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CESPIC WORKING PAPER
2021/05

Barriers to Firms' Energy Efficiency in Transition Countries

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***Abstract**: This study seeks to explore the firm' barriers of energy efficiency in a set of 28 Transition economies exploiting the enterprise survey data collected by the European Bank for Reconstruction and Development (EBRD) jointly with the European Investment Bank (EIB) and the World Bank Group (WBG). Based on the Ordinary Least Square (OLS) regression model and on the construction of three different indicators to evaluate the energy efficiency, we find that the barriers to the adoption of energy efficiency measures mainly lack financial resources and profitability. Findings obtained from the interactions are also worthy of note. In particular, we find that the absence of profitability starts being stronger for non-EU countries. Instead, there is no evidence of heterogenous effects for industry sectors.*

Key: Firms' energy efficiency, Barriers, Transition economies
Jel Codes: D22; K32; L29

1. Introduction

Improved energy efficiency is becoming a prior goal of the Energy Efficiency Directive 2012/27/EU integrated with the Directive 2018/2002. Both directives aim not only to protect the environment, mitigate climate change with 32.5 % target for 2030 and achieve zero emission electricity production by 2050, but also to reduce firms' energy costs linked to the increase in energy prices and the application of technological innovation (European Union, 2012; 2018). However, firms often fall to achieve this objective due to persistent barriers. The presence of the latter does not allow the firm to implement measures that enable it to reach an optimal level of efficiency, thus causing the so-called "energy gap" which is the difference between energy use and energy efficiency or between effective use and optimal efficiency (Backlund et., 2012; Allcott and Greenstone, 2012; Jaffe and Stavins, 1994). Therefore, there is an increasing attention among scholars and policymakers to better understand the barriers in hindering firms' energy efficiency.

A substantial theoretical literature has focused mainly on the nature of barriers to energy efficiency identifying a wide category of them (Blumstein et al., 1980; Weber, 1997; Sorrell et al., 2000; 2004; 2010; Cagno et al., 2013). If theoretical studies about barriers for improving industrial energy efficiency are broad, the same is not true for empirical investigations. Only few empirical studies have analyzed barriers to energy efficiency in specific sectors in industrialized countries such as Greece for six sectors (Sardianou 2008), Germany for commercial and service sectors Schleich (2009), and Sweden for aluminum industry (Haraldsson and Johansson, 2019).

Other studies have considered the obstacles to energy efficiency in developing countries focusing on iron-steel industry (Hasan et al., 2018; Soepardi et al., 2018) and textile sector (Hasan et al., 2018). With respect to Transition countries, only one empirical paper based on a logit model in commercial and industrial firms in Ukraine examines economic, behavioral and institutional barriers to energy efficiency (Hochman and Timilsina, 2017).

Therefore, the purpose of this paper is to study from an empirical perspective the barriers that affect the adoption of energy efficiency measures by firms operating in manufacturing, retail services and other services in a set of 28 Transition countries. To this end, since our

goal is to identify what is the correlation between potential barriers and energy expenditure, we employ an ordinary least square (OLS) regression model exploiting firm-level data taken from the latest World Bank's Enterprise Surveys conducted between 2018 and 2020.

The main findings obtained through the estimations show that the most relevant barriers that affect firms to adopt energy efficiency are both lack of finance resources and absence of profitability. These findings are also confirmed when we interact barriers with country area and industry sectors.

Thus, this paper aims to fill the gap in the literature on energy efficiency by investigating not only firms' barriers that affect firms' energy efficiency in Transition countries, but also the typology of firms' barriers for country area. To additionally study the relationship between energy efficiency and the presence of potential barriers we investigate the presence of heterogeneous effects.

These findings might be important not only for academics, but also for policy makers, specifically for policies related to incentives for Transition economies.

The remainder of this paper is organized as follows. Section 2 focuses on the literature review on the role of industrial barriers on energy efficiency. Section 3 describes the data and the variables, while Section 4 outlines the econometric strategy and presents the findings of the baseline model. In the following section, some alternative estimations are presented. Finally, the last section concludes the article.

2. Barriers of energy efficiency: a literature review

Energy efficiency is often associated with the renewable energy technology (Hearn et al., 2021) and it represents a priority in the policy strategies of most countries, especially in European economies since it reduces financial costs and mitigates environmental damages related to energy use (Gerarden et al., 2015). It is a pathway to bridge the gap between environmental issues, for this reason firms should adopt these measures by overcoming the barriers that their use might entail. The existing literature has identified several types of barriers and attempted to reveal how they may impact on energy efficiency. These contributions examine and categorize barriers from different perspectives. The first specific

study that grouped barriers in social and institutional to measure cost-effective energy savings was conducted by Blumstein et al. (1980). Weber (1997) introduces another classification, he distinguishes the barriers as follows: (i) institutional barriers produced by political institutions; (ii) market barriers or market failures; (iii) barriers within the organizational activity of firms and finally (iv) behavioral barriers or barriers among individuals. Focusing on industry, Sorrell et al. (2000; 2004; 2010) define barriers that hinder energy efficiency. Their taxonomy is based on three theoretical perspectives: (i) economic; (ii) behavioral and (iii) organizational. The economic perspective relies on the neoclassical theory, it concerns the market barriers such us imperfect and asymmetric information (Howarth and Andersson, 1993), hidden costs and risks. The behavioral perspective is based on the transaction cost theory and on satisfactory decisions, while the organizational perspective refers to the organizational theory and considers firms as social systems characterized by their relationship, power, and culture. Then, Sorrell et al. taxonomy (2000) identifies 15 barriers (see Table A1 in Appendix). However, all the classifications illustrated up to now are not readily exploitable in empirical studies. Differently from the previous classifications, the theoretical categorization suggested by Cagno et al. (2013) seems to be applied more easily to the empirical research. The authors propose a distinction based on two main causes that hinder energy efficiency: internal and external. As regards the first one, it is composed by five areas and 16 obstacles, while the second one is divided in six areas and covers 18 barriers. However, also this taxonomy is hardly applicable empirically since these barriers depend on the countries and on the sectors studied (Johansson and Thollander, 2018). Probably, given this complexity of empirical application, few analyses employ econometric model (i.e. Sardianou, 2008; Schleich, 2009), more studies are descriptive and based on semi-structured interviews (i.e. Haraldsson and Johansson, 2019; Trianni et al., 2013a; 2013b). Most of the studies are carried out on developed countries and different sectors. Rohadin and Thollander (2006) analyzing the energy efficiency measures in the Swedish manufacturing industry find several obstacles such as lack of time and cost associated with the halting of production. The results obtained for Greek firms suggest that barriers depend on business needs, and that greater investment in human capital would succeed in spreading awareness about industrial investment in energy conservation (Sardianou 2008). Focusing on the

