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Abstract

Energy intensity in Spain has increased since 1990, while the opposite has happened in the EU15. Decomposition analysis of primary energy intensity ratios has been used to identify which are the key sectors driving the Spanish evolution and those responsible for most of the difference with the EU15 energy intensity levels. It is also a useful tool to quantify which countries and economic sectors have had most influence in the EU15 evolution. The analysis shows that the Spanish economic structure is driving the divergence in energy intensity ratios with the EU15, mainly due to the strong transport growth, but also because of the increase of activities linked to the construction boom, and the convergence to EU levels of household energy demand. The results can be used to pinpoint successful EU strategies for energy efficiency that could be used to improve the Spanish metric.

Key Words
Energy intensity, decomposition analysis, EU energy efficiency

INTRODUCTION

Reducing energy costs, alleviating energy dependency, decreasing vulnerability to energy prices and reducing emissions from fuel combustion are some of the key arguments to promote energy efficiency (EE). Measuring and monitoring EE has become an important component in the design of energy strategies in many countries.

Economy-wide energy efficiency indicators have been developed and applied for evaluating, monitoring and explaining cross-country comparisons in energy performance. Energy indicators are difficult to conceptualise and there is no single accepted definition. In the literature, energy efficiency is often measured with physical-based indicators (energy per physical unit of output) and monetary-based indicators (energy per euro of output). These indicators tend to be used for different purposes and objectives: engineering design, economic productivity, sustainability,

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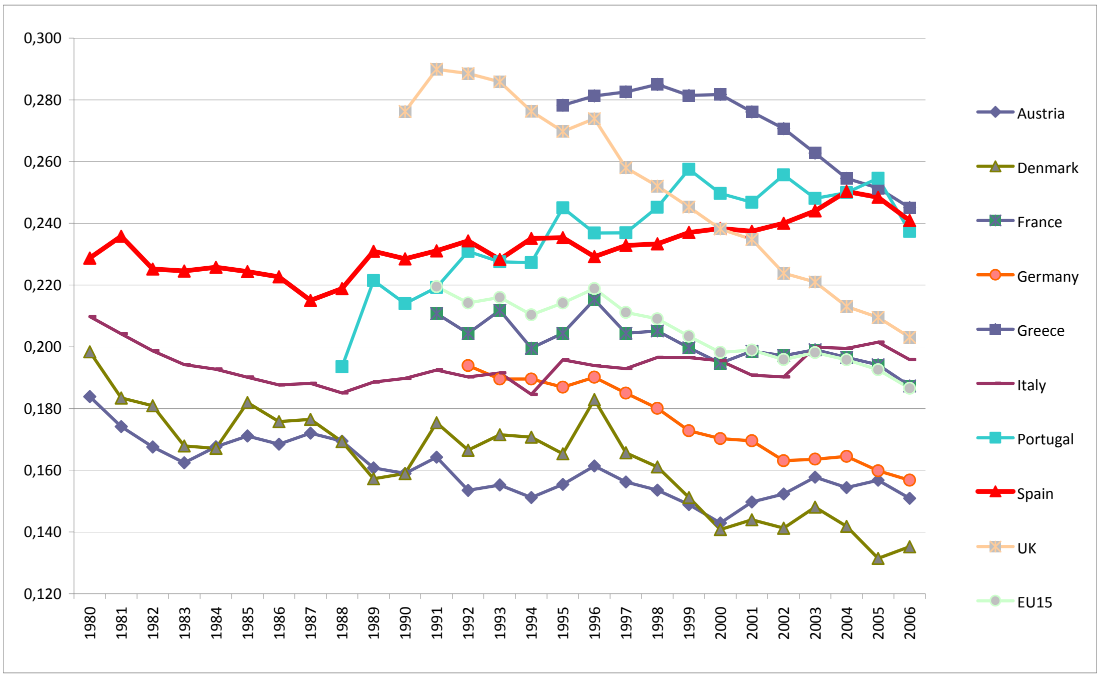
national security, etc. The most widely used monetary indicator is energy intensity (energy consumption per gross domestic product (GDP)), which is considered to be a good measure of the energy efficiency of the economy.

The Spanish case is special in Europe because while most of the European countries have decreased their energy intensity (EI) in the last decades, the Spanish ratio presented the reverse trend increasing by 10% between 1990 and 2006. Also greenhouse gas (GHG) emissions have increased by 54% in the same period and the country imported 80% of its energy needs in 2006. Policy makers and researchers are trying to understand the reasons behind this evolution and take actions to improve the energy efficiency of the Spanish economy.

