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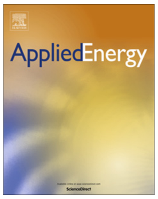

Towards a green energy economy? Tracking the employment effects of low-carbon technologies in the European Union

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HIGHLIGHTS

- The EU's energy transition between 1995 and 2009 created 530,000 jobs in the EU.
- One third of the jobs created in EU were a consequence of spill-over effects.
- In 21 out of the 27 member states the total effect in the employment was positive.
- In Russia and China the impact was positive while in Australia it was negative.

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ABSTRACT

In the view of pressing unemployment and environmental problems, different policies have been proposed to create jobs in the transition to a green economy, including the so-called "green jobs". There has been an intense debate on the quantification of these employment effects, especially in the European Union. Most studies have focused on estimating gross future employment effects and have ignored the effects between different sectors and countries. This paper looks, for the first time, at the past net employment impacts from the transformation of the EU energy sector including spill-over effects, by using a multi-regional input–output model and the World Input–Output Database. The analysis is focused on the period (1995–2009) when the EU's energy structure went through a significant shift, away from the more carbon intensive sources, towards gas and renewables. We estimate the net employment generated from this structural change at 530,000 jobs in the EU (0.24% of total employment in 2009), of which one third is due to trans-boundary effects within the EU (i.e. employment generated in one country due to the changes in another). Within the EU, the main gainers were Poland, Germany, Hungary, Italy and Spain, and the main losers were Ireland, Lithuania, France and Czech Republic.

1. Introduction

There is a great deal of interest in the employment effects resulting from the transition to a low carbon and sustainable economy. The increase in unemployment following the financial crisis of 2007–2008 and the declared commitment of different countries to reduce environmental pressures have led together to the introduction of several policies aimed to create "green jobs" [1,2].

As a prime example, the European Union (EU) has presented recently the Green Employment Initiative [3], a funding mechanism "to help Member States with employment opportunities and challenges in the transition to a greener economy". At the same time, the EU has adopted the Energy and Climate Framework [4] for the year 2030 with the aim of reducing greenhouse gas emissions by 40% (from 1990 levels), a binding target (at EU level) to boost the share of renewables to at least 27% of EU energy consumption, and a 27% improvement in energy efficiency. These types of policies are not new in the EU: in 1997 the EU-15 already committed, within the framework of the Kyoto Protocol, to reduce its greenhouse gas emissions by 8% in the period 2008–2012 with respect the year 1990; and in 2008 the EU climate and energy package agreed a reduction of at least 20% in greenhouse gas emissions by 2020 with a 20% share for renewable energies in energy consumption by that date [5]. In parallel with the imposition of these objectives, different instruments have been deployed [6] such as feed-in tariffs to support the development of renewables, which have been in place for at least two decades [7], and the Emission Trading Scheme, which was launched in the year 2005.

There has been an intense debate on the quantification of the employment effects of these policies. The literature on the employment effects associated with the low-carbon transition and,

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especially, with renewable energy promotion is abundant [8,9]. One estimate [10] suggest that policies supporting renewable sources of energy to meet the 20% target by 2020 would provide 410,000 additional jobs in the EU. Another study by Cambridge Econometrics [11] estimates that the 2050 Road Map [12], which requires a reduction in CO_2 emissions of 80–90% from 1990 levels, would result in an increase in employment ranging from 0% to 1.5%. Similar positive results emerge from more local studies in Europe [13]. They find slightly higher employment in a scenario with more renewables and less fossil fuel energy than the base case. Other studies assessing the potential employment impacts of renewables are [14] for US, [15] for China, [16] for Germany, or [17] for Greece.

All the previous studies have focused on the domestic impacts in a specific country or region, ignoring the trans-boundary effects due to changes in trade flows derived from the transformation in the energy sector of a specific country. This is especially relevant in an increasing globalized world, in which the production inputs are internationally traded. Moreover, most of the studies have focused on the *ex-ante* (predicted) impacts of different policies, rather than on the *ex-post* (confirmed) results of such interventions, something that requires them to make a number of assumptions about the evolution of the economy.

In this paper we use a novel method based on a multiregional input–output model and the World Input–Output Database [18,19] that allows us to estimate for the first time the domestic and foreign employment impacts due to the past changes in the energy sector in the EU. We quantify the impacts in employment in the whole EU27 due to the changes in the electricity and gas supply[1] of each of the member states. We answer the following question: what would have been the EU employment in 2009 if the structure of the electricity and gas supply sector of each EU country had remained the same as in 1995. We estimate the net changes in employment and the gainers and losers at the worldwide level.

The rest of this paper is organised as follows. Section 2 shows the methodology (model and data) and Section 3 presents and discusses the results. Section 4 describes the limitations of the studies and indicates directions for future research, and Section 5 concludes.

2. Materials and methods

Single region input–output methods have been extensively used to assess the employment impacts of different energy technologies including, among others, biofuels [20–23], coal-to-liquids [24], geothermal [25], energy efficiency [26], and renewables [15–17,27–29]. In addition, multiregional input–output models have been used to assess the economic and environmental implications of low carbon transitions [30,31]. In this section we present a multiregional input–output model and database for the calculation of the total employment effects generated by the changes in the electricity and gas supply sector of the EU from a multi-regional perspective.

2.1. The model

The starting point for the construction of the model used is a symmetric multiregional input–output[2] table. This table describes (in monetary terms) the flows of goods and services between all the individual sectors and countries, and the use of goods and services by final users. For the sake of simplicity, we show the structure of the multiregional input–output table for three regions, but it can be expanded for any number of regions and sectors. The three main components in the multiregional input–output table are:

$$\mathbf{Z} = \begin{bmatrix} \mathbf{Z}^{11} & \mathbf{Z}^{12} & \mathbf{Z}^{13} \\ \mathbf{Z}^{21} & \mathbf{Z}^{22} & \mathbf{Z}^{23} \\ \mathbf{Z}^{31} & \mathbf{Z}^{32} & \mathbf{Z}^{33} \end{bmatrix} \quad \mathbf{F} = \begin{bmatrix} \mathbf{f}^{11} & \mathbf{f}^{12} & \mathbf{f}^{13} \\ \mathbf{f}^{21} & \mathbf{f}^{22} & \mathbf{f}^{23} \\ \mathbf{f}^{31} & \mathbf{f}^{32} & \mathbf{f}^{33} \end{bmatrix} \quad \mathbf{x} = \begin{bmatrix} \mathbf{x}^{1} \\ \mathbf{x}^{2} \\ \mathbf{x}^{3} \end{bmatrix}$$

where $\mathbf{Z}^{rs}$ is the matrix of intermediate deliveries from country r to country s, and its element z_{ij}^{rs} denotes the sales of sector i in country r to sector j in country s; $\mathbf{f}^{rs}$ is a column vector with final demands (i.e. private consumption, government consumption and investments) and its element f_i^{rs} indicates the final demand in country s for good i produced by country r; and $\mathbf{x}^r$ is the column vector of gross outputs in country r. Further, the global multiregional input–output table is extended with a vector $\mathbf{e}^r$ with element e_i^r indicating the (national) employment by sector i in country r. We define

$$\mathbf{e} = \begin{bmatrix} \mathbf{e}^{1} \\ \mathbf{e}^{2} \\ \mathbf{e}^{3} \end{bmatrix}$$

The relation between $\mathbf{x}$, $\mathbf{Z}$ and $\mathbf{F}$ is defined by the accounting equation: $\mathbf{x} \equiv \mathbf{Zi} + \mathbf{Fi}$ where $\mathbf{i}$ is the column summation vector (i.e. a vector with ones) of appropriate length.

