIP)	€/MWh
Temperature	Average temperature of the day	Weather Forecasts & Reports, Wunderground	ºC
Price of CO_2 allowances	CO_2 allowances spot price	Bluenext	€/ton
Price of coal	Coal spot price	Standard API 2 for the	USD/ton

Variable	Description	Source	Unit
		delivered area ARA (Antwerp, Rotterdam, and Amsterdam)	
Price of oil	Oil spot price	U.S. Energy Information Administration (EIA)	USD/Barrel

Source: developed with data

The price of CO_2 is converted in €/MWh using the standard emission factors provided by the Covenant of Mayors. To convert the prices of coal and oil we use the €/USD exchange rate available in Bank of Portugal and later we used the following methodology:

$$Fuel\ cost\ (€/ton) = Fuel\ Price * (Efficiency\ Rate * Heat\ Rate)^{-1} \qquad (2)$$

The rate of efficiency and heat rate for each fuel are show in the following table:

Table 7 - Rate of efficiency and heat rate for each fuel

		Heat Rate	Efficiency Rate
Coal	Kcal/Kg	5500	0.33
Oil	Kcal/Kg	9400	0.33

Sources: AIE,CNE

Before estimating the level of CO_2 cost pass-through itself, we analyzed the behaviour of the variables analysing charts, calculating the descriptive statistics, the correlation between the variables and using the unit root tests to examine the stationarity of the series.

From the graphic analysis (see figure 6,7,8 and 9 in appendix B) of the variation in the price of electricity and the price of CO_2 allowances, we find that sometimes the series fluctuate independently or even in opposite directions. This occurs primarily in the months of February 2008 through mid-June of that year and February 2011 to December 2011. Therefore the price of electricity seems to be more influenced by the price of fuel used than by the price of the CO_2 allowances.

When comparing the variations in the price of electricity with fuel prices, we find that for both countries the coal seems to be the marginal technology in base load, since its behaviour is identical to the electricity price.

Descriptive statistics and expected signals of the variables are show in table 8. As we can see, electricity prices are higher during peak load than during base load, and prices in Spain are close to those of Portugal, although slightly lower. The price of allowances is on average 5,698€/MWh, which reflects the low prices in beginning of year 2008.

Table 8 - Descriptive statistics and expected signal of variables

Variable	Mean	Stand. deviation	Minimum	Maximum	Expected signal
$P^{Eletricity}_{BaseLoad\ PT,t}$	48,831	14,615	7,720	83,730	
$P^{Eletricity}_{PeakLoad\ PT,t}$	52,022	14,926	8,970	90,880	
$P^{Eletricity}_{BaseLoad\ SP,t}$	46,993	12,900	4,620	79,650	
$P^{Eletricity}_{PeakLoad\ SP,t}$	50,864	13,814	3,470	86,430	
CO_2	5,698	1,646	2,387	10,601	+
P^{Coal}	36,131	10,620	20,171	67,438	+
P^{Oil}	125,620	32,593	48,101	182,932	+
T_{PT}	18,080	5,130	4	32	-
T_{SP}	15,116	7,505	-2	30	+
T^2_{PT}	353,193	188,905	16	1034	-
T^2_{SP}	284,754	235,936	0	900	+

Source: developed with data

To complement the analysis of variables, we present also the study of the correlation between the different variables used. The correlation matrix is presented in table 15 in appendix B. The correlation between CO_2 and electricity prices is between 0.540 and 0.592, being the lowest value observed in Spain for peak load and the highest value recorded in Portugal for the base load. Although the correlation values are very close there seems to be a stronger correlation between CO_2 electricity prices in Portugal than in Spain.

Concerns to the correlation between the prices of CO_2 allowances and prices of coal and oil, we found a weak correlation between the oil price and CO_2 price (on the order of 0.289) while in the case of the coal price and CO_2 price the correlation is stronger, although the variables do not seem to be highly correlated in 0.630.

To test the existence of unit roots we used the Dikey-Fuller and Phillips-Perron tests. The results of both tests (see table 13 in appendix B) conclude that the variables corresponding to the price of coal, oil and CO_2 allowances, include unit roots, being integrated of order 1. Meanwhile the prices of electricity and temperature are stationary variables.

The unit root tests mentioned above, considers only the behaviour of an individual series, forgetting the possible mutual influences that the trajectories of different series can exert on each other. The study of this influences provides the existence of a long-term equilibrium between them, a concept developed by ENGLE et al. (1987).

Two or more series are said to be cointegrated when analyzed separately follow a non-stationary process, i.e. they are integrated of order 1 or I(1), but if they are considered together become stationary, i. e. I(0) (GREENE, 2003). This means that there is a linear combination between them that results in a stationary series or I(0).

To verify the existence of cointegration relationships among the variables, we use the Johansen test, that has been widely used in empirical studies. The results obtained are shown in the table 14 of appendix B. We note then that the variables included in the models 1 and 2 (see table 9) show three cointegration relationships while the variables included in the models 3 and 4 present two cointegration relationships. Therefore, we can say that the variables used in our model are cointegrated, and we do not need to differentiate the non-stationary series.

Table 9 -Variables in each model

Model 1	**Base Load PT, CO_2, Coal, TPT, TPT^2**
Model 2	**Peak Load PT, CO_2, Oil, TPT, TPT^2**
Model 3	**Base Load SP, CO_2, Coal, TSP, TSP^2**
Model 4	**Peak Load SP, CO_2, Oil, TSP, TSP^2**

Now, we estimate equation 1, to assess the impact of CO_2 emission allowances in the electricity price. This impact is usually called CO_2 cost pass-through. Due to non-significance of the variable CO_2 at time t in model 3, we introduce the one lag of the variable, to see if this was significant, and thus determine whether the CO_2 price is included in the price of electricity.

After estimating the equations, we perform the LM test for autocorrelation in VAR, and we conclude for the presence of autocorrelation. According to GUJARATI (2003) the solution is to apply the Newey-west matrix, which corrects the standard deviations for both autocorrelation and heteroscedasticity. The results obtained are shown in the table 10.

