**A Hybrid Input-Output Proposal to Identify Key Sectors for the Production and Distribution of Electricity.**

**Ana-Isabel Guerra**

**Department of International Economics**

**Faculty of Economics and Business Administration**

**University of Granada**

**Campus Universitario de La Cartuja, 18011, Granada, Spain.**

 **Email:** **anaisabelguerra@ugr.es**

**Version: January 12,2014**

Abstract:

This analysis explores the possibility of merging into a "hybrid" proposal two standard I-O methods that have been quite often used to identify key sectors, i.e. the Classical Multiplier Method and the Hypothetical Extraction Method. In the context of the latest revision of the European Union Energy Efficiency Plan, we use this proposal to single out key sectors that serve as tools for boosting all the potential energy savings in the economic system and, more specifically, in the production and distribution of electricity resources. Using the main distinctions and complementarities of the two traditional I-O key sector approaches, this hybrid formulation allows us to disaggregate the backward stimuli of the electricity sector in three indicators: the total, the internal and the external backward indicators. This "hybrid" proposal provides additional insights about the structure of the industrial linkages that participate in the production and distribution of electricity. Our results reveal that the explanation for the intensity of the backward effects of the electricity sector depends not only on the rest of energy sectors but also on some of the manufacturing industries. In our view, these findings may be important for conceiving a more balanced and cost-effective design of energy efficiency policies.

# Keywords:

Energy Efficiency Policies, Production and Distribution of Electricity, Input-Output Approaches, Key Sector Methods.

**Acknowledgements**:I am particularly grateful to Ferran Sancho, Michael Lahr, Mónica Serrano, Jan Oosterhaven, Erik Dietzenbacher and Tobias Kronenberg for all their helpful suggestions and comments that have substantially contributed to improve this paper. Support from research grant MICINN-ECO2009-11857 is acknowledged too

**1. Introduction**

In 2011, the European Commission launched a new communication[[1]](#footnote-1) related to energy efficiency policies in order to enable the European Union (EU) to reach a 20 percent energy savings target no later than 2020. This communication reflected the urgent need of reshaping this resource policy to the new baseline scenario that materialized after the global financial crisis. Similarly to previous communications, this policy mainly focuses on energy intensive manufacturing industries, along with the transport sector, since these sectors are supposed to generate the highest potential growth in final energy use[[2]](#footnote-2). Additionally, policy roadmaps have been also paved for the generation, transformation and distribution activities of energy resources. As it is well-known, the EU energy efficiency plan provides recommendations that should be adapted by each Member according to its own socio-economic and environmental situation, i.e. the National Energy Efficiency Plans (NEEAPs).

All these EU “sector-specific” recommendations and the subsequent Member States’ policy actions have their roots on sound academic and technical reports that very often rest on the key-sector methodology (Hirschmann, 1958). This approach pursues to identify which production sectors of the economy may contribute the most to the cost-effectiveness of these policy actions. Even though the key-sector analysis encompasses different analytical approaches, the Input-Output (I-O) methods are among the most popular in the literature.

Using these I-O key sector methods, several studies have already evaluated and quantified sectors’ “keyness” for energy efficiency policies in terms of their environmental and monetary costs, either from the demand side or the supply side. Applications of this type constitute a subset of the well-known Energy I-O analyses. The studies of Cumberland (1966), Strout (1967), and Blair (1980) are among the earliest works in this field. More recent examples in the academic literature are those carried out by Alcántara and Roca (1995), Alcántara and Padilla (2003) and Guerra and Sancho (2010), for the cases of Spain and the region of Catalonia, Lenzen (2003), Wang and Liang (2013), Hawdon and Pearson (1995) for Australia, China and the United Kingdom, respectively, and Tarancón et al. (2010) in the context of a group of EU economies.

These academic contributions have, in most cases, used two alternative criteria to elucidate the hierarchical order of sectors needed to implement resource policies. The first criterion is based on the Classical Multiplier Method (CMM), while the second one uses the Hypothetical Extraction Method (HEM). The CMM criterion consists in maximizing sectors’ policy outcomes when controlling for their total industrial interdependencies, i.e. the internal interdependencies that stem from its own intermediate demand plus the external interdependencies that affect the remaining sectors in the economy. The HEM, instead, makes it possible in some of its formulations to focus the selection criterion on the intensity of the potential distributive or external industrial linkages alone.

The present analysis departs from what has been common practice in the literature and offers a novel methodology constructed from merging the two aforementioned standard I-O key sector approaches and, consequently, their criteria too. Through an empirical application for the Spanish economy, we show that this “hybrid” I-O key sector methodology provides useful information to define a more balanced and cost-effective design of energy efficiency policies in general and, in particular, of those policy actions specifically oriented to increase energy savings in the production and distribution of electricity resources.

Electricity, as a secondary energy resource, is obtained from the transformation or conversion of other sources of energy like natural gas, coal, oil, nuclear power and other natural resources, the so-called primary resources. In Europe, the average transformation efficiency for electricity generation amounts to only 33 percent. Additionally, efficiency losses also occur at the transmission and distribution of electricity resources. In 2011, these losses represented, on average, 6.23 percent of the total electric power generated in the EU. In Spain, this figure accounted for 9.26 percent. For all these reasons the European Commission has proposed in its Energy Efficiency Plan (2011) measures to reduce efficiency losses at all stages of the electricity “chain” since, as revealed by all these figures[[3]](#footnote-3), efficiency gains in the production and distribution of electricity are equally important as those in its final use. In implementing the latest EU energy efficiency recommendations reflected in the provisions of the Commission Directive 2012/27/EU, analogous policy actions have been designed by all EU-28 Members. In the Spanish context, all these actions are included within the second Spanish Energy Saving and Efficiency Action Plan 2011-2020[[4]](#footnote-4).

