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Can European businesses achieve productivity gains from investments in energy efficiency?

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June, 2021

Abstract

Energy efficiency investments are essential for transitioning to a carbon-neutral economy. Nevertheless, despite being financially viable, many energy efficiency investment opportunities do not materialise. The existing literature attributes this situation to financial and non-financial factors. Research suggests that many firms focus only on direct energy savings and neglect non-energy benefits that include increased labour productivity. Up to date, due to lack of high-quality data, few studies attempted to quantify the effects of the energy efficiency investments on firm-level outcomes other than the reductions in energy consumption. This paper overcomes this barrier by using novel data from a firm-level survey conducted by the European Investment Bank that covers more than 15,000 firms in 27 European Union member states and the UK during 2018-2019. It studies the relationship between the energy efficiency investment and the labour productivity of the European firms, utilising instrumental variables methodology to account for potential endogeneity. The results show a positive and causal relationship between energy efficiency investment and labour productivity. The findings of the paper suggest that firms can benefit much more from the energy efficiency investment than what is often assumed, and highlight a need for government policies that would increase firms' awareness of the non-energy benefits.

Keywords: Energy Efficiency; Climate Investment; Productivity

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1 Introduction

Global concerns for the growing primary energy consumption and increase in greenhouse gasses (GHG) emissions have made energy efficiency improvements a priority for many countries. Enhanced energy efficiency is often described as a win-win strategy and has been broadly considered as one of the best methods to reach important climate objectives. It is a cost-reducing measure that decreases direct emissions from fossil fuel consumption, and indirect emissions from electricity generation. In fact, according to the International Energy Agency (2018) more than 40% of the reduction in global CO2 emissions until 2040, relative to the baseline, could be met by investments in energy efficiency measures. To summarise, improving energy efficiency is crucial for mitigating climate change.

Focusing on the European context, energy efficiency is the core element of the European Union's (EU) climate mitigation strategy and one of the cornerstones of the EU energy policy (European Commission, 2018). In June 2018, the EU committed to increasing the energy efficiency by 32.5% by 2030, with a possible upwards revision of this target by 2023. This ambitious goal requires unprecedented investments that need to be undertaken by all, including firms. Unfortunately, despite the great potential of the energy efficiency measures, numerous reports and studies confirm the existence of a gap between the energy efficiency improvements that could be implemented and those that are actually being realized (Hirst and Brown, 1990).

Many energy efficiency investment opportunities are missed, despite requiring limited upfront capital spending and being financially viable. This non-adoption, known as the "energy-efficiency gap", is driven by financial and non-financial factors. There exist numerous barriers to energy efficiency investments that are multi-faceted, diverse and often specific to individual technologies and sectors (for an overview see Sorrel et al. 2004)[1]. One of the most important barriers is the excessive focus of firms on how the energy efficiency investment directly affects their energy consumption and energy savings. Existing literature suggests that, when assessing potential energy-efficiency investments, firms tend to neglect other significant benefits - the so-

[1]Barriers to energy efficiency investments may be classified as: a) behavioural i.e. incapability to fully process information in the firm, b) organizational i.e. lack of climate-related culture in the organization, and c) economic i.e. imperfect and asymmetric information, hidden costs and risks (Sorrel, et al. 2004).

called *non-energy benefits* (Nehler, 2018).

Non-energy benefits may span increased labour productivity, decreased operation and maintenance costs, improved indoor work environments, and a decrease in waste and emissions (Pye and McKane, 2000; Finman and Laitner, 2001). These benefits can arise from energy efficiency investments in the production processes: replacement of old equipment with new state-of-art machinery, or in the support processes: better quality buildings with more efficient lighting systems, heating, ventilation and cooling (Fleiter et al., 2012; Rahimifard et al., 2010). While non-energy benefits i.e. labour productivity gains have positive effects on the firm's bottom line, many firms have difficulties quantifying them. As a result, non-energy benefits are often discarded during the investment decision making process. This situation has serious implications for the energy transition. Non-energy benefits can change significantly the cost assessment of the energy-efficient technologies and result in a more favourable project evaluation (Worrel et al., 2003). Quantifying non-energy benefits and highlighting their importance could increase firms' investment in energy efficiency measures that are needed to meet the ambitious targets set by the European Union. To summarise, understanding, measuring and properly incorporating the additional gains into cost-benefit analysis would more accurately depict the value of energy efficiency measures.

Up to date, research on non-energy benefits of energy efficiency investments has been limited and based on case studies. Little is known about the value of the non-energy benefits, which is largely a function of insufficient availability of data. No existing study analysed the benefits of energy efficiency investments for a large sample of diverse firms in multiple countries. This work overcomes this limitation by exploiting novel information from a unique firm-level survey carried out by the European Investment Bank: European Investment Bank Investment Survey (EIBIS). EIBIS includes information on the energy efficiency investments that is based on answers of more than 15,000 European firms. Furthermore, the data set includes a variety of firm-specific financial measures.

