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Key final energy consuming sectors in Morocco: an input-output analysis

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Abstract

In this paper, we rank productive sectors according to their final energy consumption from the perspective of final demand. We use two main primary sources of data to explore the Moroccan case. The first is the conventional input-output table for 2016 prepared by the High planning commission (HCP, 2017). The second source is the energy balance for Morocco for the year 2016 published by the United Nations (UN, 2018). The final energy consumption is the energy consumed by end users such as government, households or exported, government or exported. The point is to identify which sectors deserve more consideration in Morocco to reduce energy consumption. Identifying key sectors in final energy consumption allows policymakers to prioritize interventions and concentrate efforts on these sectors. The results show that productive sectors that deserve more consideration from energy policy makers are: Transport, Commerce and Public Services, Agriculture, Food and tobacco, and Mining and Quarrying. Moreover, acting on own impact of each sector, allows targeted energy policy measures to be implemented without affecting final demand.

Key words: Morocco, Final energy consumption, Key sectors, Input-output analysis, sectors' final energy consumption
JEL classification: D57
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1. Introduction

Morocco imports more than 90% of its primary sources of energy needs including oil, oil products, coal, gas, and electricity (El Hafdaoui et al. 2025). Consequently, this constitutes a major strain on the country's trade balance. Despite a long history of onshore and offshore exploration, only very small quantities of gas, and no commercial sources of oil, have been found and developed (IEA 2019). The coal's mines, in the Northeast of the country, went out of production in 2004 (IEA 2019). Until recently, the only remaining domestic energy supplies consisted of biofuels and waste energy, as well as hydro-electricity, which in an average provides about 7.5% of yearly domestic electricity supply (IEA, 2014).

Morocco is undertaking since 2009 what is so called the National Energy Strategy (NES) (CESE, 2020). One of the main objectives of this strategy is to reduce Morocco's reliance on imported primary sources of energy. Practically, the Moroccan NES aims to optimize the electricity mix by accelerating the development of renewables particularly wind and solar, in which Morocco enjoys a considerable potential. In addition, the NES established energy efficiency as a national priority. The NES encouraged exploration and commercial exploitation of oil and gas deposits, including oil shale. One of the objectives of the NES is to improve integration into regional electricity and gas grids (South Mediterranean, North African, West African), thereby strengthening network resilience and reducing costs. The attainment of the goals of this strategy, including the NES target of reducing final energy consumption by 15% by 2030, allows Morocco to reduce its energy imports, diversify its industrial base, and reduce the energy bill and its negative impact on trade balance.

To attain these objectives, a series of laws have been enacted since 2008 in order to establish new governing agencies, promote electricity production from renewable energy, and improve energy efficiency. Among the newly created agencies, we have the Moroccan Agency for Sustainable Energy (MASEN) created by the law **57-09** in order to lead and manage renewable energies deployment. There are also the National Agency for Energy Efficiency (AMEE) created to implement Morocco's energy efficiency policy, and the National Authority for Electricity Regulation (ANRE) set up in 2018 in accordance with the law 48-15 with the mandate to ensure an open and competitive functioning of the electricity's market.

One of the milestones in the evolution of the Moroccan energy sector is the enactment of the renewable energy law 13-09 to promote energy produced from renewable sources, its marketing, and its export by public or private entities. The electricity, produced from renewables, can either be used by its producer or sold to consumers connected to the medium- or high-voltage grid (El Bachtiri and Matagne, 2013). This law has been amended and supplemented by the law 58-15 that introduces a net metering scheme for solar and wind power plants. It has also increased the hydropower threshold from 12 to 30 MW, and has allowed private investors to sell no more than 20% excess of their annual production from renewables to the national network. The law 47-09 aims to improve energy efficiency across the economy, by avoiding waste, reducing the energy costs on the national economy, and enhancing sustainable development. This law introduces energy performance requirements for buildings, equipment, and appliances and compulsory energy audits for businesses exceeding a certain level of annual consumption (IEA, 2019).

In most reports about energy consumption in the Moroccan economy, sectors considered as "key" are the largest consumer of energy in terms of absolute amounts. These sectors[1] are the transport

[1] *These data are for the year 2018.*

sector (38%), followed by the residential sector (25%), and the industrial sector (21%) (IEA, 2019). In the industry sector, the largest consumers are the non-metallic mineral industry, and mining and quarrying industry. The less industrial sectors energy consuming are the food and tobacco's processing sector and textiles and leather sector (IEA, 2019).
However, this approach ignores the interaction between the productive sectors. The performance of economic sectors and the sectoral structure of supply and demand affect the final energy consumption, which, in turn, affects the primary energy consumption. For example, some sectors may consume relatively little energy themselves, but can induce large energy use across the economy through their outputs used by other sectors, or because they are intensive users of other sectors' outputs, therefore, understanding sectoral elasticities can greatly assist in targeting energy policies. This leads to the following question: Which productive sectors should be prioritized to achieve Morocco's NES target of a 15% reduction in final energy consumption by 2030?
The aim of this paper is the determination of ''key'' sectors in final energy consumption in the Moroccan economy from the perspective of final demand. The rest of this paper is organized as follows: Section 2 provides a literature review about the application of input-output analysis to the energy sector. Section 3 presents the methodology and the data. In section 4, we present and discuss the empirical results. Some concluding remarks are in the last section.

