ORIGINAL SCIENTIFIC PAPER
UDK: 330.341:330.322(4-12)"2017/2018"
005.336.1:620.9
339.54:061.1(4)"2006"
DOI: 10.5937/EKOPRE2502135K
Date of Receipt: November 13, 2024

Radovan Kastratović
University of Belgrade
Faculty of Economics and Business
Department of International Economic Relations

Dragan Lončar
University of Belgrade
Faculty of Economics and Business
Department of Business Economics and Management

DOES FOREIGN DIRECT INVESTMENT IMPROVE ENERGY EFFICIENCY? FIRM-LEVEL EVIDENCE FROM CEFTA 2006 ECONOMIES

Da li strane direktne investicije doprinose unapređenju energetske efikasnosti? Rezultati analize na nivou preduzeća iz privreda članica CEFTA 2006 sporazuma

Abstract

This study examines the impact of foreign direct investment on firm-level energy efficiency in CEFTA 2006 economies. Using firm-level data from 2,241 firms across seven CEFTA 2006 economies for the period 2017–2018, we employ propensity score matching to estimate the effect of foreign direct investment on energy intensity. Our findings indicate that foreign direct investment reduces firm-level energy intensity by between 1.67 and 1.89 percent points, representing approximately half of the mean energy intensity value for the entire sample. This suggests that foreign ownership and investment contribute to energy efficiency improvements, potentially through technology and knowledge transfers, which improves productivity. However, the magnitude and the statistical significance of the effect varies across countries, with stronger improvements observed in the firms operating in economies with higher energy self-sufficiency and lower reliance on fossil fuels, highlighting the role of broader energy market structures and environmental and energy policies in mediating the effects of foreign direct investment. We further explore the role of other internationalization factors, finding no significant impact of exporting and reliance on foreign-produced inputs on energy efficiency.

Keywords: *foreign direct investment (FDI), energy efficiency, energy intensity, foreign ownership, productivity, technology transfer, multinational enterprise (MNE), propensity score matching (PSM)*

Sažetak

U ovom radu istražen je uticaj stranih direktnih investicija na energetsku efikasnost firmi u privredama članicama sporazuma CEFTA 2006. Korišćenjem podataka na mikro nivou iz 2.241 preduzeća iz sedam privreda CEFTA 2006 integracije, koje se odnose na 2017. i 2018. godinu, primenili smo metodu sklonosti učešća u tretmanu, kako bismo ocenili uticaj stranih direktnih investicija na energetsku intenzivnost. Naši nalazi ukazuju na to da realizacije stranih direktnih investicija smanjuju energetsku intenzivnost posmatranih preduzeća za između 1.67 i 1.89 procentna poena, što predstavlja približno polovinu prosečne vrednosti energetske intenzivnosti svih preduzeća u uzorku. Ovakvi rezultati ukazuju na zaključak da strano vlasništvo i strane investicije doprinose poboljšanju energetske efikasnosti preduzeća u regionu putem transfera tehnologije i znanja, čime se unapređuje produktivnost preduzeća. Međutim, jačina i statistička značajnost ovih efekata varira između privreda unutar regiona, pri čemu su najjači efekti utvrđeni u slučaju preduzeća koja posluju u privredama koje karakteriše visok stepen energetske samodovoljnosti i relativno niske upotrebe fosilnih goriva. Ovakvi rezultati ističu značaj uloge širih struktura energetskih tržišta, kao i energetskih politika i politika zaštite životne sredine koji utiču na intenzitet efekata stranih direktnih investicija. Osim pomenutog, u radu je razmotrena i uloga drugih faktora internacionalizacije u unapređenju energetske efikasnosti, pri čemu nisu utvrđeni statistički značajni efekti izvoza niti korišćenja stranih inputa u proizvodnim procesima na energetsku efikasnost.

Ključne reči: *strane direktne investicije (SDI), energetska efikasnost, energetska intenzivnost, strano vlasništvo, produktivnost, transfer tehnologije, multinacionalne kompanije (MNK), metoda sklonosti ka učešću u tretmanu (PSM)*

Introduction

Energy efficiency is an important issue in contemporary economic and environmental policy literature [2; 21; 44; 58]. The economic activity of firms accounts for the largest share in global energy consumption [22; 28], making their energy efficiency strategies pivotal in addressing both economic and environmental challenges. The use of energy in industrial production significantly contributes to greenhouse gas emissions, which are the primary drivers of climate change, rising global temperatures, and increasingly extreme weather conditions [5; 35]. Understanding and improving energy efficiency at the firm level presents a pathway to mitigating these negative effects and reducing industrial carbon footprints while maintaining economic productivity.

In addition to environmental concerns, energy efficiency is a key determinant of firm competitiveness, particularly in economies with scarce energy resources [8]. This is especially relevant in the CEFTA 2006 region, where energy dependence presents a structural vulnerability [32; 51; 53], making energy efficiency a strategic necessity for firms aiming to build resilience against external shocks in the global economy. By improving energy efficiency, risks arising from fluctuations in global energy markets and disruptions in global value chains can be mitigated [14]Ahmed</author><author>Al-Muhtaseb, Shaheen</author></authors></contributors><titles><title>Climate Change and Energy Security: A Comparative Analysis of the Role of Energy Policies in Advancing Environmental Sustainability</title><secondary-title>Energies</secondary-title></titles><periodical><full-title>Energies</full-title></periodical><volume>17</volume><number>13</number><keywords><keyword>renewable energy policies</keyword><keyword>climate change mitigation</keyword><keyword>energy security</keyword><keyword>energy equity</keyword><keyword>environmental sustainability</keyword><keyword>World Energy Trilemma Index (WETI. Additionally, the evolving regulatory landscape, including the European Union's Carbon Border Adjustment Mechanism, underscores the urgency for its trading partners to align with stricter energy and environmental standards to remain competitive in international markets [47; 55], and to adequately implement complementing trade facilitation measures, which is particularly important for small and medium enterprises in the integration [52]. Understanding the determinants of firm-level energy efficiency is therefore crucial for policymakers and business leaders alike.

