Phase II CO_2 cost pass-through in MIBEL: a cointegrated VECM approach

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Summary

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Introduction

- **European Union Emission Trading Scheme (EU ETS)**
  - A cap-and-trade system implemented on January 2005
  - Reach the emissions targets set forth Kyoto Protocol
  - Design to operate in three phases
    - Phase 1: from 2005 to 2007 (pilot phase)
    - Phase II: from 2008 to 2012 (this study)
    - Phase III: from 2013 to 2020
  - Each phase corresponds to a National Allocation Plan (NAP) which specifies the total number of emissions allowances allocated
  - Transactions of allocated allowances are possible through an EU emissions allowances (EUA) market that provides a price for the CO_2
  - Electricity production (CO_2 emitting) competes with the possibility to sell the EUA in the market
    - Theoretically this so-called CO_2 opportunity cost equals the CO_2 market price

Introduction

- **European Union Emission Trading Scheme (EU ETS) on electricity sector**
  - Performance of EU ETS depends on:
    - Environmental effectiveness (inducing electricity industry to cut CO_2 emissions)
    - Economic efficiency (ensure that the cuts would be made by those firms that could achieve the most efficient abatement costs)
  - Welfare and distributive implications of EU ETS
    - Impacting on consumer's surplus and firm`s profits and competitiveness
  - Either the performance of the EU ETS or its distributive and welfare implications depends on what extent the CO_2 emission allowances prices are passed through into electricity prices.
  - **This study focuses on analyzing the impact of CO_2 prices on electricity pricing**
    - **Pass-through rate (PTR) of CO_2 costs into electricity prices**
  - Due a set of reasons the PTR may be different than 100% (among others):
    - Demand responses (price elasticity), level of power demand (peakload vs off-peakload) market structure (degree of market concentration), technology mix (fuel used in production), available generation capacity

Literature Review

- **Analyses conducted concerning estimations of the PTR of CO_2 cost into electricity prices**

  – Studies taking into account those interdependencies, developing a vector error correction model (VECM), with the electricity, fuel and carbon prices model as jointly endogenous

    - Honkatukia, Malkonen and Perrels (2006): NordPool power market
    - Chemarin, Heinen and Strobl (2008): France power market (with temperature and rainfall as exogenous regressores)
    - Fezzi and Bunn (2009): Germany and UK markets (with temperature as an exogenous regressor)
    - Fell (2010): NordPool power market (with temperature and the reservoir water level as exogenous regressores)
    - Thoenes (2011):Germany power market

Iberian Electricity Market (MIBEL) – Portuguese System

- **Iberian Electricity Market (MIBEL) – Portuguese System**
  - MIBEL: wholesale electricity market
    - Daily spot market: managed by OMEL, located at Spain
    - Derivatives market: managed by OMIP, located at Portugal
  - The spot market came into effect in July, 1st, 2007 allows participants to trade power on either side of the Portugal/Spain border
  - Load regimes
    - Peak Load: period between 8:00h and 20:00h
    - Off-Peak Load: : period between 21:00h and 8:00h
  - Technologies – Portuguese system
    - Renewables, Hydroelectric, Thermal Coal, Thermal Fuel-gas and Combined Cycle Gas Turbine (CCGT)
  - Merit Order – Portuguese system
    - Renewables → Hydroelectric → Coal → CCGT
      → CCGT → Coal

Electricity Production and Generation Capacity by Technology – Portuguese System

	2011 (July)		2010		2009		2008		2007	
Electricity Production (GWh)	30.449		53.228		51.723		51.854		55.392	
Natural Gas (CCGT)	6.671	34%	10.700	31%	11.463	32%	12.573	32%	10.494	26%
Thermal Coal (Coal)	3.855	20%	6.554	19%	11.942	33%	10.423	26%	11.662	29%
Fuel Oil/Gasoil (Fuel)	0	0%	46	0%	303	1%	801	2%	1.268	3%
Hydroelectric (Hydro)	7.725	40%	14.869	43%	7.892	22%	6.436	16%	9.523	24%
International Balance	1.130	6%	2.623	8%	4.777	13%	9.431	24%	7.488	19%
Renewables	11.068	36%	18.436	35%	15.346	30%	12.190	24%	14.957	27%
Generation Capacity (MW)	18.197		17.906		16.661		14.924		14.195	
Natural Gas (CCGT)1	3.829	32%	3.829	32%	2.992	27%	2.166	21%	2.166	21%
Thermal Coal (Coal)	1.756	15%	1.756	15%	1.756	16%	1.776	17%	1.776	17%
Fuel Oil/Gasoil (Fuel)	1.822	15%	1.822	15%	1.877	17%	1.877	18%	1.877	18%
Hydroelectric (Hydro)	4.549	38%	4.579	38%	4.579	41%	4.579	44%	4.579	44%
Renewables	6.241	34%	5.920	33%	5.457	33%	4.526	30%	3.797	27%

Notes: percentages for CCGT, Coal, Fuel, Hydro and Int. Balance were calculated excluding the renewables.
Source: REN - Rede Energéticas Nacionais (www.ren.pt).