commercial and service sectors in Germany, Schleich (2009) finds that the two sectors have similar barriers such as lack of information on energy consumption, staff time and energy efficiency measures. Another key barrier found in the study conducted for Small and Medium Manufacturing Enterprises (SMEs) in the Northern Italy (Trianni et al., 2013a) is the lack of interest in energy efficiency. This means that energy expenditure is not relevant for firms, or the firms consider themselves as being already energy efficient. On the contrary, for the SMEs in a sample of EU countries specialized in foundry sector the most relevant obstacles are the lack of capital and the existence of other priorities (Trianni et al. 2013b). A more recent analysis on Swedish aluminum industry and aluminum casting foundries (Haraldsson and Johansson, 2019) reveals that the most relevant obstacles are risks and costs related to interrupting of interruption, risks caused by the interruption of production capacity, production quality and risks connected to the change in organizational routine.

In addition, some studies have investigated the barriers of firms' energy efficiency in foundry industry in developing countries such as India (Mukherjee, 2011), and China (Li et al., 2010), other works have explored obstacles in iron-steel industry in Bangladesh (Hasan et al., 2018) and Indonesia (Soepardi et al., 2018). There are also studies on textile industry in Bangladesh (Monjurul Hasan, 2019) and in Thailand industry (Hasanbeigi et al., 2010). Barriers to energy efficiency in developing countries are like those in developed countries, but they are more persistent, and this is also due to the application of an inadequately economic policy (Sorrel et al., 2011). Only few papers (Zuoza and Pilinkienì, 2018; Hochman and Timilsina, 2017) focus on barriers in Transition economies that have been energy intensive[1] for a long time (Cornillie and Fankhauser, 2004). Hochman and Timilsina, (2017) empirically explore barriers to efficient energy use from commercial and manufacturing Ukrainian firms, Ukraine being considered as a transit country for natural gas imported from Russia into Europe. In their study based on logit analysis, they point out that despite the country's policies, especially small firms suffer from financial and economic barriers and the commercial sector invests less in energy-efficient technologies

[1] Energy intensity is defined as energy use per GDP (Cornillie and Fankhauser, 2004:1)

due to the lack of a specific economic policy. On the contrary, Zuoza and Pilinkienì (2018) with their theoretical work propose a new barrier classification which can be applied in future research to test the energy efficiency industry in the Baltic area. In other words, they show the need for a new classification. Despite this literature, evidence on the firms' barriers to energy efficiency in Transition countries remains unexplored. Therefore, the aim of this study is to contribute to the literature to bridge this gap by enriching this strand through the examination of a set of 28 Transition countries.

3. Data collection and variables

To explore the effect of barriers on the firms' adoption of energy efficiency improvement measures, we use firm-level data collected by the World Bank's Enterprise Surveys (hereinafter ES) in collaboration with the European Bank for Reconstruction and Development (EBRD), the European Investment Bank (EIB) and the World Bank Group (WBG). The survey's focus is to offer details on private sector firms; therefore, the population of the study is part of the non-agricultural economy, that is to say all manufacturing sectors, construction, services, transport, storage, communications and IT in accordance with the group classification ISIC Revision 3.1.[2]

The surveys give a representative sample of firms that have been identified according to the stratified random sample approach[3]. The surveys also provide information on: (i) innovation behavior of firms, (ii) innovative activities, organizational practices, management and employees and (iii) other general information on firms. In the last surveys, a new section has been added on environment aspects, this allows us to investigate the effect of a group of barriers on energy efficiency measures for firms across Transition economies. It is based on data from about 15,246 firms located in 28 countries of Eastern Europe and Central Asia[4]. During the first half of the 1990s, all the countries examined

2 These surveys do not provide details on firms operating in the following sectors: (i) financial intermediation, (ii) real estate and renting activities and (iii) public and utilities.

3 The stratification levels adopted are: (i) region, (ii) sector and (iii) firm dimension.

4 The following countries were considered in the dataset for our analysis: Albania, Armenia, Azerbaijan, Belarus, Bosnia and Herzegovina, Bulgaria, Croatia, Czech Republic, Denmark, Estonia, Georgia, Germany, Greece, Hungary, Kazakhstan, Latvia, Lithuania, North Macedonia, Moldova, Montenegro, Poland, Portugal, Romania, Russia, Serbia, Slovakia, Slovenia, Tajikistan, Ukraine, and Uzbekistan.

have undertaken a process of Transition from a centrally planned to a market driven economy.

The process of transformation that has affected these countries has mainly occurred in the legal, institutional, market and civil society spheres, but has also involved the area of environmental protection and management (Kudlack, 2017, Biscione et al., 2021a, Biscione et al, 2021b). In our case as Montalbano and Nenci (2018), we seek to explain the energy efficiency variable using three proxies calculated as the inverse of energy intensity. The three measures of energy intensity are calculated as follows:

(i) the ratio between the total annual energy expenditure ($C_{EN,i}$) and the value of total annual sales, S_i.

$$EI_{1i} = C_{EN,i}/S_i$$

where C_{EN} is the sum of total annual fuel and electricity costs ($C_{Fi} + C_{Ei}$).

(ii) the ratio between fuel and electricity expenditure and the annual value added of firm i. [5]

$$EI_{2i} = C_{EN,i}/VA_i$$

(iii) the cost share represents the annual energy costs over the total annual cost for variable inputs.[6]

$$EI_{3i} = C_{EN,i}/C_{variable\ inputs,i}$$

The main explanatory variables of interest are the barriers to the adoption of measures from firms that improve energy efficiency. We consider the following set of barriers: (i) lack of financial resources; (ii) lack of priority relative to other investments; (iii) not profitable; (iv) uncertainty about regulations; (v) uncertainty about future prices; (vi) operational and/or technical risk and finally, (vii) a group of undefined barriers[7]. Several control

[5] The total annual value added is calculated as follows: $S_i - (C_{RMi} + C_{IGi} + C_{Fi} + C_{Ei})$. C_{RMi} is the total annual costs for raw materials and C_{IGi} stands for the total annual costs for intermediate goods.

