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Examining the Industrial Energy Consumption Determinants: A Panel Bayesian Model Averaging Approach

Djula Borozan [1,*] and Luka Borozan [2]

1 Faculty of Economics in Osijek, Josip Juraj Strossmayer University of Osijek, Gajev trg 7, 31000 Osijek, Croatia
2 Department of Mathematics, Josip Juraj Strossmayer University of Osijek, Gajev trg 3, 31000 Osijek, Croatia; lborozan@mathos.hr
* Correspondence: borozan@efos.hr

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Abstract: The paper explores the impact of early stage and established entrepreneurs on industrial energy consumption across European countries for the period 2001–2017. It proposes that industrial energy consumption is a complex multifaceted result of value-added activities conducted by different types of entrepreneurs and the quality of macroeconomic and entrepreneurial framework conditions, which support or hinder entrepreneurial activity and consequently energy use. After selecting the most appropriate model using a panel Bayesian averaging model approach, a fixed effects panel regression analysis was conducted to investigate more deeply the impact of different types of entrepreneurs on industrial energy consumption. The results show that early stage and established entrepreneurs exhibit different behavioral patterns with respect to energy use. The former follows, although statistically insignificantly, a U-shaped energy use curve. By contrast, the latter follows statistically significantly an inverted U-shaped curve. Additionally, the results confirm the important role of the governments and other policy authorities in creating favorable framework conditions, which can support the changes in behavioral energy practices and the development of new or established businesses aiming for sustainability.

Keywords: entrepreneurial activity; industrial energy consumption; Bayesian model averaging; GEM; panel data

1. Introduction

Energy is vital to the existence and development of a modern economy. It is indispensable in the production process. It not only incurs costs to be efficiently managed but is also an opportunity for increasing the competitiveness of companies and generating social, economic, and environmental benefits for a society [1,2]. Thus, many governments and companies alike tend to shift towards efficient and sustainable energy usage.

According to Eurostat [3], the industrial sector accounts for about one quarter of all energy consumption in the European Union (EU), consuming over 276,823 thousand tons of oil equivalent (TOE) annually. Moreover, Constantinos et al. [4] claimed that small and medium-sized enterprises (SMEs) are responsible for about 64% of the industrial pollution in Europe. In the United States of America (USA), the industrial sector, which uses more delivered energy than any other end-use sector, accounts for about one third, with the annual consumption being just over 630,000 thousand TOE [5]. These numbers indicate the importance of understanding the determinants of industrial energy use, particularly within the context of depleting natural resources, climate change, and consequently raising insecurity with regard to energy availability and its affordability.

The European industry sector has improved its energy performance by 1.4% per year since 2000, but the expected potential energy cost cut and saving are still considerable [6]. Some studies show that small businesses can reduce utility costs by 10% to 30% without jeopardizing their service or quality, all while making a significant contribution to a cleaner environment (e.g., [7]). Likewise, Mohr et al. [8] claimed that manufacturers, i.e., energy-intensive industries, could reduce the amount of energy they use in production by 20% to 30%. Companies themselves, but also energy, environment, and policy authorities in general, play an important role in this process.

An increasing number of studies have investigated the relationship between businesses and the environment, particularly within the context of sustainable entrepreneurship (for a review, see Gast et al. [9]). Although issues related to energy security, energy efficiency, or energy savings are inevitable segments of sustainable entrepreneurship, only a few studies have explored them (e.g., [10–12]). In general, they confirm the important role of energy management in achieving good business performance and sustainable development.

Energy consumption in the industrial sector varies by countries, regions, and sub-sectors. It depends not only on the level and mix of economic activity and technological development [5] but also, as we propose, on different lifecycle stages of companies and prevailing energy behavioral patterns and practices. However, to the best of our knowledge, the impact of the latter on energy consumption is unknown. This paper aims to analyze the multifaceted interplay between European early stage and established entrepreneurs and energy use within the macroeconomic and entrepreneurial framework conditions for the period 2001–2017. To that end, it employs a Bayesian model averaging (BMA) approach. It enables the researchers to address the uncertainty about model specification present when energy determinants come into question. It has already been used in economics (for a review see, Steel [13]) and the energy literature as well (e.g., [14,15]) but not within the panel data framework.

Our novel contribution to the literature is twofold. First, using a panel BMA analysis, we identified the robust determinants of energy use among a rich set of possible determinants also related to entrepreneurship development. From the policy point of view, the determinants that lead to a reduction in energy use, particularly through energy efficiency and energy savings, are especially interesting. Second, unveiling the different energy use patterns between early stage and established entrepreneurial activity, which also is a novelty, we raised an important concern with respect to the effectiveness of the existing policy measures. They are commonly tailored for entrepreneurs in general, i.e., regardless of the phase of entrepreneurial activity. Understanding the impact of different types of entrepreneurial activity on energy consumption may be beneficial for energy and economic policy authorities in developing adequate measures to support the creation and development of new or established businesses aiming for sustainability. Namely, any energy efficiency gains that can be made will both save a considerable amount of money and significantly decrease carbon emissions.

The paper is structured as follows. Section 2 delineates the conceptual background and provides a brief literature review. Section 3 describes the data and the method applied. Section 4 presents and discusses the results while Section 5 concludes and suggests further research directions.

2. Conceptual Background with a Literature Review

Recent studies have commonly corroborated that entrepreneurs influence considerably sustainable economic growth and development through their contribution to the creation of new jobs, innovativeness, and competitiveness, as well as economic, environmental, and social values, particularly related to sustainability. Entrepreneurs themselves, the environment, and society benefit from sustainable entrepreneurship. From the entrepreneurship point of view, entrepreneurs gain profits by producing products that meet environmental and social requirements, such as economic prosperity, improved quality of life, and environmental protection. However, their relationship to energy consumption significantly determines their success therein. Costa et al. [16] underlined that the ability of manufacturing companies to innovate and improve their energy performance considerably contributes to the achievement of environmental objectives.

