Measuring Energy Linkages with the Hypothetical Extraction Method: An application to Spain.

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Abstract:

Efficiency improvements in energy use are nowadays one of the main concerns of policy makers and plans of action have been designed to achieve targets such as those of the Kyoto protocol. The measure of their success will depend on the degree that these plans spread through the system. In this light the interindustry linkages turn out to be quite significant for the effectiveness of policies. We propose in this paper an adaptation of the hypothetical extraction method to measure the role of energy and non-energy efficiency gains in an interconnected, multisectorial economy while relating the results to the Rebound effects literature.

Keywords: Energy linkages, Energy efficiency, Key sectors, Extraction methods.

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1. **Introduction**

Efficiency may be informally defined as the degree of achievement in producing a set of desired effects. In an economic context, the overall desired effect of efficiency gains is economic improvement through productivity growth. To achieve this goal, we bring into play “ideas” in the form of technological enhancements. As pointed out by Simon (1981), technology helps societies to maintain their life standards and even improve them using less resources and/or implementing better allocations. Some words of wisdom by Keynes (1936) can also be invoked: “even during financial crisis, resources and human ideas still are there”.

During the last few years policies aiming at promoting energy efficiency have often been directed towards reducing direct energy consumption and avoiding wastage of energy resources. These strategies pursue a limitation in the interrelationship between economic growth and energy use and, as a corollary, a limitation in environmental degradation too. Additionally they are crucial to try and reach the Kyoto Protocol commitments. This explains why efficiency improvements in energy use have become one of the main concerns of the European Union Energy Policy[1]. As a consequence, many European governments have enacted especial plans and policies seeking to attain this goal[2] . In general terms, these plans attempt to maintain the competitive level of an economy while causing minimal emission levels.

Most often energy efficiency improvements are centered on energy intensive sectors such as *Transport*, *Manufacturing*, *Energy* and *Construction*. In a market economy, however, these efficiency improvements will spread throughout the whole economic system thanks to the existing network of interactions between markets and sectors. This justifies why many analysts support the use of general equilibrium methods and techniques to provide a more comprehensive evaluation of the impact of policies in general; and environmental and energy policies in particular. Hirschman (1958) was the first author to stress the empirical relevance of inter-industry linkages for the assessment

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[1] See *“Commission Green Paper: A European Strategy for Sustainable, Competitive and Secure Energy”*, March 2006.

[2] In the case of Spain through the “*Plan de Acción 2005-07*” derived from Directive E4-2004-2012.

of policy effectiveness and pointed out how tighter interdependencies translate into stronger economy-wide impacts. Furthermore, the size of the implicit impact depends too on the sector receiving the policy inflow and henceforth, in maximizing policy effectiveness it becomes essential for the policy maker to identify so-called ‘key sectors’.

When singling out these “key sectors” under the input-output framework (Leontief, 1941), analysts have been using two methodologies: the Classical Multiplier Method (Rasmussen, 1956) and the Hypothetical Extraction Method (initially proposed by Strassert (1968) and later reformulated by Cella (1984) and Clements (1990)). The Hypothetical Extraction Method (HEM, for short) is a technique developed to measure the role of a sector within a network of sectors, typically in multisectorial models, to elicit its ‘key’ character in terms of its economic relevance or implicit weight. It is an improvement over the Classical Multiplier approach that measures ‘keyness’ merely in terms of simple averages of technical coefficients (direct and indirect). The HEM, in contrast, weights the ‘keyness’ of a sector by way of simulating the elimination of all of its external linkages from the economy, to wit the elimination of its sales to and purchases from all other sectors. The output loss that would follow this hypothetical cessation of economic activities quantifies the underlying network of linkages and provides a measure of ‘keyness’.

The empirical literature uses both of these approaches liberally to detect and measure how ‘key’ a sector is, but a consensus is emerging that the HEM goes deeper to the root of the problem (Miller and Lahr, 2001). We propose to use the HEM in a novel way consisting in a double extraction of the external linkages of both the energy and the non-energy sectors. The HEM, as adapted here, is seen to be useful to obtain information about the existing interactions between the energy and non-energy sectors that may be helpful in improving the effectiveness of energy policies intended at improving energy efficiency. In fact, the way we implement the HEM can be regarded as an extreme case of energy efficiency gains. When the external interactions of an energy sector are eliminated, this implies that its use as an input by other industries is reduced to zero while at the same time these industries eliminate their external input purchases.