Table 10- Newey-west estimation results

	Portugal		Spain	
	Model 1	Model 2	Model 3	Model 4
	$P^{Eletricity}_{BaseLoad\ PT,t}$	$P^{Eletricity}_{PeakLoad\ PT,t}$	$P^{Eletricity}_{BaseLoad\ SP,t}$	$P^{Eletricity}_{PeakLoad\ SP,t}$
$P^{Eletricity}_{l,t-1}$	0,921*** (0,019)	0,927*** (0,021)	0,882*** (0,026)	0,916*** (0,019)
$CO_{2}{}^{c,o}_{t}$	0,189** (0,094)	0,381*** (0,110)	-0,283 (0,210)	0,376*** (0,110)
$CO_{2}{}^{c,o}_{t-20}$			0,500** (0,227)	
P^{Coal}_{t}	0,067*** (0,022)		0,087*** (0,027)	
P^{Oil}_{t}		0,010** (0,004)		0,013*** (0,005)
T	-0,280** (0,125)	-0,409** (0,163)	-0,097 (0,071)	-0,223** (0,088)
T^2	0,008** (0,003)	0,011*** (0,004)	0,003 (0,002)	0,007*** (0,003)
α	2,563** (1,149)	3,724** (1,523)	1,548*** (0,643)	1,839** (0,833)

Note: Standard errors are in ( ); *,**,*** refer respectively to the 10%, 5% and 1% significance levels.

Overall all the variables included in the various models are significant, excluding only the price of CO_2 allowances at time t, the temperature and the squared temperature at base load, for Spain.

Doing the analysis of each variable separately, we found that the variable that most influences the price of electricity is the electricity price at time t-1. The variable coefficient is approximately 1, which shows that the current price is very close to the price recorded in the previous day.

The price of coal and crude oil also significantly influence the price of electricity. Although they set the price of electricity at different load times, coal appears to have a greater impact on electricity prices than the price of oil in both countries. In fact, it is estimated that an increase of 1€/MWh in the price of coal causes an increase of 0,067 and 0,087€/MWh in electricity prices of base load in Portugal and Spain respectively, ceteris paribus. In turn, an increase of 1€/MWh in the price of oil causes an estimated increase of 0,01 and 0,013€/MWh, in the price of electricity in peak load, respectively in Portugal and Spain, ceteris paribus.

Temperature affects negatively the price of electricity, which can be justified by the non-linearity of their relationship with the electricity price, as previously stated. The square of the temperature, seems to have less impact on electricity prices, with values in the range of 0,003 at 0,011€/MWh for each increase of one degree Celsius in temperature squared, ceteris paribus. However the impact is positive, showing that an increase in temperature causes an increase in the price of electricity.

Finally, we will focus on the most important variable in our study, the price of CO_2 allowances. This variable, at time t, is not significant in base load for Spain, being only significant at time t-20 (20 days). In Portugal, the price of CO_2 allowances at time t is significant for both load periods. However, we also found that unlike for Spain, in Portugal, the impact of the price of CO_2 allowances in the electricity price is greater in peak load than in base load. These two results suggest that the price of electricity in peak load is influenced by the price of CO_2 allowances at time t, while in base load is influenced by the price of allowances recorded in previous time periods.

The distinction between peak load and base load, is that in peak load power plants produce to meet verified demand, which can be greater that the amount they plan to produce to meet demand. So these periods producers can be forced to produce more that they expected, thus may be they need to purchase or use more allowances received free of charge, to cover the amount of their emissions. In base load the amount of electricity produced is in most cases equal to the expected quantity. Thus the amount of CO_2

allowances required to cover emissions may have been secured well in advance, with the acquisition or affectation of allowances made in the days before the generation.

We found that an increase of 1€/MWh in the price of CO_2 allowances, causes an estimated increase of 0,189€/MWh for base load electricity price, in Portugal. This value of CO_2 cost pass-through can be explained by increasing investment, over the past few years, in Portugal, in the production of electricity through renewable sources, free of emissions of greenhouse gases. For the same period in Spain we have load of 0,5€/MWh in electricity price.

In peak load is estimated that an increase of 1€/MWh in the price of CO_2 allowances in t, leading to an increase of 0,381 and 0,376€/MWh in electricity prices in Portugal and Spain respectively. In fact, this result is between the result of SOLIER et al. (2011), 0,21€/MWh, and the result of SIJM et al. (2008), 0,52€/MWh, for CO_2 cost pass-through during peak load in Spain. The result obtained for Portugal is also in accordance with the result of FREITAS et al. (2012), that determine that the CO_2 cost pass-through in Portugal is between 33-51%.

According to the results obtained there is effectively CO_2 cost pass-through in MIBEL. Thus, after 2012 these values may become more relevant, and therefore may increase the price of electricity. In this case, the consumers would pay the cost of CO_2, which could make them the biggest losers of the emissions trading scheme.

VI. Conclusion

The process of creating the EU ETS began to take its first steps in 1998. Before this date, the major institutions and Member States were skeptical to the idea of trade emissions. But the ratification of the Kyoto protocol and the change of staff in the European Commission determined the change in mentality.

The success in creating the EU emissions trading system, was mainly determined by the existence of a single market and the easy acceptance by the industry. But this process was also characterized by some difficulties as the decentralized approach with that as developed the EU ETS and the lack of historical data of allowances at existing firms.

The EU ETS was then created in December of 2002, and determined the free allocation of CO_2 allowances to the main emitting sectors, reserving a small portion of allowances that would be auctioned. Emissions trading has established itself as a flexibility mechanism that allow the trade of CO_2 emission allowances. The trade proved to be very significant.

Thus, the EU ETS imposed a cost on CO_2 emission, blaming the emitters for the pollution caused, and encouraging the reduction of emissions. In fact, the price of allowances represents an opportunity cost to affected firms.