[6] $C_{variable\ inputs,i} = C_{RMi} + C_{IGi} + C_{Fi} + C_{Ei} + C_{Li}$. C_{Li} are the total annual labor costs.

[7] Undefined barriers define other types of barriers which cannot be grouped in defined categories.

variables are included in the analysis to account for other factors that affect firms' energy efficiency. To evaluate whether the presence of a board of directors within the company leads to implement energy efficiency projects, we consider a dummy variable taking the value 1 if the firm has a board of directors or a supervisory board, 0 otherwise. To investigate the impact of firm's ownership on the decision to implement energy efficiency measures, we consider two variables: a dummy variable taking a value equal to 1 if the firm has female owners, 0 otherwise and a variable that describes the degree of ownership concentration in family hands. The age of the firm is calculated as the difference between the year in which the survey was conducted and the year in which the firm started business. Other characteristics have also been considered: (i) size, an ordered variable that is equal to 1 for small firms (5-19 employees), 2 for medium firms (20–99 employees) and 3 for large firms (more than 100 employees); (ii) the geographical dimension of markets and (iii) whether the firm belongs to a group of firms (taking the value of 1) or it is an independent economic entity (taking 0). We also add a sector variable: firms are classified in three sectors: (i) manufacturing; (ii) retail services and (iii) other services. To check regional differences, we grouped our countries in five geographical regions (Baltic Countries, European Former-USSR Countries, Former Yugoslavian Countries and Albania, Eurasian Former-USSR Countries and Central European countries). Finally, to observe whether companies operating in EU member states are responsive to environmental issues, we use a categorial variable equal to 1 for companies operating in a country that does not join the EU, 2 for companies based in countries that belong to the EU and 3 for firms located in EU candidate countries. Table A2 in the Appendix contains the description of variables to account for factors that could affect the adoption of energy-efficient measures from firms. Table 1 reports the descriptive statistics.

Table 1. Descriptive statistics of variables

Variable	Obs	Proportion	Mean	Std. Err.	Std.Dev
Energy Efficiency$_1$	13,707		2.275		2.311
Energy Efficiency$_2$	13,540		2.123		2.257
Energy Efficiency$_3$	13,708		1.549		1.721
Lack of financial resources	9,338	0.131		0.003	
Lack of priority relative to other investments	9,338	0.560		0.005	
Not profitable	9,338	0.131		0.003	
Uncertainty about regulation	9,338	0.050		0.002	
Uncertainty about future prices	9,338	0.050		0.002	
Operational and/or technical risk	9,338	0.025		0.002	
Other Barriers	9,338	0.054		0.002	
Firm Dimension	16,807				

Small Firms		0.460		0.004	
Medium Firms		0.322		0.004	
Large Firms		0.218		0.003	
Sector activity					
Manufacturing	16,831	0.551		0.004	
Retail Services		0.171		0.003	
Other Services		0.278		0.003	
Firm's age	16,678		17.936		13.830
Affiliation	16,828	0.099		0.002	
Female Owner	16,681	0.341		0.004	
Owner Family	16,476		42.141		47.073
Board of Directors	16,774	0.274		0.003	
Export	16,831	0.132		0.003	
Country Regions	16,831				
European Former-USSR Countries		0.215		0.003	
Central European Countries		0.279		0.003	
Baltic Countries		0.064		0.002	
Former Yugoslavian Countries and Albania		0.160		0.003	
Eurasian Former- USSR Countries		0.282		0.003	
European Union	16,831				
EU Countries		0.391		0.004	
Candidate EU Countries		0.074		0.002	
Non-EU Countries		0.535		0.004	

Note: the energy efficiency indicators are in natural logarithmic form

3.Econometric specification and results

In the baseline analysis, we estimate the impact of barriers on energy efficiency using the following cross-sectional log-linear model reported in equation (1):

$$\log\left(EE_i^j\right) = \beta_0 + \beta_1' \boldsymbol{B}_i + \beta_2' \boldsymbol{X}_i + FS_i + C_i + \varepsilon_i \quad (1)$$

where:

- i corresponds to the firm's index, j is the energy efficiency index;
- EE_i^j is, in turn, one of the three energy efficiency indicators relative to annual sales, value added and annual input costs;
- $\boldsymbol{B}_i$ is a set of dummies that identify the seven barriers to energy efficiency (lack of financial resources, lack of priority relative to other investments, lack of profitability, regulation uncertainty, future price uncertainty, operational and technical risk, other barriers);
- $\boldsymbol{X}_i$ is a set of firm characteristics including dimension, age, the presence of female and family owner, the presence of a board of directors, and the level of export;
- FS_i is a dummy that identifies the firm's sector (manufacturing, retail service, other services);

- C_i is the country dummy, replaced by dummies of a group of countries as an alternative specification;
- ε_i is the idiosyncratic error component.

Since the impact of barriers on energy expenditures can be identified only for firms that report the presence of barriers and positive energy expenditure, the regression sample includes only this type of firms. As a result, the distribution of the dependent variable has a quasi-normal shape, and we can consistently estimate the beta coefficients using OLS estimator with robust standard errors. It is important to highlight that our goal is to estimate the correlation between barriers and energy expenditure, therefore our specification should not be affected by the sample selection, a problem that would be present, instead, if our goal would have been the estimation of the probability of facing barriers.

Finally, the log-linear specification allows us to interpret these coefficients in terms of semi elasticity giving us an estimate of the percentage variation of energy efficiency associated to the presence of each barrier. Table 2 collects the empirical results.