This paper utilises EIBIS data to investigate the hypothesis that energy efficiency investments lead to labour productivity gains. Labour productivity is the core focus of the study due to its importance for firms. While labour productivity is only one of the non-energy benefits it is one of the most important metrics for firms given its direct positive effects on competitiveness (Worrell et al., 2003). Furthermore, labour productivity benefits often demonstrate in the short-term and are more easily observable than e.g. workers' satisfaction. As a result, a robust analysis that shows a positive link between energy efficiency investments and labour productivity could encourage firms to contribute to climate mitigation efforts.

The hypothesis that links energy efficiency investments to productivity gains is based on insights from the existing qualitative research that focuses on investments in production and support processes. First, energy efficiency investment results in an improvement in the quality of the machinery used by the firm. Multiple articles have shown a positive link between better machinery and labour productivity that is driven by greater control of equipment, increased speed and reliability (Baily, 1981; Skumatz et al., 2000; Laitner et al., 2001). Second, investment in more energy-efficient building stock improves workplace comfort, safety and induces workers to be more engaged and productive (Allen et al., 2016; Loftness et al., 2003). Given these improvements in the production and support process, we expect energy efficiency investments to result in labour productivity gains.

The main hypothesis is investigated using EIBIS data for firms in 28 countries over two financial years (2018-2019). First, we construct labour productivity measure and regress it on the energy efficiency investment and additional control variables. Second, we account for potential endogeneity that stems from the selection of unobservables. To guard the results against endogeneity the paper utilises two firm-specific instrumental variables (IV): 1) having conducted an energy audit in the past four years and 2) treating energy costs as an important investment obstacle. The literature has shown that both variables are valid instruments for energy efficiency investments and can be considered as exogenous to labour productivity measure. We utilise the instruments in three alternative models: 2SLS, Probit-2SLS and Probit-OLS. To further corroborate our findings, we estimate the model using Heckman two-stage methodology. The conducted analysis shows a positive and causal relationship between the energy efficiency investment and labour productivity.

This paper contributes in several ways to the existing energy transition literature, policy and practice. First, to the best of our knowledge, this work is the first study that empirically investigates the causal impact of energy efficiency investment on labour productivity. Second, the work examines a large sample of European companies, which provides insights into the behaviour of firms in different institutional contexts and results in high external validity. Finally, the results have important implications for the energy efficiency policy and practice in Europe and possibly elsewhere highlighting the need for actions that would result in greater awareness of the non-energy benefits of energy efficiency investments.

The study is organised as follows: Section 2 provides a summary of the related literature. Sections 3 and 4 describe the hypothesis and the methodology used in the study. Section 5 presents the empirical results, Section 6 discusses the implications for energy policy and practice and Section 7 concludes the discussion.

2 Literature Review

The paper enriches the literature of the additional benefits of energy efficiency investments, which are most commonly known as non-energy benefits (NEBs) (Rasmussen, 2017). Furthermore, it contributes directly to a narrower research stream that focuses on one specific NEB: firm's labour productivity.

Numerous researchers have stressed the need to analyse and quantify NEBs of energy efficiency investments that go beyond energy cost savings (for an overview see Nehler, 2018). This task is difficult given the fact that NEBs span different categories, many of which are not easily observable (Hall and Roth, 2003). According to the International Energy Agency (2014), there exist five categories of NEBs: a) macroeconomic impacts, b) public budget impacts, c) health and well-being impacts, d) energy delivery impacts and e) industrial sector impacts. The last category, which includes improved productivity, provides the most tangible financial benefits to firms that are observable also in the short term.

NEBs-focused studies are very diverse. In general, many empirical researchers concentrate only on some of the non-energy benefits. Furthermore, possibly due to data limitations, most of the existing studies use a qualitative, case study approach, that is based on interviews. Most analyses conclude that large positive NEBs do exist and that they result in higher adoption of energy-efficiency measures. Based on five case studies, Lilly and Pearson (1999) estimate the NEBs of energy efficiency measures and find that NEBs account for 24% of the total energy efficiency savings. According to their findings, the majority (81%) of the observed NEBs are related to reductions in the operation and maintenance costs and have direct financial implications. Finally, the inclusion of the NEBs in capital accounting reduces the payback period from 2.6 to 1.3 years and helps to increase the benefit-cost ratios by 27% on average. Pye and McKane (2000) estimate the monetary values of NEBs and include them in the investment cash flow analysis. Specifically, based on three case studies, they show a potential to monetize the benefits from increased production, reduced emissions, reduced material use, improved product quality and the reduced needs for cleaning and maintenance. According to their findings, accounting for NEBs, particularly productivity gains incentivises energy efficiency investments. In a similar study, Fleiter et al. (2012) and Trianni et al. (2013) account for NEBs in the energy-efficiency investments assessment framework. The first study uses an explicit category for NEBs and the second accounts for three attribute-related categories: environmental, production and implementation. Both studies conclude that large positive NEBs exist and result in higher adoption of the energy-efficiency measures. Finally, the existence of NEBs and their important role in driving the energy efficiency investment is confirmed by meta-analyses of various case studies. Finman and Laitner (2001) investigate 77 case studies in the USA and find that in 52 of them the NEBs are equal to or greater than the energy savings. Including NEBs in the investment decisions results in cutting the payback period of the energy-efficiency projects by half, to approximately two years. The existence of positive NEBs is also confirmed by Lung et al. (2005) and Nehler (2018).

