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Global value chains and energy-related sustainable practices. Evidence from Enterprise Survey data

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ABSTRACT

Participation in global value chains (GVCs) can affect the deployment of clean energy technologies and influence firm-level energy management. However, the sign of this influence is debated, especially for less developed economies, since GVCs can favor the absorption of more advanced technologies and the adoption of greener energy practices, but on the other hand they can help export polluting productions from countries with strict environmental regulations to weakly regulated developing countries. Drawing on Enterprise Surveys conducted in 2018–2020 on a large cross-section of firms operating in different industries and countries, and applying regression analyses and propensity score matching, this is the first firm-level study aiming to shed light on the relationship between firm participation in GVCs and the adoption of energy-related sustainable practices. In addition, the analysis allows for a heterogeneous impact of GVCs, conditional on firms' characteristics and external conditions, such as institutional quality. Overall, we find that participation in GVCs is positively associated with firm propensity to adopt green energy practices. For smaller and younger firms, operating in poorer institutional contexts, and/or less endowed in terms of human capital or financial resources, being engaged in GVCs has milder effects on the adoption of greener practices. By contrast, manufacturing companies located in high-income countries are those showing the strongest impact of GVCs on energy management.

1. Introduction

Ensuring "access to affordable, reliable, sustainable and modern energy for all" is one of the key Sustainable Development Goals, adopted by the United Nations in 2015, to be achieved by 2030. The decoupling of universal access to energy and the associated economic growth from environmental pollution, such as greenhouse gas (GHG) emissions, requires that firms adopt energy-related sustainable practices (ESPs), boosting energy efficiency and increasing the share of renewable energy in the global energy mix.[1]

However, the present pace of progress in this direction does not seem to be sufficient. The global share of renewable energy (including solar, wind, geothermal, hydropower, bioenergy, and marine sources) in final energy consumption only marginally increased from 16.92% in 2000 to 17.69% in 2019 (Our World in Data, 2022, https://sdg-tracker.org/energy#targets). To further complicate the transition process, the recent COVID-19 pandemic and the conflict in Ukraine have weakened or reversed advances already made in several countries. In the words of the UN (2022, p. 40): "Rising commodity, energy and shipping prices have increased the cost of producing and transporting solar photovoltaics modules, wind turbines and biofuels worldwide, adding uncertainty to a development trajectory that is already far below Goal 7 ambitions."

Adopting virtuous energy management policies to increase renewable sources and energy efficiency can be particularly problematic for firms operating in less developed and transition countries (LDTCs), whose economies are often based on energy-intensive activities such as manufacturing or running data centers (OECD, 2017), obsolete

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[1] In addition, diversifying the energy portfolio would reduce the economy's vulnerability to energy price volatility (Sarkodie and Adams, 2018) and the monopoly power of countries producing fossil fuels.

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technologies, limited infrastructure and human resources (Koirala, 2019), less stringent environmental standards and weak regulatory conformity (Ben-David et al., 2020; Ghosh and Dutta, 2022), and limited access to external resources to finance green investments (Drakos and Giannakopoulos, 2011; Koirala, 2019; Tian and Lin, 2019). Therefore, "achieving energy and climate goals will require continued policy support and a massive mobilization of public and private capital for clean and renewable energy, especially in developing countries" (UN, 2022, p. 40), for which it is imperative to foster international cooperation to absorb expertise, upgrade technology, promote investments, develop infrastructure to supply cleaner energy, and enhance energy efficiency.

The process of international integration of markets and vertical fragmentation of industries that has taken place in recent decades, leading to the development of global value chains (GVCs) (Antràs, 2020), could significantly affect the deployment of clean energy technologies and influence energy management at the firm level. From a theoretical perspective, the sign of this influence is debatable. On the one hand, diffusing advanced technologies along GVCs could contribute to exploiting new and sustainable energy sources, thus curbing emissions in LTDCs, which are usually outsourcing/offshoring destinations. In particular, GVCs can facilitate the diffusion of digital technologies (Delera et al., 2022), which can allow smart energy monitoring and control, and align energy efficiency with renewable energy production (EA, 2021). Furthermore, involvement in GVCs can force firms to comply with international standards (Pietrobelli and Rabellotti, 2011), concerning also environmental sustainability, and energy management systems in particular. In addition, the pressure of multinational companies, the leading actors in the GVCs, to pursue carbon neutrality can represent an initial impulse to overcome path dependence, foster investments in renewable energy (Wüstenhagen and Menichetti, 2012), and adopt more sustainable practices in energy management.

On the other hand, while firms operating in developed economies usually dominate the high-tech and high-value-added sections of the GVCs, firms located in LTDCs are more often engaged in energy-consuming and pollution-intensive segments. Indeed, in addition to comparative economic advantages, lower energy and emission costs are deemed to be key drivers of the outsourcing process carried out by firms of developed countries. In fact, according to the Pollution Haven hypothesis (Gill et al., 2018), stringent environmental regulations in developed countries would drive polluting firms to move or outsource production to firms operating in countries with weaker regulations, so that the deepening of GVC participation in developing countries would involve a rise in their energy consumption and polluting emissions. In summary, firms' GVC participation has uncertain consequences for LDTCs: importing advanced technologies and setting advanced standards of environmental protection can be beneficial for better energy management and the adoption of renewable energy sources, but GVCs might be a vehicle through which companies of developed countries could move the most polluting stages of production toward developing countries, thus exporting energy inefficiency and environmental degradation.

This ambiguity leaves substantial room for empirical research aimed at establishing whether GVCs help or hinder sustainability in energy management and clean energy production. It is also relevant to consider the heterogeneity of the impact of GVCs across industries and countries, according to firms' characteristics and context conditions. In particular, a firm's size, age, availability of human capital, and access to credit can be relevant to its choices about energy management, and affect the relationship between its involvement in GVCs and sustainable energy management. Finally, institutional incentives and constraints are also likely to be important, since they may affect both the effectiveness of technology transfer (Costantini and Liberati, 2014) and the adoption of green technologies (Sun et al., 2019).