Table 2- Estimation results: Barriers and Energy Efficiency

VARIABLES	EE_1	EE_2	EE_3
Ref. Other Barriers			
Lack of financial resources	-0.496***	-0.489***	-0.346***
	[0.091]	[0.097]	[0.078]
Lack of priority relative to other investments	-0.116	-0.089	-0.167**
	[0.082]	[0.086]	[0.070]
Not profitable	-0.337***	-0.313***	-0.342***
	[0.094]	[0.099]	[0.080]
Uncertainty about regulation	-0.193*	-0.182	-0.312***
	[0.116]	[0.121]	[0.100]
Uncertainty about future prices	-0.164	-0.142	-0.229**
	[0.122]	[0.129]	[0.102]
Operational and/or technical risk	-0.261*	-0.332**	-0.224*
	[0.146]	[0.150]	[0.135]
Ref. Manufacturing sector			
Retail Service	0.671***	1.144***	-0.556***
	[0.049]	[0.051]	[0.042]
Other Service Activities	0.111**	0.580***	-0.843***
	[0.045]	[0.047]	[0.037]
Firm's Age	-0.002	-0.003*	-0.002
	[0.002]	[0.002]	[0.001]
Affiliation	0.016	0.013	-0.068
	[0.072]	[0.074]	[0.058]
Board of directors	0.147***	0.162***	0.086**
	[0.050]	[0.053]	[0.043]
Female Owner	-0.029	-0.033	0.051
	[0.040]	[0.042]	[0.034]
Ref. Small Firms			
Medium Firms	0.225***	0.221***	0.153***
	[0.041]	[0.043]	[0.035]
Large Firms	0.608***	0.619***	0.473***
	[0.062]	[0.064]	[0.053]
Owner Family	-0.002***	-0.002***	-0.001***
	[0.000]	[0.000]	[0.000]
International Market	0.075	0.132*	0.204***
	[0.068]	[0.071]	[0.057]
COUNTRY DUMMIES	YES	YES	YES
Constant	3.355***	2.946***	2.550***
	[0.136]	[0.142]	[0.106]
Observations	6,846	6,703	6,846

Standard errors in parentheses ***p<0.01, **p<0.05, *p<0.10

Specifically, findings in column 1 refer to the baseline model considering the energy efficiency indicator computed as the inverse of the ratio between the total annual energy expenditure and the value of total annual sales (EI_1). Columns 2 and 3 present the results obtained when we examine estimated energy efficiency as the inverse of the ratio of (i) fuel and electricity expenditures to annual value added (EI_2) and (ii) annual energy costs to total annual cost for variable inputs (EI_3). The main results confirm that all the barriers observed impact negatively on the decision to improve the firms' energy efficiency when we consider country fixed effect. Specifically, our findings show that some of these barriers as the lack of financial resources, non-profitable investment and the operational and/or technical risk connected to the improvement of energy efficiency are statistically significant for the three specifications although they differ in magnitude; in fact, the relationship is stronger for the first two barriers. This result is in line with most of the studies (Hochman and Timilsina, 2017; Trianni et al., 2013a; Trianni et al., 2013 b; Thollander and Ottoson, 2008; Sardianou, 2008; Thollander et al., 2007; Sorrel et al., 2004), although in the literature it does not appear to be a standard combination of main barriers. The existence of other priorities for firms and the uncertainty about future prices seems to be barriers only when we focus on the energy efficiency calculated as the inverse of the share of the annual energy costs on the total annual cost for variable inputs. While the uncertainty about energy regulation seems to be a barrier for the first and the third specification. Moving on to the industry sectors in which firms produce, we find that retail and service activities are more energy efficient with respect to manufacturing sectors when energy efficiency is computed for the sales and the value added. Turning to the firms' characteristics, the presence of a board of directors impacts positively on the firms' energy efficiency for the three specifications. This means that firms with a board of directors are more prone to adopt the EU directive on energy efficiency and this probably improves the competitiveness of firms specially on international markets. The variable that captures the international export propensity, in fact, is positively and significantly associated with the decision to adopt energy technologies. This positive correlation is statistically significant when we consider the variable costs and value-added measure. This probably reflects the need to export goods with competitive prices. To this end, a better production efficiency is required, which often means lower costs. Turning to the firm size, we find that medium

and large size firms with respect to small ones reveal a significant and positive impact on energy efficiency. This result is in line with the literature which states that larger firms promote energy efficiency (Hochman and Timilsina, 2017; Hrovatin et al., 2016; Kostka et al., 2013; Sardinanou, 2008) since they have more financial resources to invest in environmental measures (Leonidou et al., 2017). On the contrary, SMEs are less energy efficient due to capital constraints (Cagno et al., 2010) and it is also less profitable for small firms to spend on the environment (Darnall et al., 2010). Family-owned firms exhibit a negative association with energy efficiency. The plausible explanation is twofold: the external stakeholders are not involved in the management and governance of the firm and consequently, reputation and ethical pressures for green actions by external agents do not influence firm decisions (Zhu and Lu, 2020) or family-owned firms with a fragmented management responsibility have different investment priorities (Kostka et al., 2013).

Table 3. Estimation results: barriers to energy efficiency and countries

VARIABLES	EE_1		EE_2		EE_3	
Ref. Other barriers						
Lack of financial resources	-0.427***	-0.506***	-0.278***	-0.347***	-0.394***	-0.485***
	[0.094]	[0.095]	[0.080]	[0.081]	[0.100]	[0.101]
Lack of priority relative to other investments	-0.099	-0.159*	-0.103	-0.131*	-0.063	-0.129
	[0.085]	[0.086]	[0.071]	[0.072]	[0.089]	[0.090]
Not profitable	-0.261***	-0.331***	-0.305***	-0.320***	-0.233**	-0.301***
	[0.097]	[0.097]	[0.081]	[0.081]	[0.102]	[0.103]
Uncertainty about regulation	0.113	0.038	-0.170*	-0.194*	0.178	0.091
	[0.121]	[0.122]	[0.102]	[0.103]	[0.128]	[0.129]
Uncertainty about future prices	0.091	0.013	-0.134	-0.139	0.160	0.072
	[0.125]	[0.126]	[0.103]	[0.104]	[0.133]	[0.135]
Operational and/or technical risk	-0.091	-0.156	-0.070	-0.083	-0.151	-0.226
	[0.153]	[0.154]	[0.140]	[0.140]	[0.158]	[0.159]
Ref. Manufacturing Sector						
Retail Services	0.588***	0.623***	-0.617***	-0.605***	1.043***	1.084***
	[0.048]	[0.049]	[0.042]	[0.043]	[0.050]	[0.051]
Other Service Activities	0.017	0.056	-0.885***	-0.868***	0.470***	0.514***
	[0.046]	[0.046]	[0.038]	[0.038]	[0.048]	[0.049]
Firm's Age	-0.006***	-0.006***	-0.004***	-0.004***	-0.007***	-0.007***
	[0.002]	[0.002]	[0.001]	[0.001]	[0.002]	[0.002]
Affiliation	-0.139*	-0.142*	-0.172***	-0.176***	-0.164**	-0.164**
	[0.075]	[0.075]	[0.059]	[0.060]	[0.078]	[0.078]
Board of directors	0.072	0.128**	0.012	0.034	0.076	0.140***
	[0.050]	[0.052]	[0.043]	[0.044]	[0.053]	[0.054]
Female Owner	-0.046	-0.053	0.069**	0.054	-0.055	-0.065
	[0.041]	[0.041]	[0.035]	[0.035]	[0.043]	[0.043]
Ref. Small Firms						
Medium Firms	0.256***	0.260***	0.178***	0.173***	0.259***	0.263***
	[0.043]	[0.043]	[0.036]	[0.036]	[0.045]	[0.045]
Large Firms	0.741***	0.702***	0.558***	0.524***	0.777***	0.730***
	[0.066]	[0.066]	[0.056]	[0.056]	[0.070]	[0.069]
Owner Family	-0.004***	-0.003***	-0.003***	-0.002***	-0.004***	-0.003***
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
International Market	-0.067	-0.018	0.111**	0.140**	-0.033	0.023
	[0.067]	[0.068]	[0.056]	[0.058]	[0.071]	[0.072]
Ref. Central European Region						
Baltic Countries		-0.462***		-0.019		-0.526***
		[0.074]		[0.064]		[0.079]
European Former-USSR Countries		-0.315***		0.067		-0.333***
		[0.062]		[0.053]		[0.065]
Former Yugoslavian Countries and Albania		-0.585***		-0.385***		-0.622***
		[0.054]		[0.045]		[0.056]
Eurasian Former- USSR Countries		-0.564***		-0.340***		-0.658***
		[0.056]		[0.049]		[0.059]
Ref. EU countries						
Candidate EU countries	-0.765***		-0.673***		-0.785***	
	[0.064]		[0.051]		[0.068]	
Non-EU countries	-0.416***		-0.250***		-0.452***	
	[0.044]		[0.038]		[0.047]	
Constant	4.336***	4.403***	3.445***	3.396***	3.895***	3.988***
	[0.096]	[0.099]	[0.082]	[0.085]	[0.102]	[0.106]
Observations	6,846	6,846	6,846	6,846	6,703	6,703