There is no doubt about the role of energy in the production process and society in general. However, Stern [17] highlighted that mainstream economists have usually been focused on the so-called primary factors of production (e.g., capital, labor, or land), thereby ignoring the role of energy and its availability in the production process. In contrast to them, resource and ecological economists, as he observed, have considered energy as an important production factor. In recent empirical research, energy has frequently been examined as a production factor. For example, Pablo-Romero et al. [18] estimated translog production functions that include energy use in different industry branches together with other production factors for 12 EU countries over the period 2000–2014.

Modern industrial companies use large amounts of energy whose efficient management is inevitable for their sustainable and competitive performance and sustainable development as a whole. However, Winston et al. [2] observed that outside of the most energy-intensive industries, the majority of companies consider energy as a cost to be managed, ignoring the new environmental, social, and business trends (e.g., climate change and global carbon regulation, increasing the pressure on natural resources, or innovation in energy technology) and not acting on the opportunities to reduce energy risks and create new values. Changes in business strategies and models with respect to energy are necessary. Reacting to these trends, a smaller but growing number of companies have started to operate in the energy sector, particularly with renewable energy, creating not only conventional economic benefits for themselves, such as profits, but also environmental and societal benefits, such as diversification of the energy sector, improvement of energy security, new jobs, or stable and sustainable development of the local areas (see, e.g., [2,19]).

The increasing importance of sustainable development, particularly through energy management, has opened a growing interest in finding out what supports sustainable entrepreneurial behavior in the energy field. Looking through the lens of entrepreneurial theory, a new paradigm, sustainable entrepreneurship, began to develop rapidly. According to it, sustainable entrepreneurs have a power to mitigate energy and environmental issues in general [20–23]. They create new value-added content that provides values for people (social), the Earth (environmental), and them (economic, profit) at the same time [21]. However, entrepreneurs have to operate in a favorable environment in order to use energy and grow in a sustainable way.

Annual Global Entrepreneurship Monitor (GEM) reports (e.g., [24]) show that macroeconomic and entrepreneurial framework conditions are important for business growth and, as we propose, its greening. The former includes social, political, economic, and cultural factors, which influence entrepreneurship through three phases of economic development, i.e., factor-, efficiency-, and innovation-driven. The latter includes factors, such as entrepreneurial financing, government policies and programs, education, infrastructure, or research and development (R&D) transfer. These factors influence entrepreneurship more directly. In turn, they influence industrial energy consumption.

Many other studies confirmed their importance when entrepreneurship through energy management comes into question. For example, Flues et al. [25] found out that energy use of European steel production may be reduced, and its energy efficiency improved by technological, market and policy factors. They observed that higher energy prices may also cause a rebound effect. Jove-Llopis and Segarra-Blasco [12] disclosed that public policies aiming to increase energy efficiency in the EU have been relying more on financial measures (cost saving) and regulations in the short term and spreading new technologies in the long term. To promote renewable energy sources, they try to increase environmental awareness and provide public support. Trianni et al. [26] observed that although energy efficiency has been recognized as an important means for increasing the competitiveness of the European industrial sector, particularly SMEs, energy efficiency measures are scarcely implemented. Therefore, the role of energy policy is extremely important. Magazzino and Cerulli [27] especially highlighted its favorable effect on investment, energy security, as well as technological innovation, and, consequently, economic growth.

Its importance has been recognized in other parts of the world as well. For example, Otsuka [28] stated that energy consumption in Japan is mainly affected by energy efficiency and policies directed to increase electrification by enhancing the productivity of factories and offices. Malen and Marcus [29] provided empirical evidence on the important role of government policy in supporting clean energy technology and clean energy market development and, in general, in creating opportunities for entrepreneurship development in the USA. Likewise, NAM [30] observed that besides companies' characteristics, government policies and programs, environmental regulations, and technological and managerial innovations are important determinants of energy consumption in the USA.

The annual GEM report [24] also detected individual attributes of entrepreneurs, commonly changing over time, as important determinants of entrepreneurship development. Such determinants refer, for example, to individual self-perception as to whether people see opportunities around them and whether they believe they are capable of starting a business and controlling their fear of failure. We propose that these individual attributes, influenced by the macro and entrepreneurial framework conditions, influence not only whether one would consider starting a business, but also the way of addressing energy. Suesser et al. [31] observed that different characteristics of entrepreneurs may be relevant for creating a renewable energy community. Moreover, they showed that energy policy, funding schemes, and administrative structures play an import role in the energy transition of modern communities. Lutz et al. [32] demonstrated that exporting, innovation, as well as environmental protection industries are more energy efficient than others. Sun and Anwar [33] explored the relationship between electricity consumption, industrial production, and entrepreneurship in Singapore's manufacturing sector. They revealed that these variables are cointegrated and electricity consumption adjusts very slowly to shocks to industrial production and entrepreneurship. Moreover, they found out that entrepreneurship Granger causes electricity consumption, which causes industrial production.

However, despite these findings, which suggest that macroeconomic and entrepreneurial framework conditions together with the characteristics of entrepreneurs and prevailed entrepreneurial practices may influence industrial energy consumption, there is still model uncertainty, i.e., the lack of knowledge about which particular variables and how they affect industrial energy use. Related to that, it is still unknown whether there are differences in energy use between entrepreneurs in different stages of their company's life. Answers to these questions may help create sustainable energy policy, programs, and measures.