Figure 1. European energy intensities (ktep/ M€ 95).



Source: IEA Energy Balances (2008), INE (2009) and Eurostat (2009)

In the past years extensive research analyses have been devoted to understanding the evolution of energy intensity and to explain the difference between regions (Sun, 2002; Shäfer, 2005), countries (Alcántara and Duro, 2004) and sectors (Unander et al, 1999). Index decomposition is a widely used methodology for the analysis of energy demand and supply, greenhouse gas emissions, dematerialization, national energy efficiency monitoring and cross-country comparisons (see Ang and Zhang, 2000 and Ang, 2004 for a survey of the research carried out with this methodology).

Previous work on the Spanish energy intensity has been mostly focused on the dematerialization analysis (Ramos-Martin, 2003; Roca and Padilla 2003), the evolution in the manufacturing sectors (Aranda et al, 2003) and sectors aggregates (Mendiluce, 2007). A comparative analysis of the EI evolution in Spain and the EU15 was done previously but only included four sectors: agriculture, manufacturing, construction and services (Marrero et al, 2008).

This article provides a comprehensive comparison of energy intensities between Spain and EU15. We propose a methodology to cover all the sectors of the economy, including the transformation[1], transport and residential sectors, which together consume 70% of the total energy supplied in Spain in 2006. With the analysis of these 16 sectors we can identify key differences both in structure and energy efficiency for the sectors, which would not be seen in the aggregated classification that other authors use.

In this article we compare the evolution of the Spanish energy intensity with the EU15. First, we define the data sources and the methodology. Second, we identify the main differences in energy intensity levels between them. Third, we use the decomposition technique to identify the key drivers of the evolution of their energy intensities, covering all the sectors of the economy and including the residential sector. Fourth, we analyse how each sector affects the difference in energy intensities in the EU15 and Spain in 2006 and we identify which countries have mostly influenced the evolution of the EU15 aggregated energy intensity. Finally, we provide some conclusions and a few recommendations.

1. DATA AND METHODOLOGY

Energy intensity is calculated for the 16 sectors for which homogeneous data is collected. Energy data comes from the energy balances, compiled by the International Energy Agency (IEA, 2008). Time series starting only in 1995 for the EU15 for Gross Value Added (GVA) are available for 1995 to 2004 in the Eurostat

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[1] The transformation sector includes the energy consumed by the electricity sector (79% of the total), refineries (17%) and other energy processes. The energy consumption includes own use and transformation and distribution losses.

Macroeconomic aggregates at constant prices, breakdown by 31 branches in million euro (at 1995 prices and exchange rates) and for 2005 and 2006 we estimate values with the chain level series (EUROSTAT, 2009).[2] The collection of GVA data is challenging because Eurostat regularly updates time series which affects results depending on when data was retrieved. When comparing the National Accounts published in Eurostat with the ones published by the Instituto Nacional de Estadística (INE, 2009) that follow Eurostat methodology, we realise that Eurostat increases the sectors GVA with a fixed percentage that represents taxes and FISIM.[3] We believe that both elements should not be included when analysing energy intensities, but we cannot obtain that information for the EU15. This affects the comparison between Spain and the EU15 in absolute terms but because the percentage stays stable the comparison of the evolution of indicators still provides valuable information on the trends.

When calculating energy intensities we make some assumptions. First, EI is calculated using data on GVA in constant euro with 1995 as a base year for the 15 productive sectors, to prevent inflation from modifying the results. However, when comparing countries it would be more appropriate to use the indicator adjusted to the purchasing power parity (PPP). We cannot use those values because the OECD only publishes them for the consumption sectors but not for productive sectors (OECD, 2002). However we show in table 4 the decomposition of the aggregate energy intensity adjusted to the PPP. Second, we use total primary energy supply (TPES) excluding non energy use. This means that we will disaggregate EI for all the sectors of the economy, including power generation, refinery processing, agriculture, industry, transport, services and residential sectors. Because energy consumption in the industry sector represents only 20% of the Spanish TPES, analysing the whole

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[2] In order to assess the dynamics of economic development irrespective of price movements, the national accounts shows GVA valued in prices of a previous "base" period, which traditionally has been a fixed year. In our analysis the fixed year has been "constant prices for the base year 1995". However recently, Eurostat has modified the reporting of national accounts to improve the volume data in view of rapidly changing price structures. From 2005 onwards a time series of volumes is obtained by multiplying successive growth rates at previous year's prices starting from an arbitrary reference year's level. As a consequence the base year is moving ahead with the observation period, providing a chain-linked series (Eurostat, 2009).