Standard errors in parentheses ***p<0.01, **p<0.05, *p<0.10

Table 3 shows the empirical results. Columns 1, 3, and 5 present the findings obtained using information on the location of firms in EU member states, EU candidate states, or non-EU countries. Columns 2, 4 and 6 show the results of the model that includes the classification of the countries in five macro regions. In line with the previous evidence, lack of financial resources and non-profitable investments are the main barriers to firms' energy efficiency. Both obstacles negatively impact on the decision to improve the firms' energy efficiency for the three specifications, while the lack of priority relative to other investments appears to be a barrier only when we check at the regional level. Other results highlight that firms' age influences negatively the adoption of energy efficiency. In other words, the younger firms are more environmentally aware and are more inclined to adopt renewable energy technologies. Looking at the corporate affiliation variable, we find that it is negatively related to the decision to implement investments in energy efficiency. It probably depends on the headquarters that do not apply the same regulation on energy efficiency or on the EU directives in the branches. A board of directors is positively associated with the energy efficiency only when we group the countries into regions, whereas the presence of female owner influences positively the decision to improve energy efficiency only for Column 3. Results on firm size and sectors are confirmed, the only exception is represented by service activities which is not statistically significant when the energy efficiency indicator is calculated by using the annual total value of sales as the denominator. Considering the firms localized in EU candidate countries and non-EU countries with respect to firms in EU member states, findings exhibit a negative relation with the adoption of energy efficiency measures. Therefore, firms operating in EU areas have a higher awareness of energy saving and environmental protection and must comply with EU directives and targets. We also obtain the same results when focusing on macro areas. Taking the Central European countries as a reference, firms in this area are more inclined to implement strategies to increase energy efficiency than the other four regional areas since the countries belonging to this region are already applying guidelines in compliance with European standards. In particular, the former Yugoslavian Countries and Albania and Eurasian Former - USSR Countries results show a lack of firms' strategies directed at the increase in the energy efficiency and therefore a poor implementation of

energy saving policies if compared to Central European countries. In fact, in these areas the application of environmental strategies is not influenced by EU standards (Biscione et al., 2021). In addition, the environmental awareness is low, and lack a specific economic policy (Hockman and Timilsina, 2017).

4.Alternative estimations

To further study the relationship between energy efficiency and the presence of potential barriers we investigate the presence of heterogeneous effects considering two dimensions. For the first dimension of analysis, as reported in equation (2), we interact each barrier with a dummy that identifies the type of country considering three groups: EU countries, potential EU candidates, non-EU countries.

$$\log\left(EE_i^j\right) = \gamma_0 + B_i^k\left(\gamma_1^k + \gamma_2^k C_i\right) + \gamma_3' \boldsymbol{X}_i + FS_i + \epsilon_i \qquad (2)$$

In equation (2) C_i is a dummy that identifies a specific group of countries, and the model is estimated separately for each barrier B^k and for each energy efficiency indicator Y^j.
For the second dimension, as reported in equation (3), we interact each barrier with the sectors dummies.

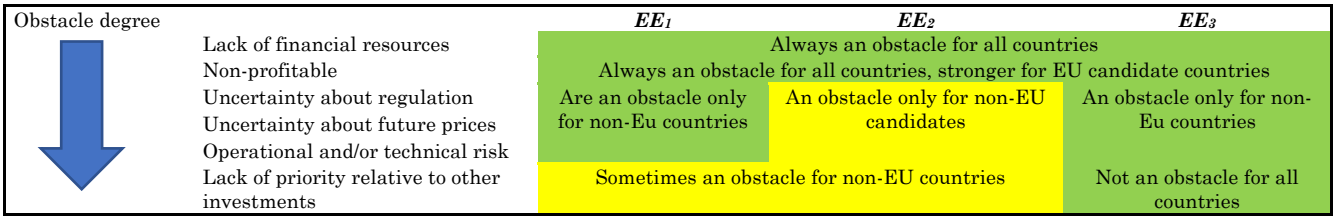
$$\log\left(EE_i^j\right) = \delta_0 + B_i^k\left(\delta_1^k + \delta_2^k FS_i\right) + \delta_3' \boldsymbol{X}_i + C_i + \epsilon_i \qquad (3)$$

In equation (3) FS_i is a dummy that identifies a specific sector, and the model is estimated separately for each barrier B^k and for each energy efficiency indicator EE^j. The main coefficients of interest are the β_1' vector and, for each barrier k, γ_2^k and δ_2^k. Tables A.3 and A.4 in Appendix report the findings. For the sake of readability, coefficients of other variables used are not shown. Figures below provide a quantitative overview of the results obtained from the interactions considering both the classification of countries and industry

sectors[8]. In particular, figures give in declining order all information on the obstacle degree to energy efficiency.

