THE IMPACT OF INDUSTRIAL ENERGY EFFICIENCY ON ECONOMIC AND SOCIAL INDICATORS

The impact of industrial energy efficiency on economic and social indicators

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Abstract

Inclusive and sustainable industrial development implies environmental friendly industrial growth with positive implications for social targets such as employment generation. One of the most important options available to policymakers for reducing CO_2 emissions is industrial energy efficiency, which is particularly relevant for the discussion on green industrialization. Despite this intuitive concept, the economics measurement toolkit still lacks a methodological framework to analyse the extent to which energy efficiency interventions can generate simultaneous economic, environmental and employment-related improvements to boost inclusive and sustainable industrial development. This study fills this gap by introducing an original approach based on input-output tables to estimate the impact of improvements in industrial energy efficiency on value added, employment and energy savings among industries in the Republic of North Macedonia. The results show that triple dividends are possible in terms of inclusive and sustainable industrial development. Whereas a positive impact on employment is found in every scenario, a positive outcome in terms of value added essentially depends on the country's capacity to produce goods that accommodate firms' increasing demand from their use of energy cost savings.

1   Introduction

Industrial activities consume a substantial share of energy at the global level, accounting for 25 per cent of total energy consumption at the global level in 2017[1]. Relying heavily on energy produced from fossil fuels, industries' energy consumption contributes to the emission of greenhouse gases. While progress has been made by shifting towards renewable energy sources, industrial development and growth have increased energy consumption and have further increased emission levels. Improving the industrial sector's energy efficiency (EE) is crucial for decoupling economic growth from the negative environmental and climate impacts of industrial development.

Improvements in industrial EE have been found to be one of the most important and cost-effective means of achieving industrial emissions mitigation (Rosen & Guenther, 2015; Worrell, Bernstein, Roy, Price, & Harnisch, 2009). EE investments are typically highly cost-effective in the short-run compared to other mitigation options as they result in a net economic benefit for the investor through the almost immediate cost savings generated from the higher energy efficiency itself (McKinsey, 2010)

The benefits of investment in EE go beyond its role in mitigating emission, as it is also associated with economic growth and job creation. EE investments have a rebound effect on the economy as a whole, as the effects of the higher efficiency spill over into the rest of the economy. From the firm's perspective, the improved efficiency in the use of energy reduces costs and increases their production's competitiveness. This increase in competitiveness leads to an expansion of production and other indirect impacts of the initial investment.

The positive economic impacts also generate positive social effects, for example, promoting the creation of jobs. In this study, we evaluate the socio-economic impacts of the implementation of UNIDO's EnMS Capacity-Building and Implementation (CBI) Programme in the Republic of North Macedonia (hereinafter North Macedonia) during 2015 and 2016.

Using data collected by Matteini et al. (2017) in a comprehensive cost-benefit analysis (CBA), we evaluate the direct and rebound effects of the programme's implementation. This study distinguishes between three main channels through which EE impacts employment: (a) through the initial investment in EE of industrial firms, (b) through the consequent reduction in demand for energy resulting from the EE increase, and (c) through the re-spending of saved resources (rebound effects). As a robustness check, we create different scenarios of how participating firms can choose to re-spend savings. Our results indicate that the implementation of the EnMS

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[1] International Energy Agency CO_2 emissions from fuel combustion database. Data takes into account the manufacturing sector, construction and industrial energy own use excluding electricity.

programme in North Macedonia has a positive impact on job creation and on value added, depending on the country's capacity to produce goods.

To the best of our knowledge, this is the first time input––output models are used to analyse the impact of projects aimed at improving firms' EE on both value added and employment by considering a comprehensive set of transmission channels. This can be very useful for policymakers in their discussion on the impact of project interventions and for researchers who can use the standard input-output methodology with an original approach. As is explained in the following section, previous studies on E differ in terms of objectives (e.g. they identify barriers to the adoption of EE or analyse the impact of EE on emissions) and methodology (e.g. econometric studies using firm data or applying a simple top down or bottom up modelling approach). Even if other studies use the input-output approach applied in the present study, they do not consider a comprehensive set of transmission channels (EE investments, reduction of energy demand and re-spending), and/or only evaluate EE improvements on the basis of modelling assumptions, and/or do not consider the impact on both employment and value added.

The new approach is applied to the case of North Macedonia, in accordance with Fias et al.'s (2016) claim: "this methodology could be easily transferred to other national settings". Fias et al. (2016) introduce a new methodological approach to better understand the industrial sector's contribution to long-term climate and energy policy targets, but they do not consider the impact of firms' EE on economic and social variables as the present study does.

Measuring the economic and employment benefits that result from EE improvements presents some challenges. This study contributes to this field of research by developing a novel framework for evaluating the socio-economic impact of industrial EE improvements obtained through the implementation of the Energy Management Systems (EnMS) and related programmes. EnMS, in line with the international standard ISO 50001, offers industrial enterprises a systematic approach to identify and tackle opportunities for energy savings and drives continuous energy performance improvements over time. It represents a proven technical management tool and policy instrument to advance sustainable EE in industry as well as other economic sectors by integrating EE in daily business operations and investment decisions.

EnMS is a unique type of energy efficiency measure (or best available technology) as it systematically addresses the management of all those organizational processes, operations, decisions and behaviours that affect a firm's energy use and consumption, with the objective of continually improving the firm's energy performance. One key element and principle of EnMS implementation is sustained optimal use and the performance of existing firms' assets and

resources, largely related to efficient energy management processes and operations control. During the initial phase of implementation of an EnMS, this key principle is always the source of numerous no-cost and low-cost energy performance improvements and measures that result in energy consumption reduction. As the EnMS matures and improves over time (years), no-cost and low-cost opportunities to save energy progressively diminish in favour of more capital-demanding measures. Taking that aspect into consideration, the implementation and economic and social impacts of EnMS differ from what has been the focus of many other studies that evaluate the rebound effects of typically high-cost industrial EE investments. Specifically, understanding the impact of the implementation of EnMS on job creation is of considerable importance due to its potential to be implemented in developing economies in light of the low up-front costs of the measures and subsequent short payback time.

The remainder of this study is organized as follows. Section 2 presents a literature review of the different methodologies that have been used to evaluate the socio-economic impacts that result from EE investments. Section 3 elaborates the case study of UNIDO's EnMS CBI Programme in North Macedonia. Section 4 discusses the methodology used in this study, and Section 5 describes the data sources used to apply the respective methodology. Finally, Section 6 presents the main findings of the study and Section 7 concludes and proposes possible extensions of this analysis.

2   Literature review

The study of the adoption of and barriers to EE has been the subject of substantial research and investigation (e.g. Palm and Thollander 2010, Trianni et al. 2016). The literature emphasizes the relevance of micro aspects at firm level such as lack of information, procedural impediments and commitment of management as key factors explaining the lack of implementation of EE measures.