Iberian Electricity Market (MIBEL) – Portuguese System

- **The pass-through rate (PTR) of CO_2 costs in the Portuguese case**

  – CO_2 emissions associated with electricity generation is a function of generation fuel used

  – Strategies implemented in order to address this problem

    - Include a set of variables which we hope that works as a proxy of the marginal producer
    - Test the hypothesis of significant differences in PTR of CO_2 according to the load regimes

Data

Endogenous Variables (prices)

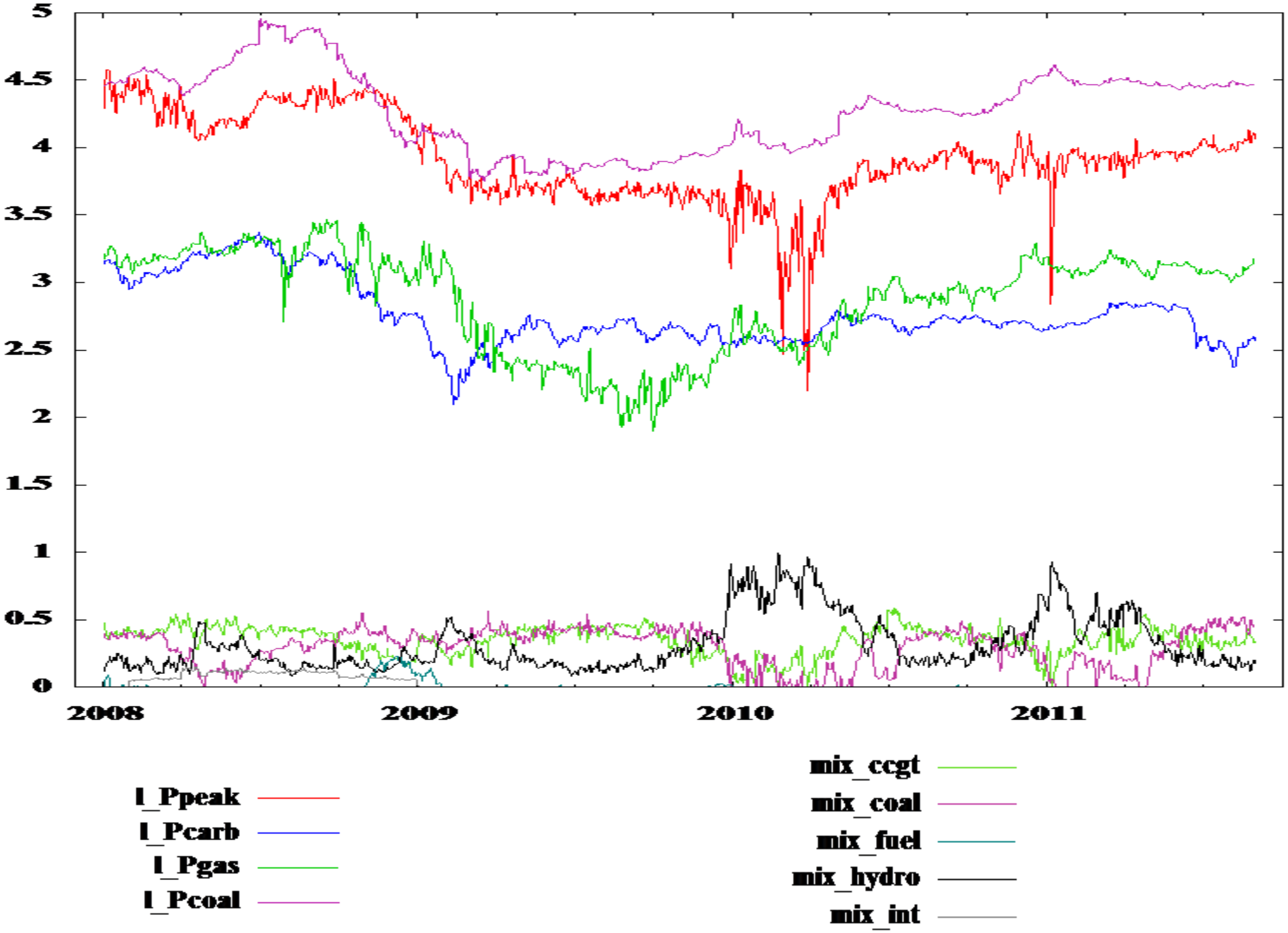
		Spot Market Price: daily price (OMEL)
Electricity Price	Ppeak	Peak load: hourly average from 8:00h to 20:00h
	Poff-peak	Off-Peak load: hourly average from 21:00h to 8:00h
	Pbase	Base load: average of the 24 hourly prices
Carbon Price	Pcarb	Spot Market Price: daily price (European Energy Exchange - EEX)
Natural Gas Price	Pgas	Spot OTC Price: daily price (Zeebrugge Hub - ZEE)
Coal Price	Pcoal	Spot OTC Price: daily price (API 2, CIF,ARA)

