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The Evolution of Electricity Prices in The EU since the Single European Act

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ABSTRACT

The development of a single European market for electricity has been a goal of EU policy makers since the Single European Act of 1986. This paper considers the impact of EU Directives on the evolution of electricity prices. Three empirical tests for convergence are applied to prices for ten EU countries; a simple test for ß-convergence; a cointegration test; and Nahar and Inder's (2002) test. Although mixed, the results suggest that convergence did occur for most of the countries in the sample over this period.

1. INTRODUCTION

THE LAST FIFTEEN YEARS have been a period of considerable change in EU electricity markets. These developments have been driven to large degree by the Single European Act (SEA), signed in 1986 and which came into force on 1 July 1987. It established the principle of a single European 'internal market' for goods and services, including vital energy supplies such as electricity and gas. The aim with regard to electricity was not only to encourage more competition between national suppliers, but also to reap the benefits of co-operation such as reserve sharing. In this way a single European electricity market would hope to increase security of supply for all Member States and increase economic welfare as prices bore greater correspondence to costs.

There have been a series of legislative measures issued by the EU with the aim of creating a single European market for electricity. The most important of these was the 1996 Electricity Directive (EU, 1996), which required all EU member states to take substantive steps to prepare for a unified market for electricity. Subsequent Directives have reinforced the development of market opening (EU, 2003a), the reduction of obstacles to cross-border trade (EU, 2003b), and the guarantee of non-discriminatory third party access (EU, 2003a). Directive 96/92/EC of the European Parliament outlines common rules for the internal market in electricity.

The new electricity directives were due to be transposed into national law by July 2004 when the regulation on cross-border exchanges also came into effect. There have, however, been substantive administrative difficulties in enacting the above legislation in different Member States. Several recent studies assessing the progress of electricity liberalisation have noted that although considerable progress has been made in the last few years, the development of free market entry and cross-border trade is still some way off in many national markets (EC, 2005; EBRD, 2005). Given these legislative changes, the aim of this paper is to investigate the degree to which electricity markets in the EU have become more competitive by analysing the extent of price convergence. In the absence of transaction costs we would expect a competitive market to result in the convergence of prices towards an equilibrium single price.

Several other researchers have considered this question. Bower (2002), Boisseleau (2004) and Armstrong and Galli (2005) compare electricity day ahead wholesale prices at different European power exchanges. Bower uses correlation and cointegration analysis to analyse prices in the Nordic countries, Germany, Spain, England and Wales as well as the Netherlands in 2001. His results imply some convergence between these markets at this time. Boisseleau (2004) uses a simpler regression approach in his study and finds little convergence between the national markets in his sample. Both Bower's and Boisseleau's studies were fairly static in that they looked at convergence over a short period. Armstrong and Galli (2005), however, study the development of wholesale price differentials between France, Germany, the Netherlands and Spain during the years 2002, 2003 and 2004. They conclude that there was convergence over this period.[2]

This paper builds further on this dynamic approach by investigating the evolution of electricity prices over a much longer time period in order to assess whether they have converged. Three popular econometric tests of convergence are applied to annual electricity prices for 10 European countries for the period 1978 to 2003. The paper is structured as follows: Section 2 describes the data to be used; Section 3 applies the ß convergence test; Sections 4 and 5 contain implementation of two recently developed econometric time series tests of convergence; and Section 6 concludes.

2. DATA

All data are obtained from the *International Energy Association* via the *Economic and Social Data Services (ESDS)* data portal. The sample is selected mainly from those nations that were Member States at the time of the initial proposals for a single European electricity market contained in the Single European Act of 1986. These were Belgium, Denmark, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, and the UK. However, complete data on electricity prices for the period under investigation were unavailable for Luxembourg, Belgium, and the Netherlands. These countries were, therefore, excluded from the sample. Finland is included in the analysis although this country did not become a member state until 1995. The intention is to include a comparator in order to observe if the development of electricity prices was markedly different for a nation whose accession was almost ten years after the SEA was signed. It is also recognised that Portugal and Spain joined the EU in 1986 and, assuming that policy makers would have planned ahead will have had less time than most of the other member states in the sample to enact liberalising policies. It will be interesting to interpret the empirical results in this context.