2. Literature Review

The input–output framework is one of the most widely applied methods in economics, including energy economics. Indeed, many studies have been conducted to analyze energy use using the input-output analysis. The studies differ in terms of approach, economic focus, and scope. For example, some studies examine energy intensity of economic sectors (Kofoworol and Gheewala, 2006; Tandon and Ahmed, 2016), others focus on energy use and the structure of demand (Alcantara and Padilla, 2003; Mayer, 2007; Bagheri et al., 2018), with the latter integrate socioeconomic and environmental factors into energy input–output modeling to assess impacts on economic growth, employment, and CO_2 emissions. while regional disparities in energy consumption and policy priorities are examined by Zheng et al. (2014). We will now, highlight some of the main methodological approaches, key results, and insights drawn from the literature on the use of the input–output model in the analysis of energy systems:
Alcantara and Padilla (2003) analyzed the identification of key sectors in final energy consumption using an input–output framework and developed a methodology based on the elasticities of final energy demand. This method was applied to the case of Spain across 18 productive sectors and made it possible to determine the degree of relevance of these sectors, as well as those that deserve greater attention and, consequently, higher priority in energy policy. The results show that the sectors considered "key" are domestic transport, the chemical industry, the metallurgical industry, the building sector, catering services, and non-ferrous metal metallurgy. Low energy-consuming sectors include textiles and footwear, paper and printing, other manufactured products, trade, other sales services, and metal products.
Lindner and Guan (2014) developed a hybrid unit input–output model to assess the primary energy embodied in the economy in order to meet China's final energy needs for the year 2007. This model uses physical units for energy flows rather than monetary units. The data used in this study combine information on different types of energy (primary and secondary), final energy consumption data for several economic sectors, as well as CO_2 emission data and conversion factors across sectors. The results demonstrate that the existence of multiple categories of final demand—such as exports, household demand, and gross fixed capital formation—affects the primary energy mix, and that a

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significant amount of energy is embodied in the supply chains of secondary sectors. These findings imply that energy policies focused on consumption are likely to be more effective than those focused on production.

Pruitichaiwiboon et al. (2011) constructed an energy input–output model to identify the links between energy demand and supply activities in order to determine energy consumption across industrial and non-industrial sectors. They defined the energy demand of a productive sector as the energy required by that sector, while the energy supply of the same sector refers to the energy required by energy sectors to provide the energy demanded by the productive sector. The data for this study were collected from two main sources: the 2005 energy balance and the conventional 2005 input–output table of South Korea. The results for 2005 show that energy demand is particularly high in sectors such as agriculture and fishing, petrochemicals, manufacturing industries, non-metallic minerals, construction, and transport. On the other hand, energy consumption on the supply side is higher than on the demand side in sectors such as mining, food and tobacco, iron and steel (basic processing), textiles and wood products, metallurgy, residential, commercial, public, and other sectors.

The energy intensity of industrial sectors was examined by Kofoworol and Gheewala (2006) using an input–output model. Data from 1998 and 2000 on economic transactions among sectors and energy use in Thailand were employed. The results show that the ten sectors with the highest energy intensities are oil refineries and gas separation plants, road freight transport, electricity, cement, maritime transport, coastal and inland water transport, road passenger transport (road and non-road), basic chemicals, agricultural services, and iron and steel. The findings of this study can help in formulating energy efficiency policies in sectors where there is scope for energy savings. Bekhet, H.A. et al. (2016) analyzed energy consumption and the performance of manufacturing sectors during the 2008 global financial crisis by applying a production multiplier model based on input–output analysis. This study uses Malaysia's input–output tables for 2005 and 2010, comprising 44 sectors including energy sectors. The results indicate significant changes in the production multipliers of manufacturing sectors between 2005 and 2010. Moreover, the production multipliers from energy sectors to manufacturing also declined during the GFC due to a downturn in export-oriented industries during the crisis. The growing importance of the manufacturing sector in the development of Malaysian trade led to a noticeable decline in the output consumption of each energy sector, particularly electricity and gas. According to the study's findings, appropriate planning in the manufacturing sector is crucial to reduce strong dependence on imports, shortages of skilled labor, lack of competitiveness, and limited local technological capabilities.

Overall, the literature consistently highlights the critical role of transport and energy-intensive industrial sectors in shaping energy consumption patterns, a finding robust across countries and methodologies. While the role of final demand in energy consumption has been analyzed in some studies, it remains largely underexplored for developing countries such as Morocco, which this article seeks to address by analyzing the structure and role of final demand through the application of an input–output framework to the Moroccan economy.

3. Methodology and Data

This section presents and describes in detail the methodology adopted, as well as the data used for the purposes of this study:

3.1. Methodology

An input-output model is an economic model used to describe and analyses the relationship between different sectors of an economy, i.e. transactions between sectors, as reflected by the flow of goods between sectors (e.g. from sector i to sector *j*). Table 1 provides a schematic input-output table (hereafter IOT). IOT is a part of a complete set of use and supply set of accounts describing the functioning of the economy (Miller and Blair, 2009).

Table 1. An input-output table for a two-sectors economy

		Intermediate consumption		**Total Final demand (*Y*)**				**Total output**
		Sector *1*	Sector *2*	*c*	*i*	*g*	*e*	*X*
Sectors	Sector *1*	z_{11}	z_{12}	c_1	i_1	g_1	e_1	x_1
	Sector *2*	z_{21}	z_{22}	c_2	i_2	g_2	e_2	x_2
Value added	*L*	l_1	l_2	l_c	l_i	l_g	l_e	*L*
(*V*)	*N*	n_1	n_2	n_c	n_i	n_g	n_e	*N*
Imports	M	m_1	m_2	m_c	m_i	m_g	m_e	*M*
Total output	*X*	x_1	x_2	x_c	x_i	x_g	x_e	*X*

Source: (Miller and Blair, 2009)

