Merging the Hypothetical Extraction Method and the Classical Multiplier Approach: A Hybrid Possibility for Identifying Key Distributive Sectors

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Abstract: The two main alternative methods used to identify key sectors within the input-output approach, the Classical Multiplier method (CMM) and the Hypothetical Extraction method (HEM), are formally and empirically compared in this paper. Our findings indicate that the main distinction between the two approaches stems from the role of the internal effects. These internal effects are quantified under the CMM while under the HEM only external impacts are considered. In our comparison, we find, however that CMM backward measures are more influenced by *within-block* effects than the proposed forward indices under this approach. The conclusions of this comparison allow us to develop a hybrid proposal that combines these two existing approaches. This hybrid model has the advantage of making it possible to distinguish and disaggregate external effects from those that a purely internal. This proposal has also an additional interest in terms of policy implications. Indeed, the hybrid approach may provide useful information for the design of "second best" stimulus policies that aim at a more balanced perspective between overall economy-wide impacts and their sectoral distribution.

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I. Introduction

The seminal work of Leontief (1941) stressed the fact that in modern economies markets are not isolated. Disregarding this fact and focusing on a partial rather than a general equilibrium perspective, where market interdependencies exist, downward biases the evaluation of changes in economic variables. The potential derived effects in the economic system should also include indirect and possibly induced interactions. Consequently, a change in a given market, i.e. a demand shock, works its way throughout the "grid" of sectoral linkages, where mutual interconnections are duly taken into account, and yield endogenous repercussions affecting most or all of the interlocking economic pieces of the system.

Hirschman (1958) was the first to suggest the relevance of sectoral linkages for economic development. The more developed an economy is, the higher the proportion of inter-sectoral transactions to total output. According to this author, industrial or sectoral linkages constitute a measure of the degree of efficiency in production in an economy (i.e. the higher the degree of industrial integration, the lower the costs of production) but they are also an index of policy effectiveness (i.e. the effects of an increase in one sector investment will be transferred to the rest of the production block thanks to the network of industrial interdependencies). In his pioneer work Hirschman stated that, within these industrial interdependencies, two inducement mechanisms might be considered at work between each pair of industries: the direct backward linkage (or input-provision effects) and the direct forward linkage (or output-utilization effects). The former informs about one sector potential capability to induce the supply of inputs by other sectors while the latter is a measure of the potential effect of this sector over other sectors' input demand. Hirschman's approach was therefore the first relevant quantitative attempt for the identification of "key sectors" as a mean for planning better and more effective industrial development policies. "Key sectors" are defined as those that have either an above average backward strength (key pull sector) or an above average forward linkage index (key push sector).

For the empirical identification of "key sectors" under the input-output framework, analysts have been using two methods: the Classical Multiplier Method (CMM) based on Rasmussen (1957) and the Hypothetical Extraction Method (HEM) initially proposed by Paelinck et al. (1965) and Strassert (1968) and later reformulated by Meller and Marfán (1981), Cella (1984) and Clements (1990). The HEM is a technique developed to measure the role of a sector (or groups of sectors) within the inter-industrial network of an economy. This is typically applied in multisectoral models to elicit its 'key' character in terms of its economic relevance or implicit weight. It is an improvement over the CMM, which 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 concrete economic connections, most of them external, of that sector to the remaining sectors. The output loss that would follow from this hypothetical cessation of economic activities quantifies the underlying network of linkages and provides a measure of 'keyness' or, in other words, a measure of the degree of dependency that one economy has on a specific sector. The empirical literature uses both of these approaches liberally to detect and measure how 'key' a sector is though a consensus is emerging that the HEM may go deeper to the root of the specific problem researchers want to tackle. Along these lines, several types of extractions have been suggested within the HEM framework (Miller and Lahr, 2001). Among them, that extraction originally presented by Cella (1984) appears to be the most widely-accepted especially when the focus is on inter-sectoral interdependencies rather than intra-sectoral or *within-block* linkages (Miller and Lahr, 2001, Miller and Blair, 2009).

Following Cella's proposal (Cella, 1984), the HEM, then, quantifies the relevance of one sector in terms of its external, i.e. *out-block*, contribution to the market interdependencies while the CMM omits this distinction since it measures the total contribution originating in a sector over the whole set of sectors. Nevertheless, the two methods share the same theoretical assumptions in the sense that both CMM and HEM have their roots in Leontief's quantity model.

The aforementioned distinctions and similarities of the two approaches suggest then that their combined use is not only feasible from a pure theoretical point of view but it may also be useful for empirical work. In fact, this constitutes the main contribution of this paper. We present a novel "hybrid" methodology that merges the two existing approaches to single out sectors' "keyness" in an economy. Since differently to the CMM the HEM only accounts for the external interdependencies of sectors, the usefulness in combining the two existing approaches stems from isolating these effects from those that are merely internal, i.e. from self-supply. Therefore, the use of our proposed "hybrid" framework allows measuring sectors' forward and backward "keyness" in terms of economy-wide impacts and the economy-distributive effects in both intra-industrial or within block effects and inter-industrial or *out-block* effects. This makes possible to attain a "second best" situation that makes compatible economy-wide policy effectiveness and its sectoral distributive impacts.

In order to illustrate the viability and the usefulness of our "hybrid" proposal, we also present an empirical exercise that aims at identifying "key sectors" for energy efficiency policies in the context of the Spanish economy. As already pointed out by Hirschman (1958), both these indices, backward and forward, provide useful information to design in a more cost-effective way general economic policy as well as more specific policies, as are those related to energy efficiency gains. Taking into account the characteristics of these policies and the seminal ideas of Hirschman, it is relevant to identify which are the sectors in the energy and non-energy blocks that play a more relevant role in providing production requirements to the remaining production blocks, that is to say, "key" push sectors. The reason behind this statement stems from the existing relationship between technology, production efficiency and cost structure. In an interconnected market economy, energy efficiency gains that occur in a specific sector reduce its overall production costs but also those of other sectors to which it provides intermediate inputs. Thanks to the existence of integrated markets, then, these efficiency gains are transferred from one sector to the other, round by round, favouring overall reduction in the intermediate use of energy in the economy as a whole. Furthermore, our proposed "hybrid" model allows also identifying those sectors with the largest external "push" effect, i.e. the larger the external "push" effect, the stronger the distributive effect of energy efficiency gains. Therefore, the combined used of the two existing methods under our "hybrid" proposal might enrich both the empirical results and the conclusions drawn for policy guidance.

This paper is organized as follows. After formally describing the characteristics and the main differences between the two existing methodologies for identifying "key-sectors" in Section II, we formally present in Section III the new "hybrid" approach whereby the two frameworks may be complementarily used to disaggregate total effects into internal and external linkages. The empirical exercise of our "hybrid" proposal related to energy efficiency policies in the Spanish context is presented and described in Section IV while Section V concludes this analysis.