Note: all prices were transformed into their natural logarithms

Exogenous (control) Variables

Maximum Temperature	Temp_Max	Daily temperatures at the representative weather stations weighted by the population
Minimum Temperature	Temp_Min	
Combined Cycle Gas Turbine	Mix_CCGT	Each variable is defined as the ratio between the quantity of electricity traded that is produced by the technology and the total amount of electricity traded in the mark
Thermal Coal	Mix_Coal	
Thermal Fuel	Mix_Fuel	
Hydroelectric	Mix_Hydro	
International Trade	Mix_Int	

Interactions between EU ETS, Fossil Fuels and the Portuguese Electricity Market



Empirical Methodology

- **Modeling techniques**
  - Empirical research in measuring pass-through of CO_2 costs into commodities or products prices typically applies one of two modeling techniques
    - Univariate approach, with a single equation regression
    - Multivariate approach of simultaneous equations, which is the only technique that avoids the endogeneity problems by treating all variables (electricity price, fuel prices and EUA prices) to be endogenous
  - Multivariate analysis has been developed using either the VAR models or cointegrated VAR (CVAR) models
  - There are strong beliefs (Engle & Granger, 1987) that economic data are non-stationary , meaning any particular price measure over time will not be tied to its historical mean
    - Modeling a VAR in first differences - risk of loss relevant information about long-term relationships
    - Specify a CVAR, if the variables show a very interesting property, namely the cointegration

Empirical Methodology

- **Vector Error Correction Model (VECM)**
  - Cointegrated variables must have an error correction representation in which an error correction term (ECT) must be incorporated into the model
  - A VECM is formulated to reintroduce the information lost in the differencing process, thereby allowing for long-run equilibrium as well as short-run dynamics

$$\Delta P_{peak,t} = \sum_{i=0}^{k} \Gamma_{carb} \Delta P_{carb,t-i} + \sum_{i=0}^{k} \Gamma_{gas} \Delta P_{gas,t-i} + \sum_{i=0}^{k} \Gamma_{coal} \Delta P_{coal,t-i} + \sum_{i=1}^{k} \Gamma_{peak} \Delta P_{peak,t-i} +$$

$$+ \alpha \, P_{peak,t-1} + \beta_{carb} P_{carb,t-1} + \beta_{gas} P_{gas,t-1} + \beta_{coal} P_{coal,t-1} + \varepsilon_t$$

$$\varepsilon_t \sim Niid(0, \Sigma)$$

Where:
- β represents the cointegration vectors or the long run coefficient
- α represents the coefficient of adjustment to the equilibrium or the error correction term (ECT)

Empirical Results

- **Estimation sequence**
  - *First*: unit root tests are conducted to test for the order of integration in individual price series (preliminary tests)
  - *Second*: assuming the tests conclude that the series are I(1), the cointegration rank is determined (cointegration tests)
  - *Third*: a VECM is estimated
  - *Fourth*: conducting post-estimation tests, including tests of exclusion and weak exogeneity tests (not presented in this presentation)
  - *Finally*, impulse response analysis and error variance decomposition to determine how innovations to the carbon price are propagated through the system, and in particular how they affect electricity prices

Empirical Results: VECM estimation

Cointegration Relationship				
P_t^{peak}	P_t^{carb}	P_t^{gas}	P_t^{coal}	Const.
1,000 ***	-0,514 ***	-0,311 ***	-0,290 ***	2,113 ***
	(0,09)	(0,06)	(0,09)	(0,64)