The CEFTA 2006 economies provide a particularly compelling context for examining the internationalization-related drivers of firm-level energy efficiency. These economies, still undergoing economic transition, occupy a strategically important position in Europe, serving as both manufacturing hubs and logistical gateways between the European Union and emerging markets. Their relatively open economies have attracted substantial inflows of foreign direct investment, which has been a key driver of economic growth and structural transformation [30; 37; 48; 49]. However, while much of the discussion surrounding foreign direct investment in the region has centered on its contributions to employment, productivity, and trade [11; 20; 29; 41], its environmental consequences—including its precursors such as the impact on energy efficiency—have received comparatively less attention.

Foreign direct investment is often regarded as an important channel for technology diffusion which has the potential to improve firm-level energy efficiency [4; 13; 39]. However, its actual impact depends on the nature and motivations of foreign investment as well as the circumstances of the host country. If FDI inflows are driven primarily by lax environmental regulations and lower energy costs, foreign-owned firms may adopt energy-intensive production techniques that exacerbate energy consumption—an argument consistent with the pollution haven hypothesis [7; 43]. Conversely, multinational enterprises typically operate with more efficient technologies that enable them to compete with domestic firms [9; 31]. It is likely that such technology will be transferred through the channels of the system of multinational enterprises in order to support the competitiveness of foreign affiliates. Thereby, with increased investment in such affiliates, comes a greater extent of control and internalization of such technology transfers [13], which should result in more efficient usage of resources, including energy. Such process mirrors the idea of the pollution halo hypothesis [56], as

foreign-owned affiliates may outperform domestic firms in environmental performance and energy efficiency due to their superior technological endowments.

The existing literature on the effects of foreign direct investment on firm-level energy efficiency remains scarce and inconclusive. While some studies identify clear energy efficiency gains from foreign investment [5; 24; 59], others find limited or no impact [6; 10], and the mechanisms through which foreign direct investment influences energy efficiency remain insufficiently explored. The existing empirical evidence is also based only on individual country case studies, particularly China and other large emerging economies, with relatively few firm-level analyses conducted in transition economies such as those in the CEFTA 2006 region.

This research aims to address this gap by providing firm-level empirical evidence on the effects of foreign direct investment on energy intensity in CEFTA 2006 economies, shedding light on the extent to which foreign ownership contributes to energy efficiency improvements and the conditions under which these effects are most pronounced. Thereby, we contribute to the existing literature in several key aspects. To the best of our knowledge, this is the first study to examine the effects of foreign direct investment on firm-level energy efficiency in a multi-country, as well as the first one to consider these effects in the CEFTA 2006 region. This cross-country perspective allows us to isolate the effects of foreign direct investment from the specific environmental and energy policies of individual economies, offering a more precise estimation of the efficiency effect and providing insight into how circumstances of individual economies modulate it. Furthermore, our study is among the first to analyze firms from transition economies, a context where the relationship between foreign direct investment and energy efficiency remains largely unexplored.

Another key contribution of this study is its micro-level approach, which remains relatively rare in studies on foreign direct investment and energy efficiency. While macroeconomic analyses capture broad effects of foreign direct investment on energy efficiency, they abstract the firm-specific mechanisms through which these impacts effectuate. By focusing on firm-level data, we identify individual causal pathway, shedding light on how foreign direct investment contributes to energy efficiency improvements through technology transfers between parent company and its affiliates. Additionally, our study contributes to the existing literature by employing propensity score matching to explicitly account for the selection of firms into foreign ownership, following the approach of Brucal, Javorcik, and Love [5]. This allows us to establish a causal relationship between foreign direct investment and firm-level energy intensity, rather than merely identifying correlations.

The aim of this study is to analyze how foreign ownership affects firm-level energy efficiency in CEFTA 2006 economies. We first develop a simple theoretical model describing the firm-level mechanism of foreign direct investment effects on energy intensity and deriving our main hypothesis – that foreign direct investment has a significant negative effect on energy intensity. We then expand our model with other relevant control variables and test it empirically. Beyond foreign ownership, we empirically examine additional internationalization factors that could contribute to improvements in firm-level energy efficiency, including exporting and the reliance on foreign-produced inputs. Finally, by considering other theoretically relevant determinants of energy efficiency, this study provides valuable implications for policymakers, relevant for enhancing energy efficiency of the economy through bottom-up approaches, leveraging foreign direct investment and technological modernization of firms.

Our empirical analysis is based on a firm-level dataset referring to the period 2017–2018, covering 2,241 firms from all seven CEFTA 2006 economies. To robustly test our hypothesis and estimate the effects of foreign direct investment on energy efficiency, we apply propensity score matching, allowing us to control for confounding factors that affect both indigenous domestic firms and foreign-owned affiliates. The results of our estimation support our initial hypothesis.

The remainder of this paper is structured as follows. Section 2 provides a literature review of theoretical and empirical studies investigating the effects of foreign direct investment on energy efficiency using various units of analysis. Section 3 presents the theoretical framework

from which our initial hypothesis is derived. Section 4 describes the data and methodology. Section 5 presents the empirical results and discusses the estimated effects of foreign direct investment on firm-level energy intensity and their regional heterogeneity. The final section concludes.

Literature Review

Numerous studies consider environmental effects of foreign direct investment [12; 35; 46; 50]. Based on their results, these studies can broadly be grouped into two categories: those supporting pollution haven hypothesis and those supporting pollution haven hypothesis [43; 56]. The effect of foreign direct investment on energy efficiency is a related topic to this body of literature. However, this issue has been less explored than the effects of foreign direct investment on emissions and pollution.