Other literature stream studies how energy efficiency investments affect labour productivity. These studies focus on investments in better machinery and building stock. First, numerous articles show that better quality of the machinery affects positively the productivity of workers (e.g. Baily, 1981; Strobel, 2011; Bini, Nascia, and Zeli, 2014). This positive relationship is largely a function of lower maintenance, better control and increased reliability of the equipment that allow the workers to produce more output (Skumatz et al., 2000; Finman and Laitner, 2001; Worrell et al., 2003). Second, the productivity of workers is greater in the presence of better quality building stock.

Positive effects can emerge through different channels e.g. better lighting, more optimal temperature or reduced noise. A case study conducted by researchers at the Harvard T.H. Chan School of Public Health's Center for Health and the Global Environment and SUNY Upstate Medical (Allen et al., 2016), proved that working in high-performing, green-certified buildings could improve employee decision-making. Loftness et al. (2003) find that better and more natural lighting can improve workers' productivity and well being. They document productivity gains due to increases in reading comprehension, letter processing speed and reduced absenteeism. Similarly, Seppanen et al. (2006) find that indoor office temperature is one of the key determinants of productivity. Their study reveals that work performance decreases with a temperature above 24 degrees Celsius. Hedge (2004) finds that when the temperatures are low employees make more mistakes than at the optimal room temperature and appear to be more distracted. Gurtekin-Celik (2004) focus on noise and find that noise can cause productivity losses in certain types of work. The estimated productivity gains from working in a more quiet environment range between 1.8% and 19.8%. Wyon (2004) proves that improved ventilation, air filtration and cleanliness of duct systems result in improved work performance that ranges from 6% to 9%. Finally, a study by Montalbano and Nenci (2018), which is most similar to ours, investigates quantitatively the productivity gains from the energy efficiency investments by a sample of Latin American firms. The authors use the World Bank Enterprise Survey and show positive effects of the energy intensity improvements on productivity.

These findings highlight the important role played by investment in energy efficiency measures. However, two important research gaps prevail. First, most studies are case study based and there exists no assessment of the links between the energy-efficient investments and labour productivity among a larger sample of European firms. Second, the current literature does not account for the potential endogeneity between energy efficiency and labour productivity. Further research is thus necessary and this paper aims to contribute to the evidence on the positive links between energy efficiency investments and important firm-level outcomes.

3 Hypothesis

Labour productivity expresses a relationship between the number of goods and services that are produced by a business or an economy and the number of workers that are needed to produce those goods and services. Labour productivity is often seen as one of the most important non-energy benefits. Firms need clear signals to invest in energy efficiency and labour productivity can act as such a signal since it leads to direct financial benefits for firms: labour productivity directly affects firms' output and their competitive position. It has been also shown that labour productivity benefits lead to larger monetary gains than, for instance, employee morale and satisfaction (Hall and Roth, 2003) and occur not only in the short-term but also continue over the long run. Furthermore, unlike many other non-energy benefits, productivity is observable and quantifiable. As a result, showing in a methodologically sound way that energy efficiency investment improves labour productivity could contribute to closing the energy efficiency investment gap, which is needed to reach the ambitious climate goals of the European Union.

According to the reviewed literature, energy efficiency investment increases labour productivity through its impact on the production and support processes. First, energy efficiency investment improves the quality of the machinery used by the firm. This results in better control of equipment, increased speed, reliability, and subsequent labour productivity gains (Baily, 1981; Skumatz et al., 2000; Laitner et al., 2001). Second, energy efficiency investment improves the energy efficiency of buildings that controls the flow of air, heat, moisture and noise. Moderate temperatures, low humidity and increased air quality make workers more engaged (Allen et al., 2016; Gurtekin-Celik, 2004; Wyon, 2004). To conclude, investment in more energy-efficient production and support processes should increase labour productivity, which we summarise in the main hypothesis of the paper:

Hypothesis 1: There exists a positive relationship between energy efficiency investment and labour productivity.