The multi-regional matrix of input coefficients is defined as: $\mathbf{A} = \mathbf{Z}(\hat{\mathbf{x}})^{-1}$ where $(\hat{\mathbf{x}})^{-1}$ denotes the inverse of the diagonal matrix of the gross output vector. The element a_{ij}^{rs} of $\mathbf{A}$ denotes the inputs from sector i of region r that are used by sector j of region s to produce one unit of output. Thus, we can define the matrix of total input coefficients as $\mathbf{B}$, where the element $b_{ij}^{s} = \sum_r b_{ij}^{rs}$ denotes the inputs from sector i that are used by sector j of region s to produce one unit of output (regardless of the origin country of those inputs).

We define the intermediate trade shares matrix as $\mathbf{T}$ where the element $t_{ij}^{rs} = z_{ij}^{rs} / \sum_r z_{ij}^{rs}$ of $\mathbf{T}$ denotes, for each sector j of country s, the share of inputs that are produced domestically (when $r = s$) or imported (when $r \neq s$).

Therefore, the multi-regional matrix of input coefficients can now be expressed as $\mathbf{A} = \mathbf{T} \circ \mathbf{B}$ (where $\circ$ denotes the element by element multiplication, i.e. Hadamard product).

Finally, the employment coefficients are defined as $\mathbf{c}^r = (\hat{\mathbf{x}}^r)^{-1}\mathbf{e}^r$. Stacking them gives the vector $\mathbf{e}$.

The accounting equation $\mathbf{x} \equiv \mathbf{Zi} + \mathbf{Fi}$, can now be written as the standard input–output model: $\mathbf{x} = \mathbf{Ax} + \mathbf{Fi}$. For arbitrary final demands $\mathbf{F}$ the solution to this model is given by $\mathbf{x} = \mathbf{LFi}$, where $\mathbf{L} \equiv (\mathbf{I} - \mathbf{A})^{-1} = (\mathbf{I} - \mathbf{T} \circ \mathbf{B})^{-1}$ denotes the Leontief inverse, and the employment would be given by

$$\mathbf{e} = \hat{\mathbf{c}}\mathbf{x} = \hat{\mathbf{c}}\mathbf{LFi} = \hat{\mathbf{c}}(\mathbf{I} - \mathbf{T}^{\circ}\mathbf{B})^{-1}\mathbf{Fi} \tag{1}$$

Previous expressions can be applied to data from different years, thus for a specific year t, the employment would be given by

$$\mathbf{e_t} = \hat{\mathbf{c}}_{\mathbf{t}}(\mathbf{I} - \mathbf{T}_t^{\circ}\mathbf{B_t})^{-1}\mathbf{F_t i} \tag{2}$$

Expression (2) can be used to compute the changes in employment due to the changes in the input structure of a specific sector j in region s between two years, $t = 0$ ant $t = 1$. The idea is to re-calculate the employment in the year 1, but with the input structure of the year 0 (for the sector analysed) and all the remain-

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[1] This sector corresponds to the section E of the NACE 1 classification "Electricity, Gas and Water supply"; it covers the production and distribution of electricity, manufacture of gas, distribution of gaseous fuels, steam and hot water supply, and collection, purification and distribution of water.

[2] Notation: Bold-face, lower-case letters refer to vectors; bold-face, capital letters refer to matrices; italic, lower-case letters refer to elements of a vector or matrix; subscripts reveal industry dimension; superscripts reveal country dimension; diagonal matrices are denoted by ^.

ing parameters constant (i.e. employment coefficients, economic structure of other sectors, trade structure and final demand of the year $t = 1$).

Assume that we want to assess the employment effects of the change in the input structure between the years t_0 and t_1 of the electricity and gas supply sector in two of the countries (countries 2 and 3).[3] The input matrices for the years t_0 and t_1 are denoted by $\mathbf{B}_{\mathbf{t}_0}$ and $\mathbf{B}_{\mathbf{t}_1}$, where the element $b^s_{ij,t}$ denotes the inputs from sector i that are used by sector j of region s to produce one unit of output, in the year t. Thus, for countries 2 and 3, the technology of the electricity and gas supply sector in the year t is defined as $b^2_{iEGW,t}$ and $b^3_{iEGW,t}$ (for all i). Thus, replacing in $\mathbf{B}_{\mathbf{t}_1}$ the elements b^2_{iEGW,t_1} by b^2_{iEGW,t_0} and b^3_{iEGW,t_1} by b^3_{iEGW,t_0} (for all i) gives a new matrix $\overline{\mathbf{B}_{\mathbf{t}_1\mathbf{t}_0}}$, representing the input structure of the year t_0 for the electricity and gas supply sector in country 2 and 3, and for all the other sectors and countries the technology of the year t_1.

Thus the change in the employment of the three regions due to the change in the electricity and gas supply of countries 2 and 3 can be calculated as

$$\Delta \mathbf{e}_\mathbf{t} = \widehat{\mathbf{c}_{\mathbf{t}_1}} \left(\mathbf{I} - \mathbf{T}^{\circ}_{\mathbf{t}_1}\mathbf{B}_{\mathbf{t}_1}\right)^{-1}\mathbf{F}_{\mathbf{t}_1}\mathbf{i} - \widehat{\mathbf{c}_{\mathbf{t}_1}}\left(\mathbf{I} - \mathbf{T}^{\circ}_{\mathbf{t}_1}\overline{\mathbf{B}_{\mathbf{t}_1\mathbf{t}_0}}\right)^{-1}\mathbf{F}_{\mathbf{t}_1}\mathbf{i} \tag{3}$$

2.2. The database

We use data from the European Commission FP7-funded World Input–Output Database [18,19]. This database comprises a set of harmonised symmetric input–output tables, valued at current and previous year prices. The World Input–Output Database distinguishes between 35 industries, spans the period 1995 (t_0) to 2009 (t_1) and covers 41 regions: 27 EU Member States, 13 other major countries in the world and the Rest of the World as an aggregated region. It also includes data on international trade and satellite accounts related to various environmental and socio-economic indicators, including the figures for employment by sector and country that we have used in this paper. The World Input–Output Database does not report employment figures for the Rest of the World. We estimate these figures using data from the International Labour Organization and the labour productivity of the World Input–Output Database countries.