In this regard, our “hybrid” I-O method provides a better understanding of the nature and structure of the industrial interdependencies that stem from the production and distribution of these secondary energy resources. The reason is that this new approach makes it possible to quantify the role played by each production unit within these industrial interdependences on the basis of three demand-pull stimuli indicators. Hence we are able to distinguish between total, internal and external backward measures. As the names themselves suggest, each indicator captures a particular type of industrial interdependencies that directly or indirectly determine economy-wide electricity consumption and thus, their potential to achieve higher efficiency levels. The internal backward indicator of the electricity sector caused by self-supply evaluates the potential of this sector to save electricity resources in its own production and distribution process. The external backward indicator of the electricity industry and its sectoral distribution inform, in contrast, about the contribution that can be traced to the remaining sectors to accomplish the final demand of electricity in the economy. Once sectors’ “keyness” as input suppliers for the production and distribution of electricity is quantified, the total and external backward indicators of each sector are used, in a complementary way, to consider its role as end-user of electricity resources too. Therefore, and differently to the standard I-O key sector methods where a single criterion or backward indicator is applied, the “hybrid” method identifies key sectors using three demand-pull stimuli measures. This novel approach may help to provide, in our view, a more comprehensive and detailed set of guidelines for energy efficiency policies.

This paper is organized as follows. In Section 2, after briefly describing the main differences and connections between the two standard I-O key sector demand-pull indicators, we proceed to formally present the new “hybrid” I-O key sector method. The empirical exercise of our “hybrid” proposal related to energy efficiency policies in the Spanish context is presented and described in Section 3. Section 4 concludes this analysis indicating the main policy implications.

**2. Merging the Traditional I-O Key-Sector Methods: A Hybrid Proposal.**

In this section we formally present the “hybrid” I-O key-sector methodology and their derived three backward linkage indicators. Since we are dealing with demand-pull stimuli measures, our point of departure is the equilibrium solution of the Leontief quantity model for an economy with N production sectors (Leontief, 1936, 1941). This equilibrium solution in reduced form is given by:

 (1)

where refers to the column vector of gross output levels, is the technical coefficient matrix, where each element is defined as the amount of input from sector *i* needed to produce one unit of output of sector *j,* and  is the column vector of final demand. The so-called Leontief inverse in equation (1) collects information about the existing economic interdependencies among all sectors. On the basis of this demand-driven I-O model, the Leontief inverse matrix transmits exogenous changes in final demand into changes in sectoral gross output.

We first proceed with a comparison of the CMM and the HEM that stresses their main differences and complementarities. To this effect, the formal description of these two standard I-O key sector methods has been notationally homogenised using partitioned matrices. In doing so, the initial N sectors are distinguished in two production blocks, or subsets of sectors, block K and block N-K. The grouping of sectors depends on the nature of the problem researchers want to tackle. For the case of energy efficiency policies, for instance, an appropriate sectoral grouping will be to distinguish between an energy sector or group of energy sectors, e.g. the Production and Distribution of Electricity and Gas, and the remaining production units. Accordingly, the demand-driven I-O model in expression (1) can be rewritten as follows:

 (2)

The partitioned Leontief inverse that solves the demand-driven I-O model outlined in (2):

 (3)

where









Because of linearity, and using the result in (3), the partitioned matrix “version” of the demand-driven I-O model of expression (2) can also be written in incremental terms, linking the exogenous changes in final demand andto the derived changes in total output and  as a result of the overall sectoral linkage effects, both direct and indirect:

 (4)

Under the CMM, as originally developed by Rasmussen (1957), sectoral backward linkage measures are calculated by the column sums of the Leontief inverse. These measures approximate sectors’ “keyness” on the basis of their demand-pull stimuli. Following this definition, the backward stimulus per unit of final demand induced, for instance, by the sectoral blockK becomes:

 (5)

Where **e** is a unit column vector of the adequate dimension and  is its transposed. Following the CMM criterion, the block of sectors K is considered a key-backward sectoral block whenever its demand-pull stimulus approximated by the scalar defined in (5) is above the economy’s sectoral block average.

The second standard approach to identify key sectors is the HEM, initially proposed by Paelinck et al (1965), Strassert (1968), Schultz (1977) and later reformulated by Meller and Marfán (1981), Cella (1984), Guccione (1986) and Clements (1990), among others. The HEM measures the role of a sector, or a block of sectors, by quantifying the changes in total gross output when a part of their industrial interdependencies are hypothetically extracted from the economic system.

An element of discussion within the HEM relates to how the extraction of a set of sectors should be simulated. In this respect, the works of Miller and Lahr (2001) and Miller and Blair (2009) offer a comprehensive exposition of the different hypothetical extractions that can be undertaken under the HEM. Recall that the objective of this analysis is to use measures of sectors’ backward stimuli based on “external” or out-block linkages in combination with total and internal backward indicators. Consequently, for the methodological objectives of this paper, we have followed the extraction first developed by Cella (1984) [[5]](#footnote-5). Cella’s HEM formulation consists in hypothetically ceasing out-block linkages, i.e. and, while retaining the internal or within-block linkages derived from own intermediate demand[[6]](#footnote-6). Then, following this vein and calculating the inverse of the leftover matrix, we immediately find:

 (6)

Subtracting (6) from expression (3) and using Cella’s definition of sectors’ backward indicators, the evaluated changes in overall output levels due to the exogenous demand-pull stimulus generated by block K per unit of final demand reads as:

 (7)

The scalar in (7) measures the relevance of block K in the economy in terms of the gross output losses occurring when the intermediate demand supplied by the remaining block N-K, i.e. the external or out-block linkages, hypothetically disappear. Therefore, under Cella’s HEM criterion, a sector becomes a key-backward sector if the size of these external industrial connections is above the sectors’ average. An analogous criterion would of course apply for sectoral blocks’ key-backward indicators.