Particularly in the electric sector this issue has triggered public attention due to the possibility to include this opportunity cost in the price of electricity, generating additional profits for the power plants. Thus the main objective of this dissertation was to evaluate the existence of this CO_2 cost pass-through in the newly created Iberian Electricity market. For this analysis we use the vector autoregressive model (VAR).

From our analysis, we conclude that there is evidence of the CO_2 cost pass-through to the price of electricity, which is slightly higher in Portugal than in Spain. The CO_2 cost pass-through was estimated lies between 0,189 and 0,381€/MWh for Portugal and between 0,376 and 0,5€/MWh, for Spain. The CO_2 cost pass-through seems to be greater in peak load than in base load. Another difference observed between peak and base load, is that the impact of CO_2 in base load appears to be more slow, mainly in Spain.

Considering the end of the free allocation of allowances to the electricity sector, it may happen that these values become more relevant, and therefore the price of electricity can increase. This can be harmful to consumers because they would be forced to pay more for electricity. Thus the consumers would pay the cost of CO_2, which could make them the biggest losers of the emissions trading scheme.

Limitations of the model and suggestions for future studies

Our model evaluates the impact of the CO_2 allowances price in electricity price, but it has some limitations that give us ideas for the future studies.

The main limitation of our model relates to the assumptions we adopted for lack of data, particularly with regard to the costs of electricity production and changes in the market structure. Thus, we suggest, for one future study, including data on the costs of maintaining the power plants and the inclusion of a proxy variable for changes in the level of market structure.

Finally, we suggest further extending the study to the year 2012, to include the entire period of the second phase of the EU ETS.

VII. References

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Appendix A

Table 11 -Theoretical Studies

Study	Hypothesis	Dependent Variable(s)	Explanatory variable(s)	Result(s)	Data & Methodology
SIJM (2004)	- The price of CO_2 allowances is fully included in the price of electricity -The price of electricity is determined by the marginal production costs	-Electricity Prices	-CO_2 allowances price -Coal, Natural Gas and Oil prices	-The increase in electricity prices derived from emissions trading is determined by the factor of marginal production.	**Data:** for Netherlands **Methodology:** simulation
KARA et al. (2008)		-Electricity Prices	-Capacity data - Demand for electricity -Hydropower input - Fuels price - Temperature	-The annual average electricity price increase by 0.74€/MWh for every 1€/ton CO_2.	**Data:** collected from historical statistics, and for the future it is based on scenario assumptions , for Finland **Methodology:** simulation
BERIZZI et al. (2009)		-Electricity Prices	-Carbon prices	-The increase in electricity prices resulting from emissions trading is significantly higher in oligopoly than under perfect competition	**Data:** for Italy **Methodology:** simulation
WALS et al. (2003)	-Elastic demand	-Electricity Prices	-Carbon prices	-An increase in CO_2 prices cause an increase in electricity prices for all countries; - In an oligopolistic market, an increase in marginal costs will not be fully integrated on	**Data:** for France, Netherlands, Belgium, and Germany **Methodology:** simulation

Study	Hypothesis	Dependent Variable(s)	Explanatory variable(s)	Result(s)	Data & Methodology
				electricity prices, since the producers will partly reduces their mark ups; -An increase in the CO_2 prices to 5€/ton represents a 10% decreases in the amount of CO2 emitted.	
RENESES et al. (2008)	-Inelastic demand; -In the first phase, renewable generation is deterministic; -In the second phase of the EU ETS the water conditions as fixed and no free allowances have been considered.	-Electricity Prices	-Carbon prices -Fuel costs -Hydro conditions -Renewable generation	-An increase of 5€/ton in the price of CO2 causes an increase of 3-3.5€/MWh in the price of electricity in the first phase and 2.5-2.8€ in the second phase.	**Data:** for Portugal and Spain **Methodology:** simulation
SOUSA et al. (2005)	-perfect competition	-Electricity prices	-Demand for Hydro and Special Regime Generation - Thermal residual demand - Marginal generation costs - Specific CO_2 emissions - Installed capacity by technology	-It can be expected an increase in electricity prices mainly when there is coal power generation, and during base load	**Data:** for Portugal and Spain **Methodology:** simulation
LINARES et al.(2006)	-oligopolistic structure -endogenous allowances price -firms make their capacity-expansion decisions as in Nash-Cournot Equilibrium	-Electricity prices	-Emission permit price -technologies considered: nuclear, fuel, natural gas, gas combined cycle, coal, hydro pumping units, and in future too biomass and wind	-Electricity prices increase about 20% due to the trading of emission allowances	**Data:** for Spain **Methodology:** simulation
BONACINA et al.(2007)	-Inelastic demand	-Electricity price	-variable costs -emission rates -allowances price	-The CO_2 cost pass-through is 100% when electricity market is	**Data:** for Italy **Methodology:** simulation

Study	Hypothesis	Dependent Variable(s)	Explanatory variable(s)	Result(s)	Data & Methodology
				assumed to be perfectly competitive -Under market power, the CO_2 cost pass trough can be lower or higher than that under competition depending of degree of market concentration, plant mix operated by either the dominant firm or the competitive fringe, the price of CO2 allowances and available capacity -Under market power the EU ETS impact is higher than under perfect competition only when there is excess of capacity and the share of most polluting plants is low enough	
SIMSHAUSER et al. (2009)		-Electricity prices	-Size, Capacity, Availability, Min. Load, Efficiency, Heat rate, Unit fuel, Fuel cost, Emissions for renewable, coal , natural gas and hydro	-The pass-through rate of CO_2 cost impost to electricity consumers is 78%	**Data:** for Victoria **Methodology:** simulation
GENOESE et al. (2007)	-Renewable electricity generation is set to zero	-Electricity prices	-Electricity demand -Renewable Electricity -power plants -emission allowances price	-Approximately 75-100% of the CO_2 allowance price is passed through to the electricity price	**Data:** for Germany **Methodology:** simulation
CHEN et al. (2008)		-Electricity prices	-CO_2 allowances price -Fuel prices	-Estimate that the rate of CO_2 marginal cost pass-	**Data:** for France, Germany, Belgium