II. The Classical Multiplier Method and the HEM: A Review

We now proceed to formally describe and discuss both methodologies. To this end we use partitioned matrices, following the usual approach in the HEM. This practise eases the comparison of the two alternative approaches, the CMM and the HEM, and helps in the presentation of the novel "hybrid" approach presented in Section III below. Our point of departure is the supply-demand balance system that corresponds to the familiar Leontief's quantity model. The solution to this system of equations in matrix notation is given by:

$$X = (I - A)^{-1} \cdot f \qquad (1)$$

where X refers to the column vector of gross sectoral production levels, and $\left(I - A\right)^{-1}$ is the so-called Leontief inverse that relates final demand f with total output X . Provided some technicalities that are associated to the productivity of matrix A are satisfied[1], the system in (1) has a unique and non-negative solution.

With the aforementioned goal in mind, i.e. comparing formally the CMM with the HEM, and using partitioned matrices expression (1) can be rewritten in the following way:

$$\begin{bmatrix} X_K \\ X_{-K} \end{bmatrix} = \begin{bmatrix} I_K - A_{KK} & A_{K-K} \\ A_{-KK} & I_{-K} - A_{-K-K} \end{bmatrix}^{-1} \begin{bmatrix} f_K \\ f_{-K} \end{bmatrix} \quad \text{with} \quad \underbrace{1,...,k,...,K}_{K}, \underbrace{K+1,...,-k,...N}_{-K} \qquad (2)$$

[1] a) Matrix $(I - A)$ is non-singular, $|I - A| \neq 0$, and b) matrix A is productive with respect to all column vectors $f \geq 0$: $AX \leq X$.

The set of equations in (2) indicates that the production block composed by *N* sectors is sub-divided into two production blocks: block *K* and block *–K*. The way sectors are grouped under the "key sectors" analysis usually depends on the nature of problem researchers want to tackle, i.e. for the case of energy efficiency policies, we disaggregate sectors into an energy block and a non-energy block. In fact, the rigorous and thorough work of Termurshoev (2010) has already demonstrated that a group of key sectors should not necessary imply a key group of sectors.

Applying the generalized inverse of partitioned matrices, following Moore (1935) and Penrose (1955), the partitioned Leontief inverse that solves the supply-demand balance in matrix and scalar notation is given by:

$$\begin{bmatrix} I_K - A_{KK} & A_{K-K} \\ A_{-KK} & I_{-K} - A_{-K-K} \end{bmatrix}^{-1} = \begin{bmatrix} Q_{KK}^{-1} & U_{K-K} \\ V_{-KK} & T_{-K-K} \end{bmatrix} =$$

$$\begin{bmatrix} Q_{KK}^{-1} & Q_{KK}^{-1} A_{K-K} (I_{-K} - A_{-K-K})^{-1} \\ (I_{-K} - A_{-K-K})^{-1} A_{-KK} Q_{KK}^{-1} & (I_{-K} - A_{-K-K})^{-1} (I_{-K} + A_{-KK} Q_{KK}^{-1} A_{K-K} (I_{-K} - A_{-K-K})^{-1}) \end{bmatrix} \tag{3}$$

where:

$$Q_{KK}^{-1} = \left(I_K - A_{KK} - A_{K-K} (I_{-K} - A_{-K-K})^{-1} A_{-KK} \right)^{-1}$$

$$\begin{matrix} [Q^{-1}]_{kk} = \alpha_{kk} & [U]_{k-k} = \alpha_{k-k} \\ [V]_{-kk} = \alpha_{-kk} & [T]_{-k-k} = \alpha_{-k-k} \end{matrix}$$

Using the notational conventions in expression (3), we derive the solution of the system in expression (2) in matrix notation as:

$$\begin{aligned} X_K &= Q_{KK}^{-1} f_K + U_{K-K} f_{-K} \\ X_{-K} &= V_{-KK} f_K + T_{-K-K} f_{-K} \end{aligned} \tag{4}$$

The system in (4) above implies that each unit of output can be decomposed in two parts: a first one that is required to satisfy self-final demand, i.e. $(Q_{KK}^{-1} f_K)$ for block

K and $(T_{-K-K} f_{-K})$ for block –*K*, and a second one that is needed to fulfil the final consumption requirements of the remaining production block, i.e. $(U_{K-K} f_{-K})$ for block K and $(V_{-KK} f_K)$ for block –*K*. Since expression (4) can also be seen in differential terms, an exogenous shock in final demand, i.e. $(\Delta f_K, \Delta f_{-K})$, gives rise to output changes with exactly the same interpretation in terms of *within-block* and *out-block* effects. Total derived shock in production levels is therefore the result of total sectoral linkage effects, both direct and indirect.

We now proceed to present the partitioned formulation of the CMM as a way of homogenizing the description of the two approaches. The CMM is also termed in the literature as Rasmussen indices (Rasmussen, 1957). We describe here its un-weighted version[2]. Furthermore, in our analysis, we have termed Rasmussen indices as *total* indices in the sense that they do consider both intra-industrial and inter-industrial interdependencies.

Therefore, under this method if the research interest relies on, let's say block K, the total backward linkages for each sector of included in this blocks (TBL_k thereafter) are defined by means of the sum of columns of the Leontief inverse. Following the scalar notation in (3), the algebraic expression of these indices reads as:

$$TBL_k = \left[\sum_{i=1}^{K} \alpha_{ik} + \sum_{i=K+1}^{N} \alpha_{ik} \right] \qquad \forall k = 1,...,K \tag{5a}$$

The coefficient in expression (5a), i.e. TBL_k provides information about the sectoral stimuli on activity levels of sectors' from *K* and –*K* which are due to a hypothetical homogenous and unitary final demand change in all sectors within block *K*.

[2] There are also different weighted versions of the Rasmussen indices. Clements and Rossi (1991) were first in suggesting weighting sectoral linkage indices by output shares. Weighting sectoral stimuli by the relevance of endogenous impacts, allows controlling not only for the size of each sector but also for the distribution of the exogenous demand shock. Laumas (1976) considered that sectoral backward stimulus indices should rather be weighted by the exogenous stimulus i.e. a final demand weighted version. Other authors have considered that linkages should even be expressed in terms of elasticities (Mattas and Shrestha, 1991).

Following the partitioned matrix notation used in (3) and defining *e* as a column vector of 1's so *e'* refers to its transpose; coefficients in (5a) become the elements of two row vectors that refer to each production block (TBL_K thereafter):

$$TBL_K = e'_K Q_{KK}^{-1} + e'_{-K}(I_{-K} - A_{-K-K})^{-1} A_{-KK} Q_{KK}^{-1} \qquad (5b)$$

Proceeding along similar lines, the total forward linkage of each sectoral unit of block *K* under the Leontief approach (TFL_k thereafter), in absolute terms is written as:

$$TFL_k = \left[\sum_{j=1}^{K} \alpha_{kj} + \sum_{j=K+1}^{N} \alpha_{kj} \right] \qquad \forall k = 1,....K \qquad (6a)$$

Alternatively, following the partitioned matrix notation, the forward linkage *a la* Leontief becomes a column vector:

$$TFL_K = Q_{KK}^{-1} e_K + Q_{KK}^{-1} A_{K-K} (I_{-K} - A_{-K-K})^{-1} e_{-K} \qquad (6b)$$

These indices, i.e. TFL_k and TFL_K are in turn interpreted as the impact on sectoral *K* block's output of a simultaneous unit change in each and every sector's net output. Forward effects indices are then an "output-utilization" measure.