We can now proceed to perform the comparison of the two standard I-O key-sector methods formally reviewed above. We simply do so subtracting expressions (5) and (7) to obtain:

 (8)

Expression (8) implies that purely internal transactions, or direct self-supply transactions, captured by the sectoral indicator are not accounted for under Cella’s HEM backward measures, i.e. the indicator. When classifying key sectors in terms of backward linkage effects, the differences between the two methods, as defined here, stem from the relevance of the production chains that are internal to the sector and that originate from their own intermediate demand. For the case of a group of sectors contained in block K, if the degree of a sectoral block’s dependency on the internal (or horizontal industrial integration) relative to its external interdependencies (or vertical industrial integration) is very strong, then block K may turn out to be a key-backward sectoral block under the CMM. The categorisation of block K might be different, however, under the HEM since only the degree of vertical industrial integration caused by intermediate demand is taken into account.

Once the distinction between the two methodologies becomes clearer, an interesting question that we would like to pose is the following: which approach is the most appropriate for identifying key-backward sectors for favouring economic efficiency, in general, and for promoting energy efficiency policies, in particular?. In this regard, some authors (Cella, 1984, and Termushoev, 2010) have stressed that what matters is how diverse sectors’ industrial linkages are, i.e. industrial linkages not including the internal or within block interdependences. This reason would justify the use of the HEM indicator that follows Cella’s formulation and its derived key-sector criterion. However within-block linkages are also important for identifying key backward sectors since they constitute part of the “grid” in sectoral linkages that also contributes to improve economic efficiency (Guccione, 1986). Furthermore, notice that although according to expression (8), the HEM backward indicator used in this analysis directly omits the internal linkages collected through the square matrix, nonetheless these linkages indirectly exert an influence over the external ones[[7]](#footnote-7).

In the context of energy efficiency policies, as advanced in Section 1, internal linkage indicators, i.e., may be crucial for some energy related sectors, as the electricity sector. The indicator of this energy sector quantifies the additional amount of electricity needed to accomplish one unit of electricity demand. Therefore, the largest this internal backward linkage indicator is the lowest the degree of efficiency in the use of its own intermediate demand. The measure of this sector, instead, informs about the role played by the remaining production units in covering this demand and, consequently, their potential to save energy in the production and distribution of electricity. Therefore, the combined use of these two backward measures captured by the “hybrid” I-O key sector method proposed here allows distinguishing and quantifying in a more accurate and refined way each sector energy efficiency “responsibility” in the production and distribution of electricity resources. Lastly, and in a complementary way, theand indicators of all those sectors that participate in the electricity production and distribution process offer additional information about each sector’s contribution as electricity consumers and, thus, their potential feedback effects in the economy-wide demand for electricity.

**3. An Empirical Exercise of the Hybrid I-O Key Sector Model.**

We apply now the “hybrid” model to Spanish data with the objective of identifying key sectors for those energy efficiency policy actions that specifically affect the production and distribution of electricity resources. Our data set refers to a 2007 symmetric I-O table constructed from the make and use tables published by the Spanish National Institute of Statistics[[8]](#footnote-8). To reconcile the economic flows coming from these tables, we have used the industry-technology assumption[[9]](#footnote-9).

In the empirical exercise carried out for the Spanish economy we have therefore used the decomposition of backward impacts formally presented in expression (8) that allows us to differentiate the internal and external effects within the sectoral total backward impact, which refer to un-weighted final demand measures. We have calculated these three backward indicators for the production and distribution of electricity and for the remaining 45 production units contemplated in our database. The sectoral disaggregation applied to the Spanish symmetric I-O table for 2007 and the corresponding code according to the Classification of Products by Activity for 2008 (CPA-2008) are included in the Annex. The sectoral decomposition chosen has tried to minimize as much as possible the potential problems of aggregation that may bias linkage measures (Hewings, 1974).

Before getting into a more concrete analysis of sectors’ “keyness” in terms of efficiency gains in the production and distribution of electricity in the context of the Spanish economy, we first present and comment the results for the three aforementioned backward indicators. The total, internal and external backward impacts in absolute terms for each production unit are shown down the three columns of Table 1. The last row of this table reports the arithmetic mean of all sectors’ backward indicators. Sectors are sorted out in decreasing order according to the size of their total backward effect. To ease the discussion of the results, all backward indicators have been expressed in positive terms. This is in contrast to what is customary under the HEM approach whereby evaluated changes in gross sectors’ output are usually presented with a negative sign since they relate to gross output losses.