In order to use expression (3) to calculate the change in the employment resulting from the change in the electricity and gas supply sector technologies, we proceed as follows. First the multiregional input–output tables in current and previous year prices are used to express the table of 1995 in 2009 prices. This step is necessary in order to keep the effects of changes in prices out of the analysis [32]. When checking the deflators of the gross output in the socioeconomic accounts of the World Input–Output Database we found that the figures for Bulgaria and Romania were not consistent with EUROSTAT data and so we decided to keep these two countries out of the analysis. Therefore the analysis was limited to the changes in the electricity and gas supply sector of the remaining 25 member states, which, in 2009, represented more than 98% of the EU GDP and 97% of the total primary energy supply.

Given the multiregional input–output tables of 1995 in 2009 prices, we calculated, for the (25) EU countries, all the technical coefficients of the electricity and gas supply sector (sector 17[4] in the World Input–Output Database) for the year 1995 at 2009 prices. Then, we replaced the total technical coefficients of the electricity and gas supply of the EU countries in 2009 by these total coefficients of 1995 at 2009 prices, which results in the $\overline{\mathbf{B}_{t_1t_0}}$ expression (3).

3. Results and discussion

During the period 1995–2009 the energy system of the EU suffered a series of transformations, characterized by an increase in the share of renewables and gas in the total primary energy supply and, especially, in the electricity and heat input mix (Fig. 1a and b).[5] According to the energy balances of the International Energy Agency [33], the contribution of gas to the total energy supply in the EU27 increased from 20% in 1995 to 25% in 2009, while renewables went up from 5% to 10% (Fig. 1a). On the contrary, coal reduced its share in the total primary energy supply from 22% in 1995 to 16% in 2009, and oil, although remaining the main component of the total primary energy supply, reduced its contribution to the energy mix from 38% to 35%. The share of nuclear energy in the total primary energy supply remained constant (14% in both years).

In the case of the electricity mix (Fig. 1b), the share of gas and renewables increased notably, from 11% and 13% respectively in 1995 to 24% and 19% in 2009. In 2009 nuclear energy was still the main source for heat and power generation in the EU (28%), but showed a decline with respect the levels of 1995 (32%). Coal fuelled technologies reduced their contribution to the mix from 35% in 1995 to 26% in 2009 and the share of oil decreased from 9% to 3%. In parallel, the transformation efficiency, measured as the quotient between the electricity and heat generation divided by the energy inputs, increased by 3 percentage points, from 37% to 40% (Fig. 1b). Detailed data at the country level can be found in Fig. A.1 of the Appendix A.[6] This increase was mainly driven by the growth in the transformation efficiency in gas powered plants (from 36% to 46%) due to the penetration of integrated gasification combined cycle technology. On the contrary, the transformation efficiency of renewables fell from 73% to 60%, due to the increase in the share of renewables electricity from biomass, biogas and waste, which have lower transformation efficiency than other renewables such as hydropower, solar or wind. All these changes contributed to reduce the emissions of CO_2 in the EU [34].

These changes in the energy system also had some impact on the input structure of the electricity and gas supply sector of the EU. Comparing these structures for the years 1995 and 2009 (see Table 1), we observe that in both years, inputs coming from the "Mining and Quarrying" (mainly from coal mining)[7] sector and the own "Electricity and gas supply" (mainly from gas supply) accounted for almost 60%. Other relevant sectors supplying inputs to the electricity and gas supply are "Renting of Machinery and Other Business Activities", "Construction", "Coke, Refined Petroleum and Nuclear Fuel", "Wholesale Trade" or "Financial Intermediation". Although this overall picture has not changed much between 1995 and 2009, we can see modifications in the patterns of use of some

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[3] Note that in our case study, countries 2 and 3 would be replaced by the 27 MS of the EU and country 1 by the other 14 regions of the World Input-Output Database.

[4] Sector 17 in the World Input–Output Database database includes also water supply. Unfortunately, it is not possible to separate out that component but it is very small and almost all the changes can be attributed to electricity and gas production. Hence, we feel it is reasonable to refer to it as the electricity and gas supply sector for the purposes of this analysis.

[5] The electricity and heat mix include the following transformation technologies: Main activity electricity plants (IEA code: MAINELEC), Autoproducer electricity plants (AUTOELEC), Main activity combined heat and power plants (MAINCHP), Autoproducer heat and power plants (AUTOCHP), Main activity heat plants (MAINHEAT) and Autoproducer heat plants (AUTOHEAT).

[6] As noted, major changes in the energy mix occurred in the analyzed period (1995–2009). From 2009 to 2014, the main change has been the increase in renewables at the expense of gas, of 3% in the primary energy supply and of 8% in the electricity mix.

[7] This sector covers the extraction of fossil fuels and other metallic and nonmetallic minerals. In the case of fossil fuel extraction in the EU, coal dominates over gas and oil.

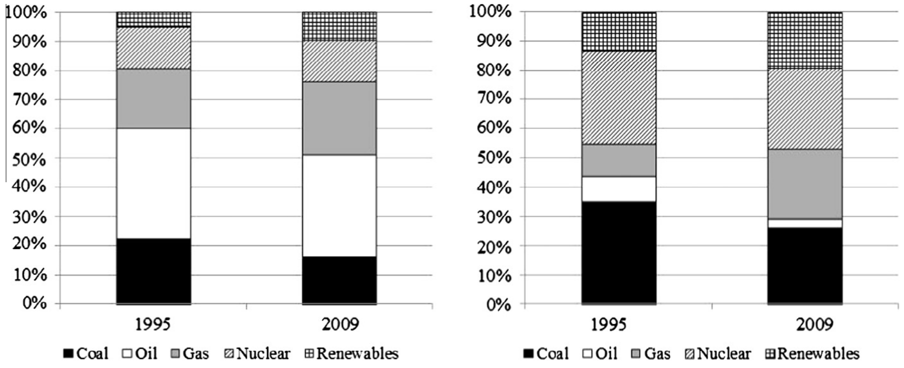

Fig. 1. Total primary energy supply and electricity and heat generation mix in the EU27, 1995 and 2009 (%). *Source:* International Energy Agency.

Table 1
Intermediate input structure of the electricity and gas sector in the EU, 1995 and 2009 (%). *Source:* Own elaboration based on data from the World Input–Output Database.