The components of the total output are, respectively, output x_1 and output x_2 of sectors *1* and *2*. The total value-added *V* includes payments *l* and *n*. Finally, we have imports *M*. The component parts of the final demand vector *Y* addressed to sectors *1* and *2* are, respectively, *c* (household), *i* (private investment), *g* (government purchases), and *e* (exports).
The components of the value-added generated by a sector are the payments to labor services l_1 and l_2 paid by sectors *1* and *2* respectively, and taxes, capital, land, and profit denoted n_1 and n_2 paid by the two sectors respectively. The value-added of final demand columns represents payments to labor services by final consumers such as payments to domestic help l_c, payments to government workers l_g, and for *n*, for example, n_c includes tax payments by households. In the intersection between imports row and final demand columns, we have for example, m_g which represents government purchases of imported items, and m_e, which represents imported items that are re-exported. In the same logic, x_c and x_i are imported products used by households or as capital items. The interindustry flow z_{ij} represents intermediate consumption of sector *j* supplied by sector *i*. The quantity $a_{ij} = \frac{z_{ij}}{x_j}$ is a technical coefficient that gives us how many units we need of the input provided by the i^{th} sector to produce one unit of the output produced by the j^{th} sector. Considering *n* sectors (i.e. $i = 1, \dots, n$) we adopt the following notation:

$$X = \begin{bmatrix} x_1 \\ \vdots \\ x_n \end{bmatrix}, Y = \begin{bmatrix} y_1 \\ \vdots \\ y_n \end{bmatrix}, Z = \begin{bmatrix} z_{11} & \dots & z_{1n} \\ \vdots & \ddots & \vdots \\ z_{n1} & \dots & z_{nn} \end{bmatrix}, \text{ and } A = \begin{bmatrix} a_{11} & \dots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{n1} & \dots & a_{nn} \end{bmatrix}$$

X is the column vector of the *n* sectors' outputs, *Y* is the vector of final demand of institutional sectors, *Z* is the matrix containing intermediate consumption, and the matrix *A* contains the technical coefficients a_{ij} such as $A = Z\hat{X}^{-1}$. The a_{ij} are also called the direct requirements coefficients. The hatted *X* is the matrix constructed by the elements of *X* in its diagonal. From table 1, we can write the accounting identity:

$$X = Zu + Y \quad \text{with } u = \begin{pmatrix} 1 \\ \vdots \\ 1 \end{pmatrix}$$

Knowing that $Z=AX$, we can write $X=AX+Y$. Which can be transformed to $(I-A)X=Y$. If $\det(I-A)\neq 0$ then the matrix $(I-A)$ is inversible and, therefore, $(I-A)^{-1}$ exists. Henceforth, a straightforward manipulation allows to deduce:

$$X=(I-A)^{-1}Y=LY \qquad (1)$$

Equation (1) represent the Leontief equation. $L \equiv (I-A)^{-1}$ is known as the Leontief inverse or the total requirements matrix. Following closely the framework proposed in Alcantra and Padilla (2003), we consider the following notation and equations.

E: total quantity of final energy consumption of the productive sectors (a scalar).
e': vector of sectors' final energy consumption intensities, with: $e_i = \frac{E_i}{x_i}$;
$s_i = \frac{y_i}{x_i}$: represents the final demand coefficient. It gives us the proportion of i^{th} sector output used as final demand.
Multiplying equation (1) by e' gives us:

$$E = e'X = e'(I-A)^{-1}Y \qquad (2)$$

In the case of a proportional increase of final demand by $\alpha = \frac{\Delta Y}{Y}$, the quantity E increases by ΔE such as:

$$\Delta E = e'\Delta X = e'(I-A)^{-1}Y\alpha \qquad (3)$$

Knowing that $s_i = \frac{y_i}{x_i}$, (3) becomes[2]:

$$\Delta E = e'\Delta X = e'(I-A)^{-1}\hat{X}s\alpha \qquad (4)$$

When we divide equation (4) by E, we get:

$$E^{-1}\Delta E = E^{-1}e'\Delta X = E^{-1}e'(I-A)^{-1}\hat{X}s\alpha \qquad (5)$$

Considering the fact that $Y = \hat{X}s$ and $e'(I-A)^{-1}\hat{X}s = E$, we deduce:

$$E^{-1}\Delta E = \alpha \qquad (6)$$

It appears that this result is trivial because it is obtained due to the linearity of the model. To obtain a more interesting breakthrough, we need to introduce some transformations to equation (5). For this, let h be a vector that represents the distribution of final energy consumption among the n productive sectors ($h_i=E_i/E$), such as $h' = (h_1\ h_2 \ldots\ h_n)$ with $\sum_{i=0}^{n} h_i = 1$. Consequently, we can express e' as follows:

$$e' = Eh'\hat{X}^{-1} \qquad (7)$$

by replacing (7) in (5), we obtain:

$$E^{-1}\Delta E = h'\hat{X}^{-1}(I-A)^{-1}\hat{X}s\alpha \qquad (8)$$

[2] *Obviously, we have* $s'=(y_1/x_1 \ \ldots.\ y_n/x_n)$.

Considering the matrix D of distribution coefficients[3] d_{ij} defined as $d_{ij} = \frac{z_{ij}}{x_i}$, we know that we can write (Miller and Blair, 2009, p. 548):

$$\hat{X}^{-1}(I - A)^{-1}\hat{X} = (I - D)^{-1} \quad (9)$$

Substituting in (8) and diagonalizing s we get:

$$E^{-1}\Delta E \equiv \varepsilon' = h'(I - D)^{-1}\hat{s}\alpha \quad (10)$$

with ε' representing the relation between the proportional variation of sectors' final energy consumption and proportional variation of final demand. To obtain a more precise expression, we diagonalize h and put $\alpha = 1\%$, now we can write:

$$\boldsymbol{E}^{y} = \hat{h}(I - D)^{-1}\hat{s} \quad (11)$$

The entry E_{ij}^{y} of the matrix $\boldsymbol{E}^{y}$ is the percentage increase of final energy consumption of sector *i* in response of an increase by 1% of final demand addressed to sector j. an increase by *1%* of the j^{th} sector final demand will increases the final energy consumption of the whole sectors of the economy by $\sum_{i=1}^{n} \boldsymbol{E}_{ij}$, which is called the total impact. The of an increase by *1%* of final demand of the whole economy will increase the final energy consumption of sector *i* by $\sum_{j=1}^{n} \boldsymbol{E}_{ij}$, which is called the distributive impact.
Using the classification method presented in Alcantara and Padilla (2003), the identification of key sectors will be based on the matrix $\boldsymbol{E}^{y}$ (Annex: Table 4)