- All estimates parameters have the expected sign

- A carbon price rise of 1%, would, in equilibrium, be associated with an electricity price rise of 0,51% (Pass-through rate of CO_2 price into electricity price)
- A natural gas price rise of 1%, would, in equilibrium, be associated with an electricity price rise of 0,31%
- A coal price rise of 1%, would, in equilibrium, be associated with an electricity price rise of 0,29%

Results: short run dynamics

Short Run Dynamics

	ΔP_t^{peak}	ΔP_t^{carb}	ΔP_t^{gas}	ΔP_t^{coal}
EC_{t-1}	-0,317 ***	0,012 *	-	-0,015 ***
ΔP_{t-1}^{peak}	-0,149 ***	-	-	-
ΔP_{t-1}^{carb}	-0,244 **	-	0,197 **	0,142 ***
ΔP_{t-1}^{gas}	-0,091 *	-	-0,124 ***	0,025 **
ΔP_{t-1}^{coal}	-	-0,110 ***	-	-
mix_t^{ccgt}	0,818 ***	-	-	0,043 ***
mix_t^{coal}	0,928 ***	-0,039 *	-	0,046 **
mix_t^{fuel}	1,240 ***	-0,109 ***	-	-
mix_t^{hydro}	0,652 ***	-	-	0,034 **
mix_t^{int}	0,417 ***	-	-	-
$temp_t^{max}$	0,004 ***	-	-	-
$temp_t^{min}$	-0,007 ***	-	-	-

- In the short run, 32% of the electricity price changes is due to the reaction to a disequilibrium in the long-term relationship
  - Exogenous variables
    - Electricity generation mix is important for the short run dynamics of electricity price
    - Weather variables are important for electricity price changes in the short-run

Pass-through rate of CO_2 according to electricity load regimes

Electricity Price: **peakload**				
P_t^{peak}	P_t^{carb}	P_t^{gas}	P_t^{coal}	Const.
1,000 ***	-0,514 ***	-0,311 ***	-0,290 ***	2,113 ***
(0,0000)	(0,0855)	(0,0617)	(0,0893)	(0,6446)
EC (t-1) =	-0,31693 ***			

Electricity Price: **baseload**				
P^{base}	P_t^{carb}	P_t^{gas}	P_t^{coal}	Const.
1,000 ***	-0,426 ***	-0,379 ***	-0,249 **	2,349 ***
(0,0000)	(0,0845)	(0,0609)	(0,0882)	(0,6381)
EC (t-1) =	-0,30530 ***			

Electricity Price: **off-peakload**				
$P_t^{offpeak}$	P_t^{carb}	P_t^{gas}	P_t^{coal}	Const.
1,000 ***	-0,325 ***	-0,469 ***	-0,187	2,380 ***
(0,0000)	(0,0987)	(0,0712)	(0,1031)	(0,7448)
EC (t-1) =	-0,36394 ***			

Notes: Standard errors in parentheses. *** Significant at 1% level; ** Significant at 5% level; * Significant at 10% level.

- Results do not permit to reject the hypotheses of significant differences in the PRT of CO_2 costs.

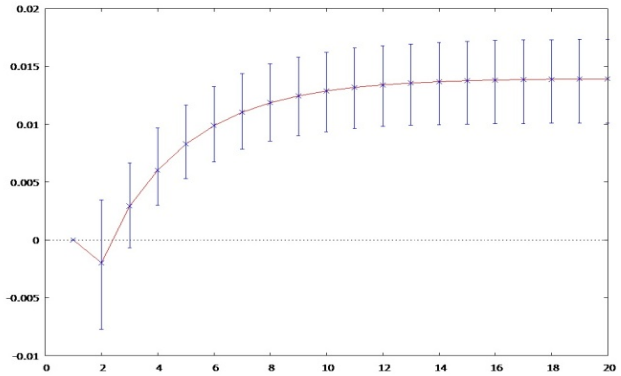
- PTR of CO_2 is higher (lower) when the PTR of coal is higher (lower), meaning that the coal thermal is probably the prevailing technology at high load periods and is responsible for the higher sensitivity of electricity price to the carbon costs at those periods of day.

- PRT of coal is not significant in the off-peakload, meaning that changes in coal price are not important in formulating the equilibrium price of electricity in low-load periods.