Motivated by these arguments, in this paper we conduct a firm-level analysis in a large sample of countries, encompassing developing and transition economies, to assess the sign and magnitude of the impact of firm participation in GVCs on the propensity to adopt measures for the abatement of energy consumption and the production of renewable energy. As far as we are aware, the present study is the first to carry out a firm-level analysis aimed at evaluating the link between the adoption of ESPs and GVC involvement. As a matter of fact, while a number of papers, surveyed in Section 2, analyze the relationship between environmental performance and integration in GVCs at country and region level, only Hua et al. (2022) use firm-level data to analyze the effects of participation of Chinese firms in GVCs, but focusing on their polluting emissions. An additional novel aspect of our paper is that for the first time the importance of GVCs for energy management is assessed by considering the interaction between participation in GVCs and both firm characteristics and institutional quality, which act as moderators of the relationship under investigation. In this approach, firm participation in GVCs is supposed to have a possibly heterogeneous impact on ESPs, depending not only on the industrial sector and domestic economic development, but also on firms' individual characteristics and the institutional context that contributes to shaping enabling conditions.

Our analysis takes advantage of a large dataset of approximately 28,000 firms, mostly operating in transition and developing countries (Eastern Europe, Central Asia, and Middle East and North Africa), drawn from the Enterprise Surveys conducted in 2018–2020. Exploiting the Green Economy Module included in the questionnaire for the first time, we compute two firm-level indexes, based on principal component analysis (PCA), one gauging the adoption of practices aimed at optimizing energy consumption, and the other capturing the generation and use of energy from renewable sources.

Regression and propensity score matching (PSM) analysis supports the hypothesis that, while firm participation in GVCs is positively associated with ESPs, smaller size, younger age, and low institutional quality tend to mitigate this effect, presumably because of lower propensity and capability to adopt greener energy management practices. By contrast, for companies located in high-income countries endowed with good institutions the impact of GVCs on the adoption of ESPs is larger.

The remainder of the paper is structured as follows. The next section develops a short survey of the related literature. Section 3 presents the empirical model and describes the data. Section 4 reports and discusses the econometric investigation results. Section 5 focuses on heterogeneity, and Section 6 concludes.

2. Related literature

2.1. International trade, GVCs and technology transfer

In the last decades, a broad literature has developed on the effects of international trade and foreign direct investments (FDIs) on technology transfer and productivity growth (Hoeckman and Javorcik, 2006; Halpern et al., 2015). The basic point of most contributions is that trade and FDIs allow firms engaged in international activities to tap into the global pool of knowledge, favoring technology adoption and leading to a boost in productivity and countrywide economic growth. Although this argument, in principle, applies everywhere, the benefits of international technology diffusion are likely to be larger for LDTCs, whose firms can exploit and absorb technologies more advanced than those used by purely domestic companies.

More recently, attention has been focused on the effects of GVCs on international technology transfers. A GVC is the whole set of operations and transactions within and between firms in which the production process is organized and through which a product is realized and marketed. This process involves many distinct stages, ranging from design, manufacturing, assembly, and logistics to marketing and distribution, which are dispersed along the GVCs over several firms, regions, and countries. A broad literature highlights the importance of GVCs as a channel for access to knowledge and foreign technology for companies located in LDTCs. Pietrobelli and Rabellotti (2011) argue that integration into GVCs is a crucial avenue for firms in developing countries to access knowledge and enhance innovation. The latter is stimulated by international competition and the need to satisfy the environmental (and other) requirements imposed by participation in the chain. According to Piermartini and Rubínová (2014), knowledge spillovers take place much more effectively within GVCs than through the trade of final goods. Gentile et al. (2021) focus on GVC-mediated access to foreign R&D as a tool to enhance domestic innovation capabilities. They also emphasize the different possibilities offered by GVCs to firms in LDTCs to upgrade by learning advanced skills or sourcing technology from suppliers within the GVCs. Rigo (2021) finds that GVCs facilitate the transfer of foreign technologies, specifically through foreign licensing.

2.2. GVCs, technological progress and energy efficiency

Improvements in technology are usually connected to reduced energy consumption, lower GHG emissions, and ultimately to greater energy efficiency, since the latter "is strongly linked to the technological level of the equipment that is used to obtain a certain energy service" (Marin and Palma, 2017, p. 86). A number of recent studies support this hypothesis. Zhang and Fu (2022) find that foreign technology introduced in China has improved domestic innovation capability and produced a significant positive effect on energy efficiency. Li and Lin (2018) show that Hicks-neutral technological progress helps promote energy efficiency, while capital-embodied technological progress contributes to energy saving. Liu et al. (2018b) argue that more advanced technologies lower the costs that a firm bears to comply with environmental regulations, thus positively affecting energy consumption. Zhu et al. (2019) find that technological progress improves energy efficiency by 7.1% per year in the Chinese construction sector owing to the lower energy consumption of machinery and equipment and a change induced toward greener energy sources.

To the extent that GVCs favor the adoption of more advanced technologies and the latter brings about a larger use of renewable energy and lower energy consumption, firms' participation in GVCs should lead to lower polluting emissions and more efficient and greener energy management. Consequently, a powerful incentive for LDTCs to join GVCs would be their beneficial impact on the environment. This argument is connected to the so-called Porter Hypothesis (Porter and Van der Linde, 1995), according to which environmental regulation and foreign direct investments induce more advanced technologies and cleaner environments. In this line, Wang et al. (2022a) investigating the dynamic relationships between GVC participation, CO2 emissions, and economic growth in a sample of 63 countries and regions from 2005 to 2015, show that participation in GVC promotes environmentally friendly growth, even if the impact of GVCs is found to be stronger in high-income countries.