Theoretical frameworks directly concerned with foreign direct investment effects on energy efficiency are also somewhat limited. One relevant theoretical framework for this issue is proposed by Imbruno, Lo Turco and Maggioni [26], which shows that presence of foreign firms in upstream manufacturing and energy industries expands the supply of inputs for downstream domestic firms, which negatively affects their energy intensity. The conclusion is supported by the empirical analysis conducted by the same authors, based on Turkish manufacturing sector observed in the period between 2010 and 2015. Building upon foundations laid by Krugman [42] and Ethier [16], Imbruno and Ketterer [25] define another theoretical model which postulates that the influx of diverse material inputs improves firm-level productivity by improving complementarity of production materials. The increased productivity enables firms to maintain output levels, while decreasing the use of inputs, such as energy. As a results, energy intensity of production decreases.

The empirical literature on the effects of foreign direct investment on energy efficiency is similarly scarce. The existing studies can be categorized into macro-, meso-, and micro-level studies. Macro-level studies observe country-level flows of foreign direct investment on energy efficiency [24]. Meso-level empirical studies are mainly concerned with cities A notable example of such study is Elliot, Su and Chen [15], who observed 206 cities in China between 2005 and 2008, and finding that foreign direct investment reduces city-level energy intensity. Thereby, the authors reported considerable regional heterogeneity of the energy efficiency effects.

Finally, micro-level empirical studies observe individual firms in trying to discern effects of foreign investment on energy efficiency [19; 25; 59]. The effects of other internationalization aspects, including sourcing from foreign suppliers [26], exports [19] and foreign training [10] are simultaneously considered.

One of the most closely related studies, conducted by Zhou et al. [59], investigates the effects of foreign ownership on firm-level energy efficiency in China using cross-sectional survey data from 2007 to 2011. Their findings suggest that foreign ownership decreases firm-level energy intensity by approximately 0.23% to 0.60%. Expanding on this, Gao and Ren [19] emphasize the role of regional and sectoral heterogeneity in modulating the impact of foreign investment on energy efficiency. Their study, based on the same dataset as Zhou et al., identifies that technology-intensive industries benefit the most from foreign investment in terms of energy efficiency gains. Additionally, they highlight that exports serve as a significant channel for energy efficiency improvements, finding that firms engaged in exporting experience an energy intensity reduction of 0.11% to 0.16%. Similarly, Bu et al. provide further evidence for efficiency gains by examining the effects of foreign ownership across different industry types in China. Their findings indicate that foreign ownership reduces energy intensity by 1.5% to 1.9% in capital-intensive industries, whereas no significant effects are observed in labor-intensive ones. These results underscore the importance of absorptive capacity, suggesting that industries with greater technological sophistication are better positioned to benefit from the efficiency-enhancing effects of foreign direct investment. Similar positive effects of foreign investment on energy efficiency have been documented in the Chinese service sector by Huang, Lin, and He [23], who find that foreign ownership leads to energy efficiency improvements.

Beyond China, Cole, Elliott, and Strobl [10] analyze the case of Ghana and find that foreign ownership does

not significantly impact total firm-level energy usage. However, their research reveals an interesting shift in the composition of energy consumption, with foreign-owned firms showing a greater reliance on electricity over fuel, which is considered a cleaner energy source in the context of their study.

Further supporting the notion that foreign involvement improves firm-level energy efficiency, Brucal, Javorcik and Love investigate the Indonesian manufacturing sector and show that foreign ownership reduces plant-level energy intensity by 30% within two years of a cross-border acquisition [5]. Their analysis of plant-level data from 1983 to 2008 attributes this efficiency gain to output expansion and technology upgrades, reinforcing the idea that foreign direct investment facilitates access to more efficient production methods. Similarly, research on the effects of importing foreign intermediaries in Indonesia suggests that firms integrating foreign-produced inputs experience notable improvements in energy efficiency.[25]

To sum up, the existing theoretical frameworks indicate possible positive and negative energy efficiency gains from internationalization. The findings based on micro-level inquiries are limited and focused on single countries, which does not allow for controlling the possible confounding effects of environmental and energy policies affecting the energy efficiency outcomes of foreign direct investment. However, collectively, these findings highlight that while the impact of foreign direct investment on energy efficiency varies across regions and industries, in the cases of sufficient technology differences and absorptive capacity, it has overwhelmingly positive effects. However, the economic significance of these effects ranges a lot, depending on which single country the study is based on. Economies of CEFTA 2006 integration have, to the best of our knowledge, not been subject to a similar inquiry. Given the region's transitional economic status and the increasing integration of its markets with the European Union, and specific policies affected by harmonization processes, the extent to which foreign direct investment affects energy efficiency improvements, remains an open empirical question. We address this gap in the literature with our empirical analysis presented in this paper.

Theoretical Framework

We present the motivation for our empirical analysis using a simple partial equilibrium model describing the energy use of a firm. We simplify the model by imposing several restrictive assumptions. First, in order to provide a framework that allows us to focus on energy usage only, we assume that the output of the firm is fixed. This means that we consider that output is given by previous contractual obligations and it cannot be changed. We denote this fixed output as . The output is sold at price level P which is exogenously determined. Another simplifying assumption is that the representative firm requires only energy (E) as an input to produce its fixed output and that its price is constant. We introduce foreign direct investment in the model, by assuming that foreign direct investment affects factor productivity. This effect could mean the transfer of new, more energy-efficient technologies, analogous to the pollution halo hypothesis [56]. In contrast, it could also mean the transfer of less efficient technologies, analogous to the pollution haven hypothesis [43]. We can describe this setup using the following equation:

$$\bar{Y} = A(FDI) \times E \tag{1}$$

To make the model tractable, we concretize the functional form for factor productivity as $A(FDI) = A_0 FDI^{\phi}$, where A_0 represents the baseline productivity of indigenous firms in the host country, while ϕ denotes the efficiency gain parameter of foreign direct investment. Since we assumed that multinational enterprises possess more energy-efficient production technology that they are willing to transfer to the firm in which they invest, the efficiency gain factor is assumed to be strictly positive, i.e. $\phi > 0$.