|  |
| --- |
| **Table 1: Total, Internal and External Backward Measures\*:** **Symmetric I-O Table for Spain. 2007** |
| **Sectors**  |  |  |  |
| **24\_Sewerage and waste collection, treatment and disposal activities** | **2.410** | **1.217** | **1.193** |
| **25\_Construction Sector** | **2.397** | **1.498** | **0.899** |
| **09\_Food products, beverages and tobacco Products** | **2.271** | **1.214** | **1.056** |
| **06\_Production and Distribution of Electricity** | **2.249** | **1.227** | **1.022** |
| **31\_Travel agency and tour operator Services** | **2.220** | 1.104 | **1.116** |
| **16\_Non-Metallic Mineral Products** | **2.168** | **1.129** | **1.040** |
| **18\_Basic Metals** | **2.114** | 1.071 | **1.042** |
| **26\_Wholesale, Retail trade and repair services of Motor Vehicles** | **2.070** | 1.100 | **0.970** |
| **11\_Wood and Cork Products**  | **2.067** | **1.320** | **0.747** |
| **13\_Printing and recording Services** | **2.039** | 1.077 | **0.961** |
| **30\_Transport Services** | **1.997** | **1.325** | 0.672 |
| **12\_Paper and paper Products** | **1.996** | **1.180** | **0.816** |
| **17\_Fabricated metal Products** | **1.965** | 1.094 | **0.871** |
| **15\_Rubber and plastics Products** | **1.946** | **1.168** | **0.778** |
| **07\_Production and Distribution of Gas** | **1.935** | 1.000 | **0.934** |
| **08\_Water Sector** | **1.926** | 1.002 | **0.923** |
| **34\_Insurance, reinsurance and pension funding Services** | **1.900** | 1.055 | **0.845** |
| **22\_Motor vehicles** | **1.897** | **1.287** | 0.610 |
| **32\_Telecommunications and Postal Services** | **1.896** | **1.157** | **0.739** |
| **27\_Other Wholesale trade services** | **1.884** | 1.034 | **0.850** |
| **44\_Services furnished by membership organisations** | **1.882** | 1.002 | **0.880** |
| **05\_Coke, refined petroleum and nuclear products** | **1.872** | **1.153** | **0.720** |
| **23\_Furniture and other manufactured Products** | **1.856** | 1.041 | **0.815** |
| **46\_Other personal Services** | **1.816** | 1.021 | **0.795** |
| **45\_Sporting, amusement and recreation Services** | 1.813 | **1.129** | 0.684 |
| **37\_Rental and leasing Services** | 1.805 | 1.030 | 0.775 |
| **29\_Accommodation and food Services** | 1.786 | 1.001 | 0.786 |
| **39\_Scientific Research and Development Services** | 1.770 | 1.006 | 0.764 |
| **01\_Agriculture and hunting**  | 1.762 | 1.046 | 0.716 |
| **14\_Chemicals and chemical Products** | 1.760 | **1.188** | 0.572 |
| **38\_Computer programming, information and consultancy Services** | 1.714 | **1.151** | 0.563 |
| **21\_Electrical Equipment** | 1.707 | **1.152** | 0.555 |
| **40\_Other Services** | 1.698 | 1.086 | 0.612 |
| **10\_Textiles, wearing apparel and leather Products** | 1.682 | **1.216** | 0.466 |
| **28\_Other Retail trade services** | 1.665 | 1.001 | 0.664 |
| **35\_Services auxiliary to financial services and insurance Services** | 1.657 | **1.175** | 0.482 |
| **19\_Machinery and equipment**  | 1.644 | 1.048 | 0.596 |
| **43\_Health and Social Services** | 1.580 | 1.054 | 0.527 |
| **36\_Real estate Services**  | 1.526 | 1.009 | 0.517 |
| **41\_Public Services** | 1.526 | 1.000 | 0.526 |
| **03\_Fishing and aquaculture** | 1.513 | 1.000 | 0.512 |
| **33\_Financial Services** | 1.336 | 1.066 | 0.27 |
| **42\_Education Services** | 1.233 | 1.002 | 0.231 |
| **02\_Forestry** | 1.199 | 1.000 | 0.199 |
| **20\_Computer, electronic and optical Products** | 1.199 | 1.038 | 0.161 |
| **04\_Mining and quarrying** | 1.184 | 1.002 | 0.182 |
| **Average Effect** | **1.816** | **1.106** | **0.710** |

*Source: Own elaboration*

 \* Backward measures in bold refer to sectors with above average backward effects.

Table 1 shows that most of the production units with a significant positive distance from the sector’s average internal backward impacts appear to be key sectors under the CMM. As mentioned in Section 2 when interpreting expression (8), the remarkable weight that these internal backward effects have on the classification under the CMM indicators explains these outcomes. Notice, for instance, that the Construction sector (Sector number **25 )***,* which has the highest internal backward effect with a value of 1.498 units of gross output per unit increase in its final demand, takes the second position in terms of its total backward effect. Under the HEM criterion, though still above the sectors’ average, the Construction sectorbackward stimulus is modest compared to other sectors, i.e. the Sewerage, waste collection, treatment and disposal activities (Sector number **24)**. A plausible justification for such imbalance between the  indicator and the  measure is that some products from the Construction sector are inputs and, at the same time, outputs of this sector, i.e. Construction products like engineering and construction equipment are needed to construct buildings. Furthermore, even for certain production units the influence of these internal linkages completely alters the classification as key-backward sectors. This is for instance the case of Transportservices(Sector number **30)** since most transport services are multimodal and Motor Vehicles industry (Sector number **22)** where similar justifications as those outlined for the Construction sector may be applied.

In most cases, however, those sectors that are key-backward sectors under the CMM criterion turn out to be also identified as such under Cella’s HEM criterion, although with a different order. This finding is not a mere coincidence but rather, as pointed out in Section 2, is due to the indirect positive effect that strong internal industrial linkages have over external industrial dependencies. As a result, external effects matter for sector “keyness”, but those internal interdependencies that stem from own intermediate demand matter too since the latter positively stimulates the former. In connecting our findings to those in the excellent analysis carried out by Temurshoev (2010), despite our different extraction approach[[10]](#footnote-10), some of his conclusions could also be applied here.