3. Materials and Methods

3.1. Data

Empirical research in the present paper covers the following 24 European countries: Belgium, Croatia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Luxembourg, the Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Span, Sweden, and the United Kingdom, which were included in the GEM research in the period 2001–2017. The sample is unbalanced since the majority of the abovementioned countries did not participate in the GEM research each year.

The dependent variable is the final energy consumption in industry per capita (*energy*). According to the Eurostat Energy Database [3], which is its source, it includes the total energy consumed by industry, i.e., construction, mining, and manufacturing industries as final users, and excludes that which is used by the energy sector itself. It is expressed in 1000 TOE that is divided by the average population. The explanatory variables are classified into three categories: (i) Variables that proxy for a new value-added created by early stage and established entrepreneurs, (ii) variables that represent the entrepreneurial framework conditions, and (iii) variables that represent the macroeconomic framework conditions. The first two columns of Table 1 show summary information on the data included in the analysis.

The source of the first and the second variable category is GEM [34], which is a reputable organization that globally studies the entrepreneurial phenomenon. GEM considers entrepreneurial activity as a process and consequently measures it from the intention to start a business to the moment of exiting a business. The focus of this paper is placed on early stage and established entrepreneurial activity. The total early stage entrepreneurial activity (TEA) rate is defined as a percentage of adult individuals (18 to 64 years old) who are in the process of starting a business (a nascent entrepreneur) or running a business that is less than 3.5 years old (an owner manager of a new business). The established business ownership rate (*established*) refers to the percentage of the adult population (18 to 64 years old) who are currently owner-managers of an established business, i.e., ones that have paid salaries or any other payments to the owners for more than 3.5 years. GEM obtains the primary data required for calculating early stage and established entrepreneurial activity through an Adult Population Survey of at least 2000 randomly selected adults in each country participating in GEM. Both variables proxy for industrial companies that use energy in the process of creating value-added. European SMEs account for 99.8% of all enterprises that operate in the EU-28 non-financial business sector; at the same time, they generate 67% of employment and 57% of value-added [35]. However, their shares vary significantly among industries [36].

Following GEM [37], entrepreneurial framework conditions may be described by 12 variables. These are funding for entrepreneurs (*finance*; financial resource, equity, and debt availability for SMEs, grants, and subsidies included), government support and policies (*g_policy*; degree of public policy support for entrepreneurship), taxes and bureaucracy (*taxes*; degree to which taxes or regulations support SME development), government programs (*g_program*; existence and quality of the direct assistance for the SMEs by programs initiated at any level of the government), basic entrepreneurial education and training at school (*educ_basic*; incorporation level of management training for SMEs within the primary and secondary education), post-school entrepreneurial education and training (*educ_post*; incorporation level of management training for SMEs within higher education), research and development transfer (*R&D*; availability of relevant national research to SMEs), commercial and professional infrastructure (*comer_infr*; relevant legal and assessment service availability for SMEs), internal market dynamics (*dynamics*; yearly market value differentials), internal market openness (*openness*; degree of market liberalization), physical and service infrastructure (*pysic_infr*; availability of the relevant physical resources at affordable prices), and cultural and social norms (*culture*; the prevailing system of value that supports entrepreneurship development). For a more detailed description of the variables, see [37]. Their data source is GEM [34], as well.

Each year, through the National Expert Survey, GEM's national teams collect at least 36 expert opinions about the factors that can either encourage or constrain entrepreneurial activity. The opinions are expressed using a Likert scale of one (highly insufficient) to five (highly sufficient). We consider that the experts' perceptions on the quality of the entrepreneurial framework conditions not only reflect entrepreneurs' perceptions thereon but also reality. For example, Boyd [38] showed that perceptions and acceptance are critical to the implementation of new environmental and energy technologies.

Besides the abovementioned variables, we introduced the energy tax variable (*e_tax*) to proxy for the impact of environmental regulations and the share of renewables in the gross final energy consumption (*renewables*) to connect more exactly the government policy in the case of the former and the market conditions to entrepreneurial activity in the case of the latter. Their source is Eurostat [3], i.e., the Environmental Tax Revenue Databases for energy taxes and the Energy Database for the share of renewables in gross final energy consumption.

The macroeconomic framework conditions are described through two dummy variables: The crisis dummy (*crisis*), which captures the effect of a difficult economic situation, the Great Recession of 2008 through 2012, and the economic development level (*development*), which reflects whether an economy is in the factor-, efficiency-, or innovation-driven phase. This classification of economies is taken from the World Economic Forum [39] and the related data from GEM reports (e.g., [24]) that cover the period under consideration. It follows the country's development evolution.

Our data set offers two advantages. First, as already mentioned, the source of macroeconomic variables is Eurostat. It ensures the data consistency, comparability, and validity. GEM is the source of the entrepreneurial framework condition variables. It provides data of high quality. This is ensured by both the research instruments that accurately measure different entrepreneurial aspects and the rigorous methodology that this organization applies in the process of data collection, processing, and quality control. Moreover, the comparability of GEM data is ensured by the harmonization process employed after the national datasets have been examined. For the description of the methodology, see GEM [37]. Secondly, the data covers 24 European countries over 17 years, which improves the ability to draw accurate inferences on industrial energy consumption determinants.

In the panel BMA specification, we set the entrepreneurial variable (the sum of early stage and established enterprises) as the focus variable and the entrepreneurial and macroeconomic framework conditions as the regressors.