In terms of the CMM, a sector or block of sectors is considered to be a "key backward" ("forward") sector if its push or dispersion (pull or absorption) power is above all sectors' average impact. Nevertheless, while there is consensus among researchers about the adequacy of the traditional matrix *A*, i.e. the matrix of technical coefficients, to extract information about sectoral backward effects, there is disagreement in the case of "output-utilization" coefficients (Beyers, 1976; Jones, 1976, Dietzenbacher et al. 1993, Dietzenbacher and van der Linden, 1997). Related to this, the output coefficient matrix from the alternative input-output model presented by Ghosh (1958) has been considered more suitable than the traditional technical coefficients matrix for computing sectors' forward effects (Dietzenbacher et al. 1993; Dietzenbacher and van der Linden, 1997). All these arguments go together with the still open debate about the "joint" stability condition (Chen and Rose, 1986, 1991; Dietzenbacher, 1989; Rose and Allison, 1989), necessary for a sound combined used of the two input-output frameworks (Cella, 1984; De Mesnard, 2009). This open source of debate is also shared with its competing methodology, the HEM. Although it is important to mention the existence of alternative forward measures to those presented in (6a)-(6b), participating in this debate is not one of the purposes of this paper. As pointed out in the introduction, the aim of this analysis is to identify under which scenarios the differences between the two approaches might be used in a complementary way to enrich the conclusions of a specific multisectoral analysis. Then, leaving aside the “joint stability” problem, we have chosen the most widely accepted input-output model, i.e. the Leontief quantity approach, to generate information about inter-industrial linkages.

The second approach to identify key sectors is the HEM. This alternative method aims at measuring the role of a sector or a production block by computing the loss in total output when the external or *out-block* relations with other sectors hypothetically disappears. A different interpretation of the evaluated output losses through this method has been proposed by Cardenete and Sancho (2006). According to these authors, the HEM also provides an efficiency measure from vertical integration. Thus, the higher the degree of vertical integration is, the greater will be the strength of the production links between sectors and, as a consequence, the stronger will be the forward and backward stimuli.

While in the case of the CMM the debate is centred on how linkage indices should be weighted and which theoretical framework should be used, as already mentioned in the introduction in the case of the HEM, a first element of discussion relates to how the extraction of a sector should be simulated (Miller and Lahr, 2001). For the objectives of this paper and especially when defining our “hybrid” proposal, we have applied that extraction firstly developed by Cella (1984) where only inter-sectoral relationships are extracted, i.e. $A_{-K,K}=0$ and $A_{K,-K}=0$. Cella proposed this hypothesis in response to the one proposed by Schultz under which within block linkages also cease, i.e. $A_{K,K}=0$ or $A_{-K,-K}=0$, basically because the HEM aims at measuring the cost of the missing linkages with other sectors and not the internal ones. Furthermore, it seems difficult to justify why one sector or block of sectors would have to stop buying itself. For this reason many authors have recently advocated for applying Cella’s hypothesis (Sánchez-Chóliz and Duarte, 2003, Cardenete and Sancho, 2006, and Guerra and Sancho, 2010). Since we agree with the view of these authors and because Cella’s hypothesis suits the most for the objectives of this analysis, this will be the methodology described and used in what follows. The second element of discussion around the HEM deals with how the evaluated impacts should be classified (Cella, 1984, and Clements, 1990). We will turn to this issue later in this section when defining backward and forward impacts under the HEM.

We therefore use the HEM under the aforementioned Cella's extraction hypothesis to examine the relevance of the *K* first sectors of the economy. We proceed by extracting the two matrices where this group of sectors has any external influence:

$$A_{-KK} = 0 \text{ and } A_{K-K} = 0 \; \overline{A}_{(K)} = \begin{bmatrix} A_{KK} & 0 \\ 0 & A_{-K-K} \end{bmatrix}$$

$$(I - \overline{A}_{(K)})^{-1} = \begin{bmatrix} (I_K - A_{KK})^{-1} & 0 \\ 0 & (I_{-K} - A_{-K-K})^{-1} \end{bmatrix} \tag{7}$$

Subtracting (7) from the formulae of the inverse for partitioned matrices obtained in (3), the vectors of the evaluated loss in the output of blocks *K* and *–K*, Δ_K and Δ_{-K} respectively, can be seen to be given in absolute terms by:

$$\begin{aligned} \Delta_K &= \left[Q_{KK}^{-1} - (I_K - A_{KK})^{-1}\right] f_K + \\ &\quad \left[Q_{KK}^{-1} A_{K-K} (I_{-K} - A_{-K-.K})^{-1}\right] f_{-K} \\ \Delta_{-K} &= \left[(I_{-K} - A_{-K-K})^{-1} A_{-KK} Q_{KK}^{-1}\right] f_K + \\ &\quad \left[(I_{-K} - A_{-K-.K})^{-1} A_{-KK} Q_{KK}^{-1} A_{K-K} (I_{-K} - A_{-K-.K})^{-1}\right] f_{-K} \end{aligned} \tag{8}$$

Similarly to the CMM, under the HEM, the absolute total linkage losses in expression (8) above can be decomposed in two parts: the one related to the costs of satisfying final demand of the *K* extracted sectors, i.e. backward linkages of group *K* on the rest of the economy and those costs that are necessary to fulfil the final consumption of the remaining sectors, i.e. forward linkages of group *K* on the rest of the economy.

The expression for the backward linkage losses of the production block *K* under the HEM is then given by:

$$BL(K) = e_K^{'} \left[Q_K^{-1} - (I_K - A_{KK})^{-1} \right] f_K + e_{-K}^{'} \left[(I_{-K} - A_{-K-K})^{-1} A_{-KK} Q_{KK}^{-1} \right] f_K \qquad (9)$$

The first term on the right hand side of expressions (9) can be interpreted as backward linkage costs derived from the "extracted group" self-supply, while the second term constitutes the backward linkage costs due to the intermediate flows from the extracted group to the other sectors. For the case of the forward linkages under the HEM and according with the proposed Cella's measure:

$$\begin{aligned} FL(K) = {} & e_K^{'} \left[Q_{KK}^{-1} A_{K-K} (I_{-K} - A_{-K-K})^{-1} \right] f_{-K} + \\ & e_{-K}^{'} \left[(I_{-K} - A_{-K-K})^{-1} A_{-KK} Q_{KK}^{-1} A_{K-K} (I_{-K} - A_{-K-K})^{-1} \right] f_{-K} \end{aligned} \qquad (10)$$

The first component in (10) is the output loss on sector K required to support the final demand requirements of block $-K$ while the second term is the feedback loss on sector $-K$ coming from self-supply requirements.

In our description of the HEM we have followed Cella's interpretation of forward and backward indicators (Cella, 1984). However, this classification has been subjected to several criticisms and constitutes the second type of debate around the HEM mentioned above. Related to this, Clements (1990) argued that the second component in (10) should rather be interpreted as a backward effect because this external impact is the response of the remaining block when block K is purchasing intermediate inputs. In fact, the nature of market interdependencies makes difficult to separate "pure" backward effects from "pure" forward impacts. Demand leads to supply and supply generates demand.