[3] Financial intermediation services indirectly measured (FISIM) is an indirect measure of the value of financial intermediation services provided but for which financial institutions do not charge explicitly.

demand should provide useful conclusions. As far as the authors are aware this is the first time this comprehensive analysis of energy use is done for Spain, because most of the studies concentrate on the industrial sectors and rarely on all the productive sectors, and always excluding the energy sector. Third, national energy balances do not provide the breakdown of transport data between freight and passengers. As a consequence the intensity ratio is overestimated because it is divided by the GVA from commercial transport and also includes GVA from the communication sector. In the case of Spain almost half of the energy consumed for transport is used by private cars.

We use a decomposition technique to analyse energy intensities. This methodology has been used to quantify the impact of structural change in industrial production since the early 1980s. The concept is similar to using index numbers to study contributions of quantity and price levels to changes in aggregate consumption.

Among the different methods for decomposing the aggregate energy intensity we have selected the Logarithmic Mean Divisia Index (LMDI), because it has several advantages: it gives perfect decomposition, i.e. the results do not contain an unexplained residual term; it can be applied to more than two factors; there is a simple relationship between multiplicative and additive decomposition; and it is consistent in the aggregation. Estimates of an effect at the sub-group level can be aggregated to give the corresponding effect at the group level, a property useful for our analysis that contains sub-groups of industry activities (Ang, 2005).

The variables for the disaggregation of energy intensity for the year t are:

E_t = Total primary energy supply (TPES).

$E_{i,t}$ = Energy consumption in sector i.

E_R= Energy consumption in households.

Y_t = Total GDP.

Y_{it} = Gross Value Added (GVA) in sector i.

$S_{i,t}$ = Percentage of sector i in GDP (=Y_{it}/Y_t).

I_t = Energy intensity EI aggregated (=E_t/Y_t).

$I_{i,t}$ = Energy intensity of sector i (=$E_{i,t}/Y_{i,t}$).

D_{tot} = Variation of total energy intensity (EI).

D_{str} = Variation of EI due to the structural effect.

D_{int}= Variation of EI due to the intrasectoral effect.

D_{resid}= Variation of EI due to the residential effect.

Equation (1) describes the change in primary energy intensity: energy consumption (E_T) per GDP (Y_T) as a function of energy intensity per sector ($E_{i,t}/Y_{i,t}$), where the index i corresponds to the economic sectors – energy, agriculture, industry, services and transport -, sector shifts in value added ($Y_{i,t}/Y_T$) in the economy and changes in the residential energy intensity (E_R/Y_T).

$$\frac{E_T}{Y_T} = \sum \frac{E_{i,t}}{Y_{i,t}} \frac{Y_{i,t}}{Y_T} + \frac{E_R}{Y_T} \quad (1)$$

Decomposition analysis can be used to analyze the evolution of EI and to identify the contribution of structural changes (D_{str}), the improvements in the energy efficiency of the sectors or the intrasectoral effect (D_{int}) and the residential sector effect (D_{resid}). The structural effect quantifies the influence of different productive structures in the aggregated ratio. This is useful because the productive specialization in certain actives that require more energy are sometimes responsible for the evolution of EI. The intrasectoral effect captures the energy efficiency at the level of disaggregation determined by the time series used, which is independent from the changing structures in the economy. When applying this technique, the effect of structural changes is always underestimated because the limited disaggregation of the National Accounts and energy balances. This leads to a higher intra-sectoral effect caused by the structural changes within the productive processes that are included in each sub sector. However, in our model we are minimizing that effect because we are providing the highest level of disaggregation available.

Finally, the residential effect quantifies the evolution of the household energy consumption when compared to the total GDP of the country. The inclusion of the residential sector allows a complete disaggregation of the energy intensity ratio.

In the LMDI multiplicative decomposition the relative change in the aggregate energy intensity is expressed in terms of indices that are related multiplicatively:

$D_{tot}=D_{str}*D_{int}*D_{resid}$

where the three effects can be calculated as follows (see Ang et al. 2003 for a detailed description of the formulation):

$$D_{str} = \exp\left[\sum_i W_i' \ln(S_{i,T} / S_{i,0})\right]$$

$$D_{\text{int}} = \exp\left[\sum_i W_i' \ln(I_{i,T} / I_{i,0})\right]$$

$$D_{resid} = \exp\left[\sum_i W_i' \ln(E_{R,T} / Y_T)/(E_{T,0} / Y_0)\right]$$

Since we are using discrete data, we calculate the weight (Wi'), a value between 0 and T, using the logarithmic mean between energy per sector by total GDP and total energy intensities (Ang, 2005):

$$W_i' = \frac{L(E_{iT} / Y_T, E_{i,0} / Y_0)}{L(E_T / Y_t, E_0 / Y_0)}$$

where

$$L(x,y) = (y - x) / \ln(y / x) \, .$$

Results from multiplicative decomposition can be easily transformed in additive form and vice versa (Ang, 2004). In the following sections we present results in additive form to facilitate the interpretation of results so that $D_{tot}=D_{str}+D_{int}+D_{resid}$