3.2. Data

We use data from two main primary sources to explore the Moroccan case. The first is the conventional input-output table for 2016 prepared by the High planning commission (2017). The second source is the 2016 energy balance for Morocco published by the United Nations (2016). The year 2016 was selected as it corresponds to the most complete and reliable datasets available at the start of this study, particularly for the detailed sectoral data required for the analysis. More recent data were either not yet published or difficult to access, making 2016 the most suitable reference for a consistent alignment with the energy balance data. The final energy consumption is the energy consumed by end users such as government, households or exported. To match the energy data with input-output data, we operate a series of aggregations and disaggregations to the HCP input-output table (Annex: table 5). For example, we aggregate agriculture and fishery into one sector. We do the same thing for chemical and petrochemical sectors. The mechanics, metallurgies and electric industry sectors, from input-output table, has been disaggregated to three sectors which are non-ferrous metal, machinery and transport equipment. Others manufacturing industries (excluding oil refinery) has been disaggregated to non-metallic minerals sector and paper-carton and print sector. The sectors hotel and restauration, commerce, and public services are aggregated into Commerce, public services sector. We should also point out that the transport sector includes only domestic transport that includes only the consumption of energy by the productive sectors serving to transport goods or persons, and the consumption by public transport. With these changes in data, we obtain, in the end, 14 productive sectors (Annex: table 5).

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[3] The coefficient d_{ij} is the proportion of the i^{th} industry output sold to the j^{th} industry. As stated by Miller and Blair, the d_{ij} "represent the distribution of sector i's outputs across sectors j that purchase interindustry inputs from i ; these are frequently called allocation coefficients, as opposed to technical coefficients, a_{ij}" (Miller and Blair, 2009, p. 543).

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The matrix $\boldsymbol{E}^{Y}$ (Annex: table 4) allows us to obtain the total impact (direct and indirect) by summing columns and the distributive impact by summing the rows. Total impact expresses the percentage increase in final energy consumption for the whole economy in response to 1% increase of the final demand of the corresponding sector. The distributive impact expresses the percentage increase in final energy consumption of the corresponding sector in response to 1% increase of the final demand of the whole economy.

4. Results and discussion

4.1. Results

In the table 2 bellow, we have the values of total and distributive impacts of sectors of the study, which represents the elasticities between each sector and the whole economy:

Table 2. Total and distributive impacts of final energy consumption

Ordering number	Sectors	Total impact	Distributive impact
1	Agriculture, forestry, fishing	0,076	0,108
2	Mining and quarrying	0,023	0,057
3	Food and tobacco	0,081	0,029
4	Textile and leather	0,013	0,01
5	Chemical and petrochemical	0,031	0,014
6	Non-ferrous metals	0,007	0,016
7	Machinery	0,001	0,005
8	Transport equipment	0,008	0,002
9	Wood and wood products	0,0001	0,0003
10	Paper, pulp and printing	0,003	0,007
11	Non-metallic minerals	0,018	0,127
12	Construction	0,132	0,007
13	Commerce, public services	0,18	0,124
14	Transport	0,427	0,504

Source: authors' computation

Based on the information on table 2, and using the classification method in Alcantra and Padilla (2003), we have now the possibility to classify the sectors to show the degree of importance of each sector in final energy consumption; by computing the median value of the total and distributive impacts respectively $E_T = 0.0204$ and $E_D = 0.0147$. The median provides a robust and balanced threshold that is less sensitive to extreme values, Consequently, this simple yet effective approach allows us to identify the key sectors in energy consumption, as presented in the table 3.

Table 3. Sectors classification

	$\sum_i E_{ij}^{y} < E_T$	$\sum_i E_{ij}^{y} > E_T$
$\sum_j E_{ij}^{y} > E_D$	Non-ferrous metals, Non-metallic minerals	Key sectors: Agriculture, forestry and fishing- Mining and quarrying- Food and tobacco- Commerce and public services-Transport
$\sum_j E_{ij}^{y} < E_D$	Textile and leather-Machinery- Wood and wood products- Paper, pulp and printing	Chemical and petrochemical, Construction

Source: authors elaboration

We can deduct from table 3, that the key sectors in final energy consumption are: the transport (14), commerce and public services (13), agriculture, forestry, fishing (1), mining and quarrying (2) and food and tobacco (3). Based on the values on table 3, the total impacts and the distributive impacts of these key sectors combined represents respectively 78.7% and 82.2%. To explain further, the results of table 2 represents the elasticities between each sector and the whole economy: For example, for agriculture, forestry, and fishing sector, a 1% increase of its final demand, increase the final energy consumption of all sectors by 0.076%. And its final energy consumption increases by 0.108% in case of a 1% increase of the final demand of all sectors. This result is consistent with those of Bekhet. et Abdullah., (2010), who highlighted the significant direct and indirect link between agriculture and energy in Malaysia. Similar findings are reported in the study by Pruitichaiwiboon et al. (2011), whose results showed that the agriculture and fishing sector is among the key sectors in energy demand in South Korea, a net energy-importing country. In the Moroccan context, the importance of this sector can be explained by the structural role of irrigated agriculture, which is highly dependent on energy for water pumping, irrigation systems, and the use of agro-industrial inputs.