2.3. The pollution haven hypothesis

In contrast to the Porter Hypothesis is the Pollution Haven Hypothesis, first postulated by Copeland and Taylor (1994). According to the latter, liberalized international trade allows firms to export dirty goods and polluting production from rich countries, which are subject to strict environmental regulations, to weakly regulated developing countries.[2] In this view, GVCs would be the channel through which companies of developed countries could move the most polluting stages of production to LDTCs, in order to circumvent domestic environmental regulations. This argument, consistent with the hypothesis that the transfer of knowledge from GVC leaders to developing countries' firms would often be strategically restricted to mature technologies to perform basic, repetitive, low value-added, and polluting tasks (Delera et al., 2022; Golini et al., 2018), is somehow supported by recent studies. For example, Wang et al. (2022b) show that GVCs bolster pollution emissions in developing countries. Zhang et al. (2021) document that GVCs consume more energy than domestic production, even if in the years 2000–2014 they realized a strong improvement in emission intensity.

More generally, other empirical studies obtain less clear-cut results. Wang et al. (2019) using panel data on 62 countries and regions for the period 1995–2011, find an inverted-U relationship between participation in GVC and CO2 emissions, due to competition, composition, spillover and scale effects. Shi et al. (2022) analyze the effect of GVC participation on carbon emissions of countries involved in the "Belt and Road initiative" during the period 2005–2016, finding that carbon intensity increase or decrease according to the forward or backward participation mode. In the same vein, Liu et al. (2018a, 2018b) and Jin et al. (2022) argue that the effect of participation depends on the position in the GVCs. Being involved in downstream, purely manufacturing stages is conducive to a detrimental "low-end lock-in" effect, which makes GVCs a vehicle through which LDTCs import energy inefficiency and environmental degradation; however, when "effectively improving their position in GVCs [...], developing countries have recorded a continuous decline in their energy intensity" (Jin et al., 2022, p. 3).

Summarizing, the overall impact of GVC participation is a priori uncertain for LDTCs. On the one hand, importing advanced technologies and setting high standards of environmental protection can foster sustainable energy management and the adoption of renewable energy sources. On the other hand, the opposite consequences may occur when GVC participation does not involve the transfer of advanced technologies, and firms do not upgrade to ameliorate their position along the chain. As the theory cannot unambiguously determine the effects of GVCs on firms' ESPs in developing countries, empirical research is needed in singling out the actual result of integration. Therefore, establishing whether GVCs and ESPs are friends or foes remains a matter of empirical investigation.

3. The empirical model

Building on the literature reviewed in Section 2, we set up an empirical model to estimate the effect of participation in GVCs on firms' ESPs. The empirical equation is as follows:

$$ESP_{i,s,j,t} = \alpha + \beta_1 GVC_{i,s,j,t} + \phi X_{i,s,j,t} + \delta_s + \delta_j + \delta_t + \epsilon_{i,s,j,t} \tag{1}$$

where *i, s, j,* and *t* represent firm, sector, country, and time, respectively. The dependent variable ESP is either an index of sustainability in energy management (EMI), based on the practices adopted by a firm to target, monitor, and use energy more efficiently; or an index based on the practices of producing and using renewable energy (REI).[3]

On the right-hand side, in line with Rigo (2021), Benkovskis et al. (2020) and others, we use, as a proxy for GVC participation, a dummy

[2] For an updated survey on the Pollution Haven Hypothesis, see Gill et al. (2018).

[3] EMI is built on five binary variables, indicating whether the firm performs energy management (EneMan), monitors its energy consumption (EneMoni), adopts targets on energy consumption (EneTarg), introduces heating and cooling (HeatCool), or introduces lighting systems improvements (Light). REI is based on indicators of whether the firm generates energy in a more climate-friendly manner on-site (GenGreenE), or uses energy from its own renewable sources (UseGreenE). Both indexes are based on principal component analysis, extracting the maximum variability from highly correlated variables. Wellalage et al. (2022) apply the same method to build a multidimensional environmental performance index, using Enterprise Surveys data during the COVID-19 pandemic. In this study, since the variables are dichotomous, we first retrieve the (maximum likelihood) estimate of the tetrachoric correlation, then perform PCA on the latter correlation matrix, and retain the principal component, which explains 66% and 83% of the total variance of the data in the EMI and REI cases, respectively.

taking a unit value if the firm is a two-way trader, that is, it both imports intermediate inputs and exports. X is a vector of control variables described below and summarized in Table A.1 (in the Appendix), which provides the summary statistics of all variables. Finally, δ_s, δ_j, and δ_t are sets of sector, country, and time dummies, respectively.

The vector X includes a number of controls. First, firm size (total number of employees) and age are considered. Larger and older firms are more susceptible to the control of external agents, such as media and stakeholders (Dekker and Hasso, 2016). Also, being more established and hence less opaque, they usually incur into lower financial constraints. It follows that the propensity to adopt ESPs should be increasing in size and age.[4] Second, since lucrative firms may have a greater capacity to invest in environment-friendly strategies (Berrone et al., 2010; Dekker and Hasso, 2016), firm revenue (SALES) is accounted for.[5] Third, we include the variable FAMILY, indicating the percentage of firm shares owned by the same family. According to the socioemotional wealth (SEW) theory, family firms could be more eager to commit to environmental protection to preserve their family's "affective endowment." Indeed, the latter comprises several dimensions, condensed in the FIBER acronym: family control, identification of members with the firm, binding social ties, emotional attachment, and renewal of family bonds through succession (Berrone et al., 2012). Overall, these dimensions can represent a prosocial and positive stimulus (Kellermanns et al., 2012), as they can inspire family firms to demonstrate care for stakeholders.[6] Fourth, human capital and the presence of a manager specifically responsible for environmental and climate issues is taken into account through the dummy variables TRAIN (coded 1 if employees attended formal training programs in the last fiscal year) and MANENV. Fifth, because pressure from clients is an important driver of firms' environmental behavior (He et al., 2016; He et al., 2018), the dummy variable REQCERT is included, coded 1 if customers require certifications or adherence to some environmental standards. Sixth, since credit rationing can limit access to the resources needed to adopt green measures (Cruz et al., 2014), the dummy variable RATIO is added, which equals 1 if firms were denied credit or did not apply because discouraged. Finally, in line with Fan et al. (2021) and Agostino and Ruberto (2021), we proxy environmental regulation with a dummy defined at the firm level, based on a question concerning the payment of energy tax (ETAX), and account for the country macroeconomic conditions by adding per capita gross domestic product (GDPPC).