Code	Sector	1995	2009	2009–1995
c1	Agriculture, hunting, forestry and fishing	0.1	0.2	0.1
c2	Mining and quarrying	25.7	22.1	−3.6
c3	Food, beverages and tobacco	0.1	0.1	0.0
c4	Textiles and textile products	0.1	0.0	0.0
c5	Leather, leather and footwear	0.0	0.0	0.0
c6	Wood and products of wood and cork	0.1	0.2	0.1
c7	Pulp, paper, paper, printing and publishing	0.5	0.4	−0.1
c8	Coke, refined petroleum and nuclear fuel	4.8	2.9	−1.9
c9	Chemicals and chemical products	0.6	0.7	0.1
c10	Rubber and plastics	0.3	0.3	0.0
c11	Other non-metallic mineral	0.3	0.3	0.0
c12	Basic metals and fabricated metal	2.0	1.7	−0.4
c13	Machinery, nec	1.2	1.4	0.2
c14	Electrical and optical equipment	1.7	2.3	0.6
c15	Transport equipment	0.2	0.2	0.0
c16	Manufacturing, nec; recycling	0.1	0.2	0.1
c17	Electricity, gas and water supply	30.8	36.0	5.2
c18	Construction	5.3	4.0	−1.3
c19	Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of fuel	0.5	0.7	0.1
c20	Wholesale trade and commission trade, except of motor vehicles and motorcycles	2.8	3.5	0.7
c21	Retail trade, except of motor vehicles and motorcycles; repair of household goods	1.7	1.6	−0.1
c22	Hotels and restaurants	0.3	0.3	0.0
c23	Inland transport	2.4	2.8	0.4
c24	Water transport	0.0	0.1	0.1
c25	Air transport	0.1	0.1	0.0
c26	Other supporting and auxiliary transport activities; activities of travel agencies	0.8	0.7	−0.2
c27	Post and telecommunications	0.6	1.1	0.4
c28	Financial intermediation	3.6	2.8	−0.8
c29	Real estate activities	1.3	1.3	−0.1
c30	Renting of machinery and other business activities	8.0	8.7	0.7
c31	Public admin and defence; compulsory social security	2.6	1.6	−1.0
c32	Education	0.2	0.2	0.1
c33	Health and social work	0.1	0.1	0.0
c34	Other community, social and personal services	0.8	1.4	0.6
c35	Private households with employed persons	0.0	0.0	0.0
		100.0	100.0	

Note: the intermediate input structure represent the share of the total intermediate inputs of the electricity and gas supply sector of the EU that is demanded from each (row) sector, regardless the country where this supplying sector is located. It has been calculated by summing the intermediate inputs of the electricity and gas supply sector of all the EU member states and dividing them by the total intermediate input of the electricity and gas supply sector.

specific inputs. For instance, the reduction in the use of coal in the electricity sector generated a decrease in the share of inputs from the "Mining and Quarrying" from 25.7% in 1995 to 22.1% in 2009. Similarly, the increase in the use of gas translated into an increase in the share of intermediate inputs from the own "Electricity and gas supply" sector, passing from 30.8% in 1995 to 36% in 2009. Furthermore, the reduction in the share of oil and nuclear energy in the electricity sector can also be observed in the decrease in the intermediate inputs from the "Coke, Refined Petroleum and Nuclear Fuel" (from 4.8% in 1995 to 2.9% in 2009).

The changes in the energy system and in the input structure of the electricity and gas supply in each member state have also been transmitted to other sectors of the economy and to other countries through supply chains. Thanks to the multiregional input–output tables we can explore these economic cascading effects. Here we focus on the effects in terms of employment. According to our calculations, if the input structure of the electricity and gas supply sector of each of the EU countries in 2009 would have remained as in 1995, a net total of 530 thousand jobs (k-jobs) less would have been needed in the EU. Or, in other words, the changes in the input structure of the electricity and gas supply between 1995 and 2009 contributed to generate 530 k-jobs (see Table A.1).

The multiregional input–output model also allows one to distinguish between the "domestic" impacts in one country due to the changes in its own electricity and gas supply sector from those impacts in the employment in one country due to the changes in the electricity and gas supply of other countries (spill-over effects). We find that two thirds of the additional jobs in the EU were directly generated in the member states where the changes in the electricity and gas supply sector took place, while the rest were generated through spill-over effects (see Fig. 2).

Fig. 2 shows the impacts on employment due to changes in the input structure of the electricity and gas supply sector by member state and differentiating the domestic and spill-over effects. In 21 out of the 27 member states the total effect in the employment was positive. The countries that most benefited in terms of employment were Poland (124 k-jobs), Germany (95 k-jobs), Hungary (55 k-jobs), Italy (50 k-jobs), Spain (40 k-jobs), Slovakia (36 k-jobs) and the Netherlands (36 k-jobs). In four Eastern European countries, the change in the employment represents more than 0.8% of the total employment in the year 2009: Slovakia (1.6%), Latvia (1.5%), Hungary (1.4%) and Poland (0.8%). These countries are more energy intensive than the average, which contributed to magnified direct and indirect employment effects due to the changes in the electricity and gas supply. By contrast, the changes in Western Europe countries were more limited and in no case exceeded 0.5% of total employment, the largest beneficiaries being Belgium, Austria and the Netherlands, with gains of 0.5, 0.4 and 0.4 percent respectively.

Sector wise (see Table A.1 in the Appendix A) one can observe that the EU industry that most benefited in terms of employment was "Renting of Machinery and Other Business Activities" (159

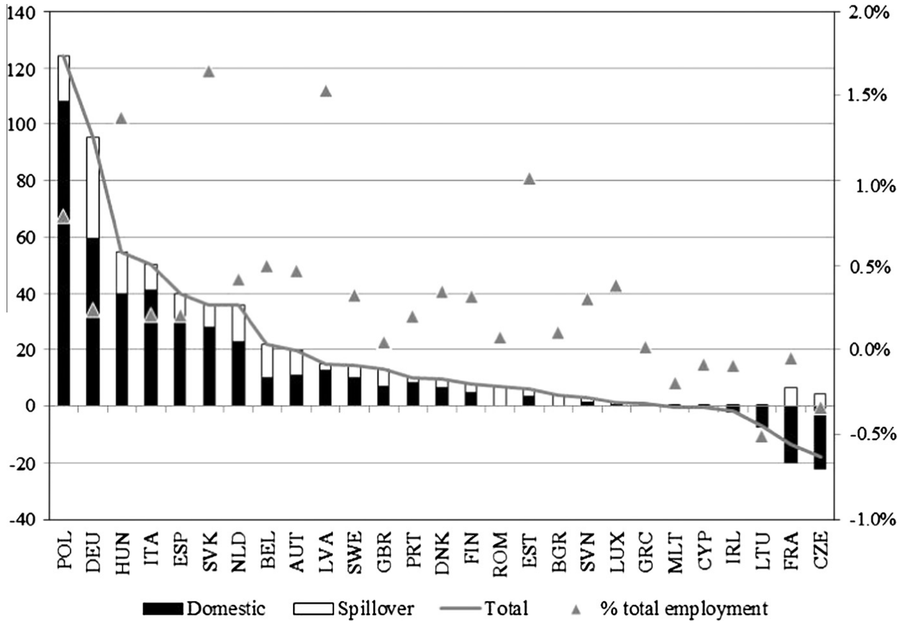

Fig. 2. Impacts on employment due to changes in the input structure of the electricity and gas sector by member state: total, domestic and spill-over effects (1000 jobs and %). Note: (1) The domestic effect refers to those impacts in one country due to the changes in its own electricity and gas supply sector, while the spill-over effect computes the impacts in the employment of one country due to the changes in the electricity and gas supply of other countries. (2) The impacts are derived from the changes in the input structure of the electricity and gas supply sector in all the 27 EU member states except Romania and Bulgaria. Thus, the impacts in the employment in Bulgaria and Romania only cover spill-overs from the change in the electricity and gas supply of other member states. *Source:* Own elaboration based on data from the World Input–Output Database.