3.2. Method

Since a large number of empirical industrial energy consumption models potentially exist, each having a different combination of regressors and probability of being the "true" model, it is very important to select the model that includes the robust determinants. This is the reason a BMA method was developed. Its main purpose is to select the "true" model based on Bayesian inference [40]. Most previous empirical cross-country studies deal with BMA in a pooled framework, and hence, fail to account for a country-specific fixed effect and the endogeneity of regressors that might cause inconsistent estimates. To address these issues, BMA was employed in a dynamic panel setting in this paper. The method was introduced by Moral-Benito [40], who extended the BMA approach based on classical ordinary least squares and employed a novel maximum likelihood estimator. Panel BMA enables us to consider both the uncertainty related to the importance of each determinant conditional for a given model and the one related to model specification. Let the standard regression be given in the form:

$$Y = \theta X + \varepsilon, \tag{1}$$

where X and Y are independent and dependent variables, respectively, ε is an error term, and θ is a vector of the parameters. Let the dimension of θ be denoted as K. The BMA method considers a total of 2^K models denoted as M_i, each corresponding to a different choice of regressors, while being dependent upon parameters θ^j.

In Bayesian terms, each model may be defined by a prior density and a likelihood function. As explained in Moral-Benito [40], the posterior model probability for the parameters of M_j can be calculated as:

$$g(\theta^j|Y, M_j) = \frac{f(Y|\theta^j, M_j)g(\theta^j|M_j)}{f(Y||M_j)}. \tag{2}$$

Which can be used to quantify the explanatory quality of M_j. Using Bayes' rule, one can calculate the posterior model probability:

$$P(M_j|Y) = \frac{f(Y|M_j)P(M_j)}{f(Y)}. \tag{3}$$

$P(M_j)$ denotes the prior model probability, i.e., a likelihood of the model correctness. As explained in Moral-Benito [40], $f(Y|M_j)$, often called the marginal likelihood, can be obtained from the posterior model probability.

The main idea of BMA is to rank the results obtained by all the models considered and choose the leading one. In order to do so, one must evaluate each M_j resulting in exponential complexity (due to 2^K models). To somewhat reduce the number of models under consideration, it is possible to employ the Markov chain Monte Carlo model composition algorithm explained in Madigan and York [41].

It is now possible to define the posterior inclusion probability (*PIP*) for each component of θ as a sum of the posterior model probabilities of all models including the said component. Let i be the index of the aforementioned variable. Then, we have:

$$PIP = P(\theta_i \neq 0|Y) = \sum_{\theta_i \neq 0} p(M_j|Y). \quad (4)$$

We followed Barbieri and Berger [42] and marked the variables with *PIP*s greater than or equal to 0.5 as robust determinants. Our empirical BMA analysis was done using the BMS R-language package [43].

4. Results

4.1. Preliminary Analysis

Descriptive statistics of the data presented in Tables 1 and A1 (in the Appendix A) indicate the presence of heterogeneity across the observed variables. Industrial energy consumption per capita was at the minimum level in Latvia in 2002 while it was at the maximum level in Iceland in 2015. In general, it is higher in countries at a higher development stage. Likewise, higher average rates of TEA were observed more in efficiency-driven economies while a higher proportion of established business ownership was recorded in innovation-driven economies. The same findings may be found in GEM [24]. Considering the whole sample, 19.69% of countries are in the efficiency-driven phase while 80.31% are in the innovation-efficiency phase.

Table 1. Descriptive statistics of the data I.

Variables	Description	Variable	Source of the Data	Obs	Mean	Std. Dev.	Minimum	Maximum	VIF
Dependent variable	Final energy consumption per capita in industry, in 000 TOE; code: nrg_100a	*energy*	Eurostat	408	12018.98	14352.93	454.1	62399.8	
Entrepreneurial variables	Total early-stage entrepreneurial activity rate, in %	*TEA*	GEM	319	6.821	2.664	1.63	19.38	1.96
	Established business ownership rate, in %	*established*		319	6.040	2.639	0.5	19.61	1.73
Entrepreneurial framework condition variables	Financing for entrepreneurs [a]	*finance*		286	2.658	0.386	1.65	3.82	2.39
	Government support and policies	*g_policy*		286	2.601	0.455	1.59	3.96	3.60
	Taxes and bureaucracy [a]	*taxes*		286	2.419	0.577	1.35	4.27	5.28
	Government programs [a]	*g_program*		286	2.761	0.451	1.72	3.71	3.78
	Basic entrepreneurial education and training [a]	*educ_basic*		286	2.110	0.372	1.32	3.43	3.34
	Post school entrepreneurial education and training [a]	*educ_post*		272	2.767	0.303	1.89	3.76	2.03
	Research and development transfer [a]	*r_d*		286	2.509	0.318	1.7	3.24	3.84
	Commercial and professional infrastructure [a]	*comer_infr*		286	3.188	0.310	2.4	3.85	3.19
	Internal market dynamics	*dynamics*		286	2.866	0.419	1.84	4.15	1.84
	Internal market openness [a]	*openness*		286	2.716	0.350	1.84	3.73	4.69
	Physical and service infrastructure [a]	*pysic_infr*		286	3.852	0.440	2.10	4.82	2.11
	Cultural and social norms [a]	*culture*		286	2.655	0.452	1.62	4.18	3.74
	Share of renewable energy in gross final energy consumption, %; code: t2020_31	*renewables*	Eurostat	336	20.846	17.763	0.90	72.6	3.85
	Energy taxes (% of GDP); code: env_ac_tax	*e_tax*	Eurostat	408	1.914	0.497	0.86	3.32	1.61
Macro-economic framework condition variables	Recession dummy (1 if the years are 2008–2012; 0 otherwise)	*crisis*		407	0.177	0.382	0	1	1.17
	Development level (1 if an economy is in an innovation driven stage; 0 if an economy is in an efficiency-driven stage)	*devel_level*	GEM based on WEF	320	0.803	0.398	0	1	2.03

Note: Industrial energy consumption per capita is used in log form in further analysis. Considering the development stage, countries which were in the transition from one to other development stage are classified into the lower one. The data for final industrial energy consumption in each country in 2017 is calculated as the average of the previous two years. [a] The opinions on entrepreneurial framework conditions are expressed by experts using a Likert scale of one (highly insufficient) to five (highly sufficient).