Study	Hypothesis	Dependent Variable(s)	Explanatory variable(s)	Result(s)	Data & Methodology
				through are between 60%-100% for Netherlands and 60%-80% in Germany	**Methodology:** simulation
CHERNYASVS'KA et al. (2008)	-Inelastic demand -Power system consists of only two groups of plants, and each group includes a very large number of homogeneous generating units -Emissions abatement is impossible or abatement cost infinitely costly -firm's offer prices are constrained to be below some threshold level	-Electricity price	-Available capacity -CO_2 allowances price -Coal prices -Gas prices -Oil prices	- The CO_2 cost pass through depends of the available capacity -In the peak hours, the marginal pass-through rate is less than 1 under scarcity of generation capacity - In the off-peak hours, electricity prices fully include the marginal carbon opportunity cost, exist or not excess of capacity	**Data:** for Italy in 2005 and 2006 **Source(s):**Italian Market Operator **Methodology:** simulation

Table 12- Empirical studies

Study	Hypothesis	Dependent Variable(s)	Explanatory variable(s)	Result(s)	Data & Methodology
FELL (2010)		-Electricity price	- Coal - Natural gas - Reservoir water - CO_2 - Air temperature	-Electricity prices have large short-term responses to CO_2 price shocks -The response of electricity prices to changes in electricity prices is generally significant and it will be dilute over time - when the marginal production technology used is coal the transfer of costs is almost complete	**Data:** for Denmark, Finland, Norway and Sweden **Source(s):**point carbon, University of Dayton's average daily temperature Archive, Elspot, Zeebrugge hub, Swedish Environment Research InstituteIVL **Methodology:** Cointegrated Vector Autoregressive (CVAR) and Vector error correction model (VECM)
SIJM et al.(2006a)	-all costs, excluding fuel or allowances, are constant -market structure does not change -the cost of the fuel is fully reflected in electricity prices	-Electricity price	- Coal prices - Natural gas prices - CO_2 allowances price	-Concluded that the rates of CO2 cost pass-through are between 60% and 117% in Germany and between 64% and 81% in the Netherlands	**Data:** for Germany and Netherlands in the year of 2005 **Source(s):** European Energy Exchange (EEX) **Methodology:** OLS
SIJM et al.(2006b)	-all costs, excluding fuel or allowances, are constant -market structure does not change	-Electricity price	- Coal prices - Natural gas prices - CO_2 allowances price	-For the period January-July 2005 CO2 pass through rates have been estimated to vary roughly between 40 and 70%. -During the period August-December the CO2 pass through rates up to 100%	**Data:** for Germany and Netherlands in the year of 2005 **Source(s):** European Energy Exchange (EEX) **Methodology:** OLS and Prais-Winston
SIJM et al. (2008)	-all costs, excluding fuel	-Electricity price	- Coal prices	-For all countries	**Data:** for France,

Study	Hypothesis	Dependent Variable(s)	Explanatory variable(s)	Result(s)	Data & Methodology
	or allowances, are constant -market structure does not change -the cost of the fuel is fully reflected in electricity prices		- Natural gas prices - Oil prices - CO_2 allowances price	analyzed there are evidence of CO_2 cost pass-through -In particular, for Spain the CO_2 cost pass-through rate is 0.5 during peak load and 0.64 during base load, for 2005 -In 2006, the CO_2 cost pass-through rate is 1.11 during peak load and 0.52 during base load, for Spain	Germany, Italy, Poland, Spain, Sweden, Czech Republic, Netherlands and United Kingdom in the years 2005 and 2006 **Source(s):** European Energy Exchange (EEX), ARA CIF API#2, Zeebrugge, Bunde, Title Transfer Facility, Nacional Balancing Point, Nord Pool and Point Carbon, OMEL **Methodology:** OLS
SOLIER et al. (2011)	-all costs, excluding fuel or allowances, are constant -market structure does not change -the cost of the fuel is fully reflected in electricity prices	-Electricity price	- Coal - Natural gas - Oil - CO_2	-The CO_2 cost pass-through is more relevant in the first phase of the EU ETS -There is no evidence of cost pass-through in 2009 for all countries	**Data:** from June 2005 to April 2011 and for Germany, France, Netherlands, United Kingdom, Italia, Spain, Nord Pool System Price, Poland, Czech Republic and Austria **Source(s):** Intercontinental exchange, Standad API2 for the delivered area ARA (Antwerp, Rotterdam, and Amsterdam), Nacional Balancing Point, Zeebrugge hub, Title Transfer Facility hub, Bluenext