The rest of the paper describes the data and the methodology used to test the hypothesis, and presents and discusses the main results.

4 Methodology

4.1 Empirical Strategy

The empirical strategy proceeds in three steps. First, we use EIBIS data on employment and value-added of the firm to estimate its labour productivity. Labour productivity Pit is defined as the ratio of firm value added to human capital and the estimation follows Equation 1:

$$P_{it} = VA_{it}/L_{it} \tag{1}$$

Where VA_{it} and L_{it} represent the value added and the number of employees for firm i at time t. Both variables come directly from EIBIS.

Second, labour productivity (Ospina and Schiffbauer, 2010) is used as a dependent variable in the main estimation that shows the correlations between the energy efficiency investment and the firm's labour productivity, following Equation 2:

$$P_{it} = \beta_i EE_{it} + \beta_{xi} X_{it} + m_i + n_i + e_{it} \tag{2}$$

Here P_{it} stands for labour productivity (in log) and EE_{it} is the main explanatory variable – the energy efficiency investment. EE_{it} is a binary variable that takes value one if, according to EIBIS, the firm invested in measures to improve energy efficiency in the last financial year. X_{it} is a vector of firm-specific control variables derived from EIBIS. It includes three dummy variables: being financially constrained, foreign-owned and exporting, and one categorical variable: firm's age. A firm is coded as financially constrained if it is either: a) quantity constrained, b) price constrained, c) its external financing request was rejected or d) it decided not to seek any external financing due to the concern of being rejected[2].Firms coded as foreign-owned stated in EIBIS that it is a subsidiary of a foreign company and exporters indicated that in the previous financial year they directly exported goods and services to another country. Firm's age is a categorical variable that ranges from one to five and is coded as follows: less than two years (coded as one); two years to less than five years (coded as two); five years to less than 10 years (coded as three); 10 years to less than 20 years (coded as four) and 20 years or more (coded as five). Finally, variables m_i and n_i denote respectively country and sector fixed effects and e_{it} represents the error term.

Despite controlling for firm-, sector- and country-specific variables Equation 2 may still suffer from endogeneity. This is because OLS assumes only selection on observables but the estimation is also likely to suffer from the selection on unobservables, which means that the Conditional Mean Independence is not sufficient to identify causal parameters. It may be the case that there exist unobservable variables that affect the relationship between the energy efficiency investment and labour productivity or that more labour productive firms invest more in energy efficiency. In an attempt to establish causality, we utilise the instrumental variable approach. We instrument the energy efficiency investment with the answers to two EIBIS questions: a) whether in the past four years the firm conducted an energy audit and b) whether the energy costs act as an obstacle to firm's investment. Kalantzis and Revoltella (2019) found that both instruments play a crucial role in determining energy efficiency investment. In our sample, the first stage estimation shows a statistically significant positive correlation between the two instruments and energy efficiency investment. Finally, both instruments can be considered as exogenous to the dependent variable: firm's labour productivity.

To ensure the robustness of our findings, we utilise instrumental variables models that are based on three alternative approaches: Two-Stage-Least-Squares (2SLS), Probit-2SLS and Probit-OLS. The two latter methods take into account the binary nature of the energy efficiency investment variable. In 2SLS we estimate the average treatment effect in two steps. In

[2]Classification as financially constraint is based on the definition used by the European Investment Bank. Quantity constrained firm is not satisfied with the received amount of external finance. Rejected firm has seen his request for external financing rejected. Price constraint firm decided to not seek any external financing due to its too expensive costs. Discouraged firm decided not to seek any external financing due to the concern of being rejected.

the first stage, we run an OLS regression of the energy efficiency on the instrumental variables and controls to estimate the predicted values of the energy efficiency investment. In the second stage, we run a second OLS regression of labour productivity on the predicted values of the energy efficiency investment and the control variables. Our second model relies on Probit-2SLS methodology that exploits the binary nature of the energy efficiency variable. Here we first use a Probit model of energy efficiency investment on the instrumental variables and controls to estimate the probabilities of observing energy efficiency investment. We then apply a 2SLS with predicted probabilities as an additional instrument for the energy efficiency investment. Our final IV model relies on Probit-OLS where the first stage follows Probit and the second stage estimates the average treatment effect using an OLS regression of labour productivity on the probabilities of observing energy efficiency investment and control variables. Finally, as a robustness check, we estimate our regression using Heckman two-stage selection model. In the first stage we formulate a model for the probability of investing in energy efficiency and estimate it using Probit regression. In the second stage, we correct for self-selection by incorporating a transformation of the predicted individual probabilities (Mills ratio) as an additional explanatory variable in the estimation of labour productivity.