k-jobs), followed by "Electricity and gas supply" (64 k-jobs), "Construction" (44 k-jobs), "Other Community, Social and Personal Services" (41 k-jobs), "Inland Transport" (38 k-jobs), "Wholesale Trade" (38 k-jobs), "Retail Trade; Repair of Household Goods; and Electrical and Optical Equipment" (26 k-jobs). The relevance of employment in the services sectors is consistent with the trends towards outsourcing observed during the last decades in developed economies. In addition, the increase in the use of gas for power generation is well reflected by the increase in employment in "Electricity and gas supply" (i.e. gas supply sector), and "Inland Transport" (linked to pipeline transportation).

On the other hand, 28 k-jobs were lost in the "Mining and Quarrying" sector, 10 k-jobs in "Public Admin and Defence; Compulsory Social Security",[8] and 3 k-jobs in "Coke, Refined Petroleum and Nuclear Fuel". These negative figures in the "Mining and Quarrying" and "Coke, Refined Petroleum and Nuclear Fuel" are linked to the changes in the electricity sector in the EU. Most of the losses in the "Mining and Quarrying" sector were concentrated in the Czech Republic (13 k-jobs), Germany (11 k-jobs), and Poland (10 k-jobs), reflecting the reduction in the share of coal in the electricity mix. In the case of "Coke, Refined Petroleum and Nuclear Fuel", 70% of the net employment losses where located in Italy and are related to the reduction in the use of oil in the electricity mix in that country (50% in 1995 versus 9% in 2009).

The employment impacts of the transformation in the European electricity and gas supply sector were not restricted to the EU (see Table A.2 of the Appendix A). These effects were transmitted through supply chains, through international trade, with a net generation of employment of 645 k-jobs (see Table A.2 of the Appendix A). Russia (171 k-jobs) and China (166 k-jobs) absorbed more than

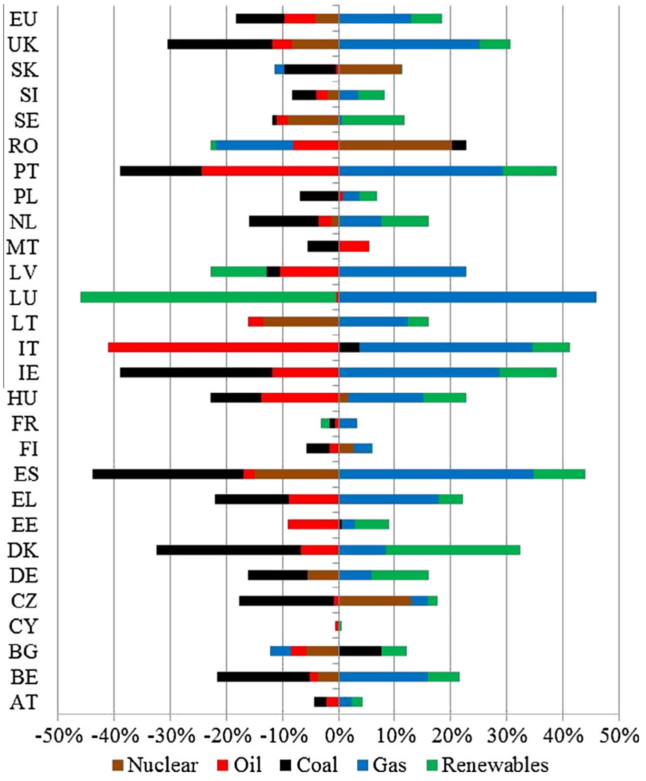

Fig. A.1. Change in the electricity and heat generation mix in the EU, 1995 and 2009 (%). Note: the change has been calculated as the difference between the share of each technology in the electricity and heat generation mix in 2009 minus the share in 1995. *Source:* International Energy Agency.

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[8] We have further investigated the losses in the "Public Admin and Defence; Compulsory Social Security" and found that it stems from an error in the French national input–output table of 1995 used in the World Input–Output Database, in which the intermediate deliveries of the "Public Admin and Defence; Compulsory Social Security" are overestimated in comparison with the official data from EUROSTAT.

Table A.1
Total impacts on employment by sector in the EU member states due to changes in the input structure of the EU electricity and gas sector between 1995 and 2009 (Thousands jobs). *Source:* own elaboration based on data from the World Input–Output Database.