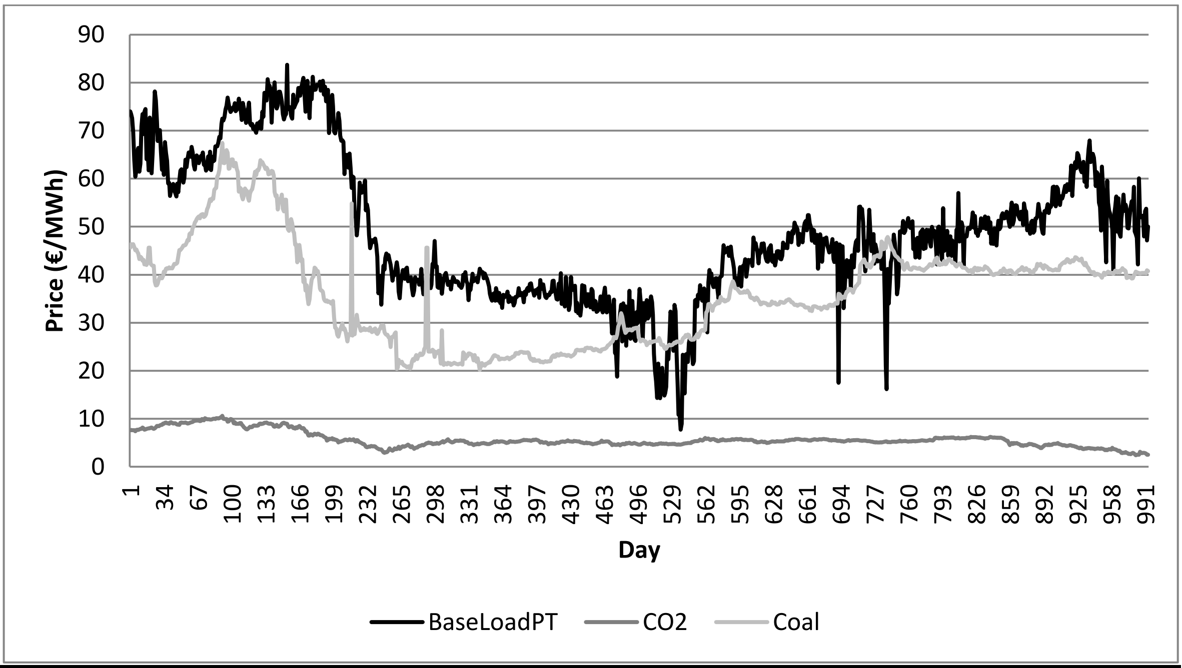
Study	Hypothesis	Dependent Variable(s)	Explanatory variable(s)	Result(s)	Data & Methodology
					Methodology: OLS
AHAMADA et al. (2012)	-Changes in electricity prices reflect changes in the marginal cost of electricity-generation	-Electricity price	- Coal - Natural gas - CO_2 - Temperature - Electricity price at time t-1	-Before October, 2008 the impact of carbon prices is not significant in both countries´ -After October 2008 carbon prices strongly influences the electricity price -An increase in the allowances price of 1% results in 0.19% to 0.21% and 0.13% to 0.14% higher electricity prices in France and Germany, respectively.	**Data:** from Germany and France for the period between March 3rd, 2008 until December 30th, 2010 **Source(s):**EPX spot Exange, Bluenext, Zeebrugge hub, Coal CIF ARA, European Climate Assessment and Dataset **Methodology:** ARCH and GARCH models
KEPPLER (2010)		-Electricity price	-CO_2 allowances price -Calendar -Gas price	-There is a causality relationship between forward prices of CO2 allowances and forward prices of electricity	**Data:** 2005 to 2007, in Europe **Source(s):** BlueNext and EEX **Methodology:** Granger Causality tests
KEPPLER et al. (2010)		-Electricity price	-CO_2 allowances price -Calendar -Gas price -Coal price -Clean Spark Spread -Clean Dark Spread	-In the first phase of EU ETS, there is a causality relationship between forward prices of CO2 allowances and forward prices of electricity - This relationship is higher in base-load because the coal is more intensive in carbon -In the second phase, the relationship is inverted, and is the price of	**Data:** 2005 to 2007, in Europe **Source(s):** BlueNext and EEX **Methodology:** Granger Causality tests

Study	Hypothesis	Dependent Variable(s)	Explanatory variable(s)	Result(s)	Data & Methodology
				electricity that determine the price of CO_2 allowances	
ZACHMANN et al. (2008)		-Electricity price	-CO_2 allowances price -Natural Gas price	-They found convincing evidence that emissions prices are passed through asymmetrically to electricity futures prices in Germany	**Data:** 2005 to 2006, in Germany **Sources:** European Energy Exchange, European Climate Exchange **Methodology:** VECM
PERRELES et al. (2006a)		-Electricity price	-Electricity price at time t-1 and t-2 -CO_2 allowances price -Hydro-reservoir filling -Utilization rate of productivity capacity -Utilization rate of Swedish-Finnish transmission capacity - Dummy for weekend days -Dummy for holidays -Deviation from the average long term daily temperature in Finland -Monthly price of natural gas in Finland for very large users	-75% to 95% of a CO_2 allowances price is passed on to the Finnish Nord Pool spot price -the spot price of electricity will be less affected by CO_2 allowances price if more capacity is installed.	**Data:** between February 7th, 2005 and May 7th, 2006, for Finland **Source(s):** NordPool, Nordel, Statistics Finland, Argus, Heren Energy, Finnish Meteorological Institute **Methodology:** ARIMA, AR-GARCH models
PERRELES et al. (2006b)		-Electricity price	-Electricity price at time t-1 and t-2 -CO_2 allowances price -Hydro-reservoir filling -Utilization rate of productivity capacity -Utilization rate of Swedish-Finnish	-75% to 95% of a CO_2 allowances price is passed on to the Finnish Nord Pool spot price -the spot price of electricity will be less affected by CO_2 allowances price if more	**Data:** between February 7th, 2005 and May 7th, 2006, for Finland **Source(s):** NordPool, Nordel, Statistics Finland, Argus, Heren Energy, Finnish

Study	Hypothesis	Dependent Variable(s)	Explanatory variable(s)	Result(s)	Data & Methodology
			transmission capacity - Dummy for weekend days -Dummy for holidays -Deviation from the average long term daily temperature in Finland -Monthly price of natural gas in Finland for very large users -Coal price	capacity is installed.	Meteorological Institute **Methodology:** ARMA, AR-GARCH, VECM models
BUNN et al. (2007)		-Electricity prices	-Carbon prices -Gas prices -Atmospheric temperature -dummy variables in order to capture the huge drop in carbon price over three days, following news of the settlement	**-**carbon price is important in determination of price of electricity and natural gas - carbon pass-through to electricity price only happen after some days - one shock of 1% in carbon causes on average one shock of 0.42% in electricity price	**Data:** 2005-2006, for United Kingdom **Source(s):** UKPX, NBP, University of Dayton and Platts **Methodology:** SVAR
ABADIE et al. (2011)		-Electricity prices	-CO2 allowances price -Coal price -Natural gas price	**-**markets are incorporating the prices of emission allowances in the price of electricity in future	**Data:** between 12/01/2009 and 11/30/2010 for European Markets **Source(s):** Intercontinental Exchange (ICE) **Methodology:** Panel Data