3.1. Data

Microdata on manufacturing firms are drawn from the EBRD-EIB-WB Enterprise Surveys, including a "green economy module", freely available at http://www.enterprisesurveys.org covering about 28,000 enterprises in an extended sample of both transition and comparator countries.[7] The index of Institutional Quality (IQ) is drawn from the Environment Social and Governance (ESG) World Bank Database, based on the Worldwide Governance Indicators (WGI).[8]

To gain some preliminary insight into the dependent variables, Fig. 1 maps the mean values of EMI (Panel A) and REI (Panel B). Both show substantial heterogeneity. According to Panel A, several countries located in Eastern Europe and Asia show a medium or high level of involvement in practices aimed at optimizing energy consumption. By contrast, North African countries (and Italy and Portugal as well) display relatively low EMI index levels. Concerning the REI (Panel B), all the developed countries belonging to the sample (Cyprus, Greece, Italy, Malta, and Portugal) and some Eastern European countries (e.g., Bosnia and Herzegovina, Bulgaria, Estonia, Kosovo, Lithuania, the Slovak Republic, and Slovenia) are characterized by higher REI values. Among the North African countries, while Morocco exhibits a high level, Egypt has a low REI value. Finally, in Central Asia, countries such as Russia and other fossil fuel producers show a definitely low propensity to use renewable energy sources.

4. Results

Columns 1 and 2 of Table 1 show the results obtained by estimating Eq. (1) by ordinary least squares (OLS), using EMI and REI as measures of ESPs, respectively. Since the GVC estimated parameter is positive and significant at any conventional level, the benchmark results fully support the hypothesis that participation in GVCs positively affects firm adoption of green practices, with regard to both sustainable energy management and the use of renewable energy. In addition, in most cases controls turn out to be relevant to explaining ESPs variability; their impact is statistically significant, and the sign of dependence consistent with expectations.

Table A.2 in the Appendix reports a set of robustness checks on the specification of Eq. (1). In columns 1 and 2, the definition of GVCs is changed, since different intensities of GVC engagement could imply a different impact on the dependent variable. Therefore, an indicator of high-intensity GVC participation (GVC2) is defined, coded 1 for firms

[4] However, younger firms could be more eager to build a reputation and more capable of absorbing new technological knowledge (Agostino et al., 2018), and therefore more inclined to engage in socially responsible policies such as green energy management.

[5] A measure of profitability is not included because information on total costs is available only for a limited number of observations.

[6] In line with this argument, Cruz et al. (2014) suggest that family firms are more likely to engage in social practices (such as ESPs) that benefit external stakeholders to obtain greater reputational benefits. On the other hand, family firms could underinvest in sustainable policies if "amoral familism" (Banfield, 1958) or the "dark side" of SEW (Cruz et al., 2014; Kellermanns et al., 2012) materialize. Moreover, kinship might exacerbate conflicts (Eddleston and Kellermanns, 2007). Fighting for their own interests, family owners can pursue the accumulation of perquisites or extraordinary dividend pay-outs, avoiding risk and investing little in new products or technologies, including those necessary to improve the firm's environmental footprint (Fan et al., 2021).

[7] The sample countries are: Albania, Armenia, Azerbaijan, Belarus, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, the Czech Republic, Egypt, Estonia, Georgia, Greece, Hungary, Italy, Jordan, Kazakhstan, Kosovo, the Kyrgyz Republic, Latvia, Lebanon, Lithuania, Malta, Moldova, Mongolia, Montenegro, Morocco, North Macedonia, Poland, Portugal, Romania, Russia, Serbia, the Slovak Republic, Slovenia, Tajikistan, Tunisia, Turkey, Ukraine, Uzbekistan, and the West Bank and Gaza. The Enterprise Surveys are a joint initiative of the European Bank for Reconstruction and Development (EBRD), the European Investment Bank (EIB), and the World Bank (WB). They succeed the Business Environment and Enterprise Performance Surveys, which have been carried out in several rounds (1999, 2002, 2005, 2009, and 2012–14), with the primary goal of providing indicators of the business environment and firm-state interaction in Central and Eastern Europe and the former Soviet Union.

[8] The IQ indicator is the average value of five institutional dimensions: Regulatory Quality (capturing perceptions of the ability of the government to formulate and implement sound policies and regulations); Rule of Law (measuring the extent to which agents have confidence in and abide by the rules of society, and in particular the quality of contract enforcement, property rights, the police, and the courts); Government Effectiveness (capturing perceptions of the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies); Voice and Accountability (perceptions of the extent to which a country's citizens are able to participate in selecting their government, and to enjoy freedom of expression, freedom of association, and free media); Control of Corruption (perceptions of the extent to which public power is exercised for private gain, as well as the "capture" of the state by elites and private interests). Data are freely available at the website WGI 2021 Interactive > Home (worldbank.org).