For mining and quarrying sector, a 1% increase of its final demand, increase the final energy consumption of all sectors by 0.023%. And its final energy consumption increases by 0.057% in case of a 1% increase of the final demand of all sectors. This confirms the findings established by Pruitichaiwiboon et al. (2011), that the Mining sector in South Korea is a key sector in increasing the supply of primary energy required to meet its needs for secondary energy.

For food and tobacco sector, 1% increase of its final demand, increase the final energy consumption of all sectors by 0.081%. And a 1% increase of the final demand of all sectors, will increase its final energy consumption by 0.021%. This result is supported by the study conducted by Pruitichaiwiboon et al. (2011), showing that the South Korean food and tobacco is among the key sectors in the supply of primary energy required to meet its secondary energy needs.

Turning now, to commerce and public services sector, 1% increase of its final demand, increase the final energy consumption of all sectors by 0.180%. And a 1% increase of the final demand of all sectors, will increase its final energy consumption by 0.124%. these values indicate that this sector is particularly important compared to the other previously mentioned sectors. this result aligns with that of Pruitichaiwiboon & al. (2011), regarding key sectors in energy demand in South Korea, which, like Morocco, is a net energy-importing country. This strong position of the commerce and public services sector reflects the growing weight of the tertiary sector in the Moroccan economy, as the rapid urbanization process and the expansion of public and commercial infrastructure have amplified energy demand in this sector.

Furthermore, we deduce from the results that the transport sector is the most significant among the key sectors in this study and deserves even greater attention in energy policies. Indeed, 1% increase of its final demand, increase the final energy consumption of all sectors by 0.427%. And a 1% increase of the final demand of all sectors, will increase its final energy consumption by 0.504%. This conclusion regarding the transport sector as the main key sector is consistent with the findings of Alcantara and Padilla (2003) on the transport sector in Spain, identified as a primary key sector in final energy consumption. This result is further supported by Kofoworol and Gheewala (2006) regarding the energy intensity of industrial sectors, revealing that the transport sector in Thailand is among the top Five sectors in terms of energy intensity. In Morocco, this dominant role of the transport sector can be explained by the overwhelming importance of road transport, which accounts for the largest part of passenger and freight activities, compared to a limited share of rail and maritime transport for domestic logistics.

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Comparative analysis of key sectors across some countries further reinforces the relevance of the Moroccan results. In Spain, key sectors include domestic transport, chemicals, food, construction, and iron and steel industries (Alcantara and Padilla, 2003), highlighting the central role of transport and food industry, similar to Morocco. In South Korea, key sectors on the demand side include agriculture and fishery, petrochemicals, non-metallic minerals, iron and steel, manufacturing, construction, and transportation, while on the supply side mining, iron and steel, textiles, fabricated metals, and residential sectors dominate (Pruitichaiwiboon & al., 2011). This mirrors the Moroccan case, where both primary sectors: agriculture and mining, and transport sector play a crucial role. Finally, in Thailand, sectors such as petroleum refining, road freight transport, electricity, cement and agriculture are among the most energy-intensive sectors (Kofoworol and Gheewala, 2006), again underlining the dominant role of transport and agriculture.

In summary, targeting these sectors through energy policies can help achieve a substantial reduction in energy consumption, thereby lowering energy costs. Now, and according to Alcantara and Padilla (2003), the logic conclusion about the policy to follow, is to act on final demand, but, that, can have a negative impact on productive activities. So, we look into the values of matrix $\boldsymbol{E^y}$, to see the share of the own impact of each key sector, more the own impact is important, more there is a wide margin to save energy in the own sector without affecting the production of economy Alcantara and Padilla (2003). This approach can help guide interventions that contribute to achieving Morocco's NES target of a 15% reduction in final energy consumption.

According to the matrix $\boldsymbol{E^y}$, the agriculture, forestry, fishing (1) sector's own impacts is equal to 0.065 representing 86% and 60% of the total and distributive impacts of the sector. For Mining and quarrying (2), the own impact is 0.018, representing 86% and 60% of the total and distributive impacts of the sector. As for the food and tobacco sector (3), the own impact is 0.026, representing 32% and 90% of the total and distributive impacts of the sector. Concerning commerce and public services (13), the own impact represent 69% and 99% of the total and distributive impacts of the sector with a value of 0.123. As for the transport sector (14), the own impact is 0.423 representing 99% and 84% respectively of the total and distributive impacts of the transport sector.

4.2. Measures and barriers

- ***Measures***

We now, present some possible interventions to reduce final energy consumption in the sectors identified as key in Morocco, aiming to guide policymakers in achieving their goal of a 15% reduction in energy consumption by 2030.

As mentioned earlier for the agriculture, forestry, and fishing sector, the total impact is 0.076, the distributive impact is 0.108, and the sector's own impact is equal to 0.065. Efficiency measures could lead to up to 23% energy savings by 2030 (AMEE, 2020). Several measures can be implemented. First, energy audit programs can be established to collect data on the energy consumption structure of farms and assess potential energy savings (AMEE, 2020). Data from recent audits show that agricultural machinery and irrigation pumping systems are the main energy consumers (Lahbabi and Touzani, 2016). Energy consumption can be reduced through regular diagnostics, repair, and maintenance of machinery, as well as promoting the use of solar energy in irrigation pumping systems (Lahbabi and Touzani, 2016). Solar pumping can be an important lever to limit the use of butane gas and reduce the energy bills associated with agricultural activities (Barradi, 2019). Indeed, recent audits have shown an energy-saving potential of 20% in large farms if solar pumping systems were widely implemented (Lahbabi and Touzani, 2016).