The first type of extraction proceeds with the energy sectors and yields information about the fictitious output losses generated in the remaining sectors due to a hypothetical extraction of their external linkages. This sheds light on the non-energy sectors' sensitivity with respect to energy efficiency gains. If a sector is observed to have large output losses, this may be interpreted as a high sensitivity respect to these efficiency improvements and thus the sector may be considered also as a key sector for energy efficiency policies. Related to the possible Rebound or Backfire effect (Khazzooms, 1980; Brookes, 1990) derived from efficiency gains, this measure of energy efficiency sensitivity may be considered as a proxy to identify in which sectors these 'perverse' effects of energy efficiency improvements may have their origin. The Rebound effect occurs when an increase in energy efficiency leads to an increase in energy use instead of the expected reduction. Rebound or Backfire effects can be traced to the decrease in the effective price of energy that follows the cost reduction induced by the energy efficiency boost. Additionally, these results might be also useful to elicit the consequences of specific policies intended to reduce these impacts.

The second type of extraction, however, can be considered as a complementary, rather than an alternative way of measuring the energy intensiveness of a sector. When the non-energy sectors are extracted, output losses generated in the energy block provide information on the role that non-energy sectors have in the underlying energy paths. Contrary to the conventional energy intensiveness indices, i.e. the energy input-output ratios, the advantage of our proposed measure lies in the fact that it considers economy-wide energy use, and thus energy intensiveness too, both in direct and indirect ways. The findings under this type of extraction may also be relevant for the cost-effectiveness of policies aiming at improving energy efficiency.

The paper is organized as follows. In Section II we present the adaptation of the HEM methodology as implemented here. In Section III we comment the empirical database and discuss some of the main empirical results. Section IV concludes the paper.

II. Methodology

The economy is partitioned into two production blocks or categories: an energy block that includes *H* energy sectors (with sub-index *E*), and a non-energy block (with sub-index –E) that encompasses the remaining *N* non-energy sectors. For notational simplicity we split the production equation accordingly with the use of a partitioned coefficient matrix. The technical coefficient sub-matrices that relate to energy inputs will be denoted by $\varepsilon_{E,-E}$ and $\varepsilon_{E,E}$. For a given final demand configuration *f*, a production equilibrium will be defined as an output vector *X* that satisfies:

$$\begin{bmatrix} X_{-E} \\ X_E \end{bmatrix} = \begin{bmatrix} \left(I_{-E} - A_{-E,-E}\right) & -A_{-E,E} \\ -\varepsilon_{E,-E} & \left(I_E - \varepsilon_{E,E}\right) \end{bmatrix}^{-1} \begin{bmatrix} f_{-E} \\ f_E \end{bmatrix} \tag{1}$$

where the elements of the row sub-matrix $\varepsilon = \left[\varepsilon_{E,-E} \quad \varepsilon_{E,E}\right]$ in equation (1) incorporate the energy technical coefficients for all sectors:

$$[\varepsilon]_j = \frac{X_{E,j}}{X_j} \tag{2}$$

In order to control for the size of the sectors of each production block, the supply-demand balance systems of the non-energy and energy sector, the system in equation (1) can be rewritten in relative output terms rather than in absolute output terms[3]. For doing so we pre-multiply expression (1) by a diagonal partitioned matrix containing the inverse of output levels of the energy and non-energy sectors:

$$\begin{bmatrix} \hat{X}_{-E}^{-1} & 0 \\ 0 & \hat{X}_E^{-1} \end{bmatrix} \begin{bmatrix} X_{-E} \\ X_E \end{bmatrix} = \begin{bmatrix} \hat{X}_{-E}^{-1} & 0 \\ 0 & \hat{X}_E^{-1} \end{bmatrix} \begin{bmatrix} \left(I_{-E} - A_{-E,-E}\right) & -A_{-E,E} \\ -\varepsilon_{E,-E} & \left(I_E - \varepsilon_{E,E}\right) \end{bmatrix}^{-1} \begin{bmatrix} f_{-E} \\ f_E \end{bmatrix} \tag{3}$$

Equation (3) can be solved using the generalised inverse of a partitioned matrix[4]. This inverse matrix can be seen to be:

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[3] This method of normalisation was first applied by Clements and Rossi (1991).