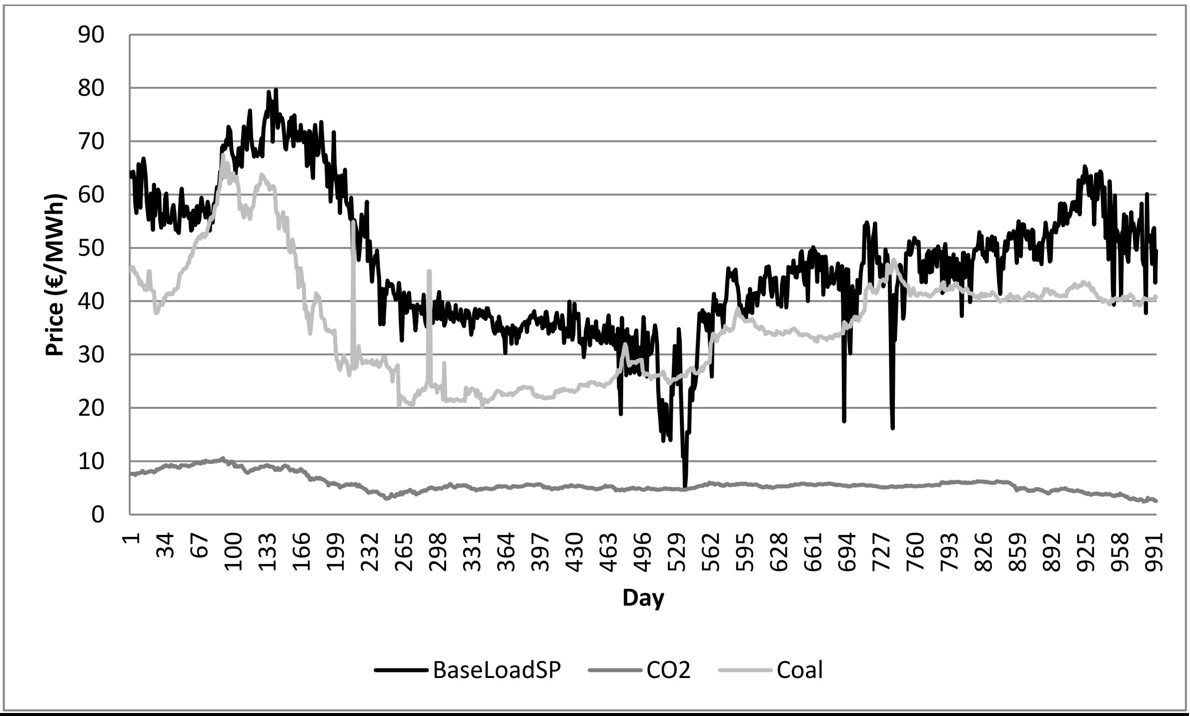
Appendix B

Figure 6 - Relationship between the price of electricity in base load for Portugal, CO_2 allowances price and coal price



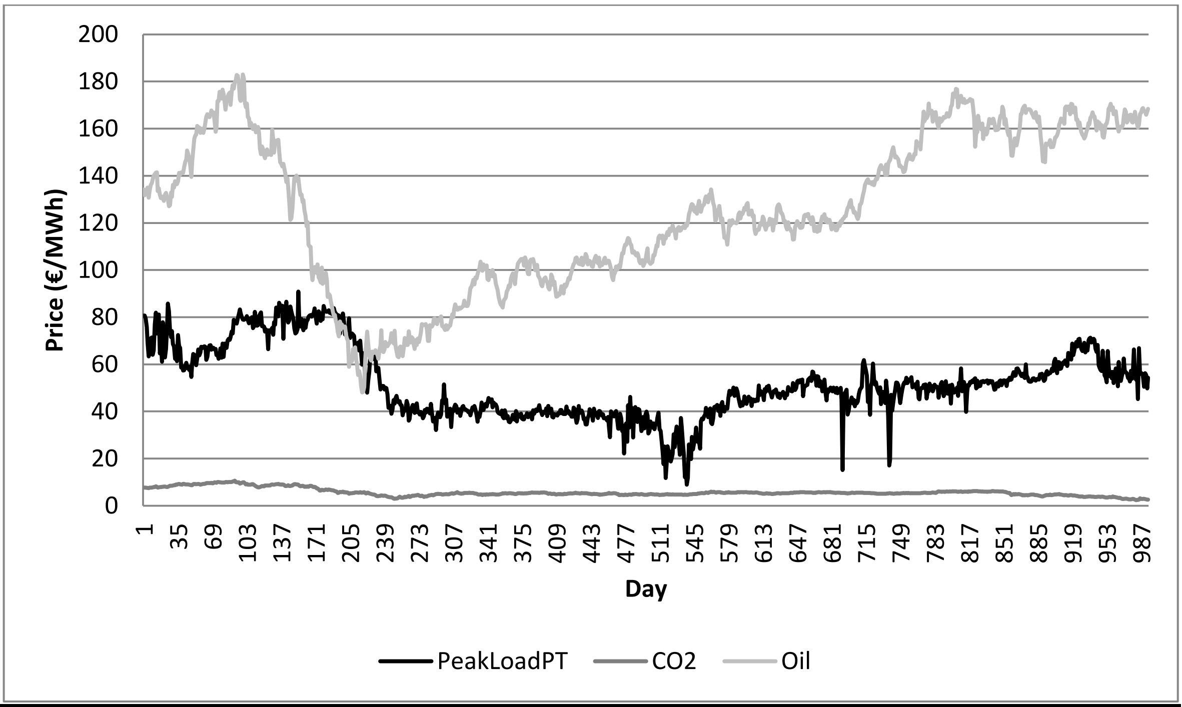
Source: developed with data

Figure 7- Relationship between electricity price in base load for Spain, CO_2 allowances price and coal price