4.2 Data

The analysis conducted in this paper is based on an unbalanced panel of more than 15,000 firms over 2018-2019[3]. The data comes from the annual European Investment Bank Group Survey on Investment and Investment Finance (EIBIS). EIBIS is an EU-wide survey, carried annually since 2016, that gathers qualitative and quantitative information on the investment activities and financing requirements of SMEs (5-250 employees) and larger corporates (more than 250 employees). EIBIS uses a stratified sampling methodology and is designed to be representative at the EU and country level and, for most countries, representative at the sectorial level (manufacturing, services, construction and infrastructure) and at the firm size class level (micro, small, medium and large). All surveyed firms are sampled from the Bureau van Dijk ORBIS database and survey answers are matched with the firm's balance sheets and income

[3]Data comes from 2018 and 2019 waves of EIBIS, which contain information from the previous financial year. If the firm participated in multiple waves of the survey, we include in the sample only the first observation. The results are robust to including the most recent observations.

statements. The main advantage of the dataset is that it provides information on the energy efficiency investment, and other variables that describe the energy profiles and financial positions of firms. EIBIS contains information on the firms' decisions to conduct an energy audit and on the importance of energy costs for the investment decisions. The dataset also includes information about the firm's value-added, fixed assets, number of employees, exporting activity, ownership status, years of operation, sectorial affiliation and access to finance.

EIBIS data shows that the average share of firms that invested in energy efficiency stands at 39% (Table 1).Some 8% of firms are financially constrained and an average firm is close to 20 years old. The average share of firms with exporting activities is 50%, and 23% of the firms are a subsidiary of a foreign multinational enterprise. Approximately 35% of firms conducted an energy audit and some 25% considers energy cost as a minor obstacle for investments. The Finally, correlation indexes between the covariates included in this analysis are very low, which indicates that the models do not suffer from multicollinearity (see Appendix).

	N	Mean	Standard Deviation	Min	Max
Labour productivity	15,394	10.23	0.97	1.84	22.09
Energy efficiency Investment	15,394	0.39	0.49	0	1
Financially-constrained	15,394	0.08	0.27	0	1
Age (categorical)	15,394	4.46	0.81	1	5
Exporter	15,394	0.5	0.5	0	1
Foreign-owned	15,394	0.23	0.42	0	1
Energy Audit	15,394	0.35	0.48	0	1
Energy Cost Concerns	15,394	0.25	0.44	0	1

Table 1: Summary statistics.

5 Results and Analysis

In this section, we present the results of our main hypothesis testing, namely whether it exists a positive relationship between energy efficiency investment and the labour productivity of firms. Model 1 of Table 2 presents the results of the baseline OLS model (counterfactual OLS), Models 2-4 present results of the second stage of the instrumental variables estimations and Model 5 presents the results of the second stage of the Heckman selection model. Appendix includes the first stage regressions from the instrumental variables models and the first step regression of the

Heckman model.

In Model 1, the dependent variable – labour productivity, is regressed on energy efficiency investment and a set of covariates that control for observable heterogeneity among firms. The visual inspection of the coefficients shows that the energy efficiency investment is positively correlated with labour productivity: on average having invested in energy efficiency is linked to a 1 percent higher labour productivity levels. However, the relationship between the two variables is not statistically significant, suffers from the selection on unobservables and does not allow establishing causality. To address the latter issues we turn to the instrumental variables approach. As seen in Models 2-4, investment in energy efficiency has a positive, statistically significant impact on labour productivity with the coefficients oscillating between 0.15 and 0.16. This positive relationship is also confirmed by the results of the Heckman selection model that show that investment in energy efficiency improves labour productivity by 18 percentage points. The estimated impacts are in line with the findings of Gurtekin-Celik (2004) and Wyon (2004).

	Labour Productivity				
	Model 1	Model 2	Model 3	Model 4	Model 5
	OLS	IV: Direct-2SLS	IV: Probit-2SLS	IV: Probit-OLS	Heckman
Variables		Second Stage	Second Stage	Second Stage	Second Step
Energy Efficiency	0.01	0.15**	0.157***	0.16***	0.18***
Investment	(0.01)	(0.06)	(0.06)	(0.06)	(0.06)
Financially-	-0.12***	-0.12***	-0.12***	-0.12***	-0.12***
constrained	(0.03)	(0.03)	(0.03)	(0.03)	(0.02)
Age	0.06***	0.06***	0.06***	0.06***	0.06***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Exporter	0.22***	0.22***	0.22***	0.22***	0.22***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Foreign-owned	0.14***	0.14***	0.14***	0.14***	0.14***
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Constant	10.28***	10.24***	10.24***	10.24***	10.23***
	(0.05)	(0.06)	(0.06)	(0.06)	(0.06)
Observations	15,394	15,394	15,394	15,394	15,394
R-squared	0.39	0.39	0.39	0.39	0.39
Cragg-Donald Wald F-stat		381.09	771.5		
Kleibergen-Paap Wald rk F-stat		368.54	743.83		
Country effects	YES	YES	YES	YES	YES
Sector effects	YES	YES	YES	YES	YES

Note: The table presents the results of the OLS model (Model 1) and the results of the second stage of the IV and Heckman models (Models 2-5). The dependent variable is labour productivity (in log). Robust standard errors are presented in parenthesis.Significance levels:*p<.10; **p<.05; ***p<.01.