Given our initial assumptions, we make the following proposition regarding the relationship between foreign direct investment and energy intensity:

Proposition. *The increase in foreign direct investment in a firm results in a decline in energy intensity.*

The proposition can be deduced from our initial setup. Namely, the production function of the firm can be rearranged to show the firm's energy demand function:

$$E = \frac{\bar{Y}}{A(FDI)} \quad (2)$$

To derive energy intensity (*EI*), we divide energy demand by sales ($S = P \times \bar{Y}$), which yields:

$$EI = \frac{E}{S} = \frac{1}{P \times A(FDI)} \quad (3)$$

After substituting concretized functional form for factor productivity in (3), we can define the effects of foreign direct investment on energy intensity for firms receiving investment as:

$$\frac{\partial EI}{\partial FDI} = -\frac{\phi}{P \times A_0 FDI^{\phi+1}} < 0 \quad (4)$$

The equation (4) shows that, if our initial assumptions are met, and multinational possess superior technology to indigenous firms in terms of its efficiency, foreign direct investment will reduce energy intensity of the production. In other words, the larger foreign investment a firm receives, the greater improvements in energy efficiency will be. Moreover, if indigenous firms are more productive, the energy efficiency potential is reduced, and the efficiency gains are lower, which is in line with theories of Findlay [18] and Kokko [40]. It should be noted that if we assumed that multinational enterprises transfer less efficient technologies, i.e. if $\phi < 0$, energy intensity would be increased with foreign direct investment. The nature of the ϕ parameter is an empirical question, and the strategy for its estimation is explained in the following section.

Empirical Methodology

We base our empirical analysis on the model of energy intensity (*EI*). Energy intensity is, thereby, defined as the ratio between costs of energy and sales of a firm. The model specification is guided by our theoretical framework. The independent variable in the focus of our analysis is, thus, foreign direct investment (*FDI*), approximated as the share of foreign ownership in the observed firm.

In addition to it, we also consider other factors of internationalization which the related theoretical frameworks deem relevant. These include exports (*EXP*), imports of foreign inputs (*FI*), and imports of technology (*IP*). However, in addition to foreign direct investment there is an array of various factors that could affect either energy efficiency directly or indirectly through effects on baseline productivity. For instance, to decouple the effects of foreign direct investment from the effects of economies of scale on energy efficiency, size of the company (*SIZE*) also needs to be controlled for. Innovation (*INN*) may result in adoption of more efficient business processes, and it is not necessarily tied to foreign direct investment, as indigenous firms may also invest in research and development activities. Similarly, the improvement of energy efficiency could be the result of capital investment (*INV*) unrelated to foreign capital. The firm may also improve their efficiency through experience (*AGE*) that accumulates over time. The specifics of the processes applied by the firm also play an important role in determining energy efficiency. For this reason, we consider capital intensity (*KL*) of firm's production, as well as sophistication of its processes approximated by the share of skilled in total workforce (*SKILL*).

Other industry-level characteristics not explicitly accounted for are controlled using industry dummy variables. Finally, differences in relevant policies are controlled using country-level dummy variables. This gives us the final specification of the baseline model, which can be represented by the following equation:

$$EI_i = \beta_0 + \beta_1 FDI_i + \beta_2 FI_i + \beta_3 SIZE_i + \beta_4 IP_i + \beta_5 INN_i + \beta_6 INV_i + \beta_7 AGE_i + \beta_8 EXP_i + \beta_9 KL_i + \beta_{10} SKILL_i + \Sigma_{j=1}^{J} \gamma_j I_{ij} + \Sigma_{k=1}^{K} \delta_k C_{ik} + \varepsilon_i \quad (5)$$

where i denotes index of firms, j denotes industries, k denotes countries, I_{ij} denotes industry-level dummy variables, C_{ik} denotes country-level dummy variables, γ_j, δ_k, and ε_i are coefficients for industry and country fixed effects and the error term, respectively. Details about the definitions of variables used in this specification, as well as their descriptive statistics are presented in Table 1.

Our sample consists of 2,241 firms from all seven CEFTA 2006 economies. All the data comes from the 2018-2020 Enterprise Survey, conducted by the European Bank for Reconstruction and Development, the European Investment Bank, and the World Bank Group.[17] The region is suitable for exploring the effects of foreign direct

investment on energy efficiency, as all of its economies are open and strongly reliant on foreign investment, as evidenced by inflows normalized by the size of the economies [3; 38]. Additionally, the observed economies are highly integrated into international trade, which enables us to identify the role of other possible mechanisms of the effects of internationalization on energy efficiency at firm-level.

The data we use is cross-sectional and refers to 2018. For some variables, values in a minority of firms were unknown, which reduces the number of observations used for our baseline estimations to 1,842. Our baseline model is estimated by applying the ordinary least squares method. Thereby, we estimate robust standard errors clustered at the country level to address the potential issues of heteroskedasticity and autocorrelation.

The situation in the CEFTA 2006 region is, however, specific, in the sense that foreign investment often results from cross-border acquisitions. This means that the foreign equity shares we observe in the FDI variable are not the result of a random process, as targets of these acquisitions are usually already highly attractive domestic firms. Such firms could already have high levels of energy efficiency. This is illustrated in Table 2, where we make a comparison between foreign affiliates and indigenous firms.