LMDI methodology can be used to disaggregate EI in a country between two periods of time for the three considered effects. But it can also be used to calculate which economic sector has contributed most to the difference of energy intensities in two countries in one year. Also, the methodology can be used to calculate how much each country is contributing to the change of energy intensity of the EU15 between any two years.

Some of the drawbacks of the EI ratio are that: GDP sometimes is underestimated because it does not include the "underground economy"; the lack of a breakdown of transport statistics, both in terms of energy consumption between freight and passenger, and in terms of GVA between Transport and Communication; and finally, the continuous revision and update of the Eurostat National Accounts, which difficults the comparison of numerical results with other analysis.

2. COMPARISON OF ENERGY INTENSITIES PER SECTOR IN THE EU15 AND SPAIN

Energy intensities in EU15 decreased by -27,7 tep/M€ (or -13%) between 1995 and 2006 and the largest reductions occurred in Sweden (-36,8%) and United Kingdom (-

24,7%). In absolute terms, in 2006 the lowest energy intensities took place in Denmark (135 tep/M€), Austria (151 tep/M€) and Germany (157 tep/M€), while Spain (241 tep/M€) and Greece (245 tep/M€) had the highest energy intensities (Figure 1).

Table 1 shows the energy intensities per sector in Spain and EU15 in 1995 and 2006. The analysis of their evolution can lead to three main conclusions: the evolution of the economic structure could drive the difference between energy intensities in Spain and the EU15; the tertiary and residential sectors in Mediterranean countries have lower energy intensities due to moderate temperatures, but EI is increasing; and, even if the Spanish industry showed improvements in the eighties and early nineties, the trend has reversed in 1995 and differs widely with the EU15 evolution.

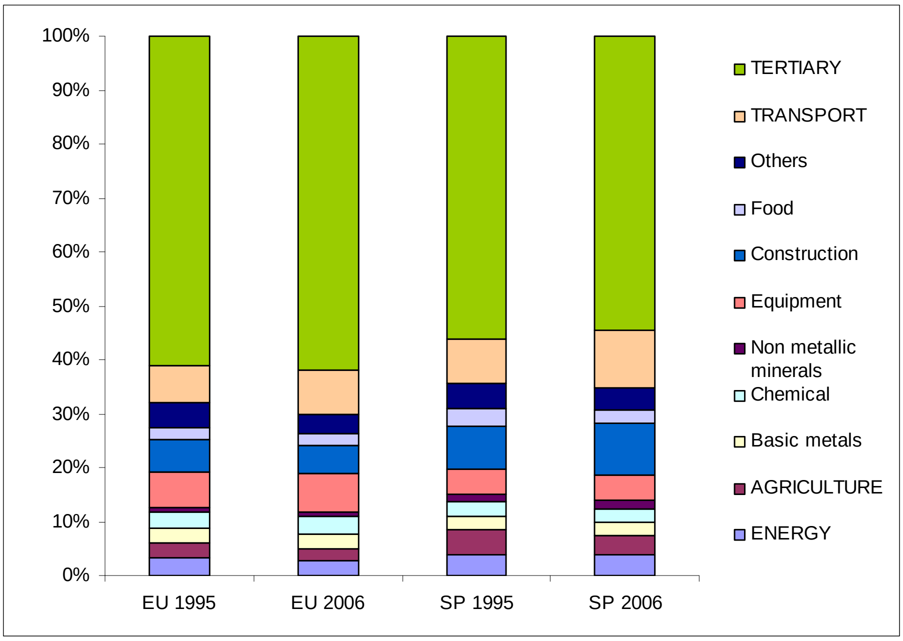
Table 1. Energy intensities by sectors in EU15 and Spain (tep/M€).