We can conclude from this formal description of the two approaches—the CMM and the HEM— that the main difference between the two methodologies stems from the simulation of output changes once there is a positive stimulus in final demand. Under the CMM, the "keyness" of a sector corresponds to output gains, while under the HEM has to do with output losses. These are, in fact, opposite ways when measuring a sector contribution to economic efficiency. However, the simultaneous use of these two methodologies is feasible leading to a "hybrid" approach that makes possible to disaggregate useful information about the strength of distributive impacts in terms of both sectoral forward and backward forces in applied analysis.

III. The Classical Multiplier Method and the HEM: A "Hybrid" Possibility.

We now move to formally compare these approaches stressing their main distinctions and complementarities. In doing so, firstly we use the un-weighted final demand versions of the two approaches assuming that under the two methodologies the exogenous shocks in final demand are unitary, i.e. output changes per unit of final demand. Secondly, differently to expressions (5b)-(6b) where backward and forward impacts are respectively column and row vectors, expressions (9)-(10) under HEM refer to scalars. Consequently, to compute and interpret the differences between the two approaches, expressions (5b)-(6b) that correspond to the CMM have also been transformed accordingly. Following the above described homogenizing procedure, in the case of the HEM, i.e. *BL* (*K*), expression (9) for sector *K* reads as:

$$BL(K)_{(f_k=1)} = e'_K \left[Q_{KK}^{-1} - (I_K - A_{KK})^{-1}\right] e_K + e'_{-K} \left[(I_{-K} - A_{-K-K})^{-1} A_{-KK} Q_{KK}^{-1}\right] e_K \qquad (11)$$

Expression (11) exactly corresponds to expression (9) when there is a homogenous unitary change in final demand of those sectors included in block *K*. In other words, $f_K = e_K$ and $f_{-K} = e_{-K}$. Applying scalar transformation in expression (5b), i.e. post-multiplication of TBL_K by the summation vector e_K, the total backward effect of block *K* under the CMM becomes:

$$TBL(K) = e'_K\, Q_{KK}^{-1} e_K + e'_{-K}\, (I_{-K} - A_{-K-K})^{-1} A_{-KK} Q_{KK}^{-1} e_K \qquad (12)$$

In the comparison of backward linkage measures under the CMM and the HEM using absolute endogenous effects per unit of final demand, we have to interpret the difference between (11) and the already defined $TBL(K)$ in expression (12):

$$TBL(K)\text{-}\, BL(K)_{(\Delta f_k=1)} = e'_K\, (I_K - A_{KK})^{-1} e_K \qquad (13)$$

Expression (13) implies that those transactions purely internal to block *K*, i.e. the direct self-dependency are not accounted for under the HEM since, under Cella's hypothesis, they are not considered to "disappear". The output of block *K* produced to satisfy internal input requirements are not accounted for, only those input requirements that are external to this block. Under the HEM, this is the weight attributed to block *K* in order to measure its economic “keyness”. Therefore, when classifying “key sectors” in terms of backward linkage effects, differences between both methods stem from the relevance of the production chains internal to the block. If the degree of block’s dependency on the internal linkages, i.e. “horizontal integration” relative to *out-block* interdependencies i.e. “vertical integration” is very strong, block *K* may turn out to be a “key backward sector” under the CMM approach. This classification of block *K* might be different however, under the HEM method under Cella’s proposal, whereby only the degree of vertical integration is considered for. The question that might arise now is the following: are *within-block* effects important for identifying key sectors?.

This question goes together with that related to the “optimal” level of sectoral block aggregation when analysing the role of industrial clusters in policy effectiveness (Oosterhaven et al, 2001; Vom Hofe and Dev Bhatta, 2007; Kelton et al, 2008 ; Titze et al. 2011) or the “key” group sectors problem (Temurshoev, 2010). In fact, *within-block* interdependencies is part of the “grid” in sectoral linkages that also contributes to improve economic efficiency. Following our example of a two-block economy and why not? and additional hypothetical situation whereby sector *K* presents stronger direct *within-block* linkages that that of block *–K*, in light of our results under expression (13) and the nature of industrial interdependencies, tighter *within-block* dependency would lead to stronger *out-block* effects, since the former has multiplicative or indirect impacts over the later. This statement will be proved empirically under the applied exercise to the Spanish economy presented in section IV.

Following the same procedure, the difference between the traditional Leontief’s forward linkage measure and the one under the *HEM* in absolute terms will be:

$$TFL(K) - FL(K)_{(\Delta f_{-k}=1)} = e'_K\, Q_{KK}^{-1} e_K - e'_{-K}\left[(I_{-K} - A_{-K-K})^{-1} A_{-KK} Q_{KK}^{-1} A_{K-K} (I_{-K} - A_{-K})^{-1}\right] e_K \quad (14)$$

Since according to Duncan (1944) and Guttman (1946), the first component in (14) fulfils the following identity:

$$e'_K Q_{KK}^{-1} e_K = e'_K \left[(I_K - A_{KK})^{-1} + (I_K - A_{KK})^{-1} A_{K-K} (I_{-K} - A_{-K-K})^{-1} A_{-KK} Q_{KK}^{-1}\right] e_K \quad (15)$$

Then inserting expression (15) into (14), we get:

$$TFI(K) - FI(K)_{(\Delta f_{-k}=1)} = e'_K (I_K - A_{KK})^{-1} e_K + e'_K \left[(I_K - A_{KK})^{-1} A_{K-K} (I_{-K} - A_{-K-K})^{-1} A_{-KK} Q_{KK}^{-1} \right] e_K - e'_{-K} \left[(I_{-K} - A_{-K-K})^{-1} A_{-KK} Q_{KK}^{-1} A_{K-K} (I_{-K} - A_{-K-K})^{-1} \right] e_K \tag{16}$$

Interpreting expression (16), the first element of the difference (that are included in the CMM but not under the HEM) refers to the effect on output levels of block *K* coming from self-demand. This is a "purely internal" effect, i.e. $e_K^{'} (I_K - A_{KK})^{-1} e_K$. The second component in the expression above, which is also excluded under the HEM, represents the derived external stimulus coming from other sectors, i.e. $e'_K (I_K - A_{KK})^{-1} A_{K-K} (I_{-K} - A_{-K-K})^{-1} A_{-KK} Q_{KK}^{-1} e_K$. Lastly, the third element in expression (16), however, is accounted for by the HEM according to Cella's forward effects definition but it is disregarded under both Clements's criteria and the CMM approach. This component refers to the impact over the output level of block *–K* as a feedback of the output of the targeted block *K* to support final demand of sectors in block *–K*. This later element is a "pure" external impact coming from sector *K* in the sense that it does not include the purely *-K* , i.e. $(I_{-K} - A_{-K-K})^{-1}$ but rather its derived sectoral-wide stimulus.

Similarly as when we compared backward measures, under the CMM, those sectors that have higher intra-industrial linkages coming from self-supply, direct and indirect, might be consider as "key forward sectors" while under the HEM they might get a very different position since only purely external final demand impacts are controlled for. Nevertheless, differently to the backward measures' comparison, expression (16) indicates that the *out-block* effects though stimulating *within-block* impacts also play a role in determining sectors' position under the CMM criteria.