We now highlight the usefulness of combining the two “pure” methodologies through our proposed “hybrid” approach for the study of energy efficiency policies in the context of the Spanish economy. These policies are currently focused at increasing efficiency levels in the intermediate use of Electricity (Sector number **06**) as an input. The reason is that the size of the external spreading out effects, as captured by the **EBL** indicator, is larger than those of the other energy related sectors, namely, Mining and quarrying industry (Sector number **04**)*,* that includes energy extractive industries, the Production and Distribution of gas (Sector number **07**) *,* and the Coke, refined petroleum and nuclear products industry (Sector number **05**) .The strong external backward linkages of the electricity sector favour the transmission of efficiency gains in a more balanced way since its suppliers of intermediate inputs also use electricity resources in their production process. In addition, the Electricity sector also presents the strongest indicator among all of the energy related sectors.

|  |
| --- |
| **Table 2:Distribution of the Total and External Backward Indicators of the Electricity Sector\*:** **Symmetric I-O Table for Spain. 2007** |
| **Sectors**  | **Sectoral Distribution of** **the** indicator of the Electricity Sector | **Sectoral Distribution of** theindicator of theElectricity Sector |
|  | % |  | % |
| **06\_Production and Distribution of Electricity** | **1.240** | **55.143** | **0.013** | **1.284** |
| **04\_Mining and quarrying** | **0.209** | **9.272** | **0.209** | **20.405** |
| **07\_Production and Distribution of Gas** | **0.152** | **6.763** | **0.152** | **14.884** |
| **05\_Coke. refined petroleum and nuclear products** | **0.123** | **5.485** | **0.123** | **12.070** |
| **40\_Other Services** | **0.107** | **4.739** | **0.107** | **10.429** |
| **32\_Telecommunications and Postal Services** | **0.044** | **1.952** | **0.044** | **4.296** |
| **25\_Construction Sector** | **0.040** | **1.781** | **0.040** | **3.919** |
| **30\_Transport Services** | **0.035** | **1.546** | **0.035** | **3.403** |
| **18\_Basic Metals** | **0.032** | **1.404** | **0.032** | **3.090** |
| **33\_Financial Services** | **0.025** | **1.122** | **0.025** | **2.470** |
| **36\_Real estate Services**  | **0.024** | **1.072** | **0.024** | **2.358** |
| **27\_Other Wholesale trade services** | **0.023** | **1.007** | **0.023** | **2.217** |
| **19\_Machinery and equipment**  | **0.022** | **0.968** | **0.022** | **2.130** |
| **21\_Electrical Equipment** | **0.022** | **0.992** | **0.022** | **2.183** |
| **17\_Fabricated metal Products** | **0.017** | **0.777** | 0.017 | 1.711 |
| **13\_Printing and recording Services** | **0.013** | **0.567** | 0.013 | 1.247 |
| **14\_Chemicals and chemical Products** | **0.010** | **0.462** | 0.010 | 1.017 |
| **16\_Non-Metallic Mineral Products** | **0.009** | **0.421** | 0.009 | 0.928 |
| **39\_Scientific Research and Development Services** | **0.009** | **0.383** | 0.009 | 0.844 |
| **26\_Wholesale. Retail trade and repair services of Motor Vehicles** | **0.008** | **0.374** | 0.008 | 0.823 |
| **37\_Rental and leasing Services** | **0.008** | **0.361** | 0.008 | 0.794 |
| **38\_Computer programming. information and consultancy Services** | **0.008** | **0.359** | 0.008 | 0.791 |
| **35\_Services auxiliary to financial services and insurance Services** | **0.007** | **0.295** | 0.007 | 0.648 |
| **45\_Sporting. amusement and recreation Services** | **0.006** | **0.273** | 0.006 | 0.601 |
| **12\_Paper and paper Products** | **0.005** | **0.232** | 0.005 | 0.512 |
| **22\_Motor vehicles** | **0.005** | **0.205** | 0.005 | 0.451 |
| **15\_Rubber and plastics Products** | 0.004 | 0.179 | 0.004 | 0.394 |
| **23\_Furniture and other manufactured Products** | 0.004 | 0.172 | 0.004 | 0.379 |
| **24\_Sewerage and waste collection. treatment and disposal activities** | 0.004 | 0.191 | 0.004 | 0.420 |
| **29\_Accommodation and food Services** | 0.004 | 0.194 | 0.004 | 0.426 |
| **42\_Education Services** | 0.004 | 0.173 | 0.004 | 0.382 |
| **08\_Water Sector** | 0.004 | 0.156 | 0.004 | 0.344 |
| **11\_Wood and Cork Products**  | 0.003 | 0.131 | 0.003 | 0.289 |
| **34\_Insurance. reinsurance and pension funding Services** | 0.003 | 0.119 | 0.003 | 0.263 |
| **09\_Food products. beverages and tobacco Products** | 0.003 | 0.127 | 0.003 | 0.281 |
| **01\_Agriculture and hunting**  | 0.002 | 0.095 | 0.002 | 0.209 |
| **10\_Textiles. wearing apparel and leather Products** | 0.002 | 0.082 | 0.002 | 0.180 |
| **20\_Computer. electronic and optical Products** | 0.002 | 0.070 | 0.002 | 0.153 |
| **28\_Other Retail trade services** | 0.002 | 0.095 | 0.002 | 0.210 |
| **43\_Health and Social Services** | 0.002 | 0.091 | 0.002 | 0.200 |
| **44\_Services furnished by membership organisations** | 0.002 | 0.067 | 0.002 | 0.147 |
| **31\_Travel agency and tour operator Services** | 0.001 | 0.060 | 0.001 | 0.132 |
| **02\_Forestry** | 0.000 | 0.019 | 0.000 | 0.042 |
| **03\_Fishing and aquaculture** | 0.000 | 0.003 | 0.000 | 0.007 |
| **41\_Public Services** | 0.000 | 0.000 | 0.000 | 0.000 |
| **46\_Other personal Services** | 0.000 | 0.018 | 0.000 | 0.040 |
| **Total** | **2.249** | **100** | **1.022** | **100** |
| **Average Effect** | **0.050** | **2.17** | **0.022** | **2.17** |
| ***Source: Own elaboration.*** ***\* Figures in bold refer to sectors with above sectors’ average effect.*** |