The data presented in Table 2 highlight notable differences between foreign affiliates and indigenous firms across several key firm characteristics, indicating potential structural divergences between the two groups. Notably, foreign-owned firms have nearly half the energy intensity of the indigenous firms, implying their much higher energy efficiency. However, they also differ in terms of other characteristics that are relevant for energy efficiency as well.

For instance, economy-of-scale effects on energy efficiency are far more present in foreign firms than in indigenous ones, as evidenced by firm size. On average, foreign affiliates are significantly larger, with a mean employment size of 247 compared to 72 for indigenous firms. At the same time, larger firms are more likely to be targets of foreign acquisitions.[33] The export intensity and investment indicators further illustrate structural differences between the two groups. Foreign-owned firms have a substantially higher mean export share (41.147%) than indigenous firms (15.968%), reinforcing the well-documented link between FDI and export orientation [34; 36]. On the other hand, investment levels (INV) appear notably lower for foreign affiliates (0.697) than for indigenous firms (2.691), suggesting that foreign firms may leverage existing capital more efficiently rather than relying on heavy new investment. Foreign affiliates also report higher innovation levels (0.376 vs. 0.223) and intellectual property acquisitions (0.152 vs. 0.073), while the capital intensity is lower in foreign affiliates compared to indigenous firms, which may reflect the sectoral composition of foreign direct investment inflows in the region. Similarly, skill intensity (SKILL) is somewhat higher among foreign-owned firms.

Table 1: Descriptive Statistics

Variable	Definition	Unit	Obs.	Mean	Std. dev.	Min	Max
EI	Energy intensity - the ratio of electricity costs and sales	Percent	1958	3.97	25.44	0	684
FDI	Foreign direct investment – share of foreign ownership in the equity of a firm	Percent	2228	8.76	27.26	0	100
FI	Foreign inputs – share of costs of foreign input in total inputs' cost	Percent	2106	50.12	40.74	0	100
SIZE	Size – number of workers	Workers	2186	89.91	250.98	1	8384
IP	Intellectual property purchase – dummy variable indicating if the firm purchased intellectual property	Unitless	2223	0.08	0.27	0	1
INN	Dummy variable indicating if the firm has introduced new business processes in the past 3 years	Unitless	2205	0.24	0.42	0	1
INV	Investment in equipment	Mil. EUR	2241	2.49	104.71	0	4954
AGE	Firm's age	Years	2230	18.58	13.81	0	204
EXP	Export share in total sales	Percent	2176	18.56	33.28	0	100
KL	Capital intensity – the ratio of assets and the number of workers	Thousands EUR per worker	2241	39.01	1410.80	0	66666
SKILL	Share of skilled workers in the total number of workers	Percent	2241	6.91	17.37	0	100

Source: Authors' calculation.

Table 2: Comparison of foreign affiliates and indigenous firms

Variable	Obs.	Mean	Std. dev.	Min	Max
Indigenous					
EI	1753	4.168	26.751	0	684.15
FI	1891	47.961	40.448	0	100
SIZE	1961	71.857	157.822	1	2249
IP	1999	0.073	0.259	0	1
INN	1979	0.223	0.417	0	1
INV	2014	2.691	110.45	0	4954.19
AGE	2014	28.518	141.788	0	204
EXP	1952	15.968	30.698	0	100
KL	2014	41.118	1486.258	0	66666.67
SKILL	2014	6.64	16.912	0	100
Foreign					
EI	205	2.328	7.695	0	88.355
FI	215	69.079	38.391	0	100
SIZE	225	247.276	607.267	1	8384
IP	224	0.152	0.36	0	1
INN	226	0.376	0.485	0	1
INV	227	0.697	4.43	0	53.741
AGE	227	27.819	134.84	1	134
EXP	224	41.147	44.555	0	100
KL	227	20.295	227.718	0	3421.62
SKILL	227	9.293	20.926	0	99

Source: Authors' calculation.

Bearing these differences in mind, a simple comparison of foreign and indigenous firms in terms of energy efficiency would likely result in biased estimates, as there could be confounding factors affecting both foreign direct investment and energy efficiency. Following the reasoning of Brucal et al. [5], we create a comparison group of domestic groups according to their likelihood of receiving foreign direct investment in order to infer the treatment effects of foreign investment, by applying propensity score matching [54].

We first determine the propensity score, by applying logistic regressions, where, as a dependent variable we consider whether a firm is foreign-owned or not, and as independent variables we use all the independent variables listed in Table 1, apart from foreign direct investment. The results of this estimation provide us with probability (propensity) scores of firms having foreign ownership given its other characteristics. The firms actually receiving foreign direct investment are then matched with the most similar domestic firms, as the matching is based on the propensity score. In our baseline estimations of treatment effects of foreign direct investment, we use the default one-to-one matching, but we check the robustness of the results by also applying one-to-many matching.

After the matching, the causal effects of foreign direct investment on energy intensity is estimated by imputing missing potential outcomes for each firm using an average of similar firms receiving foreign direct investment, and then by taking the average difference between the observed and potential outcomes for each firm. By applying this approach we reduce bias, as we use only comparable firms to estimate the effects of foreign direct investment. This allows us to not only detect and quantify the relationship between foreign direct investment and energy efficiency at the micro level but also to establish the causality from foreign direct investment to energy efficiency.

Results and Discussion

We present the estimation results for our baseline model in Table 3. Model (1) refers to the ordinary least squares estimation of the Equation (5). Models 2-4 refer to robustness checks for Model (1). For instance, in Model (2) we use alternative definition of foreign direct investment introducing it as dummy variable indicating whether the firm is foreign-owned or not rather than continuous variable. The other two specifications relate to slight changes in specification where alternative proxies were used for size and experience. In the first case, size was approximated by total assets value rather than the number of workers. In the second case, experience was approximated by the number of years of experience of the general manager, rather than the age of the firm.