In the mining and quarrying sector, as previously noted, the total impact is 0.023, the distributive impact is 0.057, and own impact is 0.018, regular energy audits can help identify opportunities for energy reduction. The operating conditions of mining equipment are the main determinant of energy consumption levels (Golik and Morkun, 2018). Moreover, some processes in the mining industry are more energy-intensive than others (Awuah-Offei, 2016). Energy savings could be achieved by considering energy efficiency in the design of mining projects, implementing effective energy management for all processes, and using new, more energy-efficient equipment in operations such as extraction and transport (Awuah-Offei, 2016). Additionally, improving cogeneration in electricity production and increasing the share of renewable energy in the energy mix of mining sites (OCP Group) can contribute to energy savings.

For the food and tobacco sector, the total energy impact is 0.081, the distributive impact is 0.029, and the own impact is 0.026. Final energy consumption can be reduced by replacing outdated production means with more efficient and less energy-consuming equipment—for example, using variable speed and frequency drives in industrial units to control machine speed (Barradi, 2019), improving boiler maintenance and insulation, detecting and minimizing compressed air leaks, optimizing cold and heat storage in industrial units, and reusing waste heat (Neusel and Hirzel, 2022).

As highlighted earlier for the commerce and public services sector, the total energy impact is 0.180, the distributive impact is 0.124, and the sector's own impact is equal to 0.123. The main sources of energy consumption are lighting, heating, and cooling systems in public and commercial buildings such as restaurants and hotels (IEA, 2019). The MNES has adopted several actions to reduce final energy consumption in this sector, including establishing a building energy code for new constructions and implementing energy audit programs for existing buildings (Barradi, 2019). The use of thermal insulation materials, double glazing, installation of low-temperature solar thermal collectors, and the widespread adoption of low-energy lamps (LEDs) in commercial and public buildings are possible solutions to save energy in lighting, heating, and cooling systems (AMEE, 2020; Barradi, 2019). It should also be noted that in some commercial sectors, switching from traditional solid biomass to electricity can improve the energy efficiency of final energy consumption (IEA, 2019).

For the transport sector, as mentioned before, the total energy impact is 0.427, the distributive impact is 0.504, and the own impact is 0.423. It is important to highlight, that, the largest part of energy consumed comes from petroleum products (Oubnaki et al., 2022). Multiple actions can be taken in this sector, such as conducting energy audits to gather information on the mechanical condition of vehicles and their usage patterns, and implementing regulations on vehicle energy efficiency (AMEE, 2020). Energy consumption can be reduced through measures such as transport public fleet renewal, as well as the modernization of freight transport fleets, to control and optimize energy consumption through the diffusion of more efficient vehicles and cleaner technologies, (Barradi, 2019). Tax incentives would be necessary to accelerate fleet modernization, along with mandatory annual technical inspections. Moreover, promoting eco-driving and public transport can also, contribute to reducing energy consumption (AMEE).

However, the implementation of these measures, may generate potential rebound effects in these sectors, where efficiency gains lead to higher energy consumption (Benounna & El Hebil, 2016). In the transport sector, reductions in energy intensity and operating costs can stimulate additional travel demand, or changes in mobility behavior, partially offsetting the energy savings. In the commerce and public services sector, improvements in energy performance may translate into extended operating hours, higher service intensity, or enhanced comfort standards, resulting in an overall increase in energy demand Consequently, the effectiveness of these measures in achieving sustained reductions in final energy consumption depends on their combination with pricing instruments and regulatory policies, thus ensuring that efficiency gains are not offset by increased final energy demand.

- ***Barriers***

Despite the relevance of the proposed measures, their effective implementation faces a range of barriers—economic, technical, institutional, and socio-cultural (Court of Accounts, 2018). These structural obstacles slow down the adoption of efficient practices and prevent the achievement of the targets set in the national energy strategy. A detailed analysis of these barriers not only helps to better understand the causes of this inertia but also identifies the most relevant levers to overcome these challenges.

For example, in the agriculture, forestry, and fishing sector, implementing these measures on agricultural machinery remains difficult for many reasons, such as the dispersion of equipment, vested interests, and the capacity of agricultural producers (Lahbabi and Touzani, 2016). The deployment of a national program to promote solar pumping in irrigation projects covering a total area of 100,000 ha across the country first requires clarifying issues related to financing mechanisms and means (Barradi, 2019).

In the food and tobacco sector, although the national energy policy has planned for mandatory energy audits in the industrial sector, these audits have not yet been widely implemented, and no schedule for their execution has been established. Support for financing energy audits and energy efficiency investments is insufficient, and existing support mechanisms are fragmented and mostly reliant on public actions (Cour des comptes, 2018).

In the trade and public services sector, however, the thermal regulation has not set minimum energy performance standards for both tertiary and public buildings and their equipment. Despite the importance of the existing building stock, the thermal regulation only applies to new buildings. For the implementation of the new building thermal regulation, additional investment costs were identified and evaluated by AMEE through pilot projects carried out during the preparation of the regulation. Moreover, there is a lack of financial incentive measures to support the implementation of energy efficiency.

For the transport sector, despite efforts to improve energy efficiency, the measures taken have not had sufficient effects. Additionally, the actions implemented have only concerned road transport activities. There is a lack of dedicated standards for the transport sector that could serve energy efficiency improvement objectives. Public authorities have not yet defined specific standards to enhance energy efficiency in this sector, such as standards for tires, fuels, and emission thresholds for major pollutants (CO_2 and heavy metals). In this context, financial incentives represent an important lever to overcome barriers hindering vehicle fleet renewal.