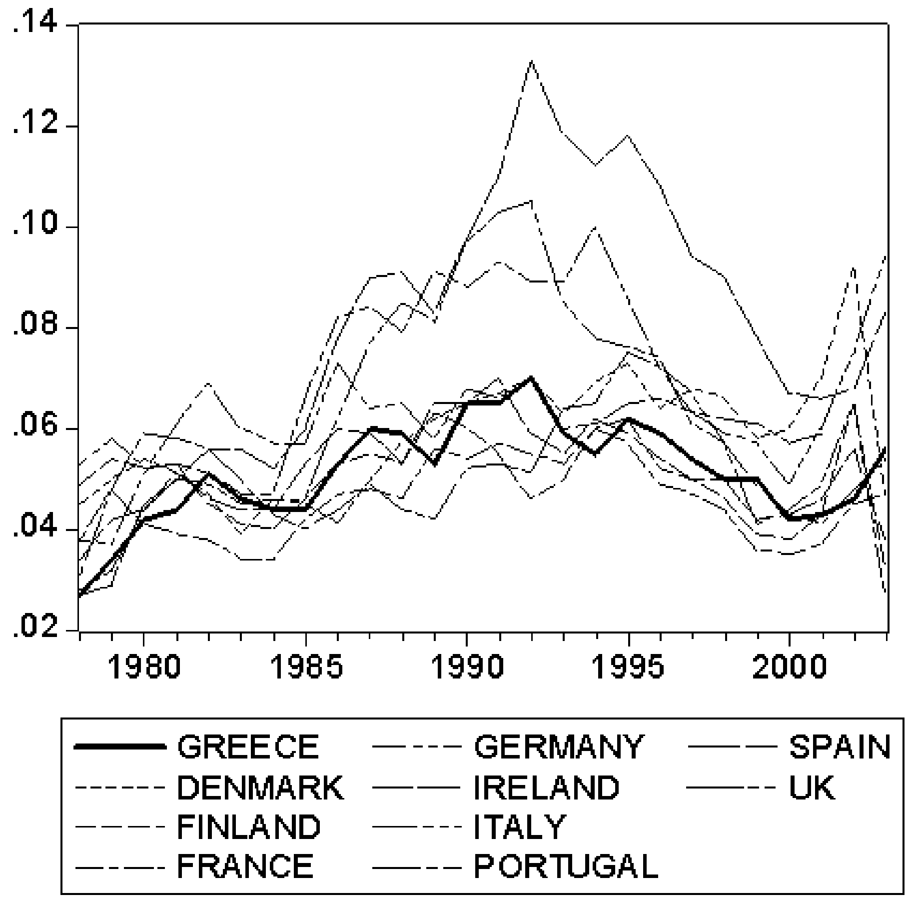
The dataset thus consists of ten countries for which a complete annual time-series from 1978 to 2003 can be extracted; these are Denmark, Finland, France, Germany, Greece, Ireland, Italy, Portugal, Spain and the UK. To be able to test for convergence the electricity prices must be converted to a common basis. The prices used are electricity prices for households and industry quoted in US dollars per kilowatt hours. Fig 1 displays the data for the selected countries.

In contrast to previous studies, retail prices rather than wholesale prices are used. The retail price is the wholesale price plus a supply and transmission element. The objective of electricity liberalisation is to enable more uniform and lower electricity prices for households and industry across Member States. The liberalisation measures above are not only designed to deregulate wholesale markets, but to introduce competition in supply and transmission also. Since the objective here is to gauge whether nations responded to the proposals of the SEA then retail prices are appropriate.

The price developments in Fig 1 clearly show the differences between countries like Finland, with relatively low electricity prices; and Portugal, with much higher prices over this period. It also shows the large decrease and obvious convergence of most prices as actual implementation of supply competition gathered pace after 2000. Interestingly, the figure shows that there seems to be a group of countries with fairly low prices from the mid 1980s to the mid-1990s (Greece, Denmark, Finland, France, Ireland, Italy) — and a group with higher and more variable prices (Germany, Portugal, Spain and the UK).