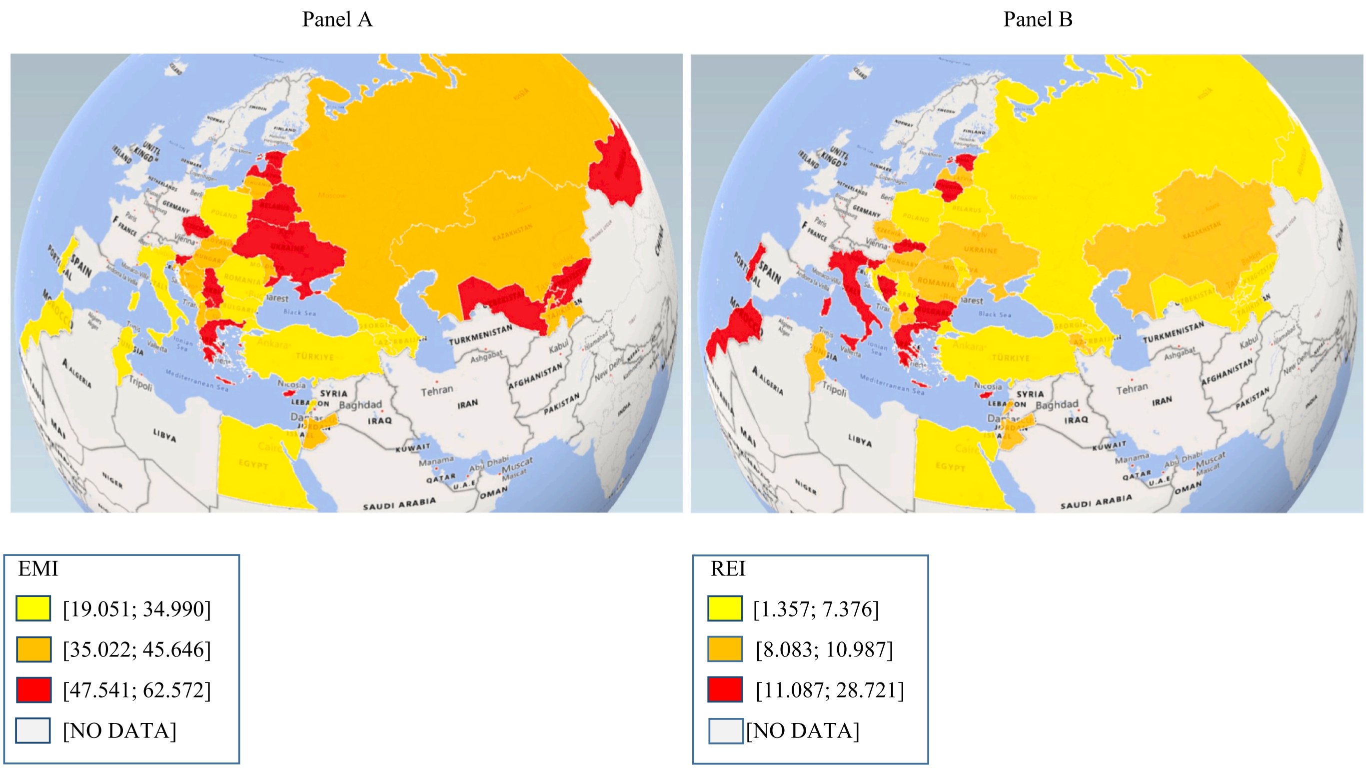

Fig. 1. Mean values of EMI and REI across countries.

that export and import more than the median values of the export (percentage of sales) and import (percentage of purchased intermediate goods) variables. In columns 3 and 4, the definition of the dependent variable is modified by substituting EMI and REI with N_EM and N_RE, respectively denoting the number of practices adopted by firms listed in footnote 3. Finally, specifications in columns 5–11 adopt as dependent variable a dummy for each of the seven variables (EneMan, EneMoni, EneTarg, HeatCool, Light, GenGreenE and UseGreenE) included in the indexes EMI and REI. In this case, given the dichotomous nature of the dependent variable, a non-linear probability model (Probit) is used. For all specifications, the results remain basically unaltered. In particular, participation in GVC affects the adoption of all green energy practices defining EMI and REI, with a very similar estimated impact across different practices.

4.1. *Addressing endogeneity concerns*

Since participants in GVC are not randomly selected from the entire population of firms, OLS estimates could be affected by selection bias. In fact, firm involvement in GVC is likely driven by ex-ante characteristics (observable or unobservable factors), correlated with energy management. For example, better managers are more likely to be adopters of green technologies, boosting green energy practices, "just as they are more likely to develop the capabilities needed to enter and succeed in export markets" (Delera et al., 2022, p. 7). In addition, firms employing a high share of renewables can be selected by multinationals involved in GVCs, as the latter companies can prefer outsourcing which grants "clean investments" (Henzelmann and Billen, 2021). Therefore, the possibility of reverse causality must be taken into account.

To tackle endogeneity concerns, we first re-estimate Eq. (1) by using the Lewbel (2012) estimator, which exploits the model heteroskedasticity to generate internal instruments employing the available regressors. This approach has been recently adopted by Delera et al. (2022) to tackle endogeneity of a binary regressor indicating GVC participation. Lewbel estimates, displayed in columns 3 and 4 of Table 1 fully confirm the importance of GVCs for ESPs. Following the Lewbel (2018) suggestions, identification based on constructed instruments is not used in isolation, but coupled with other techniques, such as two-stage least squares (2SLS) and the treatment effect model (TEM) based on an external instrument. We choose as instrument the average value of the variable GVC by region and year, driven by the consideration that individual firm involvement in GVCs is correlated with the regional diffusion of GVC, while the latter should not be directly correlated with energy management at the firm level. When adopting this instrument, the estimated coefficient of GVC is still positive and statistically significant.[9]

Second, we address the issue of possible selection bias by estimating the effect of GVC participation through the Rosenbaum and Rubin (1983) propensity score matching (PSM) method. Under the conditional independence assumption (CIA), the PSM method allows evaluating the average treatment effect on the treated (ATT), by measuring the expected difference in ESPs (EMI or REI) between firms that are very similar with respect to a set of observable variables, except participation (treatment group) or non-participation (control group) in a GVC.[10] Employing a Logit model, we estimate the firm's propensity score, that is, the conditional probability that the firm enters the treatment group, given a set of covariates.[11] Then, a control group is considered, that is as similar as possible to each treated firm, in order to reduce the selection bias driven by observable factors. Table 2 reports the PSM results obtained when comparing each GVC firm with 5 (or 10 or 20) nearest neighbors (NN) in terms of propensity score. The results show that ATT

[9] For the sake of conciseness, the results of 2SLS and TEM estimations are not reported, but available upon request.

[10] If CIA holds, the outcomes associated with treated and untreated units are independent of the treatment, conditional on the knowledge of observable factors affecting the sample selection. In other words, knowledge of observable factors restores the condition of randomization.

[11] Firms are matched within country, year and industry by SIZE, AGE, SALES, TRAIN, FAMILY, RATIO, GDPPC.

Table 1
Benchmark and IV estimations.