We will address now the following two questions: first, how “diverse”, or non-redundant, are the industrial interdependencies in the production and distribution of electricity resources? And second, which is the “responsibility” that can be assigned in these terms to each production sector, including the Electricity sector itself?. We answer these two questions decomposing the total and external backward effect of the Electricity sector, i.e. the and the  indicators, according to the sectors’ absolute and percentage contributions. The results are shown in Table 2 where sectors have been listed in descending order considering each sector’s weight over the total backward effect of the Electricity sector, i.e.  indicator. Notice first that the sectoral distribution of total and external backward effects of the Electricitysector differ only in the Electricity sector itself. This is explained by the internal backward effect of this sector that exactly corresponds to the difference between its total and external backward measures, as reported in Table 1, i.e.  which amounts to 55.14 percent over the indicator. This result clearly shows the remarkable dependency that the Electricity sector has on self-supply, validating the EU specific policy actions and consequently, those reflected in the Spanish Energy Saving and Efficiency Action Plan 2011-2020 to improve efficiency levels in the generation, transmission and distribution of this energy input, i.e. promoting “co-generation”, increasing the electricity production share of larger-scale plans and boosting the contribution of renewable energy resources in the electric power generation process, among others.

According to the decomposition shown in Table 2, the previously listed energy related sectors in the economy appear to contribute the most to the remaining part of the backward stimulus of the Electricity sector. All these energy related sectors jointly represent 47.36 percent of the  of the electricity sector. This is not a surprising result since electricity, as mentioned in Section 1, is an output in the transformation process of primary energy resources. This outcome reinforces the legitimacy of the Electricitysector as a key sector for energy efficiency policies. In addition, this result may also be used as an approximate indicator of the degree of dependence that the Electricitysector has over non-renewable primary energy sources in its generation and distribution process.

Lastly, once we have described the nature and structure of the backward interdependencies between the Electricity sector and the remaining energy related sectors using our “hybrid” I-O key sector measures, we now move to replicate the exercise for the non-energy related sectors. In doing so, we will pay special attention to the manufacturing industries since they are considered to provide the highest potential in energy savings (Tarancón et al. 2010). According to the results in Table 2, the manufacturing of Basic Metals (Sector number **18**) followed by the Electrical Equipment (Sector number **21**) and the Machinery and Non-Electrical Equipment industries (Sector number **19)**,respectively**,** are the main input suppliers of the Electricity sector among all manufacturing industries. The role played by these manufacturing industries in providing the necessary infrastructure for the production and distribution of electricity to the whole economic system backs this finding. Connecting this result with those outlined in Table 1, the manufacturing of Basic Metals alsopresents the highest total and external backward indicators among these three manufacturing industries. The size of these two indicators also suggests the potential of this manufacturing sector to affect economy-wide levels of electricity consumption.

Summing up, the information provided by all these backward measures calculated through the “hybrid” I-O key sector methodology indicates that this manufacturing sector is a good “additional” candidate to focus energy efficiency policy efforts. This is so because, firstly, the manufacturing of Basic Metals is a key-backward sector that, boosting total production may generate a remarkable influence on electricity demand in the economy; secondly, apart from other primary energy resources, the outputs produced by this manufacturing sector are also necessary inputs in the production and distribution of electricity that, at the same time, requires additional electricity resources for their fabrication.

**4. Conclusions and Policy Recommendations.**

The empirical application to the Spanish economy of the “hybrid” I-O proposal for detecting key sectors shows that, in marked contrast with other energy sectors, the Electricity sector presents the strongest total and external demand-pull effects among these energy related sectors. Considering that electricity resources are relevant inputs in the production process of all production units in the economy, this result suggests that efficiency gains in the processes of transformation, distribution and generation of electricity may be as important as those arising in its final use.

Furthermore, the sectoral relative decomposition of its external backward impact indicates that most of its “non-redundant” interdependencies are still remarkably concentrated over other energy sectors that relate to non-renewables. This is the case, at least, for the Spanish economy and for the period 2007 considered in this analysis. From this result, it seems that in the Spanish context additional efforts should be undertaken to reduce these connections, favouring both a stronger dependence on renewables and a more efficient use of non-renewables in electricity generation.

Another interesting outcome obtained through the I-O “hybrid” method, refers to the structure and nature of the interdependencies between the manufacturing industries and the Electricity sector regarding their demand-pull stimuli. Our findings indicate that, among these industries, the manufacturing of Basic Metals yields the largest contribution to the external demand-pull stimuli of the Electricity sector. A plausible explanation for this finding rests on the role played by this sector as supplier of the electricity infrastructure necessary for the production and distribution of these secondary energy resources. Additionally, it is important to consider that energy resources are also required for the fabrication of electricity infrastructure. Consequently, the question of how to improve energy efficiency may rest not only on achieving a more efficiency use of electricity resources but also a more efficient use of the available infrastructure.

Another fact that emerges thanks to the use of the “hybrid” approach is that the Electricity sector and the manufacturing of Basic Metals share the characteristic of having significant backward measures, both internal and external to their own production unit. Consequently, the strength of its demand-pull stimuli will remarkably influence economy-wide energy demand and, thus, energy efficiency levels. Taking this into account, additional special policy guidelines should be designed for this manufacturing industry going further and beyond the specific actions for manufactures contemplated in the Spanish National Action Plan for Energy Efficiency 2011-2020. The reason rests on the remarkable potential direct and indirect influence that this sector has in the final use of electricity and, also, from its relevant role as an input provider for the production and distribution of electricity resources.