Prior to price data being used for time series analysis, the characteristics of the variables must be determined. Many economic time series variables, including energy prices, are found to be non-stationary in levels, and therefore

Figure 1. Electricity prices for industry and households in US dollars/kWh



Dickey-Fuller tests are performed for all the price series, expressed in logarithmic terms, in order to detect the presence of stochastic trends, which are an important part of time series tests of convergence. A deterministic trend is included in the DF tests in order to test the hypothesis of trend stationarity.

The results are shown in table 1. They imply, at the 5% level, that all of the series, except those for Finland, Italy and Portugal, contain a unit root.

In addition to the Dickey-Fuller tests, the test from Kwiatkowski et al. (1992), is also applied (hereafter KPSS). The KPSS test differs from other unit-root testing procedures in that the data series is assumed to be stationary under the null hypothesis. The results of the KPSS test for our series expressed in logarithmic terms and differenced are also presented in Table 1. In all cases, the hypothesis of level and trend stationarity was rejected. However, when the series are differenced, stationarity cannot be rejected at the 10% level. Therefore, the combined results suggest that all the series are integrated of order one.

Table 1: Unit root tests

Prices (US dollars/kWh)	*DF/ADF Statistics with no trend*	*DF/ADF Statistics with trend*	*KPSS stat no trend*	*KPSS stat with trend*
Denmark	-2.66*	- 2.91*	0.30*	0.16
Finland	-3.14	-3.87	0.29*	0.17
France	-1.82*	- 1.65*	0.11*	0.07*
Germany	-0.95*	- 1.01*	0.38	0.13
Greece	-2.99*	- 3.23	0.30*	0.09*
Ireland	-2.38*	- 2.34*	0.30*	0.09*
Italy	-5.02	-5.45	0.34*	0.08*
Portugal	-3.04	- 3.43	0.30*	0.10*
Spain	-1.47*	- 1.56*	0.64	0.13
UK	-1.97*	-2.04*	0.52	0.05*

Note: The critical value is - 2.99 at the 5% level (indicated by * in the table) according to MacKinnon (1996). The test also includes a deterministic trend to allow for an alternative hypothesis of trend stationarity.

The KPSS stationarity test was used both with intercept only and with intercept and time trend on first differences of the series. The critical values at the 10% level are, for the model with intercept and time trend 0.119, and for the model only with intercept 0.347 (Kwiatkowski et al., 1992, Table 1, p. 166).
* Indicates that the null of stationarity cannot be rejected at the 10% level

3. Testing for ß-convergence

The econometric techniques used to determine whether variables have converged over time have been applied mainly to cross-country studies of real income convergence (Sala-i-Martin, 1995; Baumol and Wolff, 1986). To get an initial feel for whether electricity prices have converged in our set of countries, one of the most popular measures used in such studies, absolute *ß-convergence*, is applied. This approach is also referred to as the *Classical* approach to convergence analysis (Sala-i-Martin, 1995; Sala-i-Martin and Barro, 1992). To put it intuitively, a variable *ß*-converges if countries with low original values of the respective variable - in this case electricity prices — experience more rapid growth rates in this variable than the other countries in the sample. Denoting the electricity price (log values) in country i at time t by $p_{i,t}$ the measure of convergence is derived from the following panel regression, with $t - n$ indicating the first period in the sample.

$$p_{i,t} = \alpha + (1 - ß)p_{i,\ t-n} + e_i \qquad (1)$$

The coefficient on ß gives an estimate of the rate of convergence. A value close to 1 suggests absolute convergence, i.e. prices converge towards a common level (α). Where ß is not significantly different from zero we conclude there is no convergence.

Table 2: Test statistics for ß-convergence

Price (p_t)	*US$/kWh*
$\hat{\beta}$	0.79
Standard error	0.033

The estimate of ß is 0.79, and the magnitude of the standard error suggests that the parameter levels differ significantly from zero at conventional critical levels. Indications of convergence are further supported by a 10% confidence interval of [0.846, 0.734]. Initial tests indicate, therefore, that there may be some convergence of electricity prices over the period in the ß-sense.