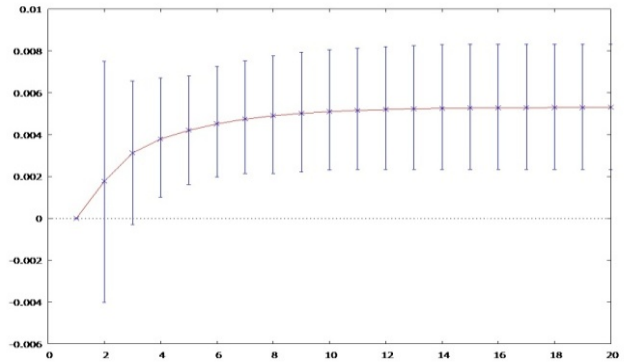
Empirical Results: Impulse Response Analysis

- **Impulse Response Analysis**

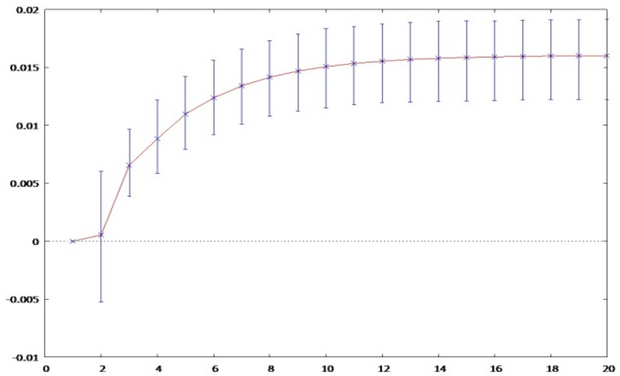
P^{carb} (impulse) → P^{peak} (response)



P^{coal} (impulse) → P^{peak} (response)



P^{gas} (impulse) → P^{peak} (response)



Once the shocks have settled (about ten working days), the effects are consistent with the cointegration relationship, meaning that the long-run equilibrium is reached roughly two weeks after the shock or innovation

Conclusion

- **Objective**
  - Conclude about the relationship between electricity prices and CO_2 emissions allowances prices for the Iberian Electricity Market (Portuguese division) in the context of the Phase II of EU ETS (2008-2011)
- **Methodology**
  - A vector error correction model (VECM) approach and a impulse response function, combined with an error variance decomposition
  - We control the effect of the input prices in electricity price by using two sets of exogenous variables
    - One, reflecting the demand for electricity conditions (temperatures)
    - Other, reflecting the production mix (weight of each technology present in the production mix on the total energy traded in the market)
  - Testing different models for the three load regimes: peak, off-peak and base load

Conclusion

Carbon price plays an important role in formulating the equilibrium price of electricity and, as the other fuels, is essentially exogenous in the long run

- Electricity prices react significantly and persistently to a shock in carbon prices and the full dynamic pass-through of carbon to the electricity prices is very similar to the others fuels (natural gas and coal) occurring only after approximately two weeks
- The long-run elasticity of electricity price to carbon price shocks in 51%
  - In the long-run, a 1% shock in carbon prices impact, on average, into a 0,51% in electricity prices
- Strong evidence of time-varying (peakload and off-peakload) electricity price responsiveness to carbon prices shocks
- In equilibrium, the marginal pass-through rate is higher in peak than in off-peak hours
  - PTR of CO_2 (peakload) - β_{carb}=51%
  - PTR of CO_2 (off- peakload) - β_{carb}=33%

Conclusion

Results show evidence of a significant link between carbon prices and the Portuguese wholesale electricity market

- Our results [33%-51%] are comparable to:
  - 93% in (Honkatukia, et al., 2006) for the NordPool market
  - 32% in (Fezzi & Bunn, 2009) for the UK market
  - [11% - 13%] in (Fell, 2010) for the NordPool market
  - 36% in (Thoenes, 2011) for the German market
- The results we found for the long-run pass-through rate of CO_2 prices into electricity price in the range [33% - 51%] are just below the simulations (COMPETES model) for the Portuguese market
  - [56%-64%] in (Sijm, et al., 2008)
  - [58%-100%] in (Lise, et al., 2010)

Final Considerations

- **Policy implications**

  – Power producers have been passed on the opportunity costs of freely allocated emissions allowances to electricity prices, enables power companies to get windfall profits

  – The competitiveness of the power producers may not be affected if companies have to pay for emissions allowances;

    - in that case there would be a distributive impact on consumer’s surplus and firm`s profits

  – Should the allocation rule of EU ETS change from grandfathering to auctioning?

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Thank you!