Our estimation results indicate a significant negative relationship between foreign direct investment and energy intensity at the 5% significance level. Specifically, the estimated coefficient value suggests that a change in ownership for the wholly foreign-owned subsidies is associated with a reduction in firm-level energy intensity by 2.5 percent points. A similar statistically significant effect remains if the foreign direct investment is redefined as a dummy variable. Other changes in specification affect negligibly the economic and statistical effect of foreign direct investment on energy intensity. The result supports our theoretical argument that foreign direct investment

Table 3: Estimation results for the baseline model (dependent variable: energy intensity)

	(1)	(2)	(3)	(4)
FDI	-0.025**		-0.025**	-0.024*
	(0.010)		(0.009)	(0.010)
FDI-dummy		-2.138*		
		(0.951)		
FI	-0.007	-0.007	-0.007	-0.007
	(0.007)	(0.007)	(0.007)	(0.007)
SIZE	0.000	0.000		0.000
	(0.002)	(0.002)		(0.002)
IP	-2.898*	-2.924*	-2.885*	-2.906*
	(1.445)	(1.469)	(1.458)	(1.473)
INN	2.993	2.968	3.043	2.922
	(2.727)	(2.718)	(2.705)	(2.672)
INV	-0.000	-0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)
AGE	-0.001	-0.001	-0.001	
	(0.002)	(0.002)	(0.002)	
EXP	0.020	0.020	0.020	0.019
	(0.032)	(0.032)	(0.033)	(0.032)
KL	-0.000**	-0.000**	0.002	-0.000**
	(0.000)	(0.000)	(0.001)	(0.000)
SKILL	-0.005	-0.005	-0.005	-0.005
	(0.015)	(0.015)	(0.015)	(0.014)
ASSETS			-0.006*	
			(0.000)	
EXPERIENCE				0.042
				(0.035)
Constant	5.060**	5.079**	5.080**	4.248*
	(1.456)	(1.433)	(1.422)	(1.854)
Observations	1839	1842	1841	1839
Adjusted coefficient of determination	0.001	0.001	0.001	0.001

Source: Authors' calculation.
Note: Robust standard errors are presented in the parentheses. ***, **, and * denote coefficients significant at 1%, 5%, and 10% significance levels, respectively. In all specifications industry and country fixed effects are estimated but not reported.

results in technological efficiencies that reflect on energy intensity.

In addition to foreign direct investment, several firm-level characteristics also exhibit statistically significant effects on energy intensity. Notably, acquisitions of intellectual property are associated with reductions in energy intensity across all model specifications. This suggests that technology transfer, regardless of whether or not it is internalized within the system of multinational enterprise, results in improvements in energy efficiency of the firms in the CEFTA 2006 region.

Capital intensity (KL) is also found to be negatively associated with energy intensity at 5% significance level in three out of four model specifications, reinforcing the notion that more capital-intensive firms tend to adopt more energy-efficient production techniques. Other firm characteristics were not found to exhibit a statistically significant effect on energy intensity.

Overall, our baseline findings provide strong evidence that foreign ownership is associated with lower energy intensity at the firm level in CEFTA 2006 economies. The robustness of this relationship across multiple model specifications supports the hypothesis that foreign direct investment contributes to improved energy efficiency, potentially through the transfer and application of more efficient technologies. The results imply that the technology level between the firms in CEFTA 2006 economies and parent companies in economies of origin are substantial and that the absorptive capacity in CEFTA 2006 is sufficient.

However, due to issues of confounding factors and possible biases of the ordinary least squares estimates outlined in the previous section, we further test the robustness of our findings by applying a propensity score matching approach. After constructing the samples using one-to-one and one-to-many matching based on the scores derived from the logit regression, we get a much more balanced subsample, suitable for isolating the effects of foreign direct investment. This is evidenced by the results presented in Table 4.

Table 4: Covariate balance summary

Variable	Whole	Matched one-to-one	Matched one-to-many
FI	0.575	-0.191	-0.146
SIZE	0.639	0.137	0.155
IP	0.166	-0.022	-0.061
INN	0.330	0.009	0.043
INV	-0.031	-0.032	-0.031
AGE	0.043	0.067	0.034
EXP	0.718	-0.003	0.011
KL	-0.020	0.047	0.040
SKILL	0.159	0.248	0.142

Source: Authors' calculation.
Note: The values refer to standardized differences across foreign direct investment treatment for the whole sample, and subsamples constructed using propensity score matching (variations of one-to-one and one-to-many matching).

Table 4 presents the standardized differences in covariates before and after propensity score matching, providing insights into the effectiveness of the matching procedure in balancing observable characteristics between treated (foreign-owned) and control (domestic) firms. The

values reported for the whole sample reflect the initial differences between foreign-owned and domestic firms prior to matching, while the values for matched one-to-one and matched one-to-many samples indicate the extent to which these differences have been reduced through propensity score matching.

As discussed previously, in the whole sample, several covariates exhibit substantial imbalances between foreign-owned and domestic firms, particularly export intensity, firm size, and the use of foreign inputs. Such pre-treatment differences underscore the necessity of employing propensity score matching to ensure a less biased estimation of the causal effect of foreign direct investment on energy intensity.

Following matching, the standardized differences across most covariates are notably reduced, indicating improved balance between treated and control groups. Under the one-to-one matching specification, the largest remaining imbalance is observed for skill and firm size. However, these values are near the accepted thresholds for balance diagnostics [57]. In the one-to-many matching specification, the imbalance in most covariates is further mitigated. These results imply that matching reduces systematic differences in firm characteristics, increasing confidence in the subsequent estimation of treatment effects. The estimation result of the average treatment effects is presented in Table 5.