4. The Bernard-Durlauf test for convergence

Although widely adopted, the ß-convergence approach does have pitfalls. Central among these is that estimation only employs the first and last time-series values of the variable. The coefficient estimates are, therefore, particularly sensitive to these values. In addition, other shortcomings of this measure of convergence have been identified by several authors including Bernard and Durlauf (1996) and Greasley and Oxley (1997), who propose a time-series approach instead. The methodology of Bernard and Durlauf (1996) will be followed here.

In this approach the convergence between country *i* and a group average of all countries is defined as:

$$\lim E(p_{i,t+k} - \overline{p}_{t+k} \mid I_t) = 0 \qquad k \to \infty \qquad (2)$$

I_t is the information set available at time *t*. It is crucial whether $(p_t - \overline{p})$ contains a non-zero mean or a unit root. If it does, the series will diverge over time — and it follows that convergence does not take place. In practice, we test this definition of convergence by testing for a unit root in the difference of the log values of the electricity price, with *t* denoting a time trend:

$$\Delta\left(p_{i,t} - \overline{p}_t\right) = \alpha + \beta t + \mu(p_{i\,t-1} - \overline{p}_{t-1}) + lags\ of\ \Delta(p_{i\,t} - \overline{p}_t) + \varepsilon_t \qquad (3)$$

If a unit root is present, electricity prices in country *i* and the average price will be characterised by unconnected stochastic trends and so will diverge over time. When there is no unit root in (3), both the intercept and the deterministic trend coefficient may be insignificant, implying long-run convergence. When the deterministic trend parameter differs significantly from zero, however, a process of catching up is likely to occur. In this case, therefore, a necessary condition for convergence is that the cointegration vector between a given set of prices is (1, -1). The Bernard-Durlauf test for convergence is performed for all ten countries in the sample and the results are presented in table 3.

Table 3: Test stats for the convergence/catching up hypothesis

Prices (US dollars/kWh)	*DF/ADF with trend*	*DF/ADF no trend*	$\hat{\alpha}$	$\hat{\beta}$
Denmark	-4.27 {2}**	-3.29 {2}*	-0.249*	0.119
Finland	-3.01 {0}*	-5.74 {0}**	-0.066	0.003
France	-6.47 {0}**	-6.47 {0}**	-0.152**	-0.007*
Germany	-3.04 {0}**	-4.52 {0}**	-0.074	0.004
Greece	-5.55 {2}**	-5.47{2}**	-0.03	-0.005**
Ireland	-4.27 {0}**	-3.46 {0}*	-0.015	-0.002
Italy	-3.26 {2}*	-3.36 {2}*	0.24	-0.018*
Portugal	-3.97 {2}**	-3.53 {2}*	0.48**	0.018
Spain	-3.28 {0}*	-3.29 {0}*	0.21*	-0.013
UK	-4.06 {2}**	-3.48 {2}*	0.13	-0.016*

Note: The critical value is -3.60 at the 5% level (indicated by ** in the table), and -3.23 at the 10% level (indicated by * in the table) according to Davidson and MacKinnon (1993). The test also includes a deterministic trend to allow for an alternative hypothesis of trend stationarity. The DF/ADF test statistics have been derived by applying a suitable lag length {0, 2 or 4} in the unit root test.

Rejection of the unit root hypothesis is the condition for convergence in this test, and this hypothesis is rejected at the 5% level in three cases — Denmark, France and Germany — and at the 10% level in seven cases — The 1995 accessionist Finland, Greece, Ireland, Italy, Portugal, Spain and the UK. With Denmark, however, the negative intercept term differs significantly from zero, implying that price differences will not disappear over time because the time trend is most likely zero. Although the results from applying the Bernard-Durlauf test of convergence indicate very strongly in favour of convergence, there is no evidence from Table 3 of a catching-up process in electricity prices. In equation (3) a catching-up process would show up as a significantly positive intercept term along with a significantly negative time trend. This applies to none of the countries in our sample.