The recommendations suggested by our new methodological approach could be useful to enhance the design and effectiveness of energy efficiency policy actions, in general, and those that affect the production and distribution of electricity, in particular. Most of the policy recommendations drawn from our “hybrid” I-O method in the context of the Spanish economy can be extended or adapted to other EU Member States economies. These policy suggestions are based on general aspects that directly relate to the production and distribution of electricity and that our approach helps to discern and quantify.

.

# References

Alcántara, V., Roca, J. (1995).‘Energy and CO2 Emissions in Spain’. *Energy Economics*, 17, 221-230.

Alcántara, V., Padilla, E. (2003). ‘Key Sectors in Final Energy Consumption: An Input-Output application to the Spanish case’. *Energy Policy*, 31, 1673-1678.

Blair, P. (1980). ‘Hierarchies and Priorities in Regional Energy Planning’. Regional Science and Urban Economics, 10, 387-405.

Cella, G. (1984). ‘The Input-output Measurement of Interindustry Linkages’.*Oxford Bulletin of Economics and Statistics*, 46, 73-84.

Clements, B.J. (1990). ‘On the Decomposition and Normalization of Interindustry Linkages’. *Economic Letters*, 33, 337-340.

Cumberland, J.H. (1966). ‘A Regional Interindustry Model for Development Objectives’. *Papers of the Regional Science Association*, 17, 65-94.

Guccione, A. (1986). ‘The Input-Output Measurement of Interindustry Linkages: A Comment’. *Oxford Bulletin of Economics and Statistics*, 48, 373–377.

Guerra, A., Sancho, F. (2010). ‘Measuring Energy Linkages with the Hypothetical Extraction Method: An application to Spain’. *Energy Economics*, 32, 831-837.

Hewings, G.J.D. (1974). ‘The Effect of Aggregation on the Empirical Identiﬁcation of Key-Sectors in a Regional Economy: A Partial Evaluation of Alternative Techniques’. *Environment and Planning A*, 6, 439–453.

Hirschman, A. (1958). *‘The Strategy of Economic Development’*. Yale University Press. New Haven.

Hawdon, D., Pearson, P. (1995) ‘Input-Output Simulations of Energy, Environment and Economy Interactions in the UK’. *Energy Economics*, 17, 73-86.

Lenzen, M. (2003). ‘Environmental Important Paths, linkages and key sectors in the Australian Economy’. *Structural Change and Economy Dynamics*, 14, 1-14.

Leontief, W.W. (1936). ‘Quantitative Input-Output Relationships in the Economic System of the United States’. *Review of Economics and Statistics*, 18, 105-1025.

Leontief, W.W. (1941). *‘The Structure of the American Economy’*. Oxford University Press. New York. NY.

Meller, P., Marfán, M. (1981). ‘Small and Large Industry: Employment Generation, Linkages and Key Sectors’. *Economic Development and Cultural Change*, 29, 263-274.

Miller, R.E. (1966). ‘Interregional Feedback Effects in Input-Output Models: Some Preliminary Results’. *Papers in Regional Science Association*, 17, 105-125.

Miller, R.E. (1969). ‘Interregional Feedback Effects in Input-Output Models: Some Experimental Results’ .*Western Economic Journal*, 7, 41-50.

Miller, R.E., Lahr, M.L. (2001). ‘A Taxonomy of Extractions’. In M.L. Lahr and R.E. Miller (eds). *Regional Science Perspectives in Economic Analysis: A Festschrift in Memory of Benjamin H. Stevens*. Elsevier Science. Amsterdam, 407-441.

Miller, R.E., Blair, P.D. (2009). *‘Input-Output Analysis: Foundations and Extensions’*. (Second Edition).Cambridge University Press. Cambridge.

Paelinck, J., de Caevel, J., Degueldre, J. (1965). ‘Analyse Quantitative de Certaines Phénomènes du Développement Régional Polarisé : Essai de Simulation Statique d’Itinéraires de Propagation’. In Bibliothèque de l’Institut de Science Économique. No. 7. *Problémes de Conversion Économique : Analyses Théoriques et Études Appliquées*. Paris : M.-Th. Génin.

Rasmussen, P.N. (1957). *‘Studies in Inter-Sectoral Relations’*. North-Holland. Amsterdam.

Schultz, S. (1977). ‘Approaches to Identifying Key Sectors Empirically by Means of Input-output Analysis’.*Journal of Development Studies*, 14, 77-96.

Strassert, G. (1968). ‘Zur Bestimmung Strategischer Sektoren mit hilfe von Input-Output modellen’. *Jahrbucher fur Nationalokonomie und Statistick*, 182, 211-215.

Strout, A. (1967). ‘Technological Change and U.S. Energy Consumption’. Ph.D. dissertation. University of Chicago.

Tarancón, M.A., Del Río. P., Callejas-Albiñana, F. (2010). ‘Assessing the Influence of Manufacturing sectors on Electricity Demand: A Cross-Country Input-Output Approach’. *Energy Policy*, 38, 1900-1908.

Temurshoev, U. (2010). ‘[Identifying Optimal Sector Groupings with the Hypothetical Extraction Method](http://ideas.repec.org/a/bla/jregsc/v50y2010i4p872-890.html)’. [*Journal of Regional Science*](http://ideas.repec.org/s/bla/jregsc.html), 50, 872-890.

Wang, Y., Liang, S. (2013). ‘Carbon dioxide mitigation target of China in 2020 and key economic sectors’. *Energy Policy*, 58, 90-96.