Sector code	AUT	BEL	BGR	CYP	CZE	DEU	DNK	ESP	EST	FIN	FRA	GBR	GRC	HUN	IRL	ITA	LTU	LUX	LVA	MLT	NLD	POL	PRT	ROM	SVK	SVN	SWE	EU
c1	0.7	0.1	0.3	0.0	0.0	0.7	0.4	0.3	0.1	1.3	1.9	0.2	0.0	3.4	0.0	0.5	−0.6	0.0	0.6	0.0	0.6	5.0	−0.8	0.6	0.2	0.0	0.5	16.1
c2	0.5	0.0	0.1	0.0	−12.9	−10.8	0.0	−0.9	2.1	−0.6	1.0	−1.1	−0.1	0.3	−0.1	2.3	0.0	0.0	0.1	0.0	−0.5	−9.6	0.1	0.5	1.2	−0.2	−0.1	−28.5
c3	0.0	0.1	0.0	0.0	−0.1	0.1	0.0	0.2	0.0	−0.1	0.1	0.0	0.0	0.5	0.0	0.3	−0.1	0.0	0.2	0.0	0.1	1.4	0.0	0.0	0.1	0.0	0.1	2.8
c4	0.0	0.0	0.0	0.0	−0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	−0.1	0.2	0.0	0.2	−0.4	0.0	0.1	0.0	0.0	0.5	−1.3	0.1	0.0	−0.1	0.0	−0.8
c5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	−0.1	0.0	0.0	0.0
c6	0.6	0.1	0.0	0.0	0.0	0.6	0.1	−0.2	0.2	0.4	0.0	0.0	0.0	0.4	0.0	0.3	0.3	0.0	0.5	0.0	0.1	2.1	−1.2	0.2	0.4	0.0	0.6	5.3
c7	0.0	0.2	0.0	0.0	−0.2	0.7	0.1	0.2	0.0	−0.1	0.1	−1.3	0.0	0.8	0.0	0.9	−0.1	0.0	0.2	0.0	0.2	2.0	−0.6	0.0	0.3	0.0	0.2	3.5
c8	0.0	0.0	0.0	0.0	−0.1	0.0	0.0	0.0	0.0	0.0	0.4	−0.6	−0.1	0.0	−0.2	−2.2	−0.1	0.0	0.0	0.0	0.0	−0.1	−0.1	0.0	0.0	0.0	0.0	−3.0
c9	0.1	0.1	0.0	0.0	0.1	0.6	0.0	0.4	0.0	0.1	0.1	0.1	0.0	0.2	0.0	0.5	0.1	0.0	0.0	0.0	0.1	0.7	0.0	0.0	0.1	0.0	0.1	3.4
c10	0.1	0.0	0.0	0.0	−0.1	1.2	0.1	−0.1	0.0	0.1	1.2	−0.2	0.0	0.3	0.0	0.6	0.1	0.0	0.1	0.0	0.0	1.7	0.1	0.1	0.2	0.0	0.1	5.6
c11	0.0	0.1	0.0	0.0	−0.2	0.4	0.1	−0.7	0.0	0.1	−0.1	0.0	0.0	0.4	0.0	0.8	0.0	0.0	0.1	0.0	0.1	3.6	0.3	0.0	0.3	0.1	0.0	5.2
c12	0.2	0.3	0.1	0.0	−3.0	2.0	0.2	−6.3	0.2	1.1	−0.1	1.5	0.0	1.5	−0.1	1.4	0.2	0.0	0.1	0.0	0.4	2.8	0.0	0.3	0.0	0.1	0.3	3.1
c13	0.1	0.1	0.1	0.0	−0.2	2.5	0.2	0.0	0.1	0.7	0.6	0.8	−0.2	0.7	0.0	1.7	0.1	0.0	0.0	0.0	0.2	1.0	0.1	0.2	0.2	0.1	0.3	9.3
c14	0.9	0.1	0.2	0.0	1.3	9.7	0.2	0.0	0.1	0.2	1.1	0.4	0.2	1.1	0.0	2.8	0.1	0.0	0.2	0.0	0.2	3.6	0.3	2.0	1.1	0.3	0.3	26.5
c15	0.0	0.0	0.0	0.0	0.1	0.8	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.2	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.1	0.1	0.0	0.1	2.5
c16	0.1	0.1	0.0	0.0	−0.1	0.2	0.0	−0.8	0.0	0.1	0.2	−0.1	0.0	0.2	0.0	1.1	0.4	0.0	0.1	0.0	0.4	1.5	0.0	0.0	0.6	0.0	0.0	4.0
c17	11.0	1.5	1.2	0.0	−9.6	35.8	0.4	15.7	0.5	0.4	9.8	−4.0	1.3	3.7	2.2	1.3	−3.2	0.3	1.2	0.0	−0.4	−13.0	2.7	0.5	3.0	1.4	0.6	64.2
c18	1.3	1.2	0.2	0.0	−3.1	−1.4	1.5	−2.2	−0.2	2.9	−9.4	−0.7	−0.6	3.8	−0.4	−5.3	0.0	0.2	3.0	0.0	−0.5	44.7	4.1	0.1	4.5	0.5	0.2	44.5
c19	0.1	0.3	0.1	0.0	−1.2	2.3	0.1	4.3	0.2	0.2	−0.8	1.6	−0.2	2.4	0.4	0.9	−0.3	0.0	0.4	−0.3	1.1	1.8	0.2	0.0	0.6	0.0	0.2	14.3
c20	0.6	0.3	0.4	−0.3	−0.6	1.8	0.6	3.5	0.2	0.5	0.1	4.0	0.0	2.7	0.2	5.8	0.3	0.1	0.9	−0.3	3.1	10.9	−1.1	0.4	3.2	0.0	1.0	38.1
c21	0.6	−0.1	0.2	0.0	0.6	−1.1	1.0	10.0	0.6	1.1	−2.0	2.5	−0.3	10.8	−0.3	1.3	−2.0	0.1	1.5	0.0	1.7	7.8	−0.4	0.2	3.5	0.0	0.7	37.9
c22	0.1	0.6	0.0	0.0	0.5	0.0	0.2	−0.6	0.0	0.0	0.0	0.4	0.0	0.5	0.2	2.0	−0.4	0.0	0.1	0.2	0.8	0.3	0.3	0.1	1.1	0.0	0.5	6.9
c23	0.2	0.7	0.2	−0.1	6.7	9.6	0.1	0.6	0.2	−0.2	−1.6	0.8	−0.3	1.6	0.0	2.2	0.0	0.0	0.5	−0.1	0.2	10.6	2.2	0.4	3.2	0.0	0.4	38.2
c24	0.0	0.0	0.0	0.0	0.0	0.2	0.0	−0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.7
c25	0.0	0.0	0.0	0.0	0.0	0.1	0.0	−0.1	0.0	−0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.2
c26	0.5	0.1	0.1	0.0	−0.3	3.5	0.1	−0.3	0.1	0.0	0.3	0.2	0.0	0.2	0.0	1.3	0.0	0.0	0.1	0.0	0.2	−1.0	0.4	0.1	1.4	0.0	0.2	7.2
c27	0.2	0.7	0.2	0.0	0.2	0.4	0.4	4.6	0.1	−0.2	0.2	1.0	0.1	1.5	−0.1	2.6	−0.1	0.0	0.4	0.0	0.4	3.4	0.2	0.3	0.5	0.1	0.4	17.5
c28	−0.5	−0.2	0.1	0.0	0.5	−2.9	0.7	−6.4	0.2	0.1	0.6	−3.0	1.0	2.7	0.0	2.8	−0.5	0.0	0.3	0.0	0.6	4.2	0.7	0.1	0.0	0.0	0.5	1.4
c29	0.1	0.1	0.1	0.0	−0.3	0.6	0.1	−0.4	0.1	0.1	−0.1	−2.1	0.0	0.4	0.0	0.2	0.0	0.0	0.6	0.0	0.1	−1.7	0.0	0.0	0.7	0.0	0.2	−1.3
c30	2.3	9.2	0.1	0.0	1.7	28.3	2.7	13.4	0.8	−0.2	−3.6	12.0	0.0	9.7	0.6	18.5	0.7	0.5	2.5	0.0	21.8	22.0	3.2	0.6	7.0	0.1	5.1	159.0
c31	0.1	1.4	0.1	0.0	−0.3	2.2	0.0	1.7	0.0	0.0	−25.0	−0.1	0.0	1.4	0.0	0.0	−0.1	0.0	0.0	0.0	0.6	5.8	0.4	0.0	0.7	0.1	0.7	−10.3
c32	0.3	0.2	0.0	0.0	0.1	3.2	0.0	1.9	0.1	−0.1	1.9	−1.1	0.0	1.4	0.0	1.3	−1.0	0.0	0.4	0.0	0.8	1.4	0.1	0.0	0.5	0.1	0.2	11.5
c33	0.0	0.0	0.0	0.0	−0.2	0.0	0.0	−0.1	0.0	0.0	0.8	0.6	0.0	0.2	0.0	0.0	−0.2	0.0	0.1	0.0	0.4	1.2	0.0	0.0	0.2	0.0	0.2	3.4
c34	0.0	4.8	0.1	0.0	2.8	4.1	0.5	1.9	0.0	0.0	8.9	1.3	0.0	1.6	−3.9	4.1	−0.2	0.0	0.8	0.1	2.8	9.0	0.1	0.1	1.1	0.1	0.9	41.0
c35	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	19.9	22.0	4.0	−0.3	−18.0	95.1	9.8	39.7	6.0	7.7	−13.3	13.3	0.9	54.9	−1.7	50.5	−7.2	1.3	15.0	−0.3	35.8	124.2	10.0	7.2	36.0	2.9	14.3	529.5

Note: sector codes can be found in Table A.3.