Different columns refer to different variants of average treatment estimations. Namely, we consider different definitions of treatment and different matching approaches. Treatments denoted by foreign direct investment follow the standard definition of foreign direct investment, where non-residents need to have at least 10% equity share in the domestic company for it to be considered to be foreign-owned. Treatments denoted as majority foreign-owned set this share threshold to 50%. However, this change in definition results in a negligible change in both the economic and statistical significance of the average treatment effect. The change in the method of matching from one-to-one to one-to-many also does not affect the statistical significance of the foreign direct investment effect, but it does slightly reduce the intensity of the effect. Considering that the propensity scores we use in the matching procedure are random variables that are estimated using our sample, we adjust standard errors of our estimates to the large sample variance of the estimated treatment effects, following the approach of Abadie and Imbens [1].

Table 5: Average treatment effects (ATE) estimates

Treatment	ATE	Standard error	Number of matches
Foreign direct investment	-1.895**	(0.833)	1
Foreign direct investment	-1.673**	(0.808)	3
Majority foreign-owned	-1.894**	(0.832)	1
Majority foreign-owned	-1.673**	(0.807)	3

Source: Authors' calculation.
Note: Abadie-Imbens standard errors are presented in parentheses. ** denote coefficients significant at 5% significance level.

The results from the propensity score matching analysis indicate that foreign direct investment has a significant negative impact on firm-level energy intensity. Regardless of the specification, the result is significant at 5% level. Specifically, firms that received foreign direct investment exhibit between 1.67 and 1.89 percentage points lower energy intensity compared to similar domestic firms that did not receive foreign direct investment. This supports the results derived from the ordinary least square estimates, although it indicates that the initial baseline estimates were somewhat downward biased. The empirical evidence also supports our theoretical framework and is in line with the models of Imbruno, Lo Turco, and Maggioni and Imbruno and Ketterer [25; 26].

Overall, our estimated effects of foreign direct investment on energy intensity for firms in CEFTA 2006 economies are comparable to previous empirical findings in other contexts. For instance, the strength of the energy intensity reduction effects are stronger in comparison to the case of China, when firms from all industries are considered [59]. Our findings are within the range of estimates reported by Bu et al., who consider only capital-intensive Chinese industries [6]. The differences in foreign direct investment effects on energy intensity between CEFTA 2006 economies and China could be attributed to the sectoral composition of the firms used in the sample. The estimated effects in our study are comparable to the results of Brucal, Javorcik, and Love determined using the data referring to the manufacturing sector of Indonesia [5], with slightly higher effects found

in the case of firms in the CEFTA 2006 region. The key factor driving this difference is likely the time frame of the analysis, as we base our results on cross-sectional data, whereas the result of Brucal et al. refers to the period between 1983 and 2008.

Finally, we explore the economy-level heterogeneity of foreign direct investment effects on energy intensity. For each country, we constructed subsamples of firms using the previously described propensity score matching methodology and its one-to-one variant. This variant was applied due to data limitations, as at country levels we could not achieve a consistent number of matches across countries. The results of our average treatment effects estimation are presented in Table 6, along with some characteristics of economy-level energy usage.

The results reveal considerable heterogeneity in the effects of foreign direct investment on energy intensity across economies. Namely, we observe significant reductions in energy intensity in the case of Albania, Bosnia and Herzegovina, Moldova, and Montenegro, while others exhibit insignificant effects. Furthermore, across the economies with significant effects, their economic significance varies significantly.

The country with the largest estimated reduction in energy intensity due to foreign direct investment is Albania where foreign ownership reduces energy intensity by over 5.3 percent points. Considering that mean energy intensity in the region is approximately 4%, the economic significance of the effect is large and may contribute considerably to the general competitiveness of Albanian firms. Incidentally, Albania also exhibits some of the lowest economy-wide energy intensity levels as well as the highest energy self-sufficiency rate indicating a greater reliance on domestic energy sources. The results could reflect specific energy-related policies in Albania as well as its specific economic structure. However, a more detailed explanation for this result would require a more extensive and focused case study.

Bosnia and Herzegovina, Moldova, and Montenegro show more modest, yet still significant, reductions in firm-level energy intensity following foreign direct investment. Most of these economies have higher energy intensity levels and relatively high carbon intensity. The continued high reliance on fossil fuels in energy supply in these economies implies that while foreign firms may use energy more efficiently, their energy mix likely remains largely dependent on carbon-intensive sources. Serbia, along with its Autonomous Province of Kosovo exhibits statistically insignificant effects of foreign direct investment on firm-level energy intensity. Similar results are obtained in the case of North Macedonia. In all cases, energy self-sufficiency is relatively lower and the share of fossil fuels in energy supply is higher. This could reflect higher energy costs which offset productivity gains from foreign investment resulting in the insignificant average effects. An exception would be Moldova, where a similar situation exists, yet the effects of foreign direct investment are significant. The exception could be explained by Moldova's lag in the transition process compared to other considered economies, which increases the technology gap between foreign and domestic companies and, despite high energy costs, the productivity gains from the transfer of technology offset the higher costs.

Table 6: Average treatment effects (ATE) estimates for individual economies

Country	ATE of FDI	Standard error	Energy intensity of the economy	Carbon intensity of the economy	Share of fossil fuels in energy supply	Energy self-sufficiency
Albania	-5.363**	(2.378)	2.6	120	60.1	85.4
Bosnia and Herzegovina	-0.877**	(0.369)	6.8	480	81.8	75.9
Moldova	-0.819**	(0.347)	5.7	270	78.4	20.2
Montenegro	-1.902***	(0.611)	n.a.	n.a.	n.a.	n.a.
North Macedonia	-4.591	(3.516)	3.5	230	78.9	44.4
Serbia	-2.706	(3.449)	5.5	390	86.8	65.3
Autonomous province of Kosovo	0.465	(3.988)	5.6	430	83.8	70.8

Source: Authors' calculation for ATE and standards errors, and International Energy Agency for economy-wide indicators [27].
Note: All estimations are based on samples constructed using the one-to-one variant of the propensity score matching. Economy-wide data for Montenegro was not available. All economy-wide indicators refer to 2018.