As far as the perceived quality of the entrepreneurial framework conditions is concerned, experts particularly assessed basic entrepreneurial education, government policies related to taxes and bureaucracy, and R&D transfer as those that hinder rather than stimulate entrepreneurial activity. By contrast, they considered physical, commercial, and business infrastructure as supportive determinants, which is in line with GEM [24] as well. The share of renewables in gross final energy consumption is below 10% in Luxembourg, the Netherlands, Ireland, Belgium, and the United Kingdom while it is higher than 50% in Norway, Sweden, and Iceland in most of the observed years. Energy taxes have varied considerably from country to country. In the last several years, they were at the lowest level in Iceland, Ireland, and Belgium while they were at the highest level in Slovenia, Latvia, and Greece. The Cronbach alpha (0.895, see Table A2 in the Appendix A) suggested that the set of entrepreneurial variables is internally consistent, meaning that it describes entrepreneurial framework conditions that influence industrial energy consumption in a satisfactory manner.

In this paper, stationarity was tested by the Im-Pesaran-Shin and Fisher-type Phillips-Peron unit root test. The latter is appropriate for an unbalanced data set. Thereby, the version of the tests in which the removed cross-sectional mean was employed to mitigate the effect of cross-sectional correlation. The results of the tests indicated that the series are stationary at a 5% critical value. The logarithmic values of dependent variables were used in the analysis. Additionally, the extracted dataset was examined for multicollinearity using the variance inflation factor (VIF). As shown in Table 1 (the last column), it is not an issue in the present study. The average VIF of 2.93 additionally supports this.

4.2. Results with Discussion

4.2.1. Determinants of Industrial Energy Use

To address the uncertainty about the choice of regressors and consequently identify important determinants of industrial energy consumption, a panel BMA analysis with a fixed estimator was conducted in the first stage. Then, the robust determinants identified therein were used in a fixed effects panel data regression to assess their effects und unveil the behavior pattern of entrepreneurs with respect to energy use. The panel BMA results for two models are presented in Table 2. The difference between them lies in addressing the entrepreneurial activity variable. In Model 1, it is calculated by adding the total early stage and established entrepreneurial activity rates (*TEAe*s) while in Model 2, these two types of entrepreneurial rates are separately included into the analysis in non-linear forms.

The entrepreneurial variables, i.e., the focus variable in the BMA analysis, are included in both specifications in the model space, and therefore have *PIP*s equal to 1. The results of Model 2 suggest that the early stage entrepreneurial rate variable follows a U-shaped energy use curve. By contrast, the established ownership rate variable follows an inverted U-shaped curve, meaning that energy use increases up to a certain level (i.e., the turning point) as the rate of this type of entrepreneur goes up; after that, it decreases.

Out of 16 regressors in both BMA specifications, eight to nine variables turned out to be the robust determinants of industrial energy consumption. Panel BMA shows that government policies and programs, particularly programs related to energy, such as energy taxes or renewables, together with ensured well-developed post-school education and physical and service infrastructure, as well as internal market openness and culture, are important determinants that shape the entrepreneurial framework conditions and consequently influence industrial energy consumption.

Table 2. Results of panel Bayesian model averaging.

	Model 1			Model 2		
Variable	Post Mean	Post SD	*PIP*	Post Mean	Post SD	*PIP*
TEAes	−0.011	0.003	1			
TEA				−0.021	0.017	1
TEA^2				0.000	0.001	1
established				0.029	0.018	1
$established^2$				−0.002	0.001	1
finance	0.000	0.006	0.018	0.001	0.010	0.057
g_policy	0.151	0.051	0.962	0.143	0.049	0.960
g_program	−0.104	0.058	0.833	−0.089	0.055	0.813
taxes	0.001	0.010	0.062	0.004	0.016	0.098
educ_basic	−0.001	0.011	0.046	−0.008	0.024	0.176
educ_post	0.051	0.062	0.458	0.125	0.054	0.927
r_d	−0.001	0.015	0.029	−0.014	0.042	0.199
comer_infr	0.003	0.018	0.042	0.002	0.016	0.063
dynamic	−0.001	0.008	0.046	0.002	0.012	0.096
openness	0.258	0.056	1	0.264	0.054	1
pysic_infr	0.032	0.045	0.390	0.039	0.043	0.532
culture	−0.089	0.066	0.718	−0.122	0.050	0.940
renewables	0.009	0.001	1	0.009	0.001	1
e_tax	−0.109	0.023	1	−0.109	0.024	1
crisis	0.001	0.006	0.025	0.000	0.006	0.048
devel_level	0.183	0.031	1	0.158	0.033	1

Note: SD = standard deviation; $TEA^2 = TEA \times TEA$; $established^2 = established \times established$.