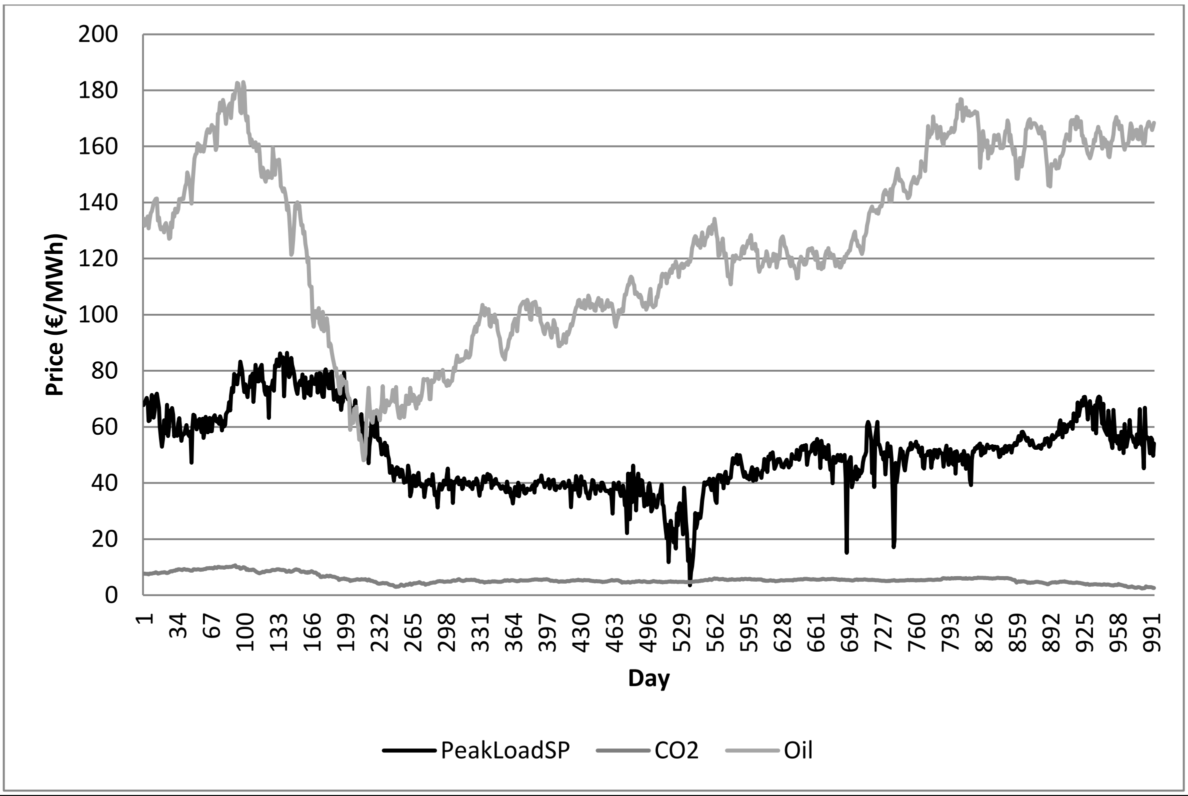
Source: developed with data

Figure 8 - Relationship between electricity price in peak load for Portugal, CO_2 allowances price and oil price



Source: developed with data

Figure 9- Relationship between electricity price in peak load for Spain, CO_2 allowances price and oil prices



Source: developed with data

Table 13 - Tests for unit roots

	Dickey-Fuller Test $t_{crit\ 5\%}$= -2,86		Phillips-Perron Test $rho_{crit\ 5\%}$= -14,100 / $t_{crit\ 5\%}$= -2,86		
	t_{obs}	p-value	rho_{obs}	t_{obs}	p-value
$P^{Eletricity}_{BaseLoad\ PT}$	-4,118	0,0009	-15,021	-2,935	0,0414
$P^{Eletricity}_{PeakLoad\ PT,t}$	-4,796	0,0001	-20,633	-2,577	0,0095
$P^{Eletricity}_{BaseLoad\ SP,t}$	-4,692	0,0001	-20,350	-3,331	0,0136
$P^{Eletricity}_{PeakLoad\ SP,t}$	-5,055	0,0000	-23,538	-3,573	0,0063
CO_2	-0,843	0,8062	-2,325	-0,882	0,7937
P^{Coal}	-1,268	0,6437	-6,174	-1,814	0,3737
P^{Oil}	-0,958	0,7682	-2,305	-0,920	0,7813
TPT	-6,538	0,0000	-59,581	-5,529	0,0000
TSP	-4,664	0,0001	-27,868	-3,733	0,0037
TPT^2	-7,015	0,0000	-70,460	-6,080	0,0000
TSP^2	-4,453	0,0002	-25,465	-3,594	0,0059

Source: developed with data

Table 14 - Johansen cointegration test

Model 1 – BaseLoad PT, CO_2, Coal, TPT, TPT^2					
Max Rank	**Parms**	**LL**	**Eigenvalue**	**Trace Statistic**	**5% Critical value**
0	30	-10698,507	-	264,341	68,520
1	39	-10611,786	0,160	90,899	47,210
2	46	-10590,227	0,042	47,882	29,680
3	51	-10570,747	0,039	8,821*	15,410
4	54	-10566,874	0,008	1,076	3,760
5	55	-10566,336	0,001		
Model 2 – PeakLoad PT, CO_2, Oil, TPT, TPT^2					
Max Rank	**Parms**	**LL**	**Eigenvalue**	**Trace Statistic**	**5% Critical value**
0	30	-11240,259	-	262,031	68,520
1	39	-11152,673	0,162	86,859	47,210
2	46	-11128,843	0,047	39,199	29,680
3	51	-11111,133	0,035	3,780*	15,410
4	54	-11109,244	0,004	0,001	3,760
5	55	-11109,243	0,000		