[4] See Moore (1935) and Penrose (1955)

$$\begin{bmatrix} B_{-E,-E}\cdot\left[I_{-E}+A_{-E,E}\cdot Q^{-1}_{E,E}\cdot\varepsilon_{E,-E}\cdot B_{-E,-E}\right] & B_{-E,-E}\cdot A_{-E,E}\cdot Q^{-1}_{E,E} \\ Q^{-1}_{E,E}\cdot\varepsilon_{E,-E}\cdot B_{-E,-E} & Q^{-1}_{E,E} \end{bmatrix} \tag{4}$$

where

$$Q^{-1}_{E,E}=\left[\left(I_{E}-\varepsilon_{E,E}\right)+\varepsilon_{E,-E}\cdot B_{-E,-E}\cdot A_{-E,E}\right]^{-1}$$

and

$$B_{-E,-E}=\left(I_{-E}-A_{-E,-E}\right)^{-1}$$

Notice that the auxiliary submatrix $Q^{-1}_{E,E}$, being an inverse matrix, includes all the direct and indirect information that relates to the energy efficiency of the production system. Any change in the energy intensity of any of the production units will be further transferred to the rest of sectors through this sub-matrix as stated in equation (4).

The supply-demand balance system of the non-energy and energy sector per unit of output will now be:

$$\begin{aligned} e_{-E}&=\hat{X}^{-1}_{-E}\cdot B_{-E,-E}\left[I_{-E}+A_{-E,E}\cdot Q^{-1}_{E,E}\cdot\varepsilon_{E,-E}\cdot B_{-E,-E}\right]\cdot f_{-E}+\hat{X}^{-1}_{-E}\cdot B_{-E,-E}\cdot A_{-E,E}\cdot Q^{-1}_{E,E}f_{E} \\ e_{E}&=\hat{X}^{-1}_{E}\cdot Q^{-1}_{E,E}\cdot\varepsilon_{E,-E}\cdot B_{-E,-E}\cdot f_{-E}+\hat{X}^{-1}_{E}\cdot Q^{-1}_{E,E}\cdot f_{E} \end{aligned} \tag{5}$$

where e_{-E} and e_{E} are unitary column vectors.

We can envision efficiency variations in the external inputs of energy and non-energy by way of two auxiliary diagonal matrixes: $\hat{\lambda}_{-E}\in M_{N\times N}$ and $\hat{\lambda}_{E}\in M_{H\times H}$. The diagonal elements of matrix $\hat{\lambda}_{-E}$ represent the sectorial percentage efficiency changes in the use of energy inputs occurring in non-energy sectors. In turn those of matrix $\hat{\lambda}_{E}$ refer to the sectorial percentage variations in non-energy intermediate demand taking place in the energy sectors. We assume that efficiency changes are sector specific and homogenous for all the inputs used in its production process. For any given efficiency change configuration $\Lambda = (\hat{\lambda}_E, \hat{\lambda}_{-E})$, and under the same final use vector, the hypothetical energy and non-energy output levels relative to the initial ones will be given by:

$$\begin{aligned}
&\hat{X}_{-E}^{-1} X'_{-E} = \hat{X}_{-E}^{-1} B_{-E,-E} \cdot \left[I_{-E} + A_{-E,E} \cdot \hat{\lambda}_E \cdot \left(Q'_{E,E}\right)^{-1} \cdot \varepsilon_{E,-E} \cdot \hat{\lambda}_{-E} \cdot B_{-E,-E} \right] \cdot f_{-E} + \\
&\quad + \hat{X}_{-E}^{-1} B_{-E,-E} \cdot A_{-E,E} \cdot \hat{\lambda}_E \cdot (Q'_{E,E})^{-1} \cdot f_E \qquad \text{(6a)} \\
&\hat{X}_{E}^{-1} X'_{E} = \hat{X}_{E}^{-1} \left(Q'_{E,E}\right)^{-1} \cdot \varepsilon_{E,-E} \cdot \hat{\lambda}_{-E} \cdot B_{-E,-E} \cdot f_{-E} + \hat{X}_{E}^{-1} \left(Q'_{E,E}\right)^{-1} \cdot f_E
\end{aligned}$$

where:

$$\left(Q'_{EE}\right)^{-1} = \left[\left(I_E - \varepsilon_{E,E}\right) + \varepsilon_{E,-E} \cdot \hat{\lambda}_{-E} \cdot B_{-E,-E} \cdot A_{-E,E} \cdot \hat{\lambda}_E \right]^{-1}$$

or alternatively in terms of relative output changes:

$$\begin{aligned}
&\hat{X}_{-E}^{-1} \Delta X_{-E} = \\
&\hat{X}_{-E}^{-1} B_{-E,-E} \cdot \left[A_{-E,E} \cdot \left(Q_{E,E}\right)^{-1} \cdot \varepsilon_{E,-E} - A_{-E,E} \cdot \hat{\lambda}_E \cdot \left(Q'_{E,E}\right)^{-1} \cdot \varepsilon_{E,-E} \hat{\lambda}_{-E} \right] \cdot B_{-E,-E} \cdot f_{-E} + \\
&\quad + \hat{X}_{-E}^{-1} \cdot B_{-E,-E} \left[A_{-E,E} \cdot (Q_{E,E})^{-1} - A_{-E,E} \cdot \hat{\lambda}_E \cdot (Q'_{E,E})^{-1} \right] \cdot f_E \\
&\qquad \text{(6b)} \\
&\hat{X}_{E}^{-1} \Delta X_{E} = \\
&\hat{X}_{E}^{-1} \cdot \left[\left(Q_{E,E}\right)^{-1} \cdot \varepsilon_{E,-E} - \left(Q'_{E,E}\right)^{-1} \cdot \varepsilon_{E,-E} \cdot \hat{\lambda}_{-E} \right] \cdot B_{-E,-E} \cdot f_{-E} + \\
&\quad + \hat{X}_{E}^{-1} \left[\left(Q_{E,E}\right)^{-1} - \left(Q'_{E,E}\right)^{-1} \right] \cdot f_E
\end{aligned}$$

Computing the difference with respect to the initial output levels in equation (5), we obtain sectorial total output changes in relative terms as a result of changes of efficiency levels in the use of external inputs. In fact, the HEM as mentioned in the introduction consists in an extreme case of external input efficiency improvements, namely $\hat{\lambda}_{-E} = 0_{N\times N}$ and $\hat{\lambda}_{-E} = 0_{H\times H}$. Introducing this assumption[5] in equation (6) and taking differences with respect to equation (3), we obtain each sector's relative output loss

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[5] Cella (1984)

when purchasers and sellers of inputs are both hypothetically eliminated and direct and indirect influences are accounted for:

$$\begin{gathered}\hat{X}_{-E}^{-1} \cdot \Delta X_{-E} = \\ \hat{X}_{-E}^{-1} \cdot B_{-E,-E} \cdot \left[A_{-E,E} \cdot Q_{E,E}^{-1} \cdot \varepsilon_{E,-E} \cdot B_{-E,-E} \right] \cdot f_{-E} + \hat{X}_{-E}^{-1} \cdot B_{-E,-E} \cdot A_{-E,E} \cdot Q_{E,E}^{-1} \cdot f_E \\ \hat{X}_E^{-1} \cdot \Delta X_E = \hat{X}_E^{-1} \cdot Q_{E,E}^{-1} \cdot \varepsilon_{E,-E} \cdot B_{-E,-E} \cdot f_{-E} + \hat{X}_E^{-1} \cdot \left(Q_{E,E}^{-1} - (I_E - \varepsilon_{E,E}) \right)\end{gathered} \tag{7}$$

When the external linkages of the energy sectors are hypothetically extracted (first type of extraction, $\hat{\lambda}_{-E} = 0_{N \times N}$), the two supply-demand balance expressions in equation (7) yield information about the relative output losses in the energy and non-energy block. This is our proposed proxy for the degree of sensitivity of sectors to the implicit energy efficiency gains. On the other hand, when the external linkages of the non-energy sectors are removed (second type of extraction, $\hat{\lambda}_{-E} = 0_{H \times H}$) the second expression in equation (7) gives us an economy-wide measure of sectors' energy intensiveness. Both types of extractions end up providing valuable information for a more effective implementation of energy efficiency policies.

III. Database and empirical results

We have applied the methodology outlined above to 2004 data from the Spanish economy. We have assembled a symmetric input-out table at basic prices merging the information provided by the official 'make' and 'use' tables for the said year. In order to generate homogenous productive units, we have used the Industry-Technology assumption[6]. The level of disaggregation of the original data distinguishes five energy sectors: two are energy extractive industries and three are energy production and

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[6] The ESA-95 describes two alternative procedures to get homogenous productive units: the commodity-technology assumption (the technology of each commodity is the same wherever it is produced) and the industry-technology assumption (every commodity produced in the same industry is subject to the same production process). Although both approaches have their limitations, we have applied the second one because of simplicity and higher data availability.

distribution industries and we have kept them in the rearranged data. For the rest of sectors and for ease of presentation, we have aggregated the intermediate and final use flows into twelve distinct economic activities. The sectorial breakdown appears in the Appendix.

We have also complemented the input-output data appending information on environmental damage. We include data in terms of the emission levels[7] of air pollutants generated by each economic activity. Since data for our reference period were not available, we have updated to 2004 the available 2003 'satellite' environmental accounts.