	OLS		Lewbel (2012)	
	1	2	3	4
	EMI	REI	EMI	REI
GVC	5.1270***	3.5207***	4.2205*	5.8803***
	0.000	*0.000*	*0.058*	*0.000*
SIZE	1.7640***	1.0317***	1.7977***	0.9449***
	0.000	*0.000*	*0.000*	*0.000*
AGE	1.1904***	0.7467***	1.1948***	0.7354***
	0.000	*0.001*	*0.000*	*0.001*
SALES	1.4397***	0.4250***	1.4573***	0.3781***
	0.000	*0.000*	*0.000*	*0.002*
FAMILY	0.0403***	0.0166***	0.0403***	0.0164***
	0.000	*0.000*	*0.000*	*0.000*
TRAIN	8.3555***	3.0775***	8.3966***	2.9638***
	0.000	*0.000*	*0.000*	*0.000*
MANENV	13.8205***	9.0710***	13.8962***	8.8756***
	0.000	*0.000*	*0.000*	*0.000*
REQCERT	16.8683***	8.6069***	16.9248***	8.4558***
	0.000	*0.000*	*0.000*	*0.000*
RATIO	−0.1756	−1.4212***	−0.1917	−1.3784***
	0.697	*0.000*	*0.672*	*0.000*
ETAX	9.4468***	3.3048***	9.4439***	3.3141***
	0.000	*0.000*	*0.000*	*0.000*
GDPPC	2.5756	11.979**	2.3857	12.493**
	0.693	*0.014*	*0.716*	*0.011*
Country, sector and year fixed effects	Yes	Yes	Yes	Yes
N.obs	19,878	19,704	19,878	19,704
Model test	138.99***	26.65***	137.78***	26.62***
R2 or Pseudo R2	0.32	0.16	0.32	0.15
Kleibergen–Paap LM test			553.41	1552.44
			0.000	*0.000*
Hansen J test			4.381	5.06
			0.112	*0.653*

For the description of the variables, see Table A.1 in the Appendix. *p*-values are reported in italics. Superscripts ***, ** and * denote statistical significance at the 1, 5 and 10% level, respectively. SIZE, AGE, SALES and GDPPC are in logarithmic form. Model test is the test of joint significance of all explanatory variables. Kleibergen–Paap LM is the test of under-identification. Hansen J is the test of overidentifying restrictions.

is always positive and statistically significant.[12]

4.2. The mechanisms at work

The evidence provided so far indicates a robust positive relationship between a firm's participation in GVC and its propensity to adopt ESPs. While this outcome corroborates the hypothesis that the beneficial effects of integration in GVCs outweigh the possible drawbacks, it does not single out the actual channels through which GVCs exert their positive influence on the choice of energy sources and green management practices. In what follows, we provide some insights to distinguish the potential mechanisms driving our results.

As recalled above, GVCs can induce a greener aptitude by allowing participating firms (and especially those located in developing countries) to benefit from positive externalities related to transfer of technologies, improvement of quality standards, and management practices (Pietrobelli and Rabellotti, 2011; Del Prete et al., 2017; Rigo, 2021).

To check which mechanism is actually at work, we run separate regressions to assess the association between GVC and different outcome variables. First, to verify whether the effect on ESPs takes place through the absorption of foreign technologies and enhanced innovation capabilities, we alternatively consider as dependent variable the dummy FORE_TEC coded 1 if the firm has employed technology licensed from a foreign owned company or INNO, coded 1 if the firm has introduced product or process innovations.

Second, firms involved in GVCs can collect, process and monitor information related to their production and environmental performance in order to comply with the requirements of the chain. Thus, we use a measure of monitor performance indicators (MP), including for example volume of production, number of errors per 10,000 units produced, cost of inputs, greenhouse gas emissions, total energy use and energy intensity, total water used, hazardous/dangerous waste generated.

Finally, we consider as dependent variable an indicator of internationally-recognized quality certifications (IQC), including ISO (International Organization for Standardization) for manufacturing and services, HACCP (Hazard Analysis and Critical Control Point) for food, and AATCC (American Association of Textiles Chemists and Colorists) for textiles. Given the dichotomous nature of the dependent variables, non-linear probability models (Probit) are adopted.

As Table 3 shows, conditioning on a set of control variables (such as SIZE, AGE, SALES, FAMILY, TRAIN, RATIO, GDPPC), all the aforementioned indicators turn out to be positively and significantly correlated with the dummy GVC. These outcomes suggest that participation in GVCs can enhance the international transmission of knowledge and the adoption of foreign technologies, as well as innovation abilities, managerial capabilities and production quality standards. Consistent to the extant literature surveyed in Section 2, this analysis confirms that through the mentioned channels, GVCs supply an incentive to ESPs, encouraging the use of renewable energy and fostering the adoption of greener energy management practices.

5. Heterogeneity analysis

5.1. Industries and countries

To gauge sectoral heterogeneity in the impact of GVCs on EMI and REI, we first focus on manufacturing and energy-intensive industries. Looking at columns 1–4 of Table 4, we observe that the estimated impact of GVC on EMI is considerably higher than in the benchmark case (Table 1, column 1) in both the subsamples of manufacturing firms (column 1) and energy-intensive industries[13] (column 3). The Chow test reported in the second last row of Table 4 indicates that differences are statistically significant at 1% and 10% level, respectively. By contrast, comparing columns 2 and 4 of Table 4 with column 2 of Table 1, no statistically significant change arises in the estimated impact of GVC on REI.

As a second source of heterogeneity, we consider per capita GDP. Indeed, the stage of economic development is likely to be associated not only to greater industrial development and technology use, but also to more environmentally conscious policies.[14] Once our sample is split into

[12] To ensure the reliability of our results, we conduct a robustness test, using the kernel or the local linear regression method as alternative matching algorithm. These results are available upon request. To check balancing, we run a *t*-test for each regressor used in the propensity score estimation, confirming that the mean of the treated equals that of the control units (Table A.3). To verify the common support between the treatment and comparison groups, we visually inspect the density distribution of the propensity score in both groups; the graphs are available upon request.

[13] Energy-intensive industries are defined by using as threshold the median value of the electricity intensity ratio (i.e. the quantity of kilowatt-hours consumed per dollar of sales). Since this variable is defined on a smaller number of observations, the estimation sample halves compared to benchmark estimations.