More specifically, the important role of government programs, policies, and measures in supporting the effective energy behavior and sustainability practice in general is well-documented in the energy literature [6,12,25,29,30]. BMA shows that targeting programs to support entrepreneurship development will commonly lead to an increase in energy consumption. By contrast, implementing specific government programs will decrease it. For example, the share of energy tax revenues in GDP turns out to be negative and significant in the BMA settings, meaning that an energy tax is an effective policy tool for influencing industrial energy consumption directly in contrast to the residential sector [44]. Evidently, since an energy tax increases business costs, it motivates them to reduce energy consumption, improve energy efficiency, and use more cleaner and greener energy and sustainable practices. The NAM [30] study as well as Suesser et al. [31] corroborated its effect on industrial energy consumption. Accordingly, the government should explore how to make a tax system even more efficient and effective, supporting and encouraging, thereby, particularly energy-intensive industries to innovate in a sustainable way.

The present paper indicates that an increase in R&D transfer will cause a reduction in energy consumption. This relationship has an expected sign, but it is not statistically significant. Lutz et al. [29] provided evidence that companies that innovate and invest in environmental protection are more energy efficient than their counterparts. Likewise, Winston et al. [2] confirmed that companies with new energy technologies experience important benefits. New energy technologies have become increasingly available for companies due to government incentives on the one hand, and relatively lower cost for their purchasing and implementing on the other. However, Stucki [45] found out that 85% of companies in Austria, Germany, and Switzerland show insignificant or negative returns from investment in green energy technologies. To facilitate energy technology R&D and its implementation in companies, governments should additionally support it, as also highlighted in other studies (e.g., [46]). Magazzino and Cerulli [27], for example, found that additional funds are needed to that end. The governments should also develop programs with businesses as partners to mutually identify, support, sustain, strengthen, and develop clean energy-efficient and energy-saving technologies.

This paper shows that well-developed physical and service infrastructure, which ensures ease of access to physical resources, such as utilities, communication, and transportation, statistically significantly and positively affect energy consumption. For example, positive effects, such as an increase in the reliability of power delivery, system efficiency, and energy efficiency, are expected from the implementation of smart energy grids, which will replace the electrical grid infrastructure and change the energy landscape [47]. However, to make the new technologies in energy infrastructure live and beneficial, cooperation, information sharing, and activities are expected from all stakeholders. Winston et al. [2] also claimed that companies need to engage with governments on building physical infrastructure that supports cleaner and energy-efficient logistics. Likewise, Goldthau [48] highlighted that the governance of energy infrastructure requires the involvement of multiple actors.

In general, these results indicate directly or indirectly that increasing the presence and the quality of specific policies and programs directly assisting SMEs at all levels of government and associating it with energy efficiency and energy saving innovation and practices seem to be promising approaches to support behavioral changes in energy consumption. Borozan [49] showed that one of the most effective ways of residential sector electricity consumption reduction are behavioral changes and we claimed the same about companies. Since technological and behavioral practices in consumption cannot be quickly changed, culture and education may play an important role therein. The present study corroborates their statistical significance and also indicates that they influence consumption differently. While social and cultural norms and the value system encourage actions leading to new business models or activities that decrease energy consumption (see [19]), higher educated and trained SMEs rebound more. It seems that this kind of SME is more prone to using energy efficient technologies and energy saving innovations. This is probably a reason why NAM [30] or Winston et al. [2] detected improving staff training, business practices, and management techniques as powerful means for better energy management. McEwen [22] also emphasized the importance of college-level education for improving the energy and environmental performance of SMEs, as well as raising awareness on energy-related issues among students, which they will use in firms. However, at the same time, they open new business opportunities, which, in turn, result in increasing value-added activities and consequently energy consumption.

An increasing share of renewable energy in gross final energy consumption, which statistically significantly leads to an increase in energy consumption, supports this hypothesis. The other studies have also found evidence on the transition of businesses toward cleaner and greener energy and sustainable practices in which renewables play an important role [2,10,19]. Openness to using new renewable and clean energy or particularly doing business in this field is related to the extent to which new companies are free to enter existing markets.

The internal market openness variable has a statistically significant and positive impact on energy consumption. If companies do not face a number of domestic rules and regulations that create market entry barriers and restrict trade flows, they may increase their activities and energy demand. The importance of the degree of openness of the economy to the behavior of investors, entrepreneurs, and energy consumption has been extensively investigated in the literature. For example, Murshed [50] and Motyka et al. [19] found that markets drive businesses more toward sustainable energy sources, the implementation of clean energy solutions, and energy efficiency and saving practices. However, Shahbaz et al. [51] revealed a nonlinear relationship between trade openness and energy consumption; this relationship has an inverted U-shaped form in high-income countries, but a U-shaped form in middle- and low-income countries. A positive effect of openness on energy consumption has also been found in Sadorsky [52]. The European energy markets are far from being fully opened and harmonized, and it is important to achieve that bearing in mind new sustainable business opportunities and benefits to societies.

Finally, the study shows that the development level variable significantly influences energy consumption, whereby the innovation-driven economies exhibit higher energy consumption per capita compared with the efficient-driven economies. Many empirical studies explored the effect of the development stage of an economy and its economic structure on energy consumption. Some of them found a strong positive relationship between them at lower energy use levels, i.e., in developing countries, while others found decoupling at a higher level, i.e., in developed countries (for a brief review, see Arto et al. [53]). Stern [17] provided an explanation for a positive relationship; he underlined that despite the tendency of technical innovations to introduce more energy-using appliances and energy-saving techniques to the industry, they can rebound, i.e., end up causing even more energy to be used.

To test the robustness of the models, we tested the effects of all regressors on the logarithmic sum of energy consumption in the industry and the service sectors. However, the results remained very similar considering the sign and the magnitude of significant variables.