5. The Nahar and Inder test for convergence

Nahar and Inder (2002) propose a broader time series test methodology that includes non-stationary as well as stationary price differences. They point out that stationarity is not a necessary condition for convergence as defined in equation (2).[2] It follows that non-stationary variables may also converge. Nahar and Inder (2002) outline a procedure that accommodates non-stationary converging processes. To briefly summarise the methodology, we begin by noting that the test, like the Bernard-Durlauf test, is for convergence towards a group average and that price differences become smaller over time (as shown in equation (2)). The next step is to form the squared price differences:

$$w_{it} = (p_{it} - \bar{p}_{it})^2 \tag{4}$$

If convergence occurs w_{it} gets nearer to zero which means

$$\lim_{k \to \infty} E_t(w_{i,t+k}) = 0 \tag{5}$$

Because w_{it} represents the squared price differences and is consequently always positive, the following condition holds:

$$(\partial / \partial t) w_{i,t} < 0; \quad w_{i,t+k} \to 0 \quad \text{as} \quad k \to \infty \tag{6}$$

By looking at the sign of condition (6) we will be able to assess whether convergence exists. A negative sign suggests convergence because $w_{i,t}$ will tend towards zero when the average slope of $w_{i,t}$ is negative. For the empirical application $w_{i,t}$ is defined as a function of time. Therefore, whether a variable is converging can be evaluated from the sign of $(\partial / \partial t) w_{i,t}$. To find $(\partial / \partial t) w_{i,t}$ let one represent w_{it} as a function of a time trend t, say $f(t)$, and consider:

$$w_{it} = f(t) + u_t = \theta_0 + \theta_1 t + \theta_2 t^2 + \ldots + \theta_{k-1} t^{k-1} + \theta_k t^k + u_{it} \tag{7}$$

where the θ_i's are parameters, and u_{it} is an error term with mean zero both unconditionally and conditionally on time. From (7) one can straightforwardly find the slope function

$$(\partial / \partial t) w_{i,t} = f'(t) \tag{8}$$

Estimates of this slope function can now be used to verify the convergence of the price variables. Although the w_{it} series is not likely to decrease unvaryingly over time, if the price variables are converging then w_{it} should be generally decreasing, and for convergence to hold the average slope of w_{it} should be negative. More formally:

$$\frac{1}{T}\sum_{t-1}^{T}\frac{\partial}{\partial t}w_{it} < 0 \tag{9}$$

This can be obtained from (9) as follows:

$$\frac{1}{T}\sum_{t-1}^{T}\frac{\partial}{\partial t}w_{it} = \theta_1 + \theta_2 r_2 + \ldots + \theta_{k-1} r_{k-1} + \theta_k r_k = r'\theta \tag{10}$$

$$r_k = \frac{k}{T}\sum_{t-1}^{T} t^{k-1}$$

$r_k = [0 \quad 1 \quad r_2 \; . \; . \; . \; r_{k-1} \quad r_k]$ and

$\theta = [\theta_0 \quad \theta_1 \; . \; . \; . \; . \; \theta_k \quad \theta_{k-1}]$

In order to test for convergence we employ the null hypothesis $H_0 : r'\theta \geq 0$ against the alternative $H_1 : r'\theta < 0$. Thus the null hypothesis is one of no convergence. To test this, Equation (7) is estimated by ordinary least squares, and a *t*-test performed on this restriction on the θ vector.

Table 4: Average slopes and test statistics for the convergence hypothesis. Prices in (US dollars/kWh)

Prices(US dollars/kWh)	*Polynomial order*	*Average slope*	*t-statistic*
Denmark	2	-0.0025	-1.71*
Finland	2	-0.012	-3.55**
France	6	-0.0089	1.08
Germany	2	-0.0078	-1.65
Greece	3	-0.0053	3.15**
Ireland	6	-0.0013	-2.64**
Italy	6	-0.0040	-1.85*
Portugal	4	-0.0219	-3.73**
Spain	2	-0.0093	- 0.17
UK	5	-0.0045	- 0.61

Note: * indicates significant at the 5% level - evidence in favour of convergence. The polynomial order is selected from the AIC-values varying the lag length from 1 to 6. An average slope value deviating from zero at the 5% level of significance indicated by ** - and * for the 10% significance level.