[14] The importance of the national environmental policy is captured by country fixed effects, included in all regressions. Ranking our sample countries according to the Environmental Performance Index (EPI, available at https://epi.yale.edu/), which provides a measure of how close nations are to environmental policy targets, we notice that countries with higher scores mostly show a positive and significant country dummy coefficient. The opposite holds for countries with low values of EPI. For the sake of conciseness, the results of this exercise are omitted and available upon request.

Table 2
Propensity score matching results.

	NN 5			*NN 10*			*NN 20*		
	ATT	*Standard error*	t	*ATT*	*Standard error*	t	*ATT*	*Standard error*	t
EMI	6.979	0.911	7.66***	6.486	0.88	7.36***	6.631	0.863	7.68***
REI	3.753	0.707	5.31***	3.679	0.68	5.38***	3.797	0.666	5.70***

NN stands for nearest neighbors; ATT for average treatment effect on the treated. *** means significant at the 1% level.

Table 3
Evidence on mechanisms.

	1	*2*	*3*	*4*
	FORE_TEC	INNO	MP	IQC
GVC	0.3309***	0.3307***	0.3560***	0.3729***
	0.000	*0.000*	*0.000*	*0.000*
SIZE	0.0920***	0.0393***	0.0974***	0.2091***
	0.000	*0.002*	*0.000*	*0.000*
AGE	−0.0417**	−0.0079	0.0144	0.1345***
	0.013	*0.587*	*0.473*	*0.000*
SALES	0.0656***	0.0311***	0.1194***	0.1322***
	0.000	*0.000*	*0.000*	*0.000*
FAMILY	−0.0003	0.0024***	−0.0006*	−0.0002
	0.278	*0.000*	*0.059*	*0.396*
TRAIN	0.4534***	0.5084***	0.5565***	0.3996***
	0.000	*0.000*	*0.000*	*0.000*
RATIO	−0.016	−0.1105***	−0.0909***	0.0508**
	0.548	*0.000*	*0.003*	*0.047*
GDPPC	−1.0771***	−0.6660*	0.2704	−2.0550***
	0.007	*0.082*	*0.529*	*0.000*
Country, sector and year fixed effects	Yes	Yes	Yes	Yes
N.obs	22,537	22,605	11,667	22,248
Model test	3028.23***	5487.61***	2966.712	8149.961
R2	0.163	0.201	0.196	0.319

For the description of the variables, see Table A.1 in the Appendix. *p*-values are reported in italics. Superscripts ***, ** and * denote statistical significance at the 1, 5 and 10% level, respectively. SIZE, AGE, SALES and GDPPC are in logarithmic form. Model test is the test of joint significance of all explanatory variables.

two subsamples of lower and higher-income countries using the median value of GDP per capita as threshold, we run separate regressions and obtain the estimates displayed in columns 5–8 of Table 4. While the GVC coefficient remains positive and significant in both subsamples, its magnitude is much lower for lower-income economies. The Chow test confirms the statistical significance of this difference.

The comparison between high and low-income countries is deepened by focusing on manufacturing firms (Table 5, columns 1–4) and energy-intensive industries (Table 5, columns 5–8). When restricting the analysis to these subsamples, differences in the importance of GVCs between relatively rich and poor countries widen. The Chow test reported at the bottom of Table 5 highlights that participation in GVCs has a significantly stronger impact on the adoption of ESPs in high-income than low-income countries. This happens for energy management (EMI) and, within the subsample of manufacturing firms, even for the production and use of renewable sources (REI).

In general, the econometric estimates show that the relationship between participation in GVCs and ESPs is positive and statistically significant for all sectors and countries. However, a significant difference in the impact of international integration emerges, suggesting that in poorer countries, the beneficial effect of involvement in GVCs (i.e., being exposed to more advanced technologies and higher standards of environmental protection) could be offset by bad positioning in the chains, which may prevent firms from absorbing foreign technologies and upgrading productivity and energy efficiency.

5.2. *Moderating factors*

The importance of firm individual characteristics and context factors such as institutional quality in moderating the effects of GVC participation is investigated by interacting the variable GVCs with firm age, size, human capital, and credit rationing, and the WGI indicator of institutional quality.

As Table 6 shows, the coefficients of the interaction term are significantly negative for younger firms, and in the case of EMI, also for smaller and credit-rationed companies. This evidence emphasizes that weaker individual features in terms of age, size and financial condition, hamper the ability of firms to reap the full potential benefits of belonging to GVCs and adopt greener practices. Conversely, at least for what concerns REI, human capital (TRAIN) has a positive moderating effect: more skilled workers amplify the advantages of participation in GVCs in terms of ESPs.

Another important result is shown in columns 9–10. For both energy management practices (EMI) and the production and use of renewable sources (REI) the interaction coefficient is positive and statistically significant. This confirms the critical role that institutions play in enhancing the effect of participation in GVCs on energy efficiency, as "adopting green technology needs a strong backing and funding of reliable government institutions" (Sun et al., 2019, p. 1).

6. Conclusions and policy implications

Drawing on firm-level data related to a large sample of countries and applying regression analyses and PSM, this study is the first to investigate the link between firm participation in GVCs and the adoption of ESPs.

Our results, corroborated by various robustness checks, show that GVCs can significantly help improve firms' energy policy. As a matter of fact, engaging in GVCs seems to encourage firms to follow a virtuous path toward sustainable practices, such as targeting and monitoring energy consumption and using renewable sources of energy. However, this impact is heterogeneous, as firm participation in GVCs affects more firms located in high-income countries, operating in manufacturing sectors and belonging to energy-intensive industries. In addition, the influence of participation in a GVC is conditioned by moderating factors related to firm characteristics, capabilities and financial endowment, as well as context conditions such as country institutional quality. The latter is an important enabling condition that allows the beneficial effects of integration in GVCs to fully unfold.