4.2.2. Using the Behavioral Energy Pattern between Early Stage and Established Entrepreneurs

GEM [24] also found the existence of a different pattern of entrepreneurial activity with respect to the economic development level. Bearing this in mind as well as the results of Table 2, we expect that there is a nonlinear relationship between different types of entrepreneurs and energy consumption. Table 3 shows the regression results of three models, which aim to test their effects.

Table 3. Regression results.

Variable	Model 3		Model 4		Model 5	
	Est. Coeff.	**R.St.E.**	**Est. Coeff.**	**R.St.E.**	**Est. Coeff.**	**R.St.E.**
TEA	−0.022	0.018	−0.001	0.006	0.001	0.008
TEA^2	0.000	0.001	0.000	0.000	0.000	0.001
established	0.031 **	0.017	0.014 *	0.005	0.014 **	0.006
$established^2$	−0.002 **	0.001	−0.001 ***	0.000	−0.001 ***	0.000
g_policy	0.143 *	0.038	0.002	0.016	0.002	0.015
g_program	−0.095 *	0.041	0.077 *	0.025	0.077 ***	0.038
educ_post	0.141 *	0.056	−0.014	0.020	−0.014	0.021
R&D	−0.057	0.075	−0.007	0.023	−0.007	0.019
openness	0.236 *	0.067	−0.055 *	0.021	−0.055 **	0.027
pysic_infr	0.074 *	0.027	0.010	0.010	0.010	0.015
culture	−0.095 **	0.042	0.016	0.018	0.016	0.022
e_tax	−0.105 *	0.022	−0.034 *	0.014	−0.034	0.024
renewables	0.008 *	0.001	0.002	0.003	0.002	0.005
crisis	0.003	0.027	−0.077 *	0.021	−0.043 *	0.014
devel_level	0.166 *	0.031	0.014	0.023	0.014	0.038
Constant	1.709	0.191	3.004	0.087	2.725	0.183
Observations	240		240		240	
R^2	0.669		0.981		0.981	
Wald test for entrepreneurial framework	F(9, 224) = 27.26; p = 0.000		F(9, 189) = 4.09; p = 0.000		F(9, 23) = 3.79; p = 0.005	
Wald test for macroeconomic framework	F(2, 224) = 14.04; p = 0.000		F(2, 189) = 6.80; p = 0.000		F(2, 23) = 4.81; p = 0.018	
Hausman test					$chi^2(23)$ = 199.69; p < 0.01	

Note: Est. coeff. = estimated coefficient; R. St.E. = robust standard error. An inclusion of time-effect is corroborated by a joint test statistics whose value for Model 4 is: F(13 190) = 5.83; p < 0.01, and for Model 5: F(13, 23) = 30.25; p < 0.01. *, **, *** indicates parameters significant at 1. 5% and 10% level, respectively.

Models 3 and 4 are pooled OLS, whereby Model 4 is estimated by including a set of time and country dummies. Model 5 is a fixed effects panel model, which includes a set of time dummies. The statistics of the Pesaran CD (cross-sectional dependence) test for an unbalanced sample (CD = 7.543; p < 0.01) indicated that the null hypothesis (errors are weakly cross-sectional dependent) can be rejected. A Huber/White covariance matrix estimator is used in each of the models to obtain autocorrelation- and heteroscedasticity-robust standard errors. Finally, as indicated by the Hausman test statistics (Table 3, Model 5), the null hypothesis of no fixed effects is rejected at the 1% significance level. The same conclusion with regards to the sign and statistical significance of the variables included into analysis holds if Driscoll and Kray standard errors are taken into account.

Each model supports the hypothesis that there exists a nonlinear relationship between established ownership rates and energy consumption. This relationship has an inverted U-shaped form. By contrast, the relationship between early stage entrepreneurs and energy consumption has a U-shaped form according to Models 3 and 4, but this relationship is statistically insignificant. The insignificance of this relationship is found in Model 5 as well. As already observed by EnergyStar [7], it seems that the lack of time, energy expertise, and/or appropriate energy technology are responsible. Entrepreneurs in this business stage are more concerned about their future, i.e., how to survive and grow, and less concerned about how to exploit new clean technology and energy opportunities. Bearing in mind the values of Wald tests, i.e., the statistical importance of entrepreneurial and macroeconomic framework conditions for industrial energy use, here we see the opportunities for and responsibility of the governments to create different policies and programs for these two types of entrepreneurs and facilitate wise energy management and changes in energy consumption behavioral practices.

Thus, a general industrial energy use pattern does not exist, indicating the need to study each entrepreneurial type individually, and create specific policy measures fitted to different lifecycle stages of companies. However, supporting energy and environment-friendly R&D activities and accelerating knowledge transfer to companies together with nurturing a culture that is sensitive to energy efficiency and saving are necessary and should be continuously and consistently implemented, both at the EU and national levels.

5. Conclusions

Led by economic, environmental, and societal interest, an increasing number of companies have become committed to reducing their energy use as well as limiting their exposure to any energy risk, such as an increase in energy prices or energy shortages. At the same time, governments and the whole of society are also more interested in improving energy efficiency and energy sustainable practices in the industrial sector, due to the impact that energy has on the environment and climate.

In this paper, our major contribution was to resolve the issue of model uncertainty related to industrial energy consumption determinants of early stage and established entrepreneurs. Namely, the present paper tested the hypothesis that energy consumption in the industrial sector is dependent not only on the quality of macroeconomic and entrepreneurial framework conditions but also on the differences in entrepreneurial activity, studied through different stages of the company lifecycle and prevailing energy behavioral patterns and practices. Unlike the concern related to model uncertainty, i.e., the choice of the critical industrial energy consumption determinants, which is an area for which limited empirical evidence exists, the issue of how early stage and established entrepreneurs influence energy consumption is unexplored in the literature. Using the panel BMA approach, the paper firstly revealed the robust industrial energy consumption determinants and then revisited the multifaceted interplay between European early stage and established entrepreneurs and energy use, also considering the impact of framework conditions on energy use, for the period 2001–2017.