	EU15			SPAIN			Difference 2006
	1995	2006	%	1995	2006	%	Spain/EU15
ENERGY	2.103	2.068	-2%	2.052	1.826	-11%	-12%
AGRICULTURE	142	125	-12%	118	142	21%	13%
INDUSTRY	152	136	-11%	182	190	4%	40%
Basic metals	267	218	-18%	399	397	-1%	82%
Chemical	253	180	-29%	327	349	7%	94%
Non metallic minerals	562	531	-6%	686	754	10%	42%
Equipment	122	93	-24%	68	78	15%	-17%
Mining	230	222	-4%	262	306	17%	38%
Food	159	154	-3%	157	188	20%	22%
Paper	241	253	5%	218	251	15%	-1%
Wood	149	156	5%	80	316	294%	102%
Construction	13	13	0%	6	8	25%	-41%
Textile	106	111	5%	160	166	4%	49%
Others	474	686	45%	610	413	-32%	-40%
TRANSPORT	684	514	-25%	783	684*	-13%	33%
TERTIARY	29	30	2%	21	26	24%	-12%
RESIDENTIAL	38	32	-16%	25	26	5%	-20%
TOTAL	214	187	-13%	235	241	2%	29%

* In 2006, Spanish freight energy intensity was 748 tep/M€ (excluding the communications GVA) and residential transport energy intensity was 24 tep/M€.

The comparison of economic structures (Figure 2) shows that an important percentage of the Spanish economic output is produced in energy intensive industries. Construction activities has a higher share of GDP in Spain (9,4%) than in EU15 (5,2%). This is connected to the strong investments in infrastructures, houses and summer residences during the Spanish housing boom which pushes the energy demand in other sectors (Alcántara and Duro, 2004) in detriment of the tertiary sector. Transport has also a higher share of GDP, although these figures might be distorted as mentioned before.

Figure 2. Breakdown of GVA in the EU15 and Spain



Source: Eurostat (2009) and INE (2009).

Energy intensities in the residential and service sectors are lower in Mediterranean countries due to climatic conditions mainly but also to different occupational levels. However they are converging to EU15 levels and, in the Spanish case, there are some symptoms of inefficiency in their energy use. One of the reasons behind this evolution is that higher temperatures and therefore lower energy heating needs do not encourage the introduction of more efficient heating systems and home insulation in Mediterranean countries. On the other hand they present higher cooling needs and a specialization in tourism activities, which have higher energy intensity ratios.

In the industrial sectors, Spanish energy intensities are much higher than in the EU15, especially in non metallic minerals (42%), basic metals (82%) and chemicals (94%). The production of these materials has an important energy efficiency improvement potential according to the Spanish Strategy on Energy Efficiency (E4, 2003). One of the reasons behind the difference in the ratios might be that the sector specializes in activities that require more energy. For example, in the case of non metallic minerals and basic metals, a large part of their markets and growth is linked to construction, that pulled the demand of materials (cement, metals, etc) with high energy intensity levels (e.g cement production needs 2.000 tep/M€ and steel production needs 878 tep/M€). Per capita cement production in Spain doubles EU15 (1.126 kg versus 527 kg)[4] and steel consumption per capita has also strongly increased (348 kg in 1997 to 527 kg in 2008[5]). The combination of two effects occurs in the two sectors: greater contribution to the Spanish GDP and the aggregated EI ratio, and higher energy intensity because they concentrate in activities that require more energy.

3. DECOMPOSITION ANALYSIS OF ENERGY INTENSITIES

Table 2 shows the results of the decomposition of energy intensities in the EU15 and Spain between 1995 and 2006 with the LMDI methodology in its additive form. The "TOTAL" column reflects the variation of energy intensities (D_{tot}), which is the sum of the structural effect (D_{str}), the intrasectoral effect (D_{int}) and the residential effect (D_{resid}), as defined before. The structural (or intra sectoral) effect represents the sum of the structural (or intrasectoral) effect of the 15 sectors. The column "%" refers to the per cent contribution of both effects, for any given sector, to the total variation of total energy intensity.

It is important to understand that we are analysing the combined structural and intensity effect per sector. For example, transport has improved its energy intensity (-13%) but because it is contributing more to the GDP it would push the total energy intensity (+7,1 tep/M€).

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[4] Spanish Cement Association (OFICEMEN)

[5] Spanish steel association (UNESID)

Table 2. Decomposition of energy intensities in Spain and the EU15 between 1995 and 2006 (tep/M€)