Tables I and II in the Annex depict the simulation results derived from the first type of extraction, namely, when the five energy sectors are sequentially extracted. Table I uses equation (7) to calculate all sectors relative output losses while Table II shows the resulting changes in emission levels. When an energy sector is extracted a large part of the 'efficiency' losses are, in general, concentrated in the block of energy sectors, and more specifically, in the energy sector being hypothetically eliminated. However, the way these relative output losses spread throughout the energy block is different in each case. For instance, should all the external linkages of the two energy extractive industries (sectors 2, 3) be deleted, we would observe their output level to decrease by almost a 100 percent while those of the remaining energy activities would hardly vary. This is not a surprising result since these two sectors constitute the main input suppliers within the energy block. They are down-the-line in the energy production chain and as a consequence their role as input purchasers is very limited. Thus, the missing external links of the energy extractive industry implies a slight impact on the activity levels of the other energy sectors.

In contrast, when the methodology is applied on the other three energy activities (sectors 5, 6, 7), relative output losses are more widely distributed among the whole of the energy activities. This is specially the case for the production and distribution of Electricity (sector 6) where the largest percentage change does not even take place in the

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[7] Sulphur oxides (SOx); Nitrogen oxides (NOx); Methane (CH_4); Non-Methane Volatile Organic Compounds ($NMVOC$) organic pollutants; Carbon Dioxide (CO_2) ; Carbon Oxide (CO); Ammonia (NH_3); Sulphur Hexafluoride (SF_6); Nitrous Oxide (NO_2); Hydrofluorocarbons (HFC) ; Particulates < 10µm (PM10); and Perfluorinated Compound (PFC).

extracted sector but in the neighbouring sector 2. This indicates the relevant role that this sector has in energy production chains both as an energy seller and as a purchaser of other energy inputs. Additionally, in terms of environmental costs, the links of the Electricity sector to the rest of the economy imply an almost 24 percent overall emission levels generated by this sector's activity, the highest among energy sectors, followed by the Gas sector. This shows that the Electricity sector turns out to be the main polluter once its intermediate market functions are considered.

According to our proposed interpretation for this type of extraction, this energy industry, sector 6, turns to be a 'key sector' for energy efficiency policies. To this extent, favouring a more efficient use of electricity would produce the strongest decline in overall energy consumption but also in emission levels. In second term, and related to the possible Rebound or Backfire effect, our findings also suggest that the contribution of the Electricity sector to this perverse effect might be larger than that of other energy sectors. Policies aiming at improving energy efficiency in the Electricity sector will tend to decrease the effective price of this input. Since this sector plays an important role both as a transferor and as a transferee of the declining energy prices, i.e. when selling its output to other industries and buying its needed inputs from other energy sectors. Consequently, this decline in the production cost will tend to favour an increase in overall energy demand which would work in the opposite direction of the potential energy savings. Any complementary policy trying to mitigate this effect, say, an ecotax, should directly tackle the energy sectors, and specially the Electricity sector, since almost all of the losses turn out to be concentrated on this production block and hence the effectiveness of energy efficiency policies would be granted a positive cumulative momentum.

We now turn to the second type of extraction to evaluate the impact that each non-energy sector has over energy paths. We are now interested in calculating the relative output and emissions losses in the energy sectors when the external links of the non-energy sectors are hypothetically removed. Table III reports output losses with a distinction between those originating using the HEM and those of the more traditional energy intensity measure, the input-output ratio. Table IV shows the derived percentage decrease in emission levels both in terms of specific pollutants and in terms of an aggregate overall indicator which is obtained from the emissions fall explained by output losses traced to the energy and non-energy sectors. From these tables we can observe that, according to the HEM, the Commercial and Transport Activities (sector 14) and the Manufacturing Industries (sector 12) would show the highest reductions in the output of the energy sectors. Taking account of their direct and indirect intermediate activities ends up yielding a relevant weight as far as energy use is concerned. The traditional energy I/O ratio, however, indicates that it is the Chemistry, Rubber and Plastic Industry the most energy intensive sector with I/O ratios in a range between 0,016 and 3,506.

The discrepancies between both energy intensity measures are glaringly shown when a non-energy sector is not a direct purchaser of a specific energy input. See for instance the case of Public Services (sector 17) and Extraction of Crude & Natural Gas (sector 3). In this case, even though the I/O ratio is zero, the fact that there are external sales to other sectors induces an indirect demand for energy that, using the HEM, has an impact evaluated at about 8.3 percent. Since indirect energy consumption is not included when using the input-output ratio as a measure of a sector's energy intensity, the conventional measure presents a systematic and quite considerable downward bias. Avoiding the omission of this 'indirect effect' is then one of the main contributions of the energy intensity measure proposed here.