Table 2: Main Analysis: Effects of the energy efficiency investment on the labour productivity.

Table 2 presents also interesting insights into how other variables may influence labour productivity. Specifically, the coefficients on the variables representing foreign ownership and exporting activities are positive and significant. Productivity gains are higher in foreign-owned firms than in domestic firms (coefficient equal 0.14) and in exporting firms (coefficient equal 0.22). These results are in line with the literature (Melitz, 2003; Helpman et al., 2004). Furthermore, being financially constrained is correlated negatively with labour productivity (Hallward-Driemeier et al., 2003 and Christopoulos and Tsionas, 2004). We find negative statistically significant coefficients that oscillate between -0.14 and 0.23. Finally, older firms are more likely to observe higher labour productivity levels.

To conclude, the analysis presented above confirms the main hypothesis of the paper that energy efficiency investment has a positive and causal effect on labour productivity.

6 Implications for the Energy Policy and Practice

The analysis presented in this paper uses robust methodology to show that, for a wide sample of European firms, investment in energy efficiency leads to higher labour productivity of firms. These findings have many important implications for the energy policy and practice.

According to the paper, the positive relationship between investment in energy efficiency and increased productivity holds across a sample of firms that represent different industries in all European members. This suggests that positive non-energy benefits of the energy efficiency investment do exist on a wide scale and benefit firms in multiple contexts. This is an important finding that highlights the competitiveness-enhancing role of energy efficiency investment.

Unfortunately, while energy efficiency investment is likely to benefit firms, currently the majority of firms are not fully aware of these positive effects. Many firms negatively discount the benefits of the energy efficiency investment during the decision-making process and require a shorter payback period (Lilly and Pearson, 1999). To meet the energy efficiency goals this situation needs to change – firms need to realise that energy efficiency investment is indeed a win-win strategy and that the benefits are tangible and quantifiable also in the short-term. The change may come from both within firm and the external stakeholders and both options should be utilised to increase the awareness of non-energy benefits.

In terms of changes within the firm, it is important for the executives to acknowledge the value of NEBs and to share this knowledge with other stakeholders i.e. middle management and workers to implement them. One example of this is the NEB web-based tool that was developed in Denmark (Gudbjerg, Dyhr-Mikkelsen and Monrad Andersen, 2014). The tool consists of five elements: 1) method for assessing NEBs of energy efficiency projects, 2) NEB database that allows users to search e.g. by branch and energy efficiency project type, 3) case examples with a more detailed description of energy efficiency projects and the associated NEBs, 4) questionnaire for identification and assessment of NEBs and 5) suggested further reading. Furthermore, such information campaigns could also spill over across firms: either as part of industry associations and voluntary groups or through the supply chain.

The external environment, particularly well-designed policies, may also raise the awareness of firms. At the moment, both the EU and its Member States, lack policies that would focus on raising the awareness of the NEBs among firms. There exist energy efficiency information campaigns – as of 2019 they were present in 23 European countries (Odyssee-Mure, 2020). Nevertheless, these campaigns tend to focus on energy consumption and potential energy savings and do not highlight enough important NEBs such as labour productivity. The potential options to change the current situation include implementing NEBs-specific information campaigns and related policies that could facilitate the measurement of NEBs at the firm level.

Implementation of the aforementioned measures, either firm-specific or policy-based, could have a significant effect on improving the awareness of NEBs and facilitating energy efficiency investment. This in turn could act as a win-win strategy for both firms and the world as a whole. For firms, increased investment in energy efficiency could lead to post cost savings and productivity improvements. This would subsequently contribute to closing the energy efficiency investment gap, which is needed to reach the ambitious EU climate goal of increasing the energy efficiency in the region by 32.5% by 2030.

In other words, an increase in the awareness of NEBs and a subsequent increase in the energy efficiency investment could improve the competitiveness of the European firms and contribute to broader climate change mitigation efforts.

7 Conclusions

Energy efficiency investment is essential for transitioning to a carbon-neutral economy. Nevertheless, despite being financially viable, many energy-efficiency investment opportunities do not materialise. The existing literature attributes this situation to financial and non-financial factors. In particular, past research suggests that many firms account only for direct energy savings and tend to neglect non-energy benefits i.e. increased labour productivity. Non-energy benefits are often seen as abstract, intangible and not easily quantifiable. This combined with the lack of firm-level data on both energy efficiency measures and NEBs led to limited awareness of NEBs by firms and to underscoring their positive role while making the investment decisions.