	EU15					SPAIN				
	Str	**Int**	**Resid**	**Total**	**%**	**Str**	**Int**	**Resid**	**Total**	**%**
ENERGY	-10,8	-1,0		-11,9	43%	1,5	-8,8		-7,3	-131%
AGRICULTURE	-0,5	-0,4		-1,0	3%	-1,6	1,0		-0,6	-10%
INDUSTRY	-2,0	-4,1		-6,1	22%	0,7	2,1		2,8	50%
Basic metals	-0,4	-1,3		-1,7	6%	0,1	-0,1		0,1	1%
Chemical	0,5	-2,3		-1,8	7%	-0,3	0,6		0,2	4%
Non metallic minerals	-0,5	-0,3		-0,8	3%	1,4	1,1		2,5	44%
Equipment	0,4	-1,1		-0,7	3%	-0,1	0,5		0,4	7%
Mining	-0,1	0,0		-0,1	0%	-0,1	0,1		0,0	0%
Food	-0,6	-0,1		-0,7	2%	-1,0	0,9		-0,1	-2%
Paper	-0,7	0,2		-0,5	2%	0,2	0,5		0,8	14%
Wood	-0,1	0,0		0,0	0%	-0,1	1,1		1,0	18%
Construction	-0,1	0,0		-0,1	0%	0,1	0,1		0,2	4%
Textile	-0,5	0,1		-0,5	2%	-1,0	0,1		-0,9	-16%
Others	-0,8	1,5		0,8	-3%	0,3	-1,6		-1,3	-24%
TRANSPORT	9,3	-12,6		-3,3	12%	16,3	-9,2		7,1	126%
TERTIARY	0,2	0,4		0,6	-2%	-0,4	2,8		2,5	44%
RESIDENTIAL			-6,0	-6,0	22%			1,2	1,2	21%
TOTAL	**-4,7**	**-16,9**	**-6,0**	**-27,7**	**100%**	**15,3**	**-10,9**	**1,2**	**5,6**	**100%**

The largest difference per sector comes from the evolution of the transport and residential sectors. The transport sector increases EI in Spain (+7,1tep/M€) while reduces it in the EU15 (-3,3 tep/M€). The main reason behind the Spanish evolution is the strong increase in road mobility which demanded 50% more energy between 1995 and 2006, both in freight (+55%) and passenger cars (+41%). In the case of freight, the geographic characteristics, the strong activity in construction and trade of agricultural and food products (demanding 53% of the freight transport) and the demand of fast supplies for short distances (delivered by more inefficient light trucks) have deteriorated its energy intensity. Increase in freight demand is delivered mainly through road transport (around 80%) and no improvements in the vehicle efficiency (consumption per kilometre) have been achieved in this period.

As regards passenger cars, the raise is linked to an increase in population (+12%) and per capita income (+28%), the move towards a more disperse urbanization model and the favourable fiscal treatment of diesel fuel, which has resulted in a rebound effect and an increase in the travelled distance. Between 1995 and 2004 diesel cars increased their travelled distance by 6%, while gasoline cars decreased it by 11% However, per capita transport in Spain is still below the average EU level (11.200 km versus 14.000 km in 2003) (Mendiluce, 2008).

The improvement in heating systems and the use of waste heat are behind the EI reductions in the EU15 residential sector (-6 tep/M€), while the Spanish households are increasing their energy demand and converging to EU levels. The reasons behind this evolution lie in changes in urban planning and urbanization; increase in population, employment and per capita income, which enhanced convergence towards European behaviour and equipment levels; finally, the delay in the approval of a more strict Building Code, which came into force in 2007, when the construction activity had already started to slow down, and low energy prices in Spain might have also contributed to inefficient consumption in households and also in the tertiary sector.

The different evolution of the sectors has resulted in a differential with the EU15 of 54 tep/M€ in 2006. We propose using the decomposition technique to analyse this gap and to find out how each sector and each effect has contributed to that difference. The formulation is the same as in the previous exercise, but instead of calculating the difference in EI within a country between 1995 and 2006, we calculate the difference between the Spanish and the EU15 energy intensities in the year 2006. The results are shown in Table 3.

Table 3. Decomposition of the difference between 2006 energy intensities in Spain and EU15 (tep/M€).

	Str	Int	Resid	Total	%
ENERGY	23,2	-7,9		15,3	28%
AGRICULTURE	1,5	0,5		2,0	4%
INDUSTRY	4,4	14,2		18,6	34%
Basic metals	-0,2	4,5		4,3	8%
Chemical	-1,7	4,9		3,1	6%
Non metallic minerals	5,3	2,8		8,2	15%
Equipment	-1,5	2,0		0,4	1%
Mining	0,1	0,2		0,3	1%
Food	0,9	0,8		1,7	3%
Paper	0,1	0,0		0,1	0%
Wood	0,0	0,7		0,7	1%
Construction	0,4	-0,4		0,0	0%
Textile	0,2	0,5		0,7	1%
Others	0,9	-2,0		-1,1	-2%
TRANSPORT	13,2	16,0		29,2	54%
TERTIARY	-2,0	-2,2		-4,2	-8%
RESIDENTIAL			-6,4	-6,4	-12%
TOTAL	**40,5**	**20,3**	**-6,4**	**54,4**	