The impacts of EE improvements on the economy and employment have been estimated using a number of different methodologies. These methodologies can be broadly distinguished between bottom-up and top-down approaches. Bottom-up studies rely on surveys, questionnaires or other sources of observed data to measure the directly observable economic and social impacts of an EE measure/programme. Cost-benefit analysis is one of the bottom-up approaches commonly used to evaluate the impact of EE. The advantage of bottom-up analysis is the absence of underlying assumptions compared to top-down approaches at the tradeoff that the analysis is only capable of capturing the directly observable effects. There are two approaches to estimate the impact of EE on green jobs according to the ILO (2011): 1) the industry approach, which counts the number of employees at firms that produce green products or services; and 2) the occupational

approach, which uses occupation classifications to count the number of employees at all types of firms engaged in activities that contribute to the greening of the economy. UNIDO (2011) estimates the payback period for different EE investments of firms in developing countries. Sorrell et al. (2009) focus on the rebound effect from EE. Improvements in energy services make them cheaper and this induces increased consumption of such services. By considering the household sector, Sorrell et al. estimate that the rebound effect is less than 30 per cent. These contributions are based on firms' observed behaviour, but they do not take into account the country's macroeconomic aspects. A flourishing emerging literature analyses the economic impact of EE through econometric studies using firm data. Montalbano and Nenci (2019) analyse the impact of EE on the economic performance of firms in Latin American countries and find a positive impact on productivity. Cantore et al. (2016) use the World Bank Enterprise Survey data to study the impact of EE on industrial firms' total factor productivity in developing countries. They find a positive impact, albeit heterogeneous across industrial sectors.

Top-down methods are impact evaluation methods based on economic modelling using input-output (IO) models or computable general equilibrium (CGE) models. Based on the model's given underlying assumptions, the method is able to capture the impact of the EE improvements beyond the directly observable effects. For example, aside from only capturing the reductions in demands for energy an EE measure/programme may generate, an IO model can estimate the indirect effects of that reduction on all other sectors of the economy. By using a CGE model, Bataille and Melton (2017) estimate the impact of EE improvements on Canadian GDP, employment, employment structure and welfare from 2002 to 2012. They find that EE increased GDP, employment and welfare over the period 2002 and 2012. The transmission channel according to Bataille and Melton (2017) is: "Energy efficiency causes a drop in energy demand resulting in a small transition of investment away from energy producing sectors which is offset by a larger increase in overall investment and activity in the rest of the economy" (p. 124). EE improvements are modelled on assumptions and not on observed EE improvements as in the present study. Garrett-Peltier (2017) uses IO tables to evaluate public and private spending in clean energy and compares it to the effects of spending on fossil fuels. The study focusses on commercial buildings, not on the industrial sector, which is the subject of our study. Garrett-Peltier finds that, on average, 2.65 full-time-equivalent (FTE) jobs are created from USD 1 million spent on fossil fuels, while that same amount of spending would create 7.49 or 7.72 FTE jobs in renewables or EE, respectively. Brown et al. (2017) use a model for the United States to investigate EE as a strategy to reduce carbon emissions. They analyse the impacts on mitigation costs and emission reduction, but do not include employment and value added. Cantore et al. (2017) study the impact of different scenarios of renewable energy penetration and EE on jobs creation in Africa, but do not

specifically consider the industrial sector. They find that greener scenarios and the gradual phasing out of fossil fuel generate jobs. Montt et al. (2018) use an IO model (MRIO) to assess the impact of global emissions cap scenarios. They focus on investments and on five categories of change: 1) gross capital formation, 2) inputs coefficients for technology production, 3) inputs coefficients for technology use, 4) emissions and employment intensity of production, and 5) value added shares, but do not explicitly discuss the impact from manufacturing firms' re-spending from energy savings, as the present study does. Moreover, energy efficiency improvements are not calculated "bottom-up" as is the case in the present paper.

Both approaches (top-down and bottom-up) are widely used. Bell et al. (2015) find that both top-down and bottom-up methodologies are equally used in analyses of employment creation in studies evaluating EE projects. The bottom-up and top-down methods can be combined in hybrid methods of impact evaluation. This can be achieved by incorporating the information collected from the bottom-up approach to define the type of "shock" and resulting impact the economic model will simulate. Bell et al. (2015) also find that the combination of bottom-up data combined with IO modelling is one of the most appropriate frameworks for capturing the employment effects of EE improvements. Rivers and Jaccard (2005) build a hybrid model with the objective of combining the strengths of the traditional top-down and bottom-up approaches by simulating consumer and firm behaviour at the technological level. They estimate behavioural parameters of technology adoption, which are then used to feed an energy-economy model. Blesl et al. (2007) use the model TIMES to analyse the impacts of efficiency improvement measures on the German energy system, measuring energy savings, technological development, emissions and costs. The scope of EE measures is examined by the project ACROPOLIS and does not derive from modelling assumptions. The results of six scenarios show that the transport sector's CO_2 reduction—using primarily bio-fuels and methanol to achieve the efficiency targets—is the most expensive, and the residential sector indicates the highest benefits in terms of cost savings.

3   A case study of EnMS implementation in North Macedonia

Over the last two decades, EnMS and related standards (national first and more recently international ones such as ISO 50001) have shown to be proven policy instruments to improve EE in industry and to drive a transition towards best available practices and technologies. EnMS provides a unique methodology to systematically bring together and manage people, information and technology with the goal of continual improvement of an organization's energy performance and the integration of EE in its daily business practices. This organizational framework allows enterprises to integrate EE in their management practices through fine-tuning production processes and the improvement of EE of industrial systems (McKane et al., 2009). EnMS

establishes the structure and processes to identify, develop and implement management and technical actions that reduce energy consumption and costs, to generate operation and maintenance savings and to minimize production downtimes, enabling the firm to achieve and sustain EE improvements over time. Through reduced energy consumption, EnMS/EE implementation contributes to the reduction of greenhouse gas (GHG) emissions and to improvements in competitiveness.

UNIDO's Industrial Energy Efficiency (IEE) Programme interventions are designed to promote and support the implementation of energy management systems (EnMS) in line with ISO 50001 and energy systems optimization (ESO) measures. UNIDO's approach to the implementation of EnMS and ESO has a strong focus on identifying and implementing first no-cost and then low-cost measures that can generate immediate energy savings and maximize the energy performance of existing technological and production assets.