Table A.2
Total impacts on employment by sector in non-EU countries due to changes in the input structure of the EU electricity and gas sector between 1995 and 2009 (Thousands jobs). *Source:* own elaboration based on data from the World Input–Output Database.

Sector code	AUS	BRA	CAN	CHN	IND	IDN	JPN	KOR	MEX	RUS	TUR	TWN	USA	RoW	Total
c1	0.0	1.7	0.0	23.4	6.5	2.8	0.1	0.2	0.1	5.9	0.2	0.0	0.1	54.6	95.6
c2	−0.9	−0.3	−0.3	2.5	0.5	1.0	0.0	0.0	−0.5	9.5	0.0	0.0	−0.9	−2.1	8.6
c3	0.0	0.1	0.0	1.2	0.2	0.1	0.0	0.0	0.0	0.2	0.0	0.0	0.0	1.4	3.4
c4	0.0	0.0	0.0	2.6	0.2	0.1	0.0	0.0	0.0	0.7	0.1	0.0	0.0	−0.5	3.3
c5	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.4
c6	0.0	0.1	0.0	2.0	0.5	0.5	0.0	0.0	0.0	1.3	0.0	0.0	0.0	2.7	7.1
c7	0.0	0.1	0.0	3.2	0.2	0.1	0.1	0.1	0.0	1.0	0.0	0.0	0.1	3.0	7.8
c8	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	−2.5	−1.8
c9	0.0	0.0	0.0	2.1	0.3	0.1	0.1	0.1	0.0	1.0	0.0	0.1	0.1	1.8	5.7
c10	0.0	0.1	0.0	4.1	0.1	0.3	0.1	0.2	0.0	0.8	0.1	0.1	0.0	1.7	7.7
c11	0.0	0.0	0.0	1.1	0.3	0.0	0.0	0.1	0.0	0.7	0.1	0.0	0.0	0.9	3.2
c12	0.0	0.1	0.0	2.8	0.6	0.1	0.3	0.2	0.0	2.1	0.2	0.2	0.2	2.2	9.2
c13	0.0	0.0	0.0	2.5	0.3	0.0	0.1	0.1	0.0	2.7	0.2	0.1	0.3	1.7	8.2
c14	0.0	0.1	0.0	11.4	0.6	0.1	0.7	1.5	0.2	1.7	0.3	0.8	0.6	5.2	23.3
c15	0.0	0.0	0.0	1.0	0.2	0.1	0.1	0.1	0.0	1.6	0.1	0.0	0.1	0.7	4.1
c16	0.0	0.0	0.0	0.9	0.9	0.0	0.0	0.0	0.0	0.6	0.1	0.0	0.1	1.4	4.1
c17	0.0	0.8	1.0	1.5	0.1	0.0	0.1	0.0	0.1	7.4	0.0	0.0	0.1	7.9	19.1
c18	−0.1	−0.1	0.1	2.0	0.8	0.1	0.1	0.0	0.0	1.2	0.1	0.0	0.0	1.6	5.7
c19	−0.1	0.1	0.0	0.0	0.2	0.0	0.0	0.0	0.4	2.1	0.1	0.0	0.0	0.2	3.1
c20	0.0	0.1	0.1	3.6	0.4	0.8	0.3	0.5	0.3	61.8	0.2	0.2	0.4	34.4	102.9
c21	−0.1	0.6	0.2	6.5	1.9	0.4	0.1	0.3	0.4	7.3	0.1	0.2	0.1	4.4	22.4
c22	0.0	0.7	0.1	3.2	1.3	0.4	0.2	0.3	0.0	1.0	0.0	0.0	0.3	4.4	11.9
c23	−0.1	0.3	0.2	5.4	2.2	1.4	0.2	0.1	0.4	37.6	0.2	0.1	0.4	40.9	89.3
c24	0.0	0.0	0.0	2.1	0.0	0.6	0.1	0.2	0.1	0.2	0.2	0.2	0.0	0.6	4.2
c25	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.1	0.0	0.2	0.0	0.0	0.0	0.2	0.8
c26	0.0	0.1	0.0	0.4	0.0	0.3	0.1	0.1	0.1	1.7	0.1	0.2	0.3	0.8	4.2
c27	0.0	0.1	0.0	1.7	1.3	0.2	0.0	0.0	0.0	2.3	0.0	0.0	0.3	2.2	8.2
c28	−0.1	0.1	0.0	1.0	0.4	0.1	0.1	0.1	0.0	1.0	0.0	0.1	0.2	1.4	4.4
c29	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.1	0.0	1.4	0.0	0.0	0.0	0.4	2.2
c30	−0.1	1.5	0.2	1.6	5.5	0.0	0.7	1.3	0.0	7.2	0.1	0.5	5.6	16.9	40.8
c31	0.0	0.0	0.0	0.1	0.0	0.3	0.0	0.0	0.0	4.4	0.1	0.0	0.0	0.1	5.1
c32	0.0	0.0	0.0	0.5	0.1	0.1	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.6	1.5
c33	0.0	0.0	0.0	0.2	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.2	0.7
c34	0.0	2.1	0.2	74.2	21.6	1.7	0.4	0.5	0.0	3.3	0.1	0.1	0.7	22.5	127.4
c35	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.9
Total	−1.5	8.8	2.2	165.9	48.0	11.8	4.0	6.2	1.8	170.6	2.7	3.0	9.1	212.3	644.7

Note: sector codes can be found in Table A.3.

50% of the impact.[9] In the case of Russia, most of the employment was generated in the sectors linked to the exports of gas to the EU: "Wholesale Trade" (62 k-jobs), "Inland transport" (which includes pipeline transportation) (38 k-jobs), and "Mining and Quarrying" (9 k-jobs).

Australia was the only country of the set analysed showing a net reduction in the employment. This negative effect was mainly concentrated in the "Mining and Quarrying" sector and is linked to the reduction to the demand of coal in the electricity and gas supply sector of the EU.