This study overcomes the severe data limitation by exploiting information from a unique firm-level survey that was carried out by the European Investment Bank. Utilising a rich sample of more than 15,000 firms in 28 European Union member states during 2018-2019, the paper studies the relationship between the energy efficiency investments and the labour productivity of the firms. First, labour productivity is regressed on the decision to invest in energy efficiency and on firm's characteristics. Second, to overcome endogeneity concerns, the paper utilises instrumental variables methodology. Two instrumental variables used in the study are: 1) having conducted an energy audit in the past four years and 2) treating energy costs as an important investment obstacle. To corroborate the findings, we utilise three alternative instrumental variables methods: 2SLS, Probit-2SLS and Probit-OLS. Finally, as a robustness check, we estimate the relationship between energy efficiency investment and labour productivity using Heckman two-stage selection model.

The conducted analysis shows a positive and causal relationship between the energy efficiency investment and labour productivity. The results are robust to the use of different instrumental variables specifications. Findings of the paper suggest that firms can benefit much more from the energy efficiency investment than what is often assumed, and highlight a need for government policies that would increase firms' awareness of the non-energy benefits.

It is important to mention that the study is subject to certain limitations that should be addressed by future research. First, the productivity gains should be monetized, as putting specific values of NEBs would make them more attractive to firms (Nehler, 2018). Second, there is a need to look at the heterogeneous effects of various energy efficiency measures, as there may exist significant differences in the benefits for i.e. production and support processes, some of which may be industry-specific. Investigating the ideas outlined above would require improvements in the quality and availability of granular data. Dedicated surveys of firms that would cover the determinants of investments in the energy-efficiency measures could shed further light on the specific productivity gains, as well as other NEBs, across different sectors and countries. Finally, further research should investigate the role of climate policies, particularly NEBs-focused informational campaigns, in fostering energy efficiency investments.

To conclude, this study illustrates that investment in energy efficiency leads to increased productivity of European firms. Investing in energy efficiency is, in fact, a win-win strategy: as it is likely to increase the productivity and competitiveness of the European firms and contribute to reaching the ambitious EU climate agenda. In this context, increasing the awareness of NEBs is crucial for reaching this goal, as it makes energy efficiency investments more attractive than other types of investments.

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9 Appendix

9.1 Correlations

	Labour Productivity	EE Investment	Financially-constrained	Age	Exporter	Foreign-owned	Energy Audit	Energy Cost Concerns
Labour Productivity	1	0.04	-0.09	0.15	0.12	0.1	0.09	-0.11
EE Investment	0.04	1	-0.04	0.09	0.06	0.02	0.23	0.1
Financially-constrained	-0.09	-0.04	1	-0.06	-0.01	-0.03	-0.03	0.02
Age	0.15	0.09	-0.06	1	0.1	-0.01	0.14	0.03
Exporter	0.12	0.06	-0.01	0.1	1	0.15	0.14	-0.02
Foreign-owned	0.1	0.02	-0.03	-0.01	0.15	1	0.06	-0.05
Energy Audit	0.09	0.23	-0.03	0.14	0.14	0.06	1	0.06
Energy Cost Concerns	-0.11	0.1	0.02	0.03	-0.02	-0.05	0.06	1

Correlations table.

9.2 Main Analysis: Direct-2SLS

	Model 2	
	IV: Direct-2SLS	
Variables	First Stage	Second Stage
Energy Efficiency Investment		0.15**
		(0.06)
Financially-constrained	-0.04***	-0.12***
	(0.01)	(0.03)
Age	0.03***	0.06***
	(0.00)	(0.01)
Exporter	0.00	0.22***
	(0.01)	(0.01)
Foreign-owned	0.00	0.14***
	(0.01)	(0.02)
Energy audit	0.21***	
	(0.01)	
Energy Cost Concerns	0.09***	
	(0.01)	
Constant	0.24***	10.24***
	(0.03)	(0.06)
Observations	15,394	15,394
R-squared		0.39
Cragg-Donald Wald F-stat	381.09	
Kleibergen-Paap Wald rk F-stat	368.54	
Country effects	YES	YES
Sector effects	YES	YES

Note: Robust standard errors in parenthesis.*p<.10; **p<.05; ***p<.01.

Table 3: Direct-2SLS Model: Effects of the energy efficiency investment on the labour productivity.