5. Conclusion

Research about Energy has increase over the years, especially for countries that depends on foreign sources for their energy needs. This paper aimed to identify the key sectors in final energy consumption from a final demand perspective in Morocco. To this end, we applied an input-output (IO) methodology based on input-output tables (IOT) and energy balance data to construct the Ey matrix, whose values were then used to estimate intersectoral energy elasticities among the productive sectors considered in the study. Based on these elasticities, a classification framework was developed to identify the key sectors contributing most to final energy consumption.

The results show that the main key sectors are Transport, Commerce and Public Services, Agriculture, food and tobacco, and mining and quarrying. These sectors combined represents 78.7% and 82.2% Of the total and distributive impacts. The transport sector is the main key sector, reflecting the dominance of road transport and the high reliance on petroleum products in Morocco. It is followed by the commerce and public services sector, which is particularly significant due to the large share of the tertiary sector in Moroccan cities and the high energy demand for lighting, heating, and cooling in commercial and public buildings. The agriculture, forestry, and fishing sector ranks next, with irrigated agriculture playing a central role in energy consumption, especially for water pumping.

These findings suggest that energy saving policies should prioritize the own impacts of the key sectors to maximize efficiency and avoid disruptions in productive activities, targeted measures can be better aligned with Morocco's National Energy Strategy (NES) and the country's 2030 energy objectives. Prioritizing these key sectors in energy saving policies can, not only help reducing energy consumption in the economy, but also, reducing the cost of energy saving policies. We signal that the disaggregation of sectors is insufficient because of the scarcity of detailed data on final energy consumption. With more data, across other sectors and sub-sectors, the identification of the key sectors could be more precise. Notwithstanding, the results of this paper could be very useful for developing, a policy aimed at reducing the final energy consumption. Building on these findings, future work could also adopt dynamic approaches and integrate CO_2 emissions, for example, the methodology could be extended to other years, allowing the analysis of how key sectors and their impacts evolve over time, enabling interannual comparisons and more comprehensive policy evaluation.

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ANNEXE

Table 4. Matrix E^y

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Distr impact
1	0,065	9,4E-06	0,037	0,0005	0,0006	1,7E-06	2,4E-05	5,7E-05	2,7E-05	8,4E-05	7,1E-06	0,0003	0,004	0,0001	0,108
2	0,001	0,018	0,002	0,0006	0,016	0,0003	0,001	0,0004	4,2E-06	6,46E-05	0,0004	0,009	0,005	0,002	0,057
3	0,001	4,2E-07	0,026	2,3E-05	1,7E-05	6,8E-08	8,4E-07	1,6E-06	5,5E-07	1,7E-06	2,8E-07	8,8E-06	0,001	1,5E-05	0,029
4	1,4E-05	2,2E-06	2,2E-05	0,009	7,8E-06	6,6E-08	5,5E-06	4,1E-06	4,94E-07	3,3E-06	3,9E-07	1,3E-05	0,0002	6,7E-06	0,001
5	0,0006	0,0001	0,0008	0,0003	0,008	1,9E-05	0,0001	0,0001	1E-06	3,1E-05	5,4E-05	0,0009	0,002	0,001	0,014
6	2,3E-05	1,1E-05	5,4E-05	5,3E-05	2, E-05	0,006	0,002	0,0008	1,1E-06	5,6E-06	0,0002	0,006	0,0004	3,1E-05	0,016
7	1,3E-05	1,3E-05	2,2E-05	2,2E-05	1,7E-05	4,2E-06	0,004	0,0002	1,1E-07	4,7E-07	3,2E-06	0,0002	0,0002	2,5E-05	0,005
8	1,1E-06	2,5E-07	1,4E-06	1,2E-07	3,1E-07	1,5E-08	2,9E-07	0,002	4E-09	1,3E-08	7,2E-08	7,31E-07	5,9E-05	2,1E-05	0,002
9	5,6E-07	4,9E-08	4E-06	4E-06	2,1E-07	2,4E-08	2,2E-06	1,3E-05	2,1E-05	1,3E-06	4,4E-07	0,0002	1,9E-05	6E-07	0,0003
10	0,0001	3,3E-05	0,0014	0,0006	0,0002	8,1E-06	9,4E-05	6,8E-05	6,4E-07	0,003	3,6E-05	0,0003	0,002	0,0001	0,007
11	0,0002	7,6E-05	0,001	0,0002	0,0003	6,2E-06	0,0002	0,003	4,6E-06	1,2E-05	0,016	0,102	0,003	0,0003	0,127
12	1,2E-05	6,2E-07	1,3E-05	2,8E-06	2,2E-06	1,5E-07	1,1E-06	1,4E-05	3,6E-08	1,3E-07	4,7E-07	0,007	0,0001	7E-06	0,007
13	0,0002	6,5E-06	0,0001	2,9E-05	3,6E-05	2, E-06	2,6E-05	3,9E-05	2,5E-07	2,1E-06	2,9E-06	5,7E-05	0,123	0,0003	0,124
14	0,007	0,005	0,013	0,0017	0,006	0,0001	0,002	0,0009	4,3E-05	0,0002	0,0005	0,0065	0,039	0,423	0,504
Total impact	0,076	0,023	0,081	0,013	0,031	0,007	0,01	0,008	0,0001	0,003	0,018	0,132	0,178	0,427	1,0000

Source: author's computation

Table 6. An aggregate input-output table of the Moroccan economy (10^6 MAD, year 2016)