Within the scope of a technical cooperation project funded by the Global Environmental Facility (GEF), UNIDO implemented an EnMS CBI Programme in North Macedonia during 2015 and 2016, engaging with a number of collaborating enterprises that committed to attending in-depth training and applying the EnMS methodology. Matteini, Pasqualetto, and Petrovska (2017) conducted a cost-benefit analysis (CBA) based on the implementation of the EnMS CBI programme using data collected through verification audits and questionnaires with participants. Costs associated with the implementation of the programme include costs related to the implementation of the programme itself (staff time for training, external expert assistance, etc.), as well as investment costs incurred by the partner enterprises to implement initial energy saving and efficiency improvement opportunities (e.g. energy meters, sensors, monitoring equipment, electric motors, etc.). The benefits achieved were measured as energy cost savings obtained by partner enterprises as a direct result of the implementation of EnMS and all associated improvement measures.

Matteini et al. (2017) find that significant energy savings were obtained by enterprises that collaborated in the EnMS CBI Programme through the implemented energy management systems (Table 1). Table 1 presents the value of energy savings of industrial firms in North Macedonia.

Table 1: Energy cost savings obtained by participant North Macedonia firms in the first year of implementation of the EnMS

Value of energy savings in North Macedonian firms (EUR)	
Company 1	1,614,474
Company 2	120,152
Company 3	7,656
Company 4	89,840
Company 5	1,601
Company 6	85,000
Company 7	59,095
Company 8	322,200

Source: Based on data collected in Matteini et al. (2017).

4 Methodology

4.1 Conceptual framework

The net impact of the introduction of EE improvements in an economy from an economic and social point of view is not immediately clear because of the different channels through which it affects the economy. Investments in new machinery and technologies to achieve higher EE have the potential to generate jobs in the short run through the positive impact EE has on demand, and jobs are generated in the short run to produce these goods. Once higher EE is achieved for the same level of production, an economy will have lower demand for energy (for electricity, refined petroleum fuel, etc.) as a result of the reduced energy intensity of production. Consequently, demand for energy (e.g. electricity, natural gas, fuel oil, etc.) would decrease and potentially result in job loss and value added loss in the energy supply sectors.

At the same time, the firm's energy costs decrease when it becomes more energy efficient. The reallocation or re-spending of these saving may also result in job and value added creation. As the use of energy and energy-related costs fall, resources in the economy are redirected from spending on energy to other sectors. The outcome of this shift has the potential of creating additional jobs and value added within the economy. The reallocation or re-spending of savings from higher EE generates demand for non-energy goods, which has a positive job and value added generating effect on the economy.

These three impacts of EE improvements can be referred to as (i) the initial investment effect, (ii) the energy effect, and (iii) the rebound effect. A full evaluation of the net impact of EE measures on jobs must include all three effects. However, the number of studies that take all three effects into account remains limited, with the majority of studies only considering the initial investment effect when evaluating the impacts of EE. The impact of the implementation of EE measures/programmes in industry on job creation has remained largely unexplored in the literature.

In addition, as industries in developing countries typically use methods of production that are not necessarily considered the best available practices and technologies, the potential for generating EE improvements from EnMS-EE may be higher. These energy savings translate into cost savings for the firm, which help boost firms' price competitiveness and may play a role in industrial development.

We evaluate the impacts of the implementation of EnMS using data collected from UNIDO's EnMS Capacity-Building and Implementation (CBI) Programme in North Macedonia in eight participant firms from different industries. Specifically, we build on the data collected in a comprehensive cost-benefit analysis (CBA) conducted by Matteini et al. (2017) to create the foundation for our analysis. We apply a mixed approach that combines the findings of the CBA with the North Macedonian IO tables to evaluate the programme's impact on job creation. Our findings indicate that the implementation of the EnMS programme in North Macedonia had a positive net job creation impact on the economy. The framework of analysis presented in this study can be easily applied to other countries and programme evaluations, as it is flexible and can be adapted to country and programme specificities.

Using the available data sources and literature review, we construct a simulation strategy to capture the direct, indirect and rebound effects of the implementation of UNDIO's Energy Management Systems in North Macedonia. To determine the project's impact on job creation, we combine survey data provided by the participant firms on the monetary energy savings generated by the programme compiled in Matteini et al. (2017) to estimate the impact on demand. Once we estimate the impact on demand, we apply the findings to an extended IO model to evaluate the programme's impact on employment in the country.

Figure 1 illustrates how the findings on the EnMS programme's impact can be incorporated into the IO framework. UNIDO's EnMS CBI team provided the participant firm with a systematic approach to identify and tackle opportunities to improve their energy performance. Opportunities derive from optimizing the firm's existing operations and changing the firm's behaviour, including increased investments in EE measures.

Once implemented, these measures allow the firm to achieve higher EE. Changing industrial EE has two direct impacts. From an individual firm's point of view, part of the resources previously spent on energy inputs are no longer necessary. If we consider that energy prices and firms' production remain the same, we can assume that an EE improvements will result in lower spending on energy inputs. However, from the energy provider's point of view, rising industrial EE means a reduction in sales. Higher EE means that the cost of energy in the inputs mix decreases. This is a negative demand shock for energy providers.

A third effect arises from the rebound generated from the firm's cost savings. For a firm that has achieved higher EE in production, some of the resources previously spent on energy inputs are saved and can be reallocated to other purposes within the firm. The equivalent monetary value of the "energy savings" obtained by the firm allows it to increase its production volume or to invest in expanding its production capacity, etc.

Figure 1: Demand shocks created by the introduction of EE improvements
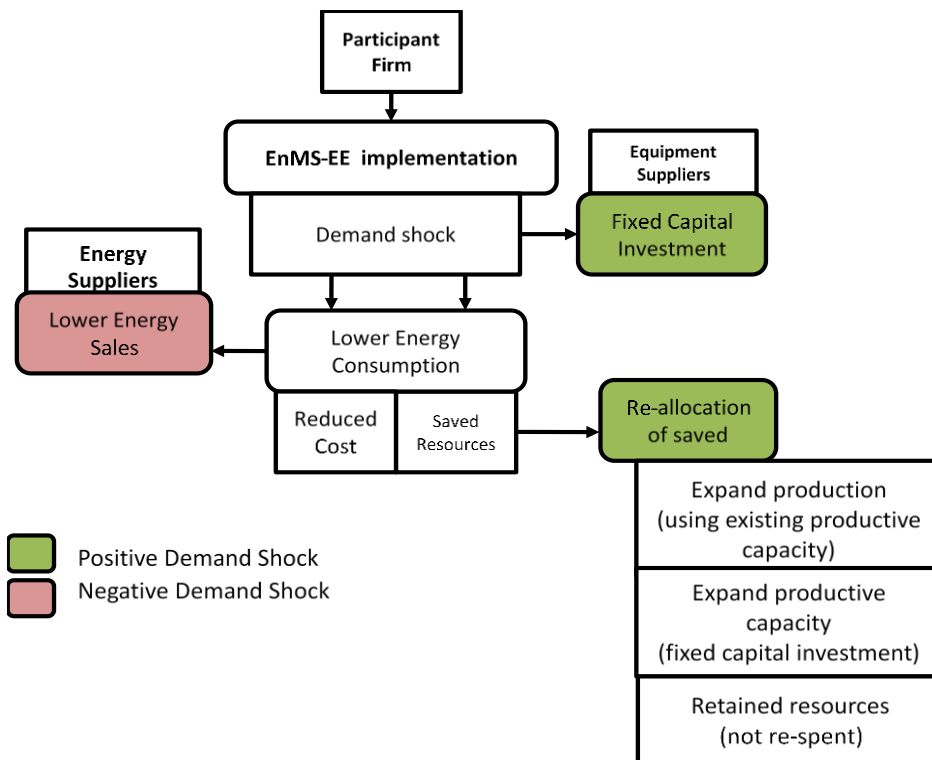
These three effects can be incorporated into an IO framework to evaluate their impact on total employment by translating these three effects into shocks to the demand vector. Values to create the shock to demand are based on energy savings (in kWh and their monetary equivalent) as reported for the North Macedonia "treatment group". In summary, this shock is determined by focussing on three main channels through which EE improvements influence demand in the economy:

i. The positive demand shock from the initial fixed capital investment made to achieve the EE gain (if the measure is no cost, this effect does not occur);

ii. The negative demand shock on the reduction of demand for energy resulting from the achieved gain in EE;

iii. The rebound effect from re-spending the equivalent monetary value of the cost savings generated from the reduction in energy consumption (deriving from either fixed capital investments or no cost measures).

The three channels through which EE and EnMS affect demand in an economy are summarized in Figure 1. While the total monetary value of the initial fixed capital investment (if any) and the monetary value of energy savings achieved are based on values reported by firms that implemented EnMS, we make several assumptions on what type of goods and services firms spend on. For the demand shock generated by the initial fixed capital investment, we refer to the literature on the composition of fixed capital investment to achieve EE.

We assume a typical investment in EE equipment consists of a similar combination of goods as proposed by Pollin et al. (2014). According to Pollin et al. (2014), investments in industrial EE equipment is composed of 20 per cent spending on construction services, 50 per cent on machinery and 30 per cent spending on professional, scientific and technical services. We use this this same investment mix when incorporating this first demand shock into the model (see Table 3, Appendix A).

The second channel examines the reduction in demand for energy inputs generated by the implementation of EnMS and the associated EE investments. Manufacturing firms typically rely on different energy sources and energy inputs for their production. Matteini et al. (2017) present the monetary savings from reduced use of energy inputs of four different fuel type: natural gas, electricity, oil and liquefied petroleum gas (LPG)[2]. These four types of energy sources represent distinct types of products that have their own distinct production process. As a result, the impacts

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[2] Based on data availability, we assume that natural gas and electricity are products from the 'Electricity, gas, steam and air conditioning' (D) industry, while oil and LPG are grouped and produced by the 'Coke and refined petroleum products' industry.

of a reduction in demand of each energy source on employment will also differ and the reduction in demand for different energy inputs should be considered separately in the model. We sum up the monetary energy savings reported by each firm for each fuel type and include them as a negative demand shock.

An additional element to take into consideration when calculating the reduction in energy demand is the country's dependence on energy imports. For energy importers, the decrease in energy demand may represent more a reduction in imports than in domestic energy sales, lessening the negative demand shock. For North Macedonia, for example, 41 per cent of oil and LPG and 12 per cent of electricity and natural gas used by the country's industry is imported. This diminishes the effect of the negative shock of energy demand on the economy[3]. This second channel is presented by the effects considered in the left half of Figure 2.

Figure 2: Domestic impact and leakages of the reduction in the demand for energy and the respending of cost savings

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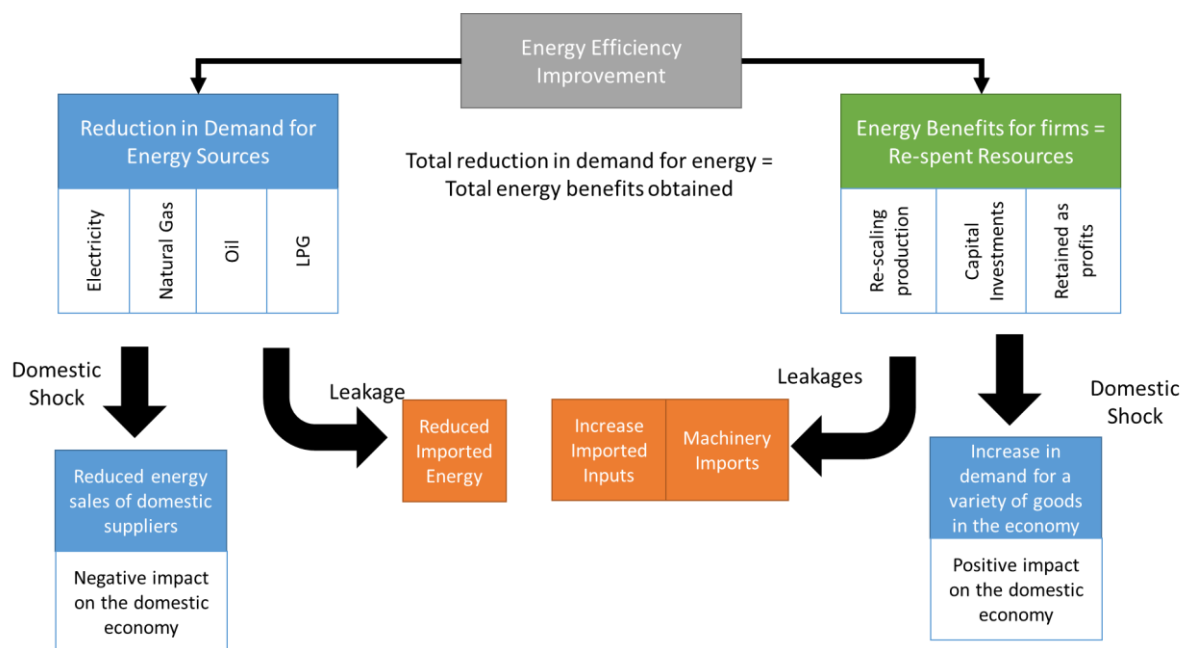
[3] Every 1 MKD (North Macedonian Denar) reduction in the demand for oil and LPG represents a 0.41 MKD reduction in imports and only a 0.59 MKD reduction in sales for domestic 'Coke and refined petroleum products' producers. The same applies to electricity, but to a lesser extent, as reliance on imported electricity is lower. Every 1 MKD reduction in the demand for electricity and natural gas represents a 0.12 MKD reduction in imports and a 0.88 MKD reduction in sales for domestic 'Electricity, gas, steam and air conditioning' producers.