## Annex: Sectoral Disaggregation for the Symmetric Spanish Input-output Table. 2007

|  |  |
| --- | --- |
| **Sectos** | **CPA-2008****Classification** |
| **01\_Agriculture and hunting**  | CPA\_A01 |
| **02\_Forestry** | CPA\_A02 |
| **03\_Fishing and aquaculture** | CPA\_A03 |
| **04\_Mining and quarrying** | CPA\_B |
| **05\_Coke, refined petroleum and nuclear products** | CPA\_C19 |
| **06\_Production and Distribution of Electricity** | CPA\_D35 |
| **07\_Production and Distribution of Gas** | CPA\_D35 |
| **08\_Water Sector** | CPA\_E36 |
| **09\_Food products, beverages and tobacco Products** | CPA\_C10-C12 |
| **10\_Textiles, wearing apparel and leather Products** | CPA\_C13-C15 |
| **11\_Wood and Cork Products**  | CPA\_C16 |
| **12\_Paper and paper Products** | CPA\_C17 |
| **13\_Printing and recording Services** | CPA\_C18 |
| **14\_Chemicals and chemical Products** | CPA\_C20 |
| **15\_Rubber and plastics Products** | CPA\_C22 |
| **16\_Non-Metallic Mineral Products** | CPA\_C23 |
| **17\_Fabricated metal Products** | CPA\_C25 |
| **18\_Basic Metals** | CPA\_C24 |
| **19\_Machinery and equipment**  | CPA\_C28 |
| **20\_Computer, electronic and optical Products** | CPA\_C26 |
| **21\_Electrical Equipment** | CPA\_C27 |
| **22\_Motor vehicles** | CPA\_C29-C30 |
| **23\_Furniture and other manufactured Products** | CPA\_C31\_C32 |
| **24\_Sewerage and waste collection, treatment and disposal activities** | CPA\_E37-E39 |
| **25\_Construction Sector** | CPA\_F |
| **26\_Wholesale, Retail trade and repair services of Motor Vehicles** | CPA\_G45 |
| **27\_Other Wholesale trade services** | CPA\_G46 |
| **28\_Other Retail trade services** | CPA\_G47 |
| **29\_Accommodation and food Services** | CPA\_I |
| **30\_Transport Services** | CPA\_H49-H56 |
| **31\_Travel agency and tour operator Services** | CPA\_N79 |
| **32\_Telecommunications and Postal Services** | CPA\_J61-J62 & CPA\_H53 |
| **33\_Financial Services** | CPA\_K64 |
| **34\_Insurance, reinsurance and pension funding Services** | CPA\_K65 |
| **35\_Services auxiliary to financial services and insurance Services** | CPA\_K66 |
| **36\_Real estate Services**  | CPA\_L68 |
| **37\_Rental and leasing Services** | CPA\_N77 |
| **38\_Computer programming, information and consultancy Services** | CPA\_J62\_J63 |
| **39\_Scientific Research and Development Services** | CPA\_M72 |
| **40\_Other Services** | CPA\_M74\_M75 |
| **41\_Public Services** | CPA\_O84 |
| **42\_Education Services** | CPA\_P85 |
| **43\_Health and Social Services** | CPA\_Q86-Q87 |
| **44\_Services furnished by membership organisations** | CPA\_S94 |
| **45\_Sporting, amusement and recreation Services** | CPA\_R90-R93 |
| **46\_Other personal Services** | CPA\_S96 |

1. Energy Efficiency Plan 2011, COM (2011) 0109. [↑](#footnote-ref-1)
2. See “A Roadmap for moving to a competitive low carbon economy in 2050”, COM (2011)112. [↑](#footnote-ref-2)
3. 3The information about efficiency losses in the transmission and distribution of electricity has been obtained from a subset of the World Development Indicators annually published by the World Bank. The remaining information was extracted from the report “2020 vision: Saving our Energy” (2007) published by the Directorate-General of Energy and Transport (European Commission). [↑](#footnote-ref-3)
4. See the executive summary of the Energy Saving and Efficiency Action Plan 2011-2020 available at the web-side of the Spanish Ministry of Industry, Energy and Tourism. [↑](#footnote-ref-4)
5. Using, for instance, the original HEM formulation of Paelinck et al. (1965) where not only external linkages but also internal linkages are extracted, i.e. , would have based the distinction between the two traditional backward indicators on the size of its final demand. Therefore, the application of this alternative HEM formulation would not be appropriate for the context of the analysis here. [↑](#footnote-ref-5)
6. Under Cella’s HEM formulation, the size of the own intermediate demand interdependencies does not have any direct impact in determining the hierarchical order of sectors. The question whether these internal linkages should be accounted for or not still remains a major source of debate in the HEM literature. This debate was first initialized by Miller (1966, 1969) in a multiregional context and later retaken in a parallel way by Guccione (1986) as a response to the extraction method suggested by Cella (1984) for addressing inter-sectoral analysis. [↑](#footnote-ref-6)
7. This explains the reason why previous studies have found strong correlation when comparing the results obtained under two traditional I-O key-sector methodologies (Miller and Lahr, 2001). This was so even though alternative HEM formulations were used for this comparison. [↑](#footnote-ref-7)
8. This data set was downloaded from the official web-side of this institution (<http://www.ine.es/daco/daco42/cne00/cneio2000.htm>) and refers to the latest update available at that moment, December 2012. [↑](#footnote-ref-8)
9. Although in our analysis we have used the product by product industry technology assumption, i.e. the so-called Model D, the empirical exercise of the “hybrid” I-O key-sector method was replicated considering alternative methods to obtain the symmetric I-O table using the industry technology assumption, i.e. known as Model B. As expected, the numerical results were slightly different. Nevertheless, the policy implications considered in this analysis remained unaltered. [↑](#footnote-ref-9)
10. This author evaluates the economy-wide gross output effects of each production unit taking out from the economic system both its external and internal linkages in order to quantify the sectors’ relevance in the economy. In addition, he goes a step further when hypothetically extracting a sector nullifying its final demand. Following this severe extraction formulation, backward indicators under the HEM and the CMM turn out to be completely identical. [↑](#footnote-ref-10)