These findings suggest that FDI's role in enhancing energy efficiency is not uniform across economies and may depend on broader structural factors, including the energy profile and self-sufficiency of each country's economy, the situation in their energy markets, and the characteristics of their energy policies. Such findings corroborate previous conclusions of regional heterogeneity of foreign direct investment effects on energy efficiency in other contexts [19].

Conclusion

In this study, we analyzed cross-sectional data for 2,241 firms from the CEFTA 2006 region in order to determine micro-level effects of foreign direct investment on energy efficiency, using the propensity score matching approach. The results of our study provide new evidence on this issue, suggesting significant effects of foreign direct investment on improving the energy efficiency of firms in the region, confirming our initial hypothesis. On average, foreign ownership of firms causes the reduction of energy intensity by up to 1.89 percent points, which is approximately half of the average energy intensity for all the firms in the sample. We also identified considerable regional heterogeneity of these effects, with the strongest effects being present in the economies lagging in the transition process and in the economies with higher energy self-sufficiency.

Our results imply that multinational companies have more energy-efficient production technologies which have a strong energy-saving prospect. This discrepancy between multinationals and indigenous firms suggests that there is a potential for positive technological spillover and demonstration effects which could further contribute to energy efficiency improvements in the region over the long run. Given these results, policymakers could address the issues of energy efficiency in the region through promoting and attracting foreign direct investment, particularly in the more energy-intensive sectors. Also, the existing incentive schemes present in foreign direct investment policies in the region should account for this additional positive effect, as, at the moment, the incentives are primarily reliant on employment and regional development. In order to maximize the benefits of energy efficiency improvement, policymakers could look into supporting greater linkages between foreign-owned and domestic firms. More generally, the results indicate the need to a more holistic approach in facilitating partnerships between investors and aligning them with Sustainable Development Goals, an example of which is the SDG investor platform [45].

The regional heterogeneity of foreign direct investment effects on energy efficiency implies that the adoption of more efficient production technologies could be fostered by reducing reliance on fossil fuels and improving energy self-sufficiency. The policymakers could, thus, maximize efficiency gains from foreign direct investment by adjusting energy policies and diversifying energy sources. Finally, the improvement in energy efficiency will make the observed economies, and particularly their export-oriented manufacturing sectors, more resilient to increasingly restrictive policies of the European Union, by adapting to the required standards, which is particularly important for emission-intensive industries in the region.

The results of our study also provide some insights for decision-makers in the individual firms seeking to improve energy efficiency. By establishing equity-based partnerships with foreign firms, domestic firms can acquire more efficient technologies that can reduce their energy intensity. Furthermore, the results imply the existence of possibilities of knowledge-sharing collaborations between the firms in the CEFTA 2006 region and foreign affiliates in the region, which could result in the adoption of more efficient technology. Finally, according to the results of our empirical analysis, improvements in energy efficiency could also be achieved through adopting more capital-intensive production processes and purchasing more efficient technologies from other firms.

While our study provides robust evidence of the positive effects of foreign direct investment on the energy efficiency of firms in the CEFTA 2006 region, it is limited to cross-sectional data. A more nuanced analysis accounting for individual firms' heterogeneity could be conducted when similar longitudinal firm-level data becomes available. This could be an interesting avenue for future research.

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Radovan Kastratović

is an assistant professor at the University of Belgrade Faculty of Economics and Business. He teaches International Economics, International Business Financing, and International Trade on undergraduate programs (including the joint program with LSE), and International Trade Policy and International Economics on graduate-level programs. He graduated from University of Belgrade Faculty of Economics in 2014, specializing in international economics and foreign trade. In 2015, he graduated from master-level program "International Economic Relations" at the University of Belgrade Faculty of Economics. He defended a Ph.D. thesis entitled "The Impact of Foreign Direct Investment on Agricultural Exports of Developing Countries" in 2021 at the University of Belgrade Faculty of Economics. He participated in two international research projects – "CEE Countries in Europe: Towards Center or Periphery in Global Value Chains" (conducted by the international academic consortium led by the Ljubljana School of Economics and financed by the China-CEE Institute Budapest) and "The Impact of Exchange Rate on Trade Balance in Crises – Sustainable Development of the New EU Member States and Western Balkans" (in cooperation with the University of Montenegro). He graduated from the prestigious regional course of the United Nations Conference on Trade and Development in 2021. The main research interests include foreign direct investment and international trade.

Dragan Lončar

is a professor and an associate dean at the Faculty of Economics and Business, University in Belgrade, and the founding partner of business consulting firm Peterhof Consulting. He graduated from the Faculty of Economics and Business, completed a Master in Management at the University of Cambridge, and acquired PhD title at the Faculty of Economics and Business. Dragan Loncar received a Fulbright scholarship in 08/09 for postdoctoral research in financial management, conducted at the University of Chicago. He is a CFA charterholder. He has had various experiences in numerous economic projects and a pivotal role in WB, USAID, GIZ, UNDP, and EU projects. Dragan is the co-author of the reference books for Strategic Management and Project Management and the author of numerous research studies and papers in academic journals. He is a member of the Board of Directors of Banca Intesa Belgrade, a member of Supervisory Board of Metalac Gornji Milanovac, and the president of the Audit Committee of Wiener Stadtische Serbia.