The third channel through which EE may affect demand is through the rebound effect. Firms that become more energy efficient achieve monetary savings, as their energy expenses are lower. This, in turn, frees up resources that can then be reallocated within the firms and invested in other uses. Garrett-Peltier (2011) assumes that any saved resources are fully re-spent on the acquisition of non-energy intermediate inputs to expand production, with the exception of labour[4]. We build on this by creating two additional uses that can arise from monetary savings generated from EnMS-EE:

i. Re-spending on inputs to re-scale production (increase production using existing productive capacity), the same effect considered by Garrett-Peltier (2011);

ii. Re-spending to make further fixed capital investments (with the intention of expanding or modernizing production)[5];

iii. Retaining as profit and not re-spending, not resulting in any additional demand. We assume the resources are retained for future use beyond the period being analysed in the study.

Resources reallocated to intermediate inputs to expand production using existing productive capacity (i) are sector-specific since the combination of intermediate inputs between industrial sectors varies significantly[6]. The energy savings of each firm must be considered as having been re-spent according to the average input mix of the industry they belong. Resources reallocated for additional fixed capital investments (ii) assume the same capital investment mix as for the initial EE capital investment (see Table 3, Appendix A). Resources retained as profit (iii) are assumed to have no further effect on demand.

Studies exist that have investigated how saved resources from industrial EE are re-spent. Accordingly, we create three scenarios assuming different combinations of how these resources are re-spent (Table 2).

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[4] For most medium-sized and large enterprises, the first 1-2 years of EnMS implementation is dominated by re-defining tasks and operations for existing staff and equipment; consequently, improvements in energy performance within a context of increasing production volumes may not require additional labour inputs. This is supported by findings in Matteini et al. (2017) for which firms did not report hiring additional workers during the first year of EnMS implementation, but reported a production expansion.

[5] This effect is also supported by findings in Matteini et al. (2017), with participant firms reporting interest in making further investments to achieve energy efficiency gains once the cost effectiveness of the initial investment is verified.

[6] We assume that each firm produces one specific type of product. Resources re-spent to re-scale the used inputs to expand production will then follow the distribution described in the product input-mix of the technical coefficient matrix. Each column of the technical coefficient matrix describes the input-mix used to produce product i ($A_{*,i}$). We distribute the reallocated resources using the technical coefficient ratios to create the shock in the final demand vector.

Table 2: Reallocated resources resulting from energy savings under different scenarios

Use	Purpose	Scenario A	Scenario B	Scenario C
Re-spent	Re-scale use of inputs to expand production	70%	60%	50%
	Capital investments	30%	25%	20%
Retained	Retained as profits	0%	15%	30%
	Total	**100%**	**100%**	**100%**

Source: Authors' own elaboration.

The main variable that has an impact on the positive effects that the reallocation of resources has on the economy is the share that *is* or *is not* re-spent or the share of resources retained. The re-spending effect on the economy is summarized in the right half of Figure 2. We assume that the energy cost savings reported by firms in Matteini et al. (2017) are equivalent to the total reduction in demand for energy and is also equivalent to the total resources reallocated.

4.2 Model formalization

The fundamental IO identity presented by Leontief, a vector with each sector's output (x) can be obtained by multiplying the Leontief inverse matrix (L) by the total final demand vector ($\tilde{f}$)[7] (equation 10). To compute the Leontief inverse matrix, we calculate the technical coefficient matrix (A) which is obtained by multiplying the intermediate consumption matrix (Z) by the transposed and diagonalized output vector ($\hat{x}'$) (equation 2). The Leontief inverse (L) is obtained from the inverse of $I - A$, where I is an identity matrix (equation 3).

The basic IO model can be extended when combined with socio-economic variables, such as employment by sector. To extend the model, we need information on the "use" of the respective unit by each section in the IO model. We assign e (employment) to the output vector which comprises the number of people employed in each sector divided by the output of that same sector. Vector w captures the employee to output ratio of each sector.

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[7]Variables in capital represent matrices, and those in lower case letters and in bold represent vectors.

$$x = Lf \tag{1}$$

$$A = Z\hat{x}' \tag{2}$$

$$L = (I - A)^{-1} \tag{3}$$

$$w = e\,x^{-1} \tag{4}$$

Direct jobs are generated from a change in spending patterns resulting from an expenditure or measure. Indirect jobs are generated in the supply chain and supporting industries of an industry that is directly impacted by an expenditure or measure. The impact that a shock to demand between two periods has on employment in an economy can be included in the IO model by comparing the two using the Leontief equation.

$$\Delta w = w^1 - w^0 = e^1 L^1 f^1 - e^0 L^0 f^0 \tag{5}$$

The approach we use here follows the "synthetic" sector methodology, which evaluates the impact of EE improvements using IO analysis. That is, all impacts on the economy are included as shocks to the economy's final demand vector instead of producing changes to the economy's technical coefficient matrix. Therefore, the Leontief inverse at the start and end of the period is assumed to be the same ($L^1 = L^0$). We also assume that the employment to output ratio does not change during this period ($e^1 = e^0$). As a result, the equation can be rewritten as:

$$\Delta w = e^1 L^1 f^1 - e^1 L^1 f^0 = e^1 L^1 \Delta f \tag{6}$$

In line with the discussion in the previous section, the shock to demand (Δf) is composed of three separate effects (equation 7) which represent: (i) the initial fixed capital investment to achieve EE improvements (effect A, Δf^a), (ii) the reduction in demand for energy inputs which results from the EE improvements achieved (effect B, $-\Delta f^b$), and (iii) the re-spending of saved resources (effect C, Δf^c).

$$\Delta f = \Delta f^a - \Delta f^b + \Delta f^c \tag{7}$$

Shock A (equation 8) is captured by multiplying the diagonalized vector k with vector b (equation 8). Vector k contains the weight of the investment goods mix that characterizes an average investment (presented in Table 5) and with the remaining value being zero. The value b is the sum of total fixed capital investment in industrial EE of all firms.