Summing up, this formal comparison between both methodologies indicates that under the Classical Multiplier Method the two types of production interdependencies are considered, both in terms of horizontal and vertical integration. When using the HEM, however, only vertical integration is accounted for in weighting sectoral "keyness" in an economy. However, the two types of production integration are relevant in terms of economic efficiency. This implies that their complementarity in applied work makes it possible to isolate the *within-block* effects, i.e. separating internal backward and forward effects from those that are purely external or distributive. In other words, the combined use of the two methodologies allows us to distinguish the contribution of a specific block in terms of vertical integration from that related to horizontal integration in an economy.

In the description of our proposed hybrid approach, the backward linkage measures under the two methods are first compared for their complementary use in a specific case of applied analysis. Through the analysis of expression (13) and using the HEM backward measure proposed by Cella (1984), we have reached the conclusion that the differences in the "push" power measure stems from the relevance of purely "internal" self-supply effects. Differently to the HEM, this effect is considered under the Classical Multiplier method. Therefore, the combined use of the two approaches through our proposed hybrid method allows us to distinguish three backward measures: internal $I^B(K)$ external $E^B(K)$and total $TBL(K)$ indicators. Following the same notation, these three measures are defined as:

$$TBL(K)=I^B(K)+E^B(K)$$
$$I^B(K)=TBL(K)-BL(K)_{(\Delta f_k=1)}=e'_K(I_K-A_{KK})^{-1}e_K \qquad (17)$$
$$E^B(K)=BL(K)_{(\Delta f_k=1)}=e'_K\left[Q^{-1}_{KK}-(I_K-A_{KK})^{-1}\right]e_K+e'_{-K}\left[(I_{-K}-A_{-K-K})^{-1}A_{-KK}Q^{-1}_{KK}\right]e_K$$

In a similar way to the decomposition of the backward indicators, using the hybrid approach we can also split the total forward effect $TFL(K)$ into "internal" forward effects ($I^F(K)$) due to self-supply and "external" forward effects ($E^F(K)$) coming from the inter-industrial linkages with other sectors. According to the previous interpretation of the three terms in expression (16), we can decompose total forward effects as:

$$TFL(K)=I^F(K)+E^F(K)^{Cella}$$
$$I^F(K)=TFL(K)-FL(K)_{(\Delta f_{-k}=1)}=e'_K(I_K-A_{KK})^{-1}e_K+e'_K\left[(I_K-A_{KK})^{-1}A_{K-K}(I_{-K}-A_{-K-K})^{-1}A_{-KK}Q^{-1}_{KK}\right]e_K-$$
$$e'_{-K}\left[(I_{-K}-A_{-K-K})^{-1}A_{-KK}Q^{-1}_{KK}A_{K-K}(I_{-K}-A_{-K-K})^{-1}\right]e_K$$

$$E^F(K)^{Cella}=FL(K)=e'_K\left[Q^{-1}_{KK}A_{K-K}(I_{-K}-A_{-K-K})^{-1}\right]e_{-K}+$$
$$e'_{-K}\left[(I_{-K}-A_{-K-K})^{-1}A_{-KK}Q^{-1}_{KK}A_{K-K}(I_{-K}-A_{-K-K})^{-1}\right]e_{-K} \qquad (18)$$

As mentioned in Section II above, the question of how these components should be assigned between forward and backward effects constitutes the second source of debate around the HEM, an issue that has not yet been cleared up in the literature. According to Clements' (1990) interpretation of forward effects in expression (10), the correct measure for the external forward effects should be different. Clements considers the second component of expression (10) as a backward effect because it measures the stimulus generated in supplying sectors of block *K* by its own intermediate demand. As a result, only the first component in expression (10) should be considered as a "pure" forward impact of block *K*. Should we adhere to Cella's interpretation, in contrast, the second term in (10) should be included (i.e. $E^F(K)^{Cella}$ above). Note that following Clements' classification allows isolating the *within-block* forward effect:

$$TFL(K) = I^F(K) + E^F(K)^{Clements}$$

$$I^F(K) = TFL(K) - FL(K)_{(\Delta f_{-k}=1)} = e'_K (I_K - A_{KK})^{-1} e_K + e'_K \left[(I_K - A_{KK})^{-1} A_{K-K} (I_{-K} - A_{-K-K})^{-1} A_{-KK} Q^{-1}_{KK} \right] e_K$$

$$E^F(K)^{Clements} = FL(K)_{(\Delta f_{-k}=1)} = e'_K \left[Q^{-1}_{KK} A_{K-K} (I_{-K} - A_{-K-K})^{-1} \right] e_{-K} \qquad (19)$$

The distinction between internal and external effects is relevant for a better understanding of industrial integration. Additionally, this information is also useful for a more complete guidance of specific policies, as it is the case of energy efficiency policies. In this sense, the hybrid approach presented in this section is helpful for knowing whether the transmission of the evaluated energy efficiency gains might be potentially concentrated within a specific block or rather transmitted to other production units. Moreover, this allows deciding how to allocate policy inflows over energy and non-energy sectors to maximise not only economy-wide impacts but also the redistribution of efficiency improvements over the whole economic system. In Section IV we present the results of this hybrid model and how the twofold information obtained through this novel approach could be interpreted and used. As an illustrative example, the detailed breaking-up of the evaluated endogenous impacts under the hybrid model outlined in this section can be used to guide the degree of effectiveness of energy efficiency policies for the case of the Spanish economy in a more complete way than if the two approaches, the CMM and the HEM were used separately.

IV. An Empirical Exercise of the Hybrid Model: Identifying Key "Distributive" Sectors for Energy Efficiency Policies in the Spanish Economy.

This section is devoted to implement an empirical exercise applying the hybrid model formally outlined in Section III to Spanish data with the objective of identifying "key sectors" for energy efficiency policies. Our data set refers to a symmetric input-output table. This table has been constructed by the author from the make and use tables published by the Spanish National Institute of Statistics for the year 2004. In reconciling the economic flows coming from these tables, we have used the industry-technology assumption as indicated in ESA-95[3]. Formal details for the application of this assumption can be found in Ten Raa (1995).

As indicated in Section II, the main objective of our proposed hybrid approach is to combine in a complementary way the two existing methodologies, the CMM and the HEM, to single out sectors' "keyness". In this empirical exercise we have therefore used expressions (17)-(18) and (19) from Section III that combine both methodologies to disaggregate the internal and the external effects from total backward and forward impacts. These six measures are computed for the 17 sectors contemplated in the database. The sectoral disaggregation applied of the Spanish input-output table for 2004 is included in the Annex. This sectoral break-down distinguishes 5 energy sectors and 11 non-energy sectors. All the backward and forward empirical indicators presented in this section refer to un-weighted measures.

For each production block, the results for the three measures presented in expression (17) in Section III that refer to backward impacts in absolute terms are shown down the first three columns of Table 1. The last two columns of this table refer, on the other hand, to the backward indices that correspond to the "pure" methodologies for detecting key sectors—the CMM and the HEM. Backward indices under these two alternative approaches have been normalized to identify key sectors' blocks (Rasmussen, 1957) and they show the distance from the average backward impact. Following the same normalization procedure, the total, internal and external backward effects defined in expression (17) are depicted in Graph 1.

[3] This acronym refers to the European Systems of Accounts (EUROSTAT, 1995).