A final observation of interest is that the sectorial ordering given by the HEM relative output measure may not coincide with the ordering in terms of emission levels and their subsequent environmental damages. Reading the results in Table III we can confirm that Construction (sector 13) has the highest direct and indirect average energy consumption. In Table IV, however, we can see that as a result of the extensive external market functions of the Manufacturing Industries, there would be more than a 20 percent overall fall in emission levels. Thus there need not be a 'perfect match' between the goals of minimising environmental damage and those of minimising energy use.

IV. Conclusions

We have used the interindustry modelling framework and Spanish data for 2004 to perform a double simulation exercise using an adaptation of the hypothetical extraction method applied to both the energy and non-energy blocks. We reformulate the HEM using a diagonal matrix and setting its coefficients selectively and sequentially to zero. These zero values can be seen as limit efficiency gains but, unlike the traditional HEM formulation, other intermediate values in the unit interval representing partial efficiency gains could also be considered. Implementing the first type of extractions we evaluate relative losses in sectorial outputs as well as their associated emissions' reductions. The main finding is that the Electricity sector presents the highest average impact among the energy sectors with the lowest variability too. This shows the significant role of this sector within the energy production chains and allows us to categorise it as a 'key sector' for energy efficiency policies. As an illustration, any policies intended to improve energy efficiency in the Electricity sector by, say, 5 percent will have a higher multiplier effect and will favour a larger decline in overall energy use than composite policies aiming to reduce energy use by 1 percent in each of the five energy sectors. In addition, if there happened to be a derived Rebound effect as a result of these policies, then complementary strategies to mitigate it should also be focused on this sector. The reason behind this is the dual role of the Electricity sector as a transferor and transferee of energy efficiency gains and the subsequent decline in the effective price of energy inputs.

The second type of extraction provides information about the role that non-energy sectors have on energy paths. According to our interpretation, this role will be more relevant the higher the relative output losses generated in the energy sectors by a hypothetical extraction of a given non-energy sector. This measure turns out to be a better, more complete approximation to a sector's energy intensity than the conventional energy input-output ratio since the former also accounts for the indirect demand for energy inputs derived from intermediate activities. This measure therefore sheds additional light as far as the goal of maximising economy-wide impacts of energy efficiency policies is concerned.

Further extensions of this work will apply the conclusions obtained here for the evaluation of energy efficiency policies and their possible Rebound effects in the context of a Computable General Equilibrium model whereby direct and indirect effects are accounted for along with additional income-expenditure linkages as well as endogenous price and cost adjustments.

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Appendix: *Sectorial breakdown for Spanish I/O 04 Data*

Aggregation ordering in symmetric table	*Classification*	*Sectors*	*NACE-93 code*
2	*Energy Sectors*	*Extraction of Anthracite, Coal, Lignite and Peat*	**10**
3		*Extraction of Crude, Natural Gas, Uranium and Thorium*	**11-12**
5		*Coke, Refinery and Nuclear fuels*	**23**
6		*Production and Distribution of Electricity*	**401**
7		*Production and Distribution of Gas*	**402-403**
1	*Non Energy Sectors*	*Primary Sector*	**01, 02, 05**
4		*Other Extraction Industries*	**13-14**
8		*Water Sector*	**41**
9		*Food, Beverage, Tobacco, Textile and Leather Products*	**151-152,** **154-155,** **156-159,** **16-19**
10		*Other Industrial Sectors & Recycling*	**20-22,37**
11		*Chemistry Industry, Rubber and Plastic Industry*	**24-25**
12		*Manufacturer Industry: Minerals, Furniture, Metallic Products, Equipment & Electronic Products.*	**261-268,** **27-36**
13		*Construction*	**45**
14		*Commercial & Transport Activities*	**50-52,** **61-62,** **601-603,** **63.1-63.2, 63.4**
15		*Market Services*	**65-67,** **70-72, 74,** **80, 85, 90, 92, 93,** **63.3**
16		*Market R & D*	**73**
17		*Non Market Servicies & Public administration*	**75, 80, 85, 90, 92**

Annex of Tables.