Shock B, in turn, captures the corresponding negative shock to demand that results from the reduction in energy demand from improvements in EE. Matrix M is an n by n matrix, which includes the sum of energy cost savings achieved in each sector of the economy as a result of the industrial EE measure in the column with inputs from each sector in the row. That is, each $m_{i,j}$ element of the matrix represents the cost savings achieved by sector j in the acquisition of inputs from sector i. Savings are only reported for energy provider sectors (e.g. electricity and petroleum producing sectors).

$$\Delta f^a = kb \tag{8}$$

$$\Delta f^b = M\mu \tag{9}$$

$$\Delta f^c = \mu\boldsymbol{\alpha} \circ \Delta f^{c,1} + \mu\boldsymbol{\beta} \circ \Delta f^{c,2} + \boldsymbol{\gamma}\Delta f^{c,3} \tag{10}$$

$$\Delta f^{c,a} = k\mu'M\mu \tag{11}$$

$$\Delta f^{c,2} = \widehat{(\mu'M)}Z\widehat{(\mu Z)}^{-1} \tag{12}$$

$$\Delta f^{c,3} = 0 \tag{13}$$

Shock C captures the re-spending of saved resources (equation 10). Based on Table 2, the reallocation of resources may be used for three different purposes. We can therefore further subdivide them into three sub-effects. The relative importance of each of these sub-effects is measured by the weights $\boldsymbol{\alpha}$, $\boldsymbol{\beta}$ and $\boldsymbol{\gamma}$, which pre-multiply each of these sub-shocks. Each of the sub-shocks not weighed represents the effects that that particular effect would have as a shock to final demand if all resources were allocated to that activity. The first of these sub-shocks captures the spending reallocated to the acquisition of new capital goods (equation 11). This can be obtained by multiplying vector k of the weights of the investment goods mix by the value of total energy savings achieved.

The second sub-shock captures the reallocation of resources to production (equation 12). The energy savings of each sub-sector are reallocated to spending on intermediate inputs used by that sub-sector against the share that each of the sectors used for production. This can be calculated as the diagonalized summation of all energy savings achieved in each sector, multiplied by the relative share of each of these inputs into that sector's production (equation 12). Finally, a third part of reallocated resources is retained and not represented, and therefore presented in the demand shock vector as zero (equation 13).

4.3　Time dimension: a comparative static exercise

Energy savings achieved from the acquisition of more energy efficient machinery are obtained *immediately* with the acquisition of the new equipment. Energy savings obtained from the implementation of EnMS are gained over a longer period during the subsequent year. We base the trajectory of energy savings included in the IO model based on Matteini et al. (2017). It should be noted that Matteini et al.'s (2017) assumptions are conservative, as reviewed studies have shown that energy savings in the subsequent year can actually be even higher.

Table 3 presents the assumed trajectory of firm-wide energy savings between year 1 to year 5. We observe that energy savings are already achieved in the first year of EnMS implementation and that the improvement rate further increases over time. The EnMS implementation period considered for the purpose of the analysis in Matteini et al. (2017) was five years, though the actual implementation of the EnMS continued. According to the assumptions made in Matteini et al. (2017), energy savings after 5 years would reach 3.5 times those obtained in the first year.

Table 3: Assumed trajectory of energy savings from no- and low-cost measures

		Annual saving rate	Accumulated savings
EnMS Set Up	Year t	i	i
EnMS Implementation	Year t+1	i	$2* i$
	Year t+2	$0.75* i$	$2.75* i$
	Year t+3	$0.5* i$	$3.25* i$
	Year t+4	$0.25* i$	$3.5* i$

Source: Based on Matteini et al (2017).

To fully capture the effects of EnMS on the North Macedonian economy, we include the savings achieved during this entire period. As the only input-output table (IOT) available is for 2010, we simulate the effects of these savings assuming a fixed economic structure. That is, we assume the technical coefficient matrix is the same for the entire period. Therefore, using the 2010 IOT, we design five different shocks to the table, with each representing the effect of EnMS in a different year.

As linkages in an economy change slowly over time, this is a reasonable assumption for estimating the effects of EnMS. According to D'Hernoncourt et al. (2011), IO technical coefficient ratios and multipliers can be assumed to be stable for typically up to 6 years, unless the region's economy has changed significantly. Furthermore, according to Miller and Blair (2009), attempting to update and correct technical coefficients when updated tables are not available frequently generates less precise results than assuming that the economic structure does not change.

5 Data sources

To apply the methodology outlined in Section 3, we combine data from different sources: the North Macedonian IOTs, North Macedonian employment statistics and the findings from the cost-benefit analysis conducted by Matteini et al. (2017) on the energy savings generated by the implementation of UNIDO's EnMS programme in North Macedonia. By combining these different data sources, we arrive at an estimate of the impact of EE improvements implemented on total employment. This section describes the different data sources used.

5.1 North Macedonian input-output table

The North Macedonian Symmetrical Input-Output Tables are published by the country's Statistical Office. The most recent IOT is for the year of 2010, which was published in 2013. The product-level classification used in the North Macedonian 2010 IOT consists of 34 products following the CPA 1995 classification. The complete product classification of the table is presented in Appendix B. In 2010, the country's gross domestic product (GDP) was MKD 381 billion (EUR 6.2 billion), while the manufacturing sector represented 14.6 per cent of GDP (MKD 56 billion, in 2010 current prices). The import intensity of domestic manufacturing production is significantly higher than in other sectors of the economy, with direct intermediate imports used in domestic production representing 42 per cent of the sector's output.

5.2 Employment data

For data on employment, we use Eurostat's "Employment by detailed economic activity series" of industry-level employment at the two-digit level for manufacturing for 2016, which reported 711,000 jobs in North Macedonia for that year. Data shows that jobs are concentrated in the agriculture sector (112,000 jobs in 2016, 15.8 per cent of total employment) and trade services (104,000 jobs, 14.6 per cent of total employment). Manufacturing industries employed 137,000 people in North Macedonia, mostly in the foods and beverages (27,000) and textile (48,000) industries (see Figure 5).

6   Main findings

We apply the data on energy savings from the implementation of the Energy Management Systems Programme in North Macedonia to the modelling framework outlined in Section 3. We analyse the impact of reduced demand for energy on employment and value added, the rebound effects of the cost savings generated by firms and the increasing investments of firms in EE interventions over a 5-year period. The impacts for three different scenarios are presented, demonstrating firms' willingness to spend savings from lower energy costs derived from EE improvements. Scenario A assumes that firms re-spend the entire value of their energy savings, whereas scenarios B and C assume that firms retain 15 per cent and 30 per cent, respectively, of their total energy savings. The three scenarios are evaluated on the basis of two alternatives: leakage and no leakage. The no leakage scenario assumes that North Macedonian firms purchase all goods from energy cost savings in the local economy whereas the leakage scenario assumes that some of the goods purchased by firms from energy cost savings are purchased abroad based on the country's current import basket.

We quantify the impact on employment captured by the IO model in terms of (net)[8] job-years rather than jobs. This may also reflect the work of two employees for six months each, or of three people for four months each. Without more detailed information on the number of full-time and part-time workers in each sector, we can only estimate the job-years impact. Often, "jobs" and "job-years" are used interchangeably; however, referring to "jobs" created without a duration can be misleading.

A "job created" in the model is sufficient new labour demand to hire someone full time for a year, even if the actual outcome is something like the creation of two half-jobs or the avoidance of a year's worth of hours reductions spread out among a large number of workers. Therefore, the job (job-year) impact reported in the IO models is equivalent to an increase in labour demand sufficient to employ one person full time for one year at an average wage.