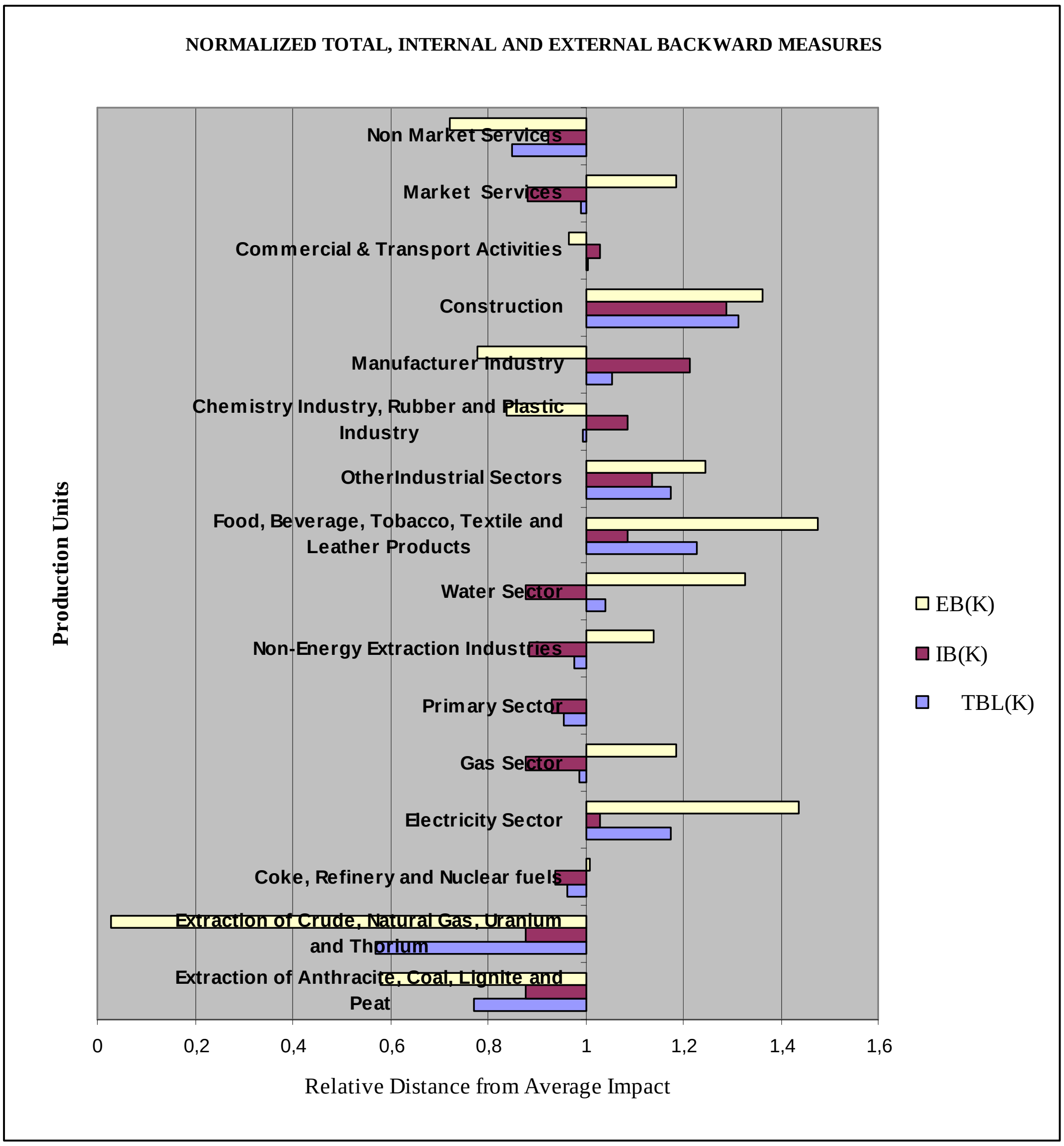
TABLE 1

Hybrid and "Pure" Methods: Backward Indicators.
Symmetric input-output Table for Spain 2004.

TOTAL BACKWARD EFFECTS. INTERNAL AND EXTERNAL COMPONENTS IN ABSOLUTE TERMS				NORMALIZED BACKWARD INDICATORS ACCORDING TO "PURE" METHODOLOGIES	
PRODUCTION UNITS	TBL(K)	$I^B(K)$	$E^B(K)$	CMM	HEM
Extraction of Anthracite, Coal, Lignite and Peat	1,376	1,001	0,375	0,771	0,580
Extraction of Crude, Natural Gas, Uranium and Thorium	1,019	1,000	0,019	0,571	0,029
Coke, Refinery and Nuclear fuels	1,718	1,067	0,651	0,962	1,008
Electricity Sector	2,099	1,171	0,928	1,176	1,437
Gas Sector	1,764	1,000	0,764	0,988	1,183
Primary Sector	1,705	1,059	0,646	0,955	1,000
Non-Energy Extraction Industries	1,743	1,008	0,735	0,976	1,138
Water Sector	1,858	1,001	0,857	1,041	1,327
Food, Beverage, Tobacco, Textile and Leather Products	2,190	1,238	0,952	1,227	1,474
OtherIndustrial Sectors	2,097	1,293	0,804	1,175	1,245
Chemistry Industry, Rubber and Plastic Industry	1,777	1,237	0,540	0,995	0,836
Manufacturer Industry	1,882	1,380	0,502	1,054	0,777
Construction	2,346	1,466	0,880	1,314	1,362
Commercial & Transport Activities	1,796	1,172	0,624	1,006	0,966
Market Services	1,770	1,005	0,765	0,992	1,184
Non Market Services	1,515	1,050	0,465	0,849	0,720
Average Impact	1,784	1,138	0,645	1	1

GRAPH 1

Hybrid Method: Normalized Total, Internal and External Backward Indicators. Symmetric input-output Table for Spain 2004.



Before applying the hybrid approach to identify key sectors for energy efficiency policies in the Spanish context, we first compare the hybrid model to the “pure” methodologies in terms of our empirical results for this economy. As it can be asserted from Table 1 and Graph 1, most of the sectors or blocks with a strong internal backward effect (second column of Table 1) appear to be key sectors under the CMM (fourth column of Table 2). As mentioned above when interpreting expression (13), the remarkable weight that internal or *within-block* backward effect has on the classification under the indicators CMM explains these outcomes. Notice, for instance, that the *Construction* sector, which has the highest internal effect, i.e. one unit increase in the final demand of the *Construction* sector potentially increases its output by 1.466 units that stem from its self-supply requirements, has also the first position in the “key backward sectors” whereas under the HEM criteria it is the *Food, Beverage, Tobacco, Textile and Leather products* sector the one that takes the first place. Even for certain sectors the classification as “key backward sector” is completely different as in the case of the *Manufacturer Industry* sector. This sector was considered to have a backward effect under the CMM criteria that accounts for 5.4 percent above average but not under the HEM measure with almost 23 percent below average. Again, this result is due to the higher relevance of the internal backward effects over the total backward impact in this sector as a result of its horizontal inter-dependencies.

Nevertheless, in most of the cases those sectors that are “key backward sectors” under the CMM criteria (fourth column of Table 1), i.e. the *Construction* sector followed by the *Food, Beverage, Tobacco, Textile and Leather products* sector and the *Electricity* sector, the *Water* Sector and *Other Industrial* sectors are also identified so under the HEM criteria (fifth column of Table 1) though with a different order. This finding is not mere coincidence but rather, as pointed out in section III, the indirect effect positive that strong *within-block* linkages have over *out-block* impacts.