	Intermediate consumption															
Sectors	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**Final demand**	**Total production**
1	25626	0	76788	741	1701	0	19	52	615	441	20	28	4328	77	119023	229459
2	0	157	117	10	19210	436	819	1	17	2	1430	3774	935	5	8296	35209
3	16060	0	22752	102	65	0	0	0	2	0	4	0	9090	78	191112	239265
4	154	41	97	31654	70	0	46	25	46	73	14	36	1408	45	70362	104071
5	11444	3010	4626	2975	11489	490	1333	1234	88	990	4498	5780	15434	14330	92268	169989
6	12	18	26	70	11	10159	4434	1243	23	29	3306	8545	372	5	12273	40526
7	343	716	276	440	181	195	11518	4615	23	21	415	4271	4333	459	78780	106586
8	60	1	17	1	0	1	12	17554	1	0	20	3	3186	1404	97636	119896
9	0	0	95	112	0	1	77	414	2136	119	97	6139	451	5	650	10296
10	59	164	3053	1312	658	35	208	108	13	3236	529	97	3447	182	4984	18085
11	0	58	363	61	94	2	56	1077	17	9	3881	34864	559	36	5484	46561
12	378	30	151	55	55	7	24	301	8	6	70	50	2140	158	149407	152840
13	501	16	52	54	99	9	58	76	4	10	35	62	44301	681	252621	298579
14	1388	1762	1291	192	259	17	252	76	64	76	380	155	4906	2880	56425	70123

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Table 5: aggregation and disaggregation of sectors.

Sectors HCP	Aggregation (A) Disaggregation (D)	Sectors Paper
Agriculture, forestry and ancillary services	A	Agriculture, forestry, fishing (1)
Fishing, aquaculture	A	Agriculture, forestry, fishing (1)
Mining and quarrying		Mining and quarrying (2)
Food and tobacco		Food and tobacco (3)
Textile and leather		Textile and leather (4)
Chemical and Para chemical	A	Chemical and petrochemical (5)
Oil refinery and others energy products	A	Chemical and petrochemical (5)
Mechanics, metallurgies and electric industry	D	Non-ferrous metals (6) Machinery (7) Transport equipment (8)
Others manufacturing industries (excluding oil refinery)	D	Wood and wood products (9) Paper, pulp and printing (10) Non-metallic minerals (11)
Construction		Construction (12)
Commerce	A	Commerce, public services (13)
Hotels et restaurants	A	Commerce, public services (13)
Public administration and social security	A	Commerce, public services (13)
Transport		Transport (14)

Table 8. Vectors s and h

Ordre	Sectors	Vector s	Vector h (%)
1	Agriculture, forestry, fishing	*0,519*	*0,108*
2	Mining and quarrying	*0,356*	*0,051*
3	Food and tobacco	*0,799*	*0,029*
4	Textile and leather	*0,676*	*0,01*
5	Chemical and petrochemical	*0,543*	*0,014*
6	Non-ferrous metals	*0,303*	*0,016*
7	Machinery	*0,739*	*0,005*
8	Transport equipment	*0,814*	*0,002*
9	Wood and wood products	*0,063*	*0,0003*
10	Paper, pulp and printing	*0,276*	*0,007*
11	Non-metallic minerals	*0,118*	*0,127*
12	Construction	*0,978*	*0,007*
13	Commerce, public services	*0,846*	*0,123*
14	Transport	*0,805*	*0,503*

Source: authors' computation

Table 7. Energy Balance of Morocco (2016)

	2016	Primary coal and peat	Primary Oil	Oil Products	Natural Gaz	Biofuels and waste	Electricity	Heat	Total Energy	Of which: Renewables
	Primary production		212		2 552	67 480	15 322	4 320	89 886	84 112
	Imports	185 804		532 899	40 678		19 040		778 422	
	Exports			-524			-486		-1 010	
	International marine bunkers			-5 595					-5 595	
	International aviation bunkers			-28 312					-28 312	
	Stock changes	-6 466	3724						-2 742	
	Total energy supply	179 338	212	502 192	43 231	67 480	33 876	4 320	830 648	84 112
	Statistical difference	0	212	-1 550	117	0	-4	0	-1 225	16 762
	Transfers									
	Transformation	-178 592		-31 664	-40 561	-1 709	98 921	-4 320	-157 925	-4 589
	Electricity plants	-178 592		-31 664	-40 561		98 921	-4320	-156 217	-2 880
	Oil refineries			0					0	
	Other transformation					-1 709			-1 709	-1 709
	Energy industries own use						-619		-619	
	Losses						-20 354		-20 354	
Sectors										
	Final consumption	746		472 078	2 552	65 771	111 827		652 974	62 762
	Final energy consumption	746		450 933	2 552	65 771	111 827		631 829	62 762
	Manufacturing, const., mining	746		75 773	2 552	5 244	40 284		124 600	2 235
5	Chemical and petrochemical			2 191		445	3 694		6 329	85
6	Non-ferrous metals	83		2 402			4 763		7 248	
11	Non-metallic minerals			46 229		4 507	7 816		58 552	1 858
8	Transport equipment			176			670		846	
7	Machinery			47			2 138		2 186	
2	Mining and quarrying			12 777	941		9 601		23 320	
3	Food and tobacco	663		6 400		202	5 936		13 202	202
10	Paper, pulp and printing			727	1611		1 044		3 382	
9	Wood and wood products					11	112		122	11
4	Textile and leather			1 663		49	2 714		4 426	49
12	Construction			2 297		30	1 015		3 342	30
	Industries n.e.s	0		864	0	0	781		1 646	0
14	**Transport**			230 718			1267		231 985	
	Road			229 228					229 228	
	Rail			387			1 267		1 654	
	Domestic aviation			1 103					1 103	
	Other			144 441		60 527	70 276		275 244	60 527
1	**Agriculture, forestry, fishing**			35 648			14 033		49 681	
13	Commerce, public services			5 850		32 586	18 554		56 990	32 586
	Households			102 783		27941	37 688		168 412	27 941
	Other consumers			161					161	
	Non-energy use			21 145					21 145	

Source : https://unstats.un.org (2018)