Considering the first interactions (see Figure 1), the main findings confirm those obtained by the baseline estimation. The lack of financial resources and the absence of profitability seem to appear barriers for all considered countries. More specifically the absence of profitability starts being stronger for non-EU countries. Moving on to the uncertainty about regulation and future price, findings reveal that they are never an obstacle for both EU countries and EU candidate countries. On the contrary, these barriers hinder energy efficiency measures for companies operating in non-EU countries. This result can be explained considering that EU countries and candidates have a well-defined set of regulations to comply with differently from non-EU countries. While future energy price is an uncertain component of the investment profitability and probably it is perceived as a high risk since subject to large fluctuations (Sardianou, 2008; Zilahy, 2004; Velthuijsen, 1993) specially in non-EU countries. Results also show that a barrier only for non-EU countries is operational and/or technical risk that hinders energy efficiency measures. At last, the barrier relative to the lack of priority is sometimes an obstacle for non-EU countries.

Figure 1. Obstacle degree to energy efficiency in EU, non-EU and EU candidate countries



Given that part of the existing literature (Sardianou, 2008; Schleich, 2009; Schleich and Gruber, 2008) states that barriers to energy efficiency have different effects on companies operating in different sectors, we consider the interaction between barriers and sectors to study the obstacle degree to energy efficiency (see Figure 2).

[8] In both figures we use two colors to identify the sharpness of the results. Specifically, the green color is used to define net results, on the contrary the yellow is employed to show more nuanced findings.

Figure 2. Obstacle degree to energy efficiency in industry sectors

Obstacle degree	Manufacturing	Other services	Retail services
Lack of financial resources	Barrier for all services		
Lack of priority relative to other investments	Not a barrier for any sector		
Non-profitable	A barrier for manufacturing industry		
Uncertainty about regulation	Does not seem to be a barrier		Weak barrier
Uncertainty about future prices	Does not seem to be a barrier		Weak barrier
Operational and/or technical risk	Not a barrier	Does not seem to be a barrier	

Results show that among the considered barriers, there is no well-defined effect on industry sectors. This result probably derives from the different specific regulation for each sector (Hrovatin et al., 2016), anyway this regulation must be better applied in the countries considered. The uncertainty about both regulation and future prices seems to be a weak barrier for the retail sector. While operational and/or technical risk does not seem to be an obstacle only for the manufacturing sector. However, findings related to the lack of capital and the absence of priority relative to other investments support the results obtained by the baseline model.

5.Conclusions

The purpose of this study was to investigate how barriers influence energy efficiency of firms in 28 Transition countries by using firm-level data drawn from the World Bank's Enterprise Surveys conducted between 2018 and 2020. We have employed an ordinary least square estimator to analyze the different effect of barriers on firms' energy efficiency measured as the inverse of energy intensity, the latter computed using three different specifications. Depending on the energy efficiency indicator considered, the results may differ, although some main barriers appear homogeneous: (i) the lack of finance resources and (ii) the absence of profitability. This evidence is consistent with some previous research in which emerges that the lack of budget funding represents one of the most relevant obstacles to energy efficiency. These main findings are confirmed also when we interact barriers with the country area and the industry sectors.

Our results should be interpreted with some a priori limitations. These relate mainly to the generalizability of the results, given that our analysis comes from a survey performed

over a short period of time. Indeed, we employ cross-sectional data, so nothing can be said on causality. Further future research performed exploiting panel data could provide us information about the direction of causality. The second limitation is related to industry sectors analysis since these barriers depend on the specific sub-sector and industry characteristics. Therefore, further research should be performed for each barrier category and each sector to better explain the energy efficiency deployment.

Nevertheless, from our findings it is possible to draw some suggestion for policy makers. First, institutions have the task of synchronizing national energy policy with the guidelines of EU energy policy. Then, they should develop a set of strategies to attract direct foreign investment in the country and energy sector that needs coordination and cooperation of all stakeholders belonging to the energy market. Thus, government should provide proactive measures to implement the transparency mechanisms of financial reporting in the energy sector and develop the national reporting system on green investment increasing the green investors' trust and attracting additional financial resources to green technologies from the worldwide organization.

Second, policymakers should design different policies depending on the profitability of energy efficiency. If adoption of energy efficiency measures is profitable, a package of non-mandatory policies such as information programs and specific financial subsidies and incentives may be useful for smaller and owned family firms that do not invest in energy efficiency. Conversely, if implementation of these measures is more expensive, it is necessary to have a policy package containing strict regulations.

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Appendix

Table A.1. Energy efficiency barriers in the literature

Area/Barriers	Blumstein et al. (1980)	Weber (1997)	Sorrel et al., (2000; 2004; 2010)	Cagno et al. (2013)	Rohadin and Thllander (2006)	Sardianou (2008)	Schleich (2009)	Trianni et al. (2013a)	Trianni et al. (2013b)	Hochman and Timilsina (2017)	Haraldsson and Johansson (2019)
					Non-energy industry in Sweden	Six sectors in Greece*	Service sectors in Germany	Manufacturing in Italy	Foundry sector in some EU countries	Commercial and manufacturing in Ukraine	Aluminum industry in Sweden
Theoretical analysis	X	X	X	X							
Descriptive analysis					X			X	X	X	X
Econometric model						X	X				
Social	X										
Organizational											
Lack of power and/or influence by people in charge of energy management			X								
Behavioral			X								
Values			X								
Bounded rationality			X								
Credibility and trust			X								
Economic			X								
Imperfect information			X								
Adverse selection			X								
Split incentives			X								
Principal-agent relationship			X								
Heterogeneity			X								
External				X							
Market		X		X							
Energy prices distortion				X							
Low diffusion of technologies				X							
Low diffusion of information			X	X			X				
Market risks			X	X							X
Difficulty in Gathering External Skills				X							
Government	X	X		X							
Lack of proper regulation				X						X	
Distortion in fiscal policies				X							
Technology/Services Suppliers				X							
Lack of interest in energy efficiency				X							
Technology Suppliers not updated				X							
Scarce communication skills				X							
Designers and manufactures				X							
Technical Characteristics not adequate				X							
High initial costs				X	X						X
Energy suppliers				X							
Scarce communication skills				X							
Distortion in energy policies				X							
Lack of interest in energy efficiency				X							
Capital suppliers				X							
Cost for investing capital availability				X							
Difficulty in identifying the quality of the investments				X							