Table I. Relative Output Losses for all sectors under the Hypothetical Extraction of Energy Sectors. Spanish I/O Data 2004**.**

Production Units	***2. Extraction of Anthracite, Coal, Lignite and Peat***	***3. Extraction of Crude and Natural Gas***	***5. Coke, Refinery and Nuclear fuel;***	***6. Production and distribution of electricity***	***7. Production and distribution of Gas***
1.Primary Sector	0,0158	0,007	0,102	0,263	0,018
2. Extraction of Anthracite, Coal, Lignite and Peat	98,592	0,031	1,056	84,661	0,270
3. Extraction of Crude, Natural Gas, Uranium and Thorium	0,162	99,697	76,772	14,468	19,74
4. Other Extractive Industries	0,070	0,0142	0,357	0,626	0,042
5. Coke, Refinery and Nuclear fuels	0,173	0,0398	55,274	10,425	0,172
6. Production and Distribution of Electricity	0,371	0,033	1,013	71,902	0,208
7. Production and Distribution of Gas	0,134	0,089	0,782	30,261	73,881
8. Water Sector	0,032	0,006	0,712	1,522	0,034
9.Food,Beverage,Tobacco,Textile and Leather Products	0,014	0,009	0,093	0,237	0,021
10. Other Industrial Sectors + Recycling	0,157	0,014	0,326	0,906	0,054
11. Chemistry Industry, Rubber and Plastic Industry	0,096	0,018	0,442	0,454	0,030
12. Manufacturing Industries: Minerals, Furniture, Metallic Products, Equipment and Electronic Products.	0,050	0,021	0,262	0,740	0,057
13. Construction	0,009	0,004	0,075	0,372	0,027
14. Commercial and Transport Activities	0,032	0,008	0,486	0,681	0,027
15. Market Services	0,034	0,031	0,385	1,010	0,099
16. Market R & D	0,064	0,068	1,517	1,640	0,152
17. Not Market Servicies+Public administration	0,004	0,002	0,075	0,128	0,014

Table II. Percentage Emission Losses by Air Pollutant under the Hypothetical Extraction of Energy Sectors. Spanish I/O Data 2004**.**

Air Pollutant	***2. Extraction of Anthracite, Coal, Lignite and Peat***	***3. Extraction of Crude & Natural Gas***	***5. Coke, Refinery & Nuclear fuel***	***6. Production and distribution of Electricity***	***7. Production and distribution of Gas***
SOx	0,624	0,162	6,243	45,481	10,047
NOx	0,300	0,086	3,094	17,469	5,261
NMVOC	0,036	0,016	0,587	0,972	1,364
CH_4	2,776	0,049	0,405	3,652	0,360
CO	0,094	0,025	1,883	3,033	4,043
NH_3	0,018	0,007	0,161	0,274	0,133
CO_2	0,463	0,133	4,880	23,898	6,850
SF_6	0,050	0,021	0,262	0,740	5,700
NO_2	0,059	0,017	0,540	1,912	0,804
PM10	1,056	0,055	2,539	10,856	3,786
PFC	0,157	0,014	0,326	0,906	5,400
HFC	0,096	0,018	0,442	0,454	3,000
OVERALL* REDUCTION IN EMISSION LEVELS OF AIR POLLUTANTS	**0,472**	**0,130**	**4,797**	**23,551**	**6,753**

*All emissions have been transformed to the same measurement units **(*tones*)** for aggregation and calculations.

Table III. Relative output losses of Energy Sectors under the Hypothetical Extraction of Non-Energy Sectors. Spanish I/O Data 2004.

Production Units	***Energy Intensity Measures****	***2. Extraction of Anthracite, Coal, Lignite***	***3. Extraction of Crude & Natural Gas***	***5. Coke, Refinery &Nuclear fuel***	***6. Production and distribution of Electricity***	***7. Production and distribution of Gas***	***Average impact Energy Sectors***
1. Primary Sector	***HEM***	2,468	3,126	3,514	2,704	1,882	2,738
	I/O Ratio	0,001	0,000	0,019	1,226	0,651	
4. Other Extractive Industries	***HEM***	0,031	0,792	0,862	1,020	0,599	1,279
	I/O Ratio	0,072	0,000	0,805	2,858	3,188	
8. Water Sector	***HEM***	0,270	0,335	0,342	0,509	0,336	0,358
	I/O Ratio	0,002	0,000	0,011	1,180	1,80	
9. Food Beverage, Tobacco, Textile and Leather Products	***HEM***	0,475	6,049	5,326	8,490	8,902	5,848
	I/O Ratio	0,007	0,002	0,026	0,118	0,768	
10. Other Industrial Sectors & Recycling	***HEM***	7,659	2,396	1,840	4,335	4,603	4,166
	I/O Ratio	0,001	0,000	0,044	0,176	1,417	
11. Chemistry Industry, Rubber and Plastic Industry	***HEM***	3,920	10,94	12,072	5,320	7,701	7,990
	I/O Ratio	0,017	0,016	0,516	3,506	1,025	
12. Manufacturing Industries	***HEM***	5,410	13,151	10,859	22,027	22,482	14,785
	I/O Ratio	0,053	0,002	0,836	0,239	1,008	
13. Construction	***HEM***	28,026	6,945	6,124	8,551	7,663	11,461
	I/O Ratio	0,010	0,037	0,589	0,203	0,229	
14. Commercial & Transport Activities	***HEM***	10,195	21,395	21,703	17,267	14,709	17,053
	I/O Ratio	0,002	0,135	0,040	2,428	1,462	
15. Market Services	***HEM***	15,575	10,929	9,675	18,602	13,526	13,661
	I/O Ratio	0,007	0,020	0,019	0,245	0,643	
16. Market R & D	***HEM***	18,343	0,511	0,376	0,525	0,525	4,056
	I/O Ratio	0,094	0,335	0,176	1,011	1,434	
17. Not Market Servicies & Public administration	***HEM***	0,720	8,276	7,303	14,200	12,441	8,588
	I/O Ratio	0,008	0,00	0,014	0,364	1,011	