We confirm that transport and industry account for most of the difference. The former contributes with more than half of the difference; unfortunately the lack of data on the disaggregation of freight and residential transport does not help in explaining the main differences. In the case of the industrial sectors, the main difference comes from non metallic minerals and basic metals, which as mentioned before are strongly linked to the strong construction activity in Spain. The worsening of the intrasectoral effect in basic metals and chemicals is a matter of concern. It is worth mentioning that highly intensive energy sectors benefited from special electricity tariffs until 2006. However we believe that part of this intrasectoral effect is determined by structural reasons (the type of product being produced). The sector structural component is captured in the model and might be explained because many EU15 countries have already built their main infrastructures and buildings, while Spain has had a booming construction period, both in residential, second homes and infrastructures (road and railway systems). Therefore the EU15 activities in these sectors do not contribute as much to GDP, nor does the range of construction products included in these production activities, which are mostly driven by other high value added products and activities. This can also be interpreted as a signal of the minor weight of the service sector in the Spanish economy, which also shows –with respect to the EU– a different level of economic development.

4. KEY COUNTRIES IN DRIVING THE EU15 ENERGY INTENSITY

When comparing countries with different energy supplies, diverse degree of economic specialization, and different size, it is important to distinguish how much of the overall evolution of an aggregate is due to the evolution of specific countries. Finding those key countries will help in identifying successful energy policies, and will be also useful to assess if the Spanish case is an exception.

We can also use the referred LMDI technique to decompose the change in energy intensity in the EU15 between countries (D_{tot}) in a period of time between two effects, the structural change (D_{str}), which reflects how changes in each country's GDP affect the total GDP, and the intensity effect (D_{int}), which reflects how each country's energy intensity affects the EU15 energy intensity. Since we are only decomposing aggregate energy intensities, we can use the ratios adjusted to the purchase power parities of each country. We use the IEA total energy supply without non energy use divided by the GDP in million dollars of 2000 adjusted to the power purchase parities (tep/M USD PPP). Therefore these results cannot be compared in magnitude with the previous sections, although they show similar trends.

The energy intensity in EU15 can be decomposed into these two effects:

$$\frac{E_{EU,T}}{Y_{EU,T}} = \sum_{c} \frac{E_{c,T}}{Y_{c,T}} \frac{Y_{c,T}}{Y_{EU,T}}$$

where $E_{EU,T} = \sum_{c} E_{c,T}$, $Y_{EU,T} = \sum_{c} Y_{c,T}$ and c represents each EU15 country.

In the multiplicative decomposition the relative change in the EU15 aggregate energy intensity is expressed in terms of indices related multiplicatively, $D_{tot}=D_{str}*D_{int}$ and the two effects, as mentioned before, are:

$$D_{str} = \exp\left[\sum_{c} W_{c}' \ln\left(\frac{S_{C,T}}{S_{C,0}}\right)\right] \text{ and } D_{\text{int}} = \exp\left[\sum_{c} W_{c}' \ln\left(\frac{I_{C,T}}{I_{C,0}}\right)\right]$$

where again we calculate Wc' as an approximation of the value between 0 and T:

$$W_C' = \frac{L(E_{c,T}/Y_{EU,T}, E_{i0}/Y_{EU,0})}{L(E_{EU,T}/Y_{EU,T}, E_{EU,0}/Y_{EU,0})}$$

We show again the results in the additive form in table 4. The row “str” shows the effect on energy intensity due to the change in the countries´ economic structure and how it influences the EU15 aggregated energy intensity. The row “int” refers to the changes in the country’s energy intensity and how it affects the total. The “total” row is the addition of both effects and the influence of each country on the total is calculated in the percentage row.

The main conclusion is that 61% of the energy intensity reduction in the EU15 is due to improvements in Germany (37%) and UK (24%). Most of the changes come from the intensity effect, while the changes in the economic structure are minor.

Table 4. Decomposition of energy intensities in the EU15 between 1995 and 2006 (tep/MUSD 2000 PPP).