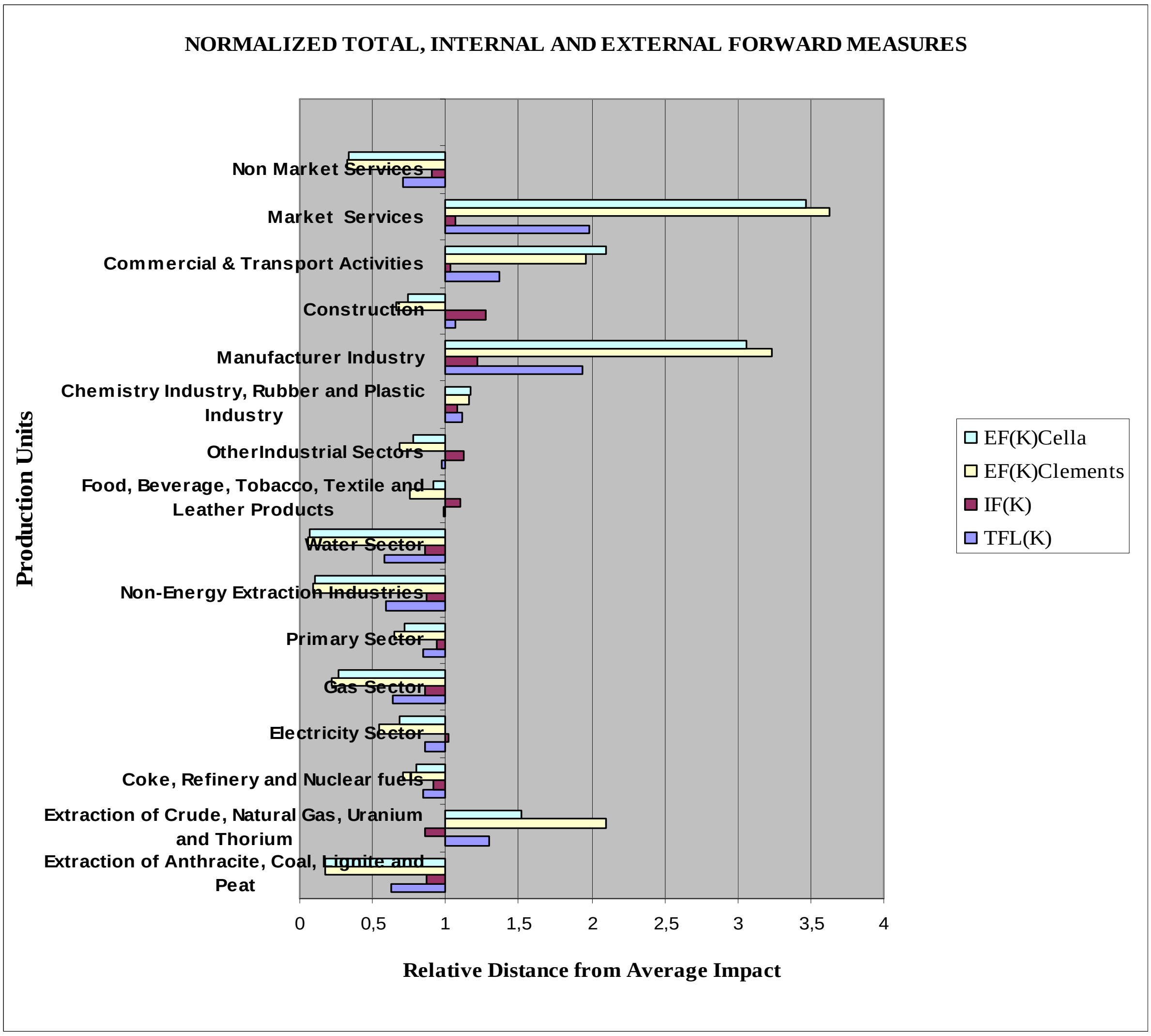
TABLE 2

Hybrid and "Pure" Methods: Forward Indicators.
Symmetric input-output Table for Spain 2004.

TOTAL FORWARD EFFECTS. INTERNAL AND EXTERNAL COMPONENTS IN ABSOLUTE TERMS					*NORMALIZED FOWARD INDICATORS ACCORDING TO "PURE" METHODOLOGIES*		
PRODUCTION UNITS	***TFL(K)***	$I^F(K)$	$E^F(K)^{Clements}$	$E^F(K)^{Cella}$	**CMM**	$\mathbf{HEM}^{\mathbf{Clements}}$	$\mathbf{HEM}^{\mathbf{Cella}}$
Extraction of Anthracite, Coal, Lignite and Peat	*1,114*	*1,004*	*0,110*	*0,151*	***0,624***	***0,174***	***0,170***
Extraction of Crude, Natural Gas, Uranium and Thorium	*2,321*	*1,000*	*1,321*	*1,346*	***1,301***	***2,095***	***1,515***
Coke, Refinery and Nuclear fuels	*1,514*	*1,070*	*0,444*	*0,712*	***0,848***	***0,702***	***0,801***
Electricity Sector	*1,525*	*1,181*	*0,344*	*0,610*	***0,854***	***0,544***	***0,686***
Gas Sector	*1,137*	*1,001*	*0,136*	*0,239*	***0,637***	***0,215***	***0,269***
Primary Sector	*1,503*	*1,091*	*0,412*	*0,642*	***0,842***	***0,651***	***0,723***
Non-Energy Extraction Industries	*1,065*	*1,010*	*0,055*	*0,096*	***0,597***	***0,088***	***0,108***
Water Sector	*1,038*	*1,002*	*0,036*	*0,066*	***0,581***	***0,056***	***0,074***
Food, Beverage, Tobacco, Textile and Leather Products	*1,762*	*1,286*	*0,476*	*0,810*	***0,987***	***0,753***	***0,911***
OtherIndustrial Sectors	*1,739*	*1,308*	*0,431*	*0,691*	***0,974***	***0,683***	***0,778***
Chemistry Industry, Rubber and Plastic Industry	*1,979*	*1,248*	*0,731*	*1,041*	***1,109***	***1,158***	***1,172***
Manufacturer Industry	*3,453*	*1,411*	*2,042*	*2,722*	***1,935***	***3,234***	***3,064***
Construction	*1,895*	*1,480*	*0,415*	*0,657*	***1,062***	***0,656***	***0,739***
Commercial & Transport Activities	*2,435*	*1,196*	*1,239*	*1,859*	***1,364***	***1,961***	***2,092***
Market Services	*3,537*	*1,246*	*2,291*	*3,082*	***1,982***	***3,628***	***3,469***
Non Market Services	*1,260*	*1,055*	*0,205*	*0,294*	***0,706***	***0,325***	***0,331***
Average Impact	**1,784**	**1,162**	**0,631**	**0,888**	**1**	**1**	**1**

GRAPH 2

Hybrid Method: Normalized Total, Internal and External Forward Indicators. Symmetric input-output Table for Spain 2004.