Model 3 –Base Load SP, CO_2, Coal, TSP, TSP^2					
Max Rank	**Parms**	**LL**	**Eigenvalue**	**Trace Statistic**	**5% Critical value**
0	30	-11038,571	-	163,336	68,520
1	39	-10997,607	0,080	81,409	47,210
2	46	-10970,151	0,054	26,497*	29,680
3	51	-10961,176	0,018	8,547	15,410
4	54	-10957,463	0,007	1,121	3,760
5	55	-10956,903	0,001		
Model 4 –Peak Load SP, CO_2, Oil, TSP, TSP^2					
Max Rank	**Parms**	**LL**	**Eigenvalue**	**Trace Statistic**	**5% Critical value**
0	30	-11555,078	-	150,628	68,520
1	39	-11512,797	0,082	66,064	47,210
2	46	-11490,853	0,043	22,177*	29,680
3	51	-11481,619	0,018	3,709	15,410
4	54	-11479,771	0,004	0,014	3,760
5	55	-11479,764	0,000		

Source: developed with data

Table 15 - Correlation matrix

	BaseLoadPT	PeakLoadPT	BaseLoadSP	PeakLoadSP	TPT	TSP	CO_2	Oil	Coal	TPT^2	TSP^2
BaseLoadPT	1,000										
PeakLoadPT	0,991	1,000									
BaseLoadSP	0,979	0,972	1,000								
PeakLoadSP	0,969	0,980	0,986	1,000							
TPT	0,103	0,097	0,116	0,116	1,000						
TSP	0,136	0,126	0,158	0,151	0,898	1,000					
CO_2	0,592	0,573	0,539	0,540	0,199	0,235	1,000				
Oil	0,328	0,335	0,380	0,377	0,181	0,226	0,289	1,000			
Coal	0,726	0,726	0,752	0,756	0,112	0,167	0,630	0,749	1,000		
TPT^2	0,090	0,088	0,103	0,107	0,987	0,875	0,168	0,161	0,097	1,000	
TSP^2	0,126	0,122	0,151	0,150	0,854	0,973	0,196	0,187	0,153	0,854	1,000

Source: developed with data

Appendix C

Table 16 - Annual external transactions of allowances for Portugal

Transfers and acquisitions	2008		2009		2010	
	Addiction	Subtraction	Addiction	Subtraction	Addiction	Subtraction
Germany (DE)	0	397.117	3.003.316	115.691	0	2.665.152
Czech Republic (CZ)	0	0	2.607.082	0	297.000	0
France (FR)	451.000	864.189	930.045	6.312.292	614.254	4.749.465
Great Britain (GB)	NO	1.457.944	4.162.000	1.462.794	384.733	3.199.475
Estonia (EE)	0	0	0	0	1.905	0
Spain (ES)	222.500	317.559	2.065.421	7.602.846	2.522.367	1.493.675
Denmark (DK)	2.828.001	2.623.005	12.491.009	10.953.059	5.000	58.000
Italy (IT)	2.000	2.000	131.522	21.522	3	394.001
Belgium (BE)	0	20.625	0	27.201	0	0
Ireland (IE)	0	0	0	50.000	0	140.000
Liechtenstein (LI)	0	0	0	0	100.000	0
Latvia (LV)	0	0	2.000.000	0	2.000.000	0
Netherlands (NL)	0	0	629.000	494.410	224.163	283.210
Norway (NO)	0	0	0	0	200.000	0
Romania (RO)	0	0	0	0	0	85.000
European Union (EU)	0	2.235.418	0	0	0	0
Sub-total	3.503.501	7.917.857	28.019.395	27.039.815	6.349.425	13.067.978

Source: National Inventory Submissions, United Nations – Framework Convention for Climate Change, Available in http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/5888.php

Table 17 - Annual external transactions of allowances for Spain

Transfers and acquisitions	2008		2009		2010	
	Addiction	Subtraction	Addiction	Subtraction	Addiction	Subtraction
Austria (AT)	80.000	80.000	2.017.879	73.286	0	175.000
Belgium (BE)	1	81.289	5.000	1.601.396	404.251	1.579.888
Czech Republic (CZ)	75.000	0	5.128.500	0	1.000.000	0
Germany (DE)	2.545.515	4.088.426	4.259.125	1.247.232	8.664.784	1.649.130
Denmark(DK)	1.031.000	434.006	28.027.721	8.808.697	121.371	7.392.111
European Union (EU)	0	10.229.902	0	0	0	0
Estonia(EE)	0	0	0	0	6.285.714	0
Finland (FI)	100.000	41.490	0	80.359	1.200	47.390
France (FR)	881.261	4.700.509	4.567.442	31.542.605	9.250.217	7.649.908
Great Britain(GB)	10.897.316	11.243.141	5.346.884	22.791.958	7.118.555	27.095.990
Greece (GR)	0	0	0	0	70.000	0
Hungary (HU)	6.650.000	0	39.300	0	0	0
Ireland (IE)	14.000	1.500	360.954	227.400	421.000	646.500
Italy (IT)	4.500	19.500	475.315	69.594	2.270.438	8.273.560
Japan (JP)	0	0	0	0	0	0
Luxembourg (LU)	0	0	0	310.000	0	0
Latvia (LV)	0	20.000	5.000.000	0	0	0
Netherlands (NL)	355.000	1.622.503	527.482	999.398	1.666.060	3.105.302
Norway(NO)	0	0	0	0	133.961	133.961
Poland (PL)	0	0	1.084.100	31.100	3.199.791	302.200
Portugal (PT)	317.559	222.500	7.602.846	2.065.421	1.493.675	2.522.367
Romania (RO)	0	0	0	0	40.000	30.000
Sweden (SE)	0	10.000	0	0	0	0

Transfers and acquisitions	2008		2009		2010	
	Addiction	**Subtraction**	**Addiction**	**Subtraction**	**Addiction**	**Subtraction**
Slovenia (SI)	13.820	0	0	0	1.424	0
Ukraine (UA)	0	0	3.236.254	0	0	0
Sub-total	22.964.972	32.794.766	67.678.802	69.848.446	42.142.441	60.603.307

Source: National Inventory Submissions, United Nations – Framework Convention for Climate Change, Available in http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/5888.php