	Str	Int	Total	%
Austria	0,0	0,0	0,0	0%
Belgium	-0,1	-1,0	-1,0	4%
Denmark	0,0	-0,4	-0,5	2%
Finland	0,6	-0,6	0,0	0%
France	-0,3	-3,7	-4,0	16%
Germany	-3,7	-5,3	-9,0	37%
Greece	0,5	-0,4	0,1	0%
Ireland	0,7	-0,6	0,1	-1%
Italy	-2,0	-0,4	-2,4	10%
Luxembourg	0,1	-0,1	0,0	0%
Netherlands	0,3	-1,7	-1,3	5%
Portugal	0,0	-0,2	-0,2	1%
Spain	2,1	-1,1	0,9	-4%
Sweden	0,5	-1,8	-1,3	5%
United Kingdom	1,5	-7,3	-5,8	24%
Total	**0,1**	**-24,6**	**-24,5**	

In the case of Germany, the energy intensity between 1995 and 2006 decreased by -16% mainly due to the improvements in the energy (50%), transport (21%) and residential (25%) sectors. The energy sector reduced its energy intensity because electricity demand only increased by 18% and was covered by more efficient energy sources: renewable energies (growing from 9.415 GWh in 1995 to 54.265 GWh in

2006) and natural gas (contributing with 43.180 GWh in 1995 and 76.077 GWh in 2006)[6]. In the residential sector, changes in energy supplies were also behind the positive evolution. In fact energy demand was reduced in this period thanks to the replacement of coal and oil products by renewable energies, natural gas and heat.

The case of the UK energy intensities is, in general, similar. The electricity generation only increased by 19% and moved towards cleaner and more efficient energy sources (although renewables do not show such an impressive growth). But the main driver of energy intensity reductions in the UK is the spectacular growth in the transport GVA (most probably due to the inclusion in this category of the telecommunication business, which do not consume as much energy as transport) and in the tertiary services, with lower energy intensities.

Spain followed a similar behaviour in the electricity generation mix, improving its energy intensity ratio as a consequence of a move to more efficient fuels. However this effect is less visible because electricity demand grew by 81% in the period.

The analysis shows that the Spanish case is an exception because it is the only country that pushes EU15 energy intensity upwards (+4%) and it is the only country where the structural effect is driving up its energy intensity in this period.

5. CONCLUSIONS

There are two main drivers in the evolution of energy intensities: changes in the economic structure and changes in the sectors’ energy intensity. The numerical results show that the Spanish economic structure is driving the divergence in energy intensity ratios with the EU15. The structural effect in the transport and energy sectors is responsible for two thirds of the difference with the EU15. In the case of energy this effect is partially compensated by an improvement in its energy intensity. In the case of transport both effects –structure and in energy intensity– increases the EI and the disparity with the average EU15.

This conclusion cannot be obtained from the conventional analysis of energy intensities, because authors generally focus the analysis in the industry sector, and therefore missing the contribution from 70% of the energy demand to EI.

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[6] In the IEA Energy Balances the electricity generation efficiency in Germany was 38% for coal, 45% for gas and 100% for renewable energies.

Besides the strong growth in the demand for transportation, at a finer level of detail, the Spanish energy intensity has increased because of the large volume of activities with relatively higher energy intensities associated to the construction sector, the tertiary activities connected to tourism and the increment in energy demand from households, due to the escalation in per capita income and population.

The EU15 evolution is driven by improvements in the German and the UK energy intensities due to policies that encourage energy efficiency and the move towards more efficient fuels in power generation (renewable energies and natural gas); reduction in household energy demand, thanks to the introduction of most efficient heating systems; and the increase in the economic activity of low energy intensity activities (communications, tertiary).

All the above suggests that improvements in the Spanish energy intensity could be achieved by structural shift away from energy intensive production to high value added activities. This could be achieved through more efficient energy pricing and removing subsidies to inefficient industries. The slow down of the construction sector in Spain, together with the restructuring of some industries will have a positive effect in terms of energy intensities in the forthcoming years.

Several studies demonstrate the potential for further increase the penetration of renewable energies both in the power sector, transport and buildings, which will require tailored policy approaches. In the case of the building sector, there is a need to adopt a holistic approach to encourage integrated design approaches, strengthen building codes and energy labelling, use subsidies and price signals to incentivize energy-efficient investments, develop workforce capacity for energy saving in buildings and educate society in an energy efficiency culture. In particular, it is necessary to introduce incentives to retrofit the existent buildings to comply with the highest efficiency levels of the recent building code.

Finally, the transport sector requires urgent and deep reforms both in policies and approaches. These should move from the traditional focus on supply to a demand approach, aiming at a sustainable mobility that meets the user’s needs in an efficient manner. A combination of fiscal reforms in fuel taxation, congestion charges in medium and large cities, more strict vehicle and fuel standards, the promotion of alternatives to road mobility and the scale up of electric vehicles for daily mobility, are some of the measures that could help reverse the unsustainable transport trend.

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