**HEM and I/O Ratio denote respectively energy intensity measure obtained when applying the second type of extraction and the energy input-output ration in percentage terms.*

Table IV. Percentage Emission Losses by Air Pollutant under the Hypothetical Extraction of Non-Energy Sectors. Spanish I/O Data 2004.

Air Pollutant	*1. Primary Sector*	*4. Other Extractive Industries*	*8. Water Sector*	*9. Food Beverage, Tobacco, Textile & Leather Products*	*10. Other Industrial Sectors & Recycling*	*11. Chemistry Industry, Rubber & Plastic Industry*
SOx	2,785	0,801	0,471	7,846	4,079	6,276
NOx	13,927	1,555	0,379	15,558	5,957	4,909
NMVOC	39,357	1,395	0,135	32,375	4,408	4,128
CH_4	41,579	25,987	0,090	32,903	3,090	2,238
CO	12,906	1,328	0,299	13,034	4,263	2,859
NH_3	56,424	6,427	0,083	44,002	3,388	3,446
CO_2	4,833	2,144	0,460	8,905	5,052	5,654
SF_6	1,038	0,255	0,333	2,916	1,925	1,512
NO_2	47,978	7,213	0,137	38,237	3,547	6,332
PM10	24,706	1,401	0,263	22,186	5,001	3,583
PFC	1,538	0,217	0,435	8,353	76,256	3,233
HFC	3,583	0,480	0,501	8,685	3,179	51,822
Overall Reduction in Emission Levels Of Air Pollutants	**5,482**	**2,285**	**0,453**	**9,339**	**5,036**	**5,607**
% Explained by Energy Sectors	**1,155**	**0,394**	**0,192**	**3,371**	**1,657**	**2,916**
% Explained by Non-Energy Sectors	**4,326**	**1,891**	**0,261**	**5,967**	**3,378**	**2,690**

Air Pollutant	*12. Manufacturing Industies.*	*13. Construction*	*14. Commercial & Transport Activities*	*15. Market Services*	*16. Market R & D*	*17. Not Market Servicies & Public administration*
SOx	21,629	9,186	16,078	15,230	0,457	11,414
NOx	16,571	8,588	16,619	13,416	0,313	7,811
NMVOC	7,733	6,056	8,387	13,218	0,188	5,067
CH_4	4,590	2,517	6,458	11,767	0,163	5,637
CO	22,249	11,897	11,462	10,691	0,269	5,369
NH_3	4,157	2,513	6,996	13,551	0,169	5,046
CO_2	20,824	10,136	15,545	13,126	0,363	8,631
SF_6	33,927	17,366	4,978	8,328	0,305	4,458
NO_2	6,372	3,497	7,799	13,119	0,200	5,634
PM10	15,684	8,372	12,180	13,032	0,275	6,535
PFC	24,034	14,482	8,409	29,981	0,410	12,645
HFC	20,756	9,121	5,617	9,850	0,489	10,320
Total Reduction in Emission Levels Overall Air Pollutants	**20,581**	**10,038**	**15,409**	**13,124**	**0,360**	**8,577**
% Explained by Energy Sectors	**8,509**	**3,383**	**7,488**	**6,874**	**0,211**	**5,368**
% Explained by Non-Energy Sectors	**12,071**	**6,655**	**7,921**	**6,249**	**0,148**	**3,208**