The results confirmed that there is a difference in energy use patterns between early stage and established entrepreneurial activity, which also is a novelty. Moreover, the results showed that government policies and programs, particularly programs related to energy, such as energy taxes or renewables, together with ensured well-developed post-school education and physical and service infrastructure, as well as internal market openness and culture that promotes new business methods and activities, are important determinants that shape entrepreneurial framework conditions and consequently influence industrial energy consumption. At the same time, macroeconomic conditions, proxied by the development level variable, significantly positively influence energy consumption.

Although the higher development level is connected to the usage of more energy efficient and energy-saving innovations as well as the construction of smart energy infrastructure, it leads to the rebound effect.

Consequently, three particularly important policy implications can be drawn. The first one is related to R&D activities. The fact that an increase in industries' R&D, which supports the development of new energy-efficient technologies, production methods, and cleaner and greener energy, will cause a reduction in energy consumption, but not statistically significant, indicates that the government should play a more important role here. Entrepreneurs should be supported in their R&D energy activities, especially associated with renewables. To that end, the government may increase grants for such activities, stimulate private–state cooperation, or induce/increase energy incentives (e.g., the R&D tax credits) as well as empower its own research facilities, particularly in relation to fundamental energy research in which the private sector is not adequately interested in. Since renewable energy has a favorable effect on industrial energy consumption, the government should encourage innovations in this area as well. The second policy implication is related to the responsibility of the governments in the creation of fair, dynamic, and competitive entrepreneurship conditions, which will drive entrepreneurs to continuously care about their production costs, including energy. Energy taxes turned out to be an efficient price instrument of energy policy, which clearly motivated producers to reduce energy consumption, improve energy efficiency, and use cleaner and greener energy and sustainable practices. However, energy taxes significantly vary across EU countries, and they have to be revised and harmonized in order to ensure greater industrial energy efficiency gains and more efficiently respond to climate change challenges. Finally, bearing in mind that technological and behavioral practices in energy consumption cannot be quickly changed and that highly educated people and high-tech SMSs may rebound, the government should promote a sustainable culture and support the creation of specialized energy-related post-educational programs fitted for the country and industry. Certainly, further research should compare, evaluate, and discuss different government policies and programs in order to find out those that are particularly promising for the development of efficient energy management and sustainable entrepreneurship in general.

Moreover, the results show that the early stage entrepreneurial activity rate mainly follows a statistically insignificant U-shaped energy use curve. By contrast, the established ownership rate follows statistically significantly an inverted U-shaped curve. In light of these findings, we would like to highlight the importance of tailoring policy measures to specific types of entrepreneurs in order to achieve energy efficiency gains that can both save a considerable amount of money and significantly decrease carbon emissions. Further research should pay more attention to deepening our understanding of the practices and opportunities specifically fitted to different types of entrepreneurs. Moreover, it would be interesting to explore whether there are differences between different types of entrepreneurial activity and different development levels of countries considering energy consumption. Additionally, further research may pay more attention to test the time properties of the variable of interests since this issue has important implications not only for modeling but also for policy authorities, as discussed in Magazzino [54].

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Appendix A

Table A1. Descriptive statistics of the data II.

Variables	Variable	Obs	Median	Kurtosis	Skewness	25th Percentile	75 Percentile
Dependent variable	*energy*	408	5965.65	5.948	1.800	1889.60	15324.33
Entrepreneurial variables	*TEA*	319	6.29	4.583	1.025	4.94	8.47
	established	319	5.78	5.878	1.076	4.31	7.46
Entrepreneurial framework condition variables	*finance*	286	2.66	3.303	0.322	2.4	2.87
	g_policy	286	2.57	2.307	0.103	2.27	2.96
	taxes	286	2.36	2.547	0.466	1.93	2.85
	g_program	286	2.77	2.160	−0.035	2.4	3.12
	educ_basic	286	2.09	3.592	0.604	1.84	2.33
	educ_post	272	2.77	3.448	0.135	2.59	2.95
	r_d	286	2.51	2.432	0.059	2.27	2.75
	comer_infr	286	3.21	2.330	−0.153	2.96	3.42
	dynamics	286	2.84	2.955	0.259	2.56	3.13
	openness	286	2.7	2.943	0.148	2.47	2.95
	pysic_infr	286	3.91	3.214	−0.542	3.58	4.18
	culture	286	2.63	3.728	0.733	2.32	2.9
	renewables	336	15.3	4.313	1.414	8.26	27.9
	e_tax	408	1.87	3.029	0.517	1.57	2.22
Macro-economic framework condition variables	*crisis*	407	0.00	3.868	1.693	1.00	1.00
	devel_level	320	1.00	3.325	−1.525	1.00	1.00

Note: the data source for calculation [3,34].

Table A2. Cronbach alpha test results.

Variable	Obs.	Cronbach Alpha
finance	286	0.8885
g_policy	286	0.8791
taxes	286	0.8781
g_program	286	0.8793
educ_basic	286	0.8876
educ_post	272	0.8919
r_d	286	0.8805
comer_infr	286	0.8821
dynamics	286	0.9035
openness	286	0.8791
pysic_infr	286	0.893
culture	286	0.8877
Test scale		0.8947

Note: the data source for calculation [34].

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