We now proceed to compare our hybrid model with the “pure” methods in terms of forward effects. Recall that these forward indicators refer to the absolute effect over each sector’s output if final demand for goods of each block increases by one unit. The results of the three disaggregated forward measures isolated thanks to our hybrid model, i.e. expression (19) in Section III, are depicted in the first three columns of Table 2. Similarly as when we presented the backward indicators, we show the results of the normalised forward effects under both the Classical Multiplier method and the HEM in the three last columns. Additionally, and to complete our analysis, under the HEM approach we report both Cella’s (1984) and Clements’ (1990) criteria. As already indicated in section III, Clements’ forward measure definition is more appropriate when trying to isolate the pure *within block* effect. Graph 2 shows the normalized disaggregated forward measures based on our hybrid proposal, i.e. normalized total, internal and external forward impacts according to expressions (18) and (19).

We have already explained when describing expression (19) in Section III that those sectors that have a high forward internal effect take also the first positions under the CMM. This is the case of the *Construction* sector followed by the *Manufacturer* sector and the *Chemistry Industry* sector. Consequently, the size of this internal effect explains the reason why under the CMM a sector might turn to be “key forward sector” while not being so under the HEM. The *Construction* sector is a case in point. According to the CMM, this sector presents a forward effect that accounts for 6,2 percent above sectors’ average while under the HEM its push impact is almost 35 percent and 26 percent below all sectors’ average according respectively to Clements’ and Cella’s criteria. Nevertheless, backward measures under the CMM are more purely influenced by *within-block* impacts than forward measures. Recall that the second component in expression (16) in Section III reflects that, differently to CMM backward measures, *out-block* linkages play also a role in the strength of CMM forward impacts though in a lower degree than the HEM.

Lastly, we use the illustrative example of resource policies and, more specifically energy efficiency policies, to highlight the usefulness of combining the two “pure” methodologies through our proposed hybrid approach. Policy makers may well consider, in fact, that what matters is not only the total effect of a policy but also how this impact ends up spreading out in the economy. Thus, when seeking to further economy-wide impulses, the most effective solution might be to stimulate final demand in those sectors with the largest total backward-linkage. However, this policy might not turn out to be the more efficient and the more balanced when taking into account the relative impact at the sectoral level. If the target of the policy is to spread its impacts throughout the whole economic system, policy makers should be more concerned about those "key backward sectors" that present a higher external backward impact. In relation to energy efficiency policies, according to the results presented in Table 2 and Graph 2 that refer to absolute and normalized forward effects measures, those policies targeted at increasing energy efficiency in final demand should be directed over the final use of *Electricity* not only because the economy-wide impact would be the strongest but also because of its external spreading out effects favouring in a more proportionate way sectoral output growth.

We can draw similar conclusions when we examine policies that aim at improving, in a general sense, technological efficiency. It might be more effective to concentrate investment in those sectors that have not only the highest total forward linkage but also the strongest external component, again for reasons related to a more balanced distribution of effects. This is in fact how technological change is transferred throughout the economy since this change is reflected in production costs (Rosenberg, 1982). Those sectors that have high external forward effects make possible a more encompassing distribution of technological improvements as are, for example, the *Manufacturer Industry* sector and the *Chemistry, Rubber and Plastic Industry* sector in the Spanish context. Coming back again to the specific case of energy efficiency policies, those policies that aim at improving energy efficiency in its intermediate use should specially be directed to the *Extraction of Crude, Natural Gas, Uranium and Thorium Industry* and the *Electricity* sectors. By doing so, efficiency gains would lead to the highest economy-wide impacts while also allocating these improvements in a more proportionate way among recipient sectors.

V. Conclusions

The work of Hirschman (1958) constituted a milestone for the analysis of "key sectors" within the input-output framework. The relevance of identifying key sectors for specific policies pursues the maximisation of their cost-effectiveness. The main motivation behind the approach was, therefore, to concentrate the policy inflow over those sectors that might potentially maximise economy-wide impacts. The related literature in this field has been using alternatively two main approaches, the CMM (Rasmussen, 1957) and the HEM (Schultz, 1977, Cella, 1984, and Clements, 1990). Despite the fact that the HEM seems to have a deeper economic foundation, as it virtualises and measures the role of a disappearing sector, the debate is not yet closed. Furthermore, and to the best of our knowledge, the differences between these two existing methods have not been fully explored. The first main contribution of this paper has been to clarify the distinctions, conceptual and numerical, between these two approaches. The second main contribution has been to develop a different approach, what we have referred to as the "hybrid" model, which combines informational aspects of these two approaches, to help identify "key sectors".

The formal comparison of the two "pure" approaches carried out in this analysis indicates that the most important distinction between them stems from the internal effects that are captured by the CMM whereas under the HEM only external impacts are considered. However, it seems that when comparing forward and backward effects under the two approaches, CMM forward measures are also affected by external effects though its weight in determining key sectors positions is lower than the internal or within block impacts. Consequently, the interest of our proposed "hybrid" model that combines simultaneously aspects of these two approaches relies on making possible the disaggregation of external (*out-block*) and internal (*within-block*) backward and forward effects. An additional advantage of the "hybrid" approach outlined in this analysis is that it also makes possible to find a balance between economy-wide impacts and their sectoral repercussion as a kind of "second best". When seeking to pursue this kind of mixed objective, policy makers should concentrate policy inflows over those sectors that present not only strong total "push" and "pull" effects but also over those that show above average external impacts.

According to the empirical application for the Spanish economy related to energy efficiency policies, the recommendation is that policies whose target is to improve energy efficiency in intermediate use should be specially focused on the *Extraction of Crude, Natural Gas, Uranium and Thorium* industry and the *Electricity* sector. This is because these two energy sectors present the highest total and external forward effects that are relevant for transferring technological efficiency improvements**.**

Following these guidelines, the energy efficiency improvements that initially occur in these production sectors would spread more evenly throughout the whole economic system while leading at the same time to the highest economy-wide impacts. The design of policies and their social results, therefore, could be improved using the guidelines established here in relation to the definition of "key sectors" since interdependencies can be globally measured, identified and sectorally categorised in regard to their internal and external impacts, an information that is not directly available from standard "key sectors" analysis.

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Annex A: Sectoral breakdown for the Spanish Input-output Table. 2004

Classification	*Sectors*	*NACE-93 code*
Energy Sectors	*Extraction of Anthracite, Coal, Lignite and Peat*	**10**
	Extraction of Crude, Natural Gas, Uranium and Thorium	**11-12**
	Coke, Refinery and Nuclear fuels	**23**
	Electricity Sector	**401**
	Gas Sector	**402-403**
Non Energy Sectors	*Primary Sector*	**01, 02, 05**
	Other Extraction Industries	**13-14**
	Water Sector	**41**
	Food, Beverage, Tobacco, Textile and Leather Products	**151-152, 154-155, 156-159, 16-19**
	Other Industrial Sectors & Recycling	**20-22,37**
	Chemistry Industry, Rubber and Plastic Industry	**24-25**
	Manufacturer Industry	**261-268, 27-36**
	Construction	**45**
	Commercial & Transport Activities	**50-52, 61-62, 601-603, 63.1-63.2, 63.4**
	Market Services	**65-67, 70-72, 74, 80, 85, 90, 92, 93, 63.3**
	Non Market Services & Public administration	**75, 80, 85, 90, 92**