This metric is often called "job-year" when reported year over year in an analysis of a multiyear project or investment. When we examine different impacts in different years, we always consider that the total effect of a shock occurred exclusively or almost entirely in that same year. That is, if a shock to demand occurs in year 1 that results in an increase of 10 job-years, we assume that those 10 FTE jobs are created in that same year 1.

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[8] The job numbers presented in the following section of the paper are net numbers because they refer to the combined effect of the three demand shocks described in the methodological section.

The results are interesting; we find that employment in North Macedonia increased in all scenarios (considering direct, indirect and induced effects) as a result of EE interventions. Job losses from lower energy utilities revenues are counterbalanced by higher employment deriving from higher investments in EE and spending by North Macedonian firms on local goods resulting from energy cost savings. The value added results are more nuanced. Value added from EE is only higher than the baseline if we consider the no leakage scenario. In other words, value added losses of energy utilities are lower than value added gains deriving from higher capital investments in EE and the re-spending of North Macedonian firms on local goods from energy cost savings when North Macedonian firms purchase all their goods from the national economy. When North Macedonian firms use energy cost savings to buy a high share of goods from abroad, the positive impact in terms of value added from EE measures is less evident. This finding highlights the importance for countries to have in place a broad spectrum of industrial production capacity to fully capture the opportunities from higher spending and multiplier effects induced by energy cost savings.

Table 4: Impact of EE measures on value added and employment

	Leakage	No leakage
Cumulative net employment (gain or loss in jobs/year) in 5 years		
Scenario A	225	897
Scenario B	135	745
Scenario C	43	594
Cumulative net value added (gain or loss in millions MKD) in 5 years		
Scenario A	-82	386
Scenario B	-144	282
Scenario C	-206	177

7   Final remarks and possible extensions

Highlighting the employment generation potential of EE and related programmes/policies is often used to create an additional incentive for the creation of programmes with a focus on these types of interventions and investments (Bell et al., 2015). Detailed studies on the net effects of the implementation of EE programmes, which consider the total socio-economic outcome of these measures, may also contribute to dispelling policymakers' concerns about potential job losses in the economy associated with a green industry transition.

By considering the rebound effects of EE improvements, a much more robust modelling exercise of the impacts can be carried out. The case study of North Macedonia represents a first attempt at creating a methodological framework to better capture the broad effects of EnMS-EE programmes in industry using IO tables. The set of equations that describe the model's effect can be easily applied to study the economic and social effects of an implemented EE policy when combined with data collected from similar cost-benefit analysis exercises.

Furthermore, the model presented here goes one step further than the existing literature on the impact of EE investments on employment. Our approach moves away from modelling the impact on employment and value added of the capital investment required to produce goods and achieve EE, focussing on the impact of operating an industry that is more energy efficient. The effects of reduced demand for energy and its indirect impacts are considered by fuel type, while the reallocation of saved resources in the model is sector-specific. These additional levels of complexity in the modelling of the impacts of energy savings combined with the effects of imports add to the analysis and create a more complex modelling tool to evaluate the impacts of the EnMS-EE programme and other similar EE interventions, while maintaining the IO model structure.

Possible extensions of this model include verifying some of the underlying weights used for scenario construction. In the current version, the composition of spending on fixed capital investments for EE is fixed and does not vary by sector of analysis within each industry. Collecting further data on how investments in EE may vary by sector allows for tailoring the investment's sector-specific impacts. In a similar vein, collecting data on the reallocation of saved resources would provide a more robust approach for selecting the weights used to construct different re-spending scenarios.

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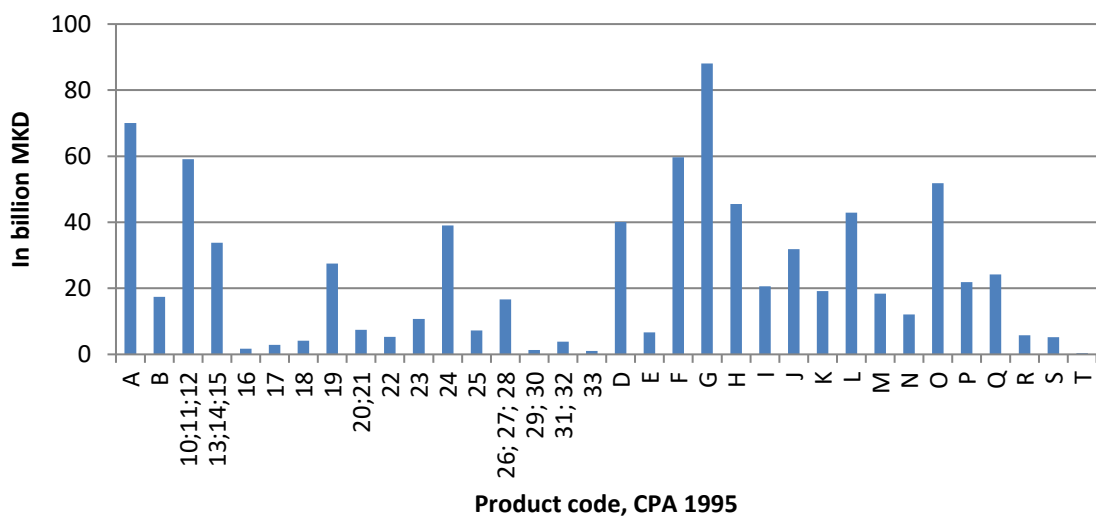
Appendix A

Table 5: Average spending composition

Code	Product Group Name	Share
26; 27; 28	Computer, electronic and optical products, electrical equipment, machinery and equipment n.e.c.	50%
33	Repair and installation services of machinery and equipment	30%
F	Construction works	20%