Continue to the next page

Area/Barriers	Blumstein et al. (1980)	Weber (1997)	Sorrel et al., (2000; 2004; 2010)	Cagno et al. (2013)	Rohadin and Thllander (2006)	Sardianou (2008)	Schleich (2009)	Trianni et al. (2013a)	Trianni et al. (2013b)	Hochman and Timilsina (2017)	Haraldsson and Johansson (2019)
					Non-energy industry in Sweden	Six sectors in Greece*	Service sectors in Germany	Manufacturing in Italy	Foundry sector in some EU countries	Commercial and manufacturing in Ukraine	Aluminum industry in Sweden
Internal				X							
Economic			X	X						X	
Low capital availability			X	X		X			X	X	
Hidden costs			X	X							
Intervention-related risks				X							
Behavioral		X	X	X							
Lack of interest in energy-efficiency			X	X				X			
Other priorities				X					X		
Inertia			X	X							
Imperfect evaluation criteria				X							
Lack of sharing the objectives				X							
Organizational		X	X	X							
Low status of energy efficiency				X							
Divergent interests				X							
Complex decision chain				X							
Lack of time				X	X		X				
Lack of internal control				X							
Barriers related to competences				X							
Identifying the inefficiencies				X							
Implementing the interventions				X							
Awareness				X							
Lack of awareness				X		X					
Others											
Business needs						X					
Lack of energy efficiency measures							X				
Change in organization routine											X

*Metals, machinery, Foodland beverages, chemicals, paper and textile sectors

Table A.2. Description of variables

Variable	Description
Energy Efficiency$_1$	Inverse of the ratio between the total annual energy expenditure and the value of total annual sales
Energy Efficiency$_2$	Inverse of the ratio between the total annual energy expenditure and the annual value added
Energy Efficiency$_3$	Inverse of the ration between the annual energy expenditure and the total annual cost for variable inputs
Lack of financial resources	1 if the lack of financial resources is a barrier to energy efficiency, 0 otherwise
Lack a priority relative to other investments	1 if the not a priority relative to other investments is a barrier to energy efficiency, 0 otherwise
Not profitable	1 if the not profitable is a barrier to energy efficiency, 0 otherwise
Uncertainty about regulation	1 if the uncertainty about regulation is a barrier to energy efficiency, 0 otherwise
Uncertainty about future prices	1 if the uncertainty about future prices is a barrier to energy efficiency, 0 otherwise
Operational and/or technical risk	1 if the operational and/or technical risk is a barrier to energy efficiency, 0 otherwise
Other Barriers	1 if the undefined barriers obstacle energy efficiency, 0 otherwise
Firm Dimension	
Small Firms	1 if a firm has >=5 and <=19 employees
Medium Firms	2 if a firm has >=20 and <=99 employees
Large Firms	3 if a firm has >=100 employees
Sector activity	
Manufacturing	1 if a firm is a part of manufacturing sector
Retail Services	2 if a firm is a part of retail services sector
Other Services	3 if a firm is a part of other services sector
Firm's Age	Difference between the current year and the year the firm registers to start the business activity
Female Owner	1 if the firm has female owners, 0 if firm ownership is exclusively male
Owner Family	Percentage of the firm is owned by the same family
Board Director	1 if the firm has a board directors or supervisory board, 0 otherwise
Export	1 if the firm has a board directors or supervisory board, 0 otherwise
Country Regions	
European Former-USSR Countries	1 for European Former-USSR Countries
Central European Countries	2 for Central European Countries
Baltic Countries	3 for Baltic Countries
Former Yugoslavian Countries and Albania	4 for Former Yugoslavian Countries and Albania
Eurasian Former- USSR Countries	5 for Eurasian Former- USSR Countries
European Union	
Non-EU Countries	0 for non-EU countries
EU Countries	1 for EU countries
Candidate EU Countries	2 for EU candidate countries

Table A.3. Interaction barriers countries

VARIABLES	EE_1	EE_1	EE_1	EE_1	EE_1	EE1	EE_2	EE_2	EE_2	EE_2	EE_2	EE_2	EE_3	EE_3	EE_3	EE_3	EE_3	EE_3
Lack of financial resources	-0.237***						-0.226**						-0.149**					
	[0.087]						[0.092]						[0.073]					
Not a priority relative to other investments		0.017						0.024						0.089**				
		[0.041]						[0.043]						[0.035]				
Not profitable			-0.195***						-0.204***						-0.197***			
			[0.058]						[0.062]						[0.049]			
Uncertainty about regulation				0.233**						0.265***						-0.029		
				[0.092]						[0.098]						[0.078]		
Uncertainty about future prices					0.212**						0.247**						0.010	
					[0.098]						[0.105]						[0.080]	
Operational and/or technical risk						0.017						-0.082						0.074
						[0.130]												[0.123]
Ref. EU countries																		
Candidate EU countries	-0.772***	-0.749***	-0.738***	-0.739***	-0.740***	-0.745***	-0.808***	-0.787***	-0.776***	-0.775***	-0.777***	-0.786***	-0.668***	-0.667***	-0.644***	-0.652***	-0.651***	-0.649***
	[0.068]	[0.068]	[0.068]	[0.067]	[0.068]	[0.068]	[0.073]	[0.072]	[0.072]	[0.072]	[0.072]	[0.072]	[0.054]	[0.053]	[0.053]	[0.053]	[0.053]	[0.053]
Non-Eu Countries	-0.417***	-0.389***	-0.365***	-0.387***	-0.386***	-0.389***	-0.445***	-0.420***	-0.395***	-0.417***	-0.417***	-0.421***	-0.271***	-0.254***	-0.229***	-0.253***	-0.253***	-0.252***
	[0.047]	[0.046]	[0.047]	[0.045]	[0.046]	[0.046]	[0.049]	[0.048]	[0.049]	[0.048]	[0.048]	[0.048]	[0.040]	[0.039]	[0.040]	[0.039]	[0.039]	[0.040]
Lack of financial resources*Candidate EU countries	-0.094						0.070						-0.081					
	[0.193]						[0.201]						[0.156]					
Lack of financial resources*Non-Eu Countries	-0.161						-0.208*						0.023					
	[0.112]						[0.120]						[0.098]					
Not a priority relative to other investments *Candidate EU countries		-0.316*						-0.137						-0.161				
		[0.176]						[0.182]						[0.141]				
Not a priority relative to other investments*Non-Eu Countries		-0.387***						-0.420***						-0.073				
		[0.075]						[0.081]						[0.069]				
Not profitable*Candidate EU countries			-0.352**						-0.178						-0.252*			
			[0.173]						[0.179]						[0.139]			
Not profitable*Non-Eu Countries			-0.438***						-0.476***						-0.167**			
			[0.072]						[0.078]						[0.067]			
Uncertainty about regulation *Candidate EU countries				-0.322*						-0.147						-0.230*		
				[0.173]						[0.179]						[0.139]		
Uncertainty about regulation *Non-Eu Countries				-0.383***						-0.417***						-0.127*		
				[0.071]						[0.077]						[0.066]		
Uncertainty about future prices *Candidate EU countries					-0.322*						-0.146						-0.229*	
					[0.173]						[0.179]						[0.139]	
Uncertainty about future prices *Non-Eu Countries					-0.384***						-0.419***						-0.125*	
					[0.071]						[0.077]						[0.066]	
Operational and/or technical risk*Candidate EU countries						-0.330*						-0.156						-0.229*
						[0.173]						[0.179]						[0.139]
Operational and/or technical risk*Non-Eu Countries						-0.396***						-0.436***						-0.123*
						[0.071]						[0.077]						[0.066]
Constant	4.243***	4.205***	4.237***	4.195***	4.197***	4.213***	3.833***	3.794***	3.831***	3.785***	3.786***	3.810***	3.312***	3.248***	3.317***	3.296***	3.293***	3.290***
	[0.058]	[0.062]	[0.057]	[0.057]	[0.057]	[0.057]	[0.062]	[0.067]	[0.062]	[0.062]	[0.061]	[0.062]	[0.050]	[0.053]	[0.049]	[0.049]	[0.049]	[0.049]
Observations	6,846	6,846	6,846	6,846	6,846	6,846	6,703	6,703	6,703	6,703	6,703	6,703	6,846	6,846	6,846	6,846	6,846	6,846