4. Limitations and future work

Our analysis has the typical limitations of input–output studies: not accounting for time lags, homogeneity of outputs, sectoral aggregation, absence of economies of scale, invariance of technological coefficients, linearity of technological coefficients and missing interactions between prices and quantities [35].

In addition, this analysis does not capture the employment due to changes in investments in different technologies across the sectors. On the one hand, a net positive effect could be expected as more jobs would have been created from the investments related to manufacturing and installation of renewables [9,14]. But, on the other hand, there could also have been an indirect but negative effect due to the increase in the price of electricity and gas in the EU compared to other Non-European countries that may have affected competitiveness [36,37] and, hence, the investment decisions across the economy. Such increases could be ameliorated with a well-designed mechanism for recycling revenues from subsidies [38] and from a further integration on the EU electricity market but the extent to which they do needs further investigation, which is beyond the scope of this paper.

Besides, data availability has restricted the exercise to the period 1995–2009. The World Input–Output Database contains data for the period 1995–2011. However, the deflators that are necessary for the exercise are only available until 2009. Future exercises may expand the analysis beyond 2009 as soon as the data are available.

Finally, it is important to highlight that this database has been constructed by integrating data from different official statistics, mainly the National Accounts and Input–Output Tables developed by National Statistics Institutes and trade statistics from EUROSTAT and United Nations. Accordingly, the level of accuracy of the database is aligned with the quality standards of the data in those sources. It is possible that the final dataset derived from the integration process might have deviated slightly from the original data, partly as a result of errors during the integration process, although such errors are normally detected and corrected in the

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[9] Most of the employment generated in China was located in "Other Community, Social and Personal Services" sector (74 k-jobs), which is usually not very relevant in the supply chain of the electricity and gas supply. In this case, this number is due to the high imports from the Chinese "Other Community, Social and Personal Services" of the Dutch electricity and gas supply reported by the World Input–Output Database in comparison with the official data from EUROSTAT.

updated versions. Thus, even if we cannot provide a formal interval of confidence for our results, the accuracy of the results should be understood in the context of the quality of official statistics that have been used to build the database.[10]

5. Conclusions

The results presented here provide some new, interesting evidence on the implications of the changes in the input structure of the European electricity and gas supply sector in the 14 years from 1995 to 2009. The use of a multiregional input–output model allows us to capture, not only the impacts directly and indirectly generated in each of the member states, but also the employment effects generated abroad as a result of international trade, something that closes a gap in this research line.

The analysis shows that the change in the input structure of the European electricity and gas supply sector, motivated in significant part by the desire for a shift towards a green economy, had a net positive impact on employment in the EU as a whole (+530 k-jobs), and specifically in 21 out of 27 of its member states. Furthermore, it shows that one third of the employment generated was due to spill-over effects. In other words, 176 k-jobs were generated in other member states different from those in which the change in the electricity and gas supply sector took place. These spill-over effects have traditionally been ignored when assessing the impacts of the deployment of new energy technologies. However, in the light of these results, spill-over effects should be taken into account in order to give a more accurate picture of the employment effects of European energy and climate policies, as is being done in other areas such as trade policy [41].

Previous studies [42] have pointed out that the promotion of renewable energy supports not only the creation of jobs in the short to medium term, but also the development of a globally competitive industry in the longer term. These new industries (like the renewable energy industry), which are knowledge-intensive, enable leading countries to maintain first-mover advantages for longer, since competition via labour costs is not feasible in many cases, which limits the possibilities of relocation [43,44]. Hence, certain export-oriented countries have created enabling environments (via economic instruments, regulations, etc.) for the development of these industries, with the hope that other countries will follow the promotion of these technologies, becoming new markets for the domestic industry [45]. Our results about the relevance of spill-over effects partly corroborate this and suggest the strategy makes sense, since changes in the energy mix of some countries benefit other countries involved in the production of renewable energy-related goods and services.

The analysis also shows which trading partners gained and lost in employment terms as a result of the structural changes. In this case, Russia was a major beneficiary due to the increase in the use of gas in the electricity and gas supply sector, while Australia was a loser due to the negative effect of the fall in the demand for coal.

Finally and in conclusion, our results support a relatively positive impact on employment from historical deployment of renewables and gas in the EU. Given our findings, the forward looking estimates for the EU [10,11] do not appear to be overly optimistic. Of course a direct comparison is not possible as the changes being compared are different, but an overall picture of a small gain in employment from the technology shifts involved in moving to a lower carbon future is probably right.

Table A.3
Sector classification.

Sector code	Sector
c1	Agriculture, hunting, forestry and fishing
c2	Mining and quarrying
c3	Food, beverages and tobacco
c4	Textiles and textile products
c5	Leather, leather and footwear
c6	Wood and products of wood and cork
c7	Pulp, paper, paper, printing and publishing
c8	Coke, refined petroleum and nuclear fuel
c9	Chemicals and chemical products
c10	Rubber and plastics
c11	Other non-metallic mineral
c12	Basic metals and fabricated metal
c13	Machinery, nec
c14	Electrical and optical equipment
c15	Transport equipment
c16	Manufacturing, nec; recycling
c17	Electricity, gas and water supply
c18	Construction
c19	Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of fuel
c20	Wholesale trade and commission trade, except of motor vehicles and motorcycles
c21	Retail trade, except of motor vehicles and motorcycles; repair of household goods
c22	Hotels and restaurants
c23	Inland transport
c24	Water transport
c25	Air transport
c26	Other supporting and auxiliary transport activities; activities of travel agencies
c27	Post and telecommunications
c28	Financial intermediation
c29	Real estate activities
c30	Renting of machinery and other business activities
c31	Public admin and defence; compulsory social security
c32	Education
c33	Health and social work
c34	Other community, social and personal services
c35	Private households with employed persons

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Appendix A

See Fig. A.1 and Tables A.1–A.3.

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[10] Statistical agencies commonly report official economic statistics without including measures of error [39]. A comparison of 25 economies of the OECD finds that the Relative Mean Absolute Revision (RMAR, a measure used to approximate uncertainty) for the GDP figures ranges between 0.07 and 0.33 percent during the period 2002–2013 [40]. To this we need to add the effects of errors in the employment-output coefficients and the other coefficients of the input–output tables. Unfortunately error estimates are not available for the EUROSTAT input-output tables. Given the small base errors in the overall GDP figures, and given that the input–output coefficients are derived from the same sources as the GDP data, we believe that overall errors in the estimates are unlikely to be more than a few percent.

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Glossary

Multiregional input–output model: Quantitative representation of the interdependencies of sectors and final users from many countries or regions. The single region model was proposed by Wassily Leontief. The multiregional extension is based on the "column-coefficient" model proposed by Chenery–Moses

Spill-over effects: Economic impact in a country or region different from the one where the exogenous stimulus occurs

Symmetric input–output tables: Sector-by-sector tables containing the transactions between sectors, the demand by final users and the contribution of value added components to production