Source: Authors' own elaboration based on Pollin et al. (2014)
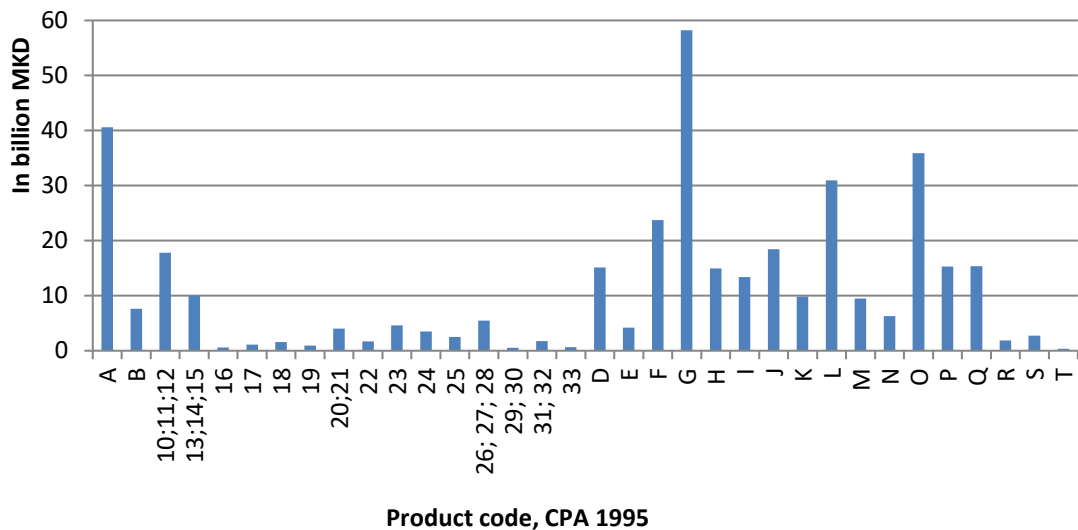
Appendix B

Figure 3: Gross output of the North Macedonian economy, 2010

Source: North Macedonian State Statistical Office (2013).

Note: For product code correspondence to product name, please refer to Appendix B.
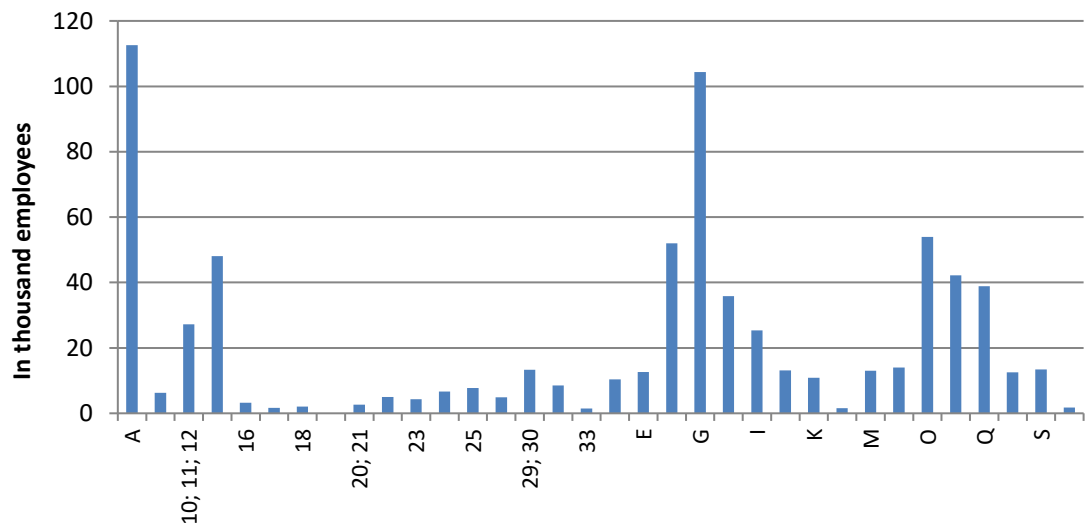
Figure 4: Value added of the North Macedonian economy, 2010

Source: North Macedonian State Statistical Office (2013).

Note: For product code correspondence to product name, please refer to Appendix B.

Figure 5: Employment by industry in North Macedonia, 2016

Source: Eurostat (2017).

Note: For product code correspondence to product name, please refer to Appendix C.

Appendix B

Table 6: Macedonian 2010 Symmetric Input-Output Product Groups

Code	CPA 1995 Products Description
A	Products of agriculture, forestry and fishing
B	Mining and quarrying
10; 11; 12	Food products, beverages and tobacco products
13; 14; 15	Textiles, wearing apparel and leather products
16	Wood and products of wood and cork, except furniture; articles of straw and plaiting materials
17	Paper and paper products
18	Printing and recording services
19	Coke and refined petroleum products
20; 21	Chemicals, chemical products, basic pharmaceutical products and pharmaceutical preparations
22	Rubber and plastic products
23	Other non-metallic mineral products
24	Basic metals
25	Fabricated metal products, except machinery and equipment
26; 27; 28	Computer, electronic and optical products, electrical equipment, machinery and equipment n.e.c.
29; 30	Motor vehicles, trailers, semi-trailers and other transport equipment
31; 32	Furniture; other manufactured goods
33	Repair and installation services of machinery and equipment
D	Electricity, gas, steam and air conditioning
E	Water supply, sewerage; waste management and remediation services
F	Construction works
G	Wholesale and retail trade services; repair services of motor vehicles and motorcycles
H	Transport and storage services
I	Accommodation and food services
J	Information and communication services
K	Financial and insurance services
L	Real estate services

M	Professional, scientific and technical services
N	Administrative and support services
O	Public administration and defence services; compulsory social security services
P	Education services
Q	Human health and social work services
R	Arts, entertainment and recreation services
S	Other services
T	Services of households as employer; undifferentiated goods and services produced by households for own use

Source: State Statistical Office of Macedonia.

Appendix C

Table 7: Industry Classification of Employment in Macedonia, 2016

NACE Rev. 2	Industry Name
A	Agriculture, forestry and fishing
B	Mining and quarrying
10; 11; 12	Manufacture of Food products, beverages and tobacco products
13; 14; 15	Manufacture of Textiles, wearing apparel and leather products
16	Manufacture of Wood and products of wood and cork, except furniture; articles of straw and plaiting materials
17	Manufacture of Paper and paper products
18	Manufacture of Printing and recording services
19	Manufacture of Coke and refined petroleum products
20; 21	Manufacture of Chemicals, chemical products, basic pharmaceutical products and pharmaceutical preparations
22	Manufacture of Rubber and plastic products
23	Manufacture of Other non-metallic mineral products
24	Manufacture of Basic metals
25	Manufacture of Fabricated metal products, except machinery and equipment
26; 27; 28	Manufacture of Computer, electronic and optical products, electrical equipment, machinery and equipment n.e.c.
29; 30	Manufacture of Motor vehicles, trailers, semi-trailers and other transport equipment
31; 32	Manufacture of Furniture; other manufactured goods
33	Manufacture of Repair and installation services of machinery and equipment
D	Electricity, gas, steam and air conditioning
E	Water supply, sewerage; waste management and remediation services
F	Construction
G	Wholesale and retail trade services; repair services of motor vehicles and motorcycles
H	Transport and storage services
I	Accommodation and food services
J	Information and communication services

K	Financial and insurance services
L	Real estate services
M	Professional, scientific and technical services
N	Administrative and support services
O	Public administration and defence services; compulsory social security services
P	Education services
Q	Human health and social work services
R	Arts, entertainment and recreation services
S	Other services
T	Services of households as employers; undifferentiated goods and services produced by households for own use

Source: Eurostat