9.3 Main Analysis: Probit-2SLS

	Model 3		
		IV: Probit-2SLS	
Variables	Probit	2SLS: First Stage	2SLS: Second Stage
Energy Efficiency Investment		1.01***	0.16***
		-0.04	(0.06)
Financially-constrained	-0.12***	0	-0.12***
	(0.04)	(0.01)	(0.03)
Age	0.08***	0.00	0.06***
	(0.01)	(0.01)	(0.01)
Exporter	0.01	0.00	0.22***
	(0.02)	(0.01)	(0.01)
Foreign-owned	0.00	0	0.14***
	(0.03)	(0.01)	(0.02)
Energy audit	0.55***		
	(0.02)		
Energy Cost Concerns	0.26***		
	(0.03)		
Constant	-0.71***	-0.00	10.24***
	(0.09)	(0.04)	(0.06)
Observations	15,394	15,394	15,394
R-squared			0.387
Identification tests:			
Cragg-Donald Wald F-stat	771.5		
Kleibergen-Paap Wald rk F-stat	743.83		
Country effects	YES	YES	YES
Sector effects	YES	YES	YES

Note: Robust standard errors in parenthesis.*p<.10; **p<.05; ***p<.01.

Table 4: Probit-2SLS Model: Effects of the energy efficiency investment on the labour productivity.

9.4 Main Analysis: Probit-OLS

	Model 4	
	IV: Probit-OLS	
Variables	Probit	OLS
Energy Efficiency Investment		0.16***
		(0.06)
Financially-constrained	-0.12***	-0.12***
	(0.04)	(0.03)
Age	0.08***	0.06***
	(0.01)	(0.01)
Exporter	0.01	0.22***
	(0.02)	(0.01)
Foreign-owned	0.00	0.14***
	(0.03)	(0.02)
Energy audit	0.55***	
	(0.02)	
Energy Cost Concerns	0.26***	
	(0.03)	
Constant	-0.71***	10.24***
	(0.09)	(0.06)
Observations	15,394	15,394
R-squared		0.39
Country effects	YES	YES
Sector effects	YES	YES

Note: Robust standard errors in parenthesis.*p<.10; **p<.05; ***p<.01.

Table 5: Probit-OLS Model: Effects of the energy efficiency investment on the labour productivity.

9.5 Main Analysis: Heckman Selection Model

	Model 5	
	Heckman Selection Model	
Variables	First Step (Selection)	Second Step
Energy Efficiency Investment		0.18***
		(0.06)
Financially-constrained	-0.12***	-0.12***
	(0.04)	(0.02)
Age	0.08***	0.06***
	(0.01)	(0.01)
Exporter	0.01	0.22***
	(0.02)	(0.01)
Foreign-owned	0.00	0.14***
	(0.03)	(0.02)
Energy audit	0.55***	
	(0.02)	
Energy Cost Concerns	0.26***	
	(0.03)	
Constant	-0.71***	10.23***
	(0.09)	(0.06)
Observations	15,394	15,394
Country effects	YES	YES
Sector effects	YES	YES

Note: Robust standard errors in parenthesis.*p<.10; **p<.05; ***p<.01.
Lambda equal -0.11***.

Table 6: Heckman Selection Model: Effects of the energy efficiency investment on the labour productivity.

9.6 Sectoral Analysis

The testing hypothesis remains valid for all sectors, with the exception of the service sector (Table 7). This sector consists of NACE classification of economic activities of groups G (wholesale and retail trade) and I (accommodation and food services activities) that are quite heterogeneous. When we conduct our analysis based on the two groups, we observe that only for group G the impact is negative, while for group I it is positive and similar to the other sectors. Turning now to the remaining sectors, infrastructure sectors present the highest impact of energy efficiency investment on labour productivity, followed by the construction and the manufacturing sectors.

	Probit-2SLS			
Variables	Manufacturing	Construction	Infrastructure	Services
Energy efficiency Investment	0.32***	0.37**	0.42***	-0.32***
	(0.10)	(0.15)	(0.12)	(0.12)
Financially-constrained	-0.08	-0.08*	-0.08	-0.19***
	(0.05)	(0.05)	(0.06)	(0.05)
Age	0.04*	0.07***	-0.00	0.10***
	(0.02)	(0.02)	(0.02)	(0.02)
Exporter	0.16***	0.17***	0.10***	0.40***
	(0.03)	(0.03)	(0.03)	(0.03)
Foreign-owned	0.17***	0.08**	0.05	0.20***
	(0.03)	(0.04)	(0.04)	(0.03)
Constant	10.43***	10.11***	10.65***	10.05***
	(0.11)	(0.11)	(0.12)	(0.11)
Observations	4,878	3,238	3,641	3,637
R-squared	0.41	0.43	0.35	0.33
Country effects	YES	YES	YES	YES

Note: Robust standard errors in parenthesis.*p<.10; **p<.05; ***p<.01.

Table 7: Probit-2SLS Model: Effects of the energy efficiency investment on the labour productivity by sector.

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