Table 4 presents the results of the convergence tests based on average slope estimates of the squared de-meaned electricity prices. These tests offer strong evidence in favour of the Nahar and Inder convergence hypothesis for Greece, Finland, Ireland and Portugal, for whom the average slope coefficient is negative and significantly different from zero at the 5 per cent level. The estimated average slopes for Denmark and Italy are negative and significantly different from zero, but only at the 10 per cent level. However, for four countries the average slope coefficient is negative but insignificantly different from zero, meaning there is no evidence of convergence using the Nahar and Inder criteria.

Application of the Nahar and Inder convergence methodology, therefore, results in a less favourable conclusion towards convergence than found in the unit root procedure. The main conclusion from this test is that for some countries electricity prices converged towards the group average over our period, but for others they did not. These results are particularly interesting for Portugal and Finland. These countries did not become Member States until 1986 and 1995 respectively, yet there is still strong evidence of price convergence over the sample period.

6. Conclusion

Almost two decades have passed since the signing of the Single European Act and ten years since the first of several Electricity Directives were agreed by the member states. The main objective of this EU legislation has been to reduce barriers to trade and to compel Member States to liberalise their electricity industries, thereby increasing efficiency and reducing prices. Hence, despite differences in industry structure and ownership, Member States have been required to liberalise their electricity supply industries — although this has occurred more rapidly in some countries than others.

Notwithstanding the variable speed of transition to a freer market, as the development of a single market for electricity gathers pace across the EU we would expect to see national prices for this commodity converging. Indeed, in the long-run large price differences should be eliminated. As Figure 1 illustrates, retail electricity prices have certainly converged markedly in the last few years and this observation has been mainly confirmed by studies using spot daily wholesale prices over one or two years. The objective of this paper however, has been to consider whether convergence has taken place since the first serious steps to deregulate the electricity market were taken in the Single European Act.

To test whether convergence has occurred during the 1980s and 1990s three empirical tests of convergence have been applied. The test for ß-convergence suggests that there was an absolute convergence of electricity prices between the sample of ten European countries between 1978 and 2003. This finding is backed up by the findings of the Dickey-Fuller (Bernard-Durlauf) unit root tests, with all ten countries in the sample exhibiting some signs of diminishing differences in electricity prices. These results correspond with the findings of other researchers using daily spot market prices. However, the results of applying the less restrictive Nahar and Inder time series methodology are more mixed, with just over half of the countries exhibiting signs of convergence of electricity prices.

The overall implication is that there is some evidence that electricity prices in the ten countries in question did converge over the period 1978 - 2003. This would suggest that the clearly visible trend of converging retail prices so evident after 2001 began earlier, in response to the de-regulatory actions of the European Commission and national governments. The fact that the results of the tests for the 'late' accessionists, particularly Portugal and Finland, imply convergence over the sample period confirm this view. One explanation is that energy policies in such countries were framed on the assumption of EU entry and early liberalisation measures were enacted. Clearly further research into the energy policies of these countries is required.

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ENDNOTES

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2. Several papers have considered the long-run relationship of oil and gas prices, most recently Panagiotidis and Rutledge (2007) who found no evidence to show that oil and gas prices 'decoupled' after liberalisation.

3. For instance, assume $p1_t - p_{mt}$ is a non-stationary process represented by the following model $p1_t - p_{mt} = \theta/t + u_t$ where $E(u_t) = 0$ and u_1 is a stationary process. As $t \to \infty$ then $\theta/t \to 0$, so $p1_t - p_{mt}$ is also converging, since $\lim_{n\to\infty} E(p_{1t+n} - p_{mt+n} \mid I_t) = 0$. However, a test for stationarity of p1t - pmt may perhaps lead to non-rejection of the unit root hypothesis and result in the incorrect inference that there is no convergence (Nahar and Inder 2002, p.2013).

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