Standard errors in parentheses ***p<0.01, **p<0.05, *p<0.10

Table A.4. Interaction barriers sectors activities

VARIABLES	EE_1	EE_1	EE_1	EE_1	EE_1	EE_1	EE_2	EE_2	EE_2	EE_2	EE_2	EE_2	EE_3	EE_3	EE_3	EE_3	EE_3	EE_3
Lack of financial resources	-0.341***						-0.335***						-0.194***					
	[0.069]						[0.077]						[0.065]					
Not a priority relative to other investments		0.057						0.049						0.178***				
		[0.054]						[0.058]						[0.049]				
Not profitable			-0.212***						-0.253***						-0.246***			
			[0.078]						[0.087]						[0.068]			
Uncertainty about regulation				0.433***						0.523***						-0.043		
				[0.118]						[0.129]						[0.111]		
Uncertainty about future prices					0.334***						0.413***						0.068	
					[0.120]						[0.131]						[0.104]	
Operational and/or technical risk						0.351*						0.233						0.282
						[0.189]						[0.193]						[0.191]
Ref. EU countries																		
Retail Services	0.568***	0.554***	0.543***	0.619***	0.608***	0.605***	1.025***	0.997***	0.988***	1.079***	1.069***	1.056***	-0.629***	-0.543***	-0.644***	-0.612***	-0.595***	-0.596***
	[0.052]	[0.074]	[0.052]	[0.049]	[0.049]	[0.049]	[0.054]	[0.077]	[0.054]	[0.051]	[0.051]	[0.051]	[0.046]	[0.063]	[0.046]	[0.043]	[0.043]	[0.043]
Other Service Activities	0.022	-0.011	0.017	0.050	0.054	0.052	0.475***	0.423***	0.458***	0.507***	0.511***	0.501***	-0.882***	-0.789***	-0.883***	-0.865***	-0.860***	-0.850***
	[0.049]	[0.070]	[0.049]	[0.047]	[0.047]	[0.046]	[0.052]	[0.074]	[0.052]	[0.049]	[0.049]	[0.049]	[0.041]	[0.058]	[0.041]	[0.039]	[0.039]	[0.038]
Lack of financial resources*other services	-0.039						-0.061						0.102					
	[0.131]						[0.139]						[0.110]					
Lack of financial resources*retail services	0.100						0.089						0.131					
	[0.130]						[0.137]						[0.118]					
Not a priority relative to other investments *other services		0.061						0.089						-0.151**				
		[0.091]						[0.096]						[0.075]				
Not a priority relative to other investments *retail service		0.051						0.071						-0.136*				
		[0.095]						[0.099]						[0.082]				
Not profitable*other services			-0.212***						0.124						0.089			
			[0.078]						[0.145]						[0.114]			
Not profitable*retail services			-0.212***						0.372***						0.242**			
			[0.078]						[0.142]						[0.116]			
Uncertainty about regulation *other services				-0.272						-0.393*						0.039		
				[0.223]						[0.234]						[0.179]		
Uncertainty about regulation *retail services				-0.572**						-0.699***						0.094		
				[0.237]						[0.249]						[0.193]		
Uncertainty about future prices *other services					-0.293						-0.425*						-0.021	
					[0.224]						[0.237]						[0.189]	
Uncertainty about future prices *retail services					-0.222						-0.325						-0.326*	
					[0.326]						[0.333]						[0.198]	
Operational and/or technical risk*other services						-0.746***						-0.712**						-0.456*
						[0.286]						[0.299]						[0.254]
Operational and/or technical risk*retail services						-0.687***						-0.593**						-0.477*
						[0.262]						[0.268]						[0.261]
Constant	4.257***	4.189***	4.250***	4.186***	4.193***	4.210***	3.849***	3.787***	3.850***	3.773***	3.781***	3.809***	3.318***	3.204***	3.329***	3.298***	3.290***	3.286***
	[0.058]	[0.065]	[0.058]	[0.057]	[0.057]	[0.058]	[0.062]	[0.071]	[0.062]	[0.062]	[0.062]	[0.062]	[0.050]	[0.056]	[0.050]	[0.049]	[0.049]	[0.049]
Observations	6,846	6,846	6,846	6,846	6,846	6,846	6,703	6,703	6,703	6,703	6,703	6,703	6,846	6,846	6,846	6,846	6,846	6,846

Standard errors in parentheses ***p<0.01, **p<0.05, *p<0.10