Our findings confirm that policy makers should carefully consider the role of firm participation in GVCs in facilitating the adoption of energy-related sustainable practices. However, the complexity in policy making increases with involvement in GVCs. Indeed, on one hand, interactions among firms along the value chain can represent an important channel for accessing foreign knowledge and resources, thus improving green technological capabilities. On the other hand, "market externalities abound in lead firms' willingness to share knowledge through their GVC linkages and the development of suppliers' capabilities to absorb it" (Pietrobelli et al., 2022, page 3). In addition, economic shocks to foreign

Table 4
Industry and country heterogeneity.

	1	2	3	4	5	6	7	8
	Manufacturing firms		*Energy-intensive industries*		*Low-income countries*		*High-income countries*	
	EMI	REI	EMI	REI	EMI	REI	EMI	REI
GVC	7.3822***	3.7388***	6.1639***	2.8669***	2.5417***	2.3185***	6.9734***	4.3436***
	0.000	*0.000*	*0.000*	*0.000*	*0.004*	*0.001*	*0.000*	*0.000*
SIZE	1.4582***	1.1064***	2.0012***	1.2198***	1.2707***	1.1567***	2.3533***	0.7491**
	0.000	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.012*
AGE	1.1037***	0.5741**	0.5724	0.5526*	0.5207	0.0902	1.8420***	1.2826***
	0.002	*0.03*	*0.146*	*0.054*	*0.195*	*0.736*	*0.000*	*0.000*
SALES	1.3812***	0.4931***	1.2102***	0.3616**	1.7752***	0.0894	1.0163***	0.9027***
	0.000	*0.002*	*0.000*	*0.03*	*0.000*	*0.54*	*0.000*	*0.000*
FAMILY	0.0458***	0.0152***	0.0476***	0.0104**	0.0398***	0.0091**	0.0348***	0.0257***
	0.000	*0.001*	*0.000*	*0.034*	*0.000*	*0.042*	*0.000*	*0.000*
TRAIN	8.8101***	3.5770***	8.8151***	3.9872***	9.8790***	2.2350***	6.8802***	3.4287***
	0.000	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*
MANENV	13.2931***	8.7326***	14.6259***	10.7348***	14.7638***	7.3598***	12.5881***	10.4371***
	0.000	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*
REQCERT	17.3142***	8.5100***	16.4940***	6.4601***	12.9272***	8.0215***	19.8830***	8.7955***
	0.000	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*
RATIO	−0.3461	−1.6008***	−0.0241	−1.7807***	0.6323	−0.564	−1.1990*	−2.2700***
	0.534	*0.000*	*0.97*	*0.000*	*0.304*	*0.18*	*0.071*	*0.000*
ETAX	8.5261***	3.6754***	7.1907***	3.6431***	6.3849***	2.6246***	12.3177***	3.7990***
	0.000	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*
GDPPC	3.6476	9.7593	−1.811	6.7559	6.3013	−4.112	3.6407	38.790***
	0.657	*0.124*	*0.845*	*0.335*	*0.537*	*0.608*	*0.757*	*0.000*
Country, sector and year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N.obs	12,822	12,763	9993	9946	9819	9706	10,059	9998
Model test	117.08***	23.97***	91.01***	17.962***	94.90***	12.80***	94.69***	21.43***
Chow test	35.72***	0.45	3.11*	1.6	13.12***	3.54*		
R2	0.35	0.18	0.34	0.17	0.34	0.11	0.32	0.18

For the description of the variables, see Table A.1 in the Appendix. *p*-values are reported in italics. Superscripts ***, ** and * denote statistical significance at the 1, 5 and 10% level, respectively. SIZE, AGE, SALES and GDPPC are in logarithmic form. Model test is the test of joint significance of all explanatory variables. The Chow test checks whether estimated coefficients over different groups of data are statistically different.

Table 5
Deepening country heterogeneity.

	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*
	Manufacturing firms in low-income countries		*Manufacturing firms in high-income countries*		*Energy-intensive industries in low-income countries*		*Energy-intensive industries in high-income countries*	
	EMI	REI	EMI	REI	EMI	REI	EMI	REI
GVC	3.8139***	2.2633***	9.9995***	4.7999***	3.5611***	1.9303**	8.8117***	3.7744***
	0.000	*0.007*	*0.000*	*0.000*	*0.002*	*0.027*	*0.000*	*0.003*
SIZE	1.0083**	1.2516***	1.9691***	0.7443*	1.9132***	1.5907***	2.1540***	0.5702
	0.03	*0.000*	*0.000*	*0.051*	*0.000*	*0.000*	*0.000*	*0.224*
AGE	0.281	0.2626	1.8624***	0.7883*	0.1068	0.1251	1.2415**	0.8957*
	0.579	*0.416*	*0.000*	*0.06*	*0.837*	*0.711*	*0.041*	*0.074*
SALES	1.7761***	0.0945	0.9697***	1.0618***	1.5735***	−0.0654	0.8102**	1.0841***
	0.000	*0.607*	*0.002*	*0.000*	*0.000*	*0.731*	*0.03*	*0.001*
FAMILY	0.0437***	0.0102*	0.0396***	0.0211***	0.0436***	0.0063	0.0438***	0.0170**
	0.000	*0.063*	*0.000*	*0.003*	*0.000*	*0.269*	*0.000*	*0.05*
TRAIN	11.3482***	3.4557***	6.7354***	3.2849***	9.3888***	2.5815***	7.9404***	4.8162***
	0.000	*0.000*	*0.000*	*0.000*	*0.000*	*0.002*	*0.000*	*0.000*
MANENV	14.0181***	6.0837***	12.2439***	10.9153***	14.7149***	8.7647***	14.0827***	12.8651***
	0.000	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*
REQCERT	13.4560***	7.3365***	19.9856***	9.0266***	13.9330***	5.6211***	18.3719***	7.0634***
	0.000	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*
RATIO	0.319	−0.7774	−1.2922	−2.3885***	−0.5296	−1.1077**	0.6436	−2.6069***
	0.681	*0.136*	*0.106*	*0.000*	*0.519*	*0.043*	*0.518*	*0.001*
ETAX	4.5212***	2.7009***	11.9560***	4.4138***	3.2796***	3.0725***	11.7443***	4.1460***
	0.000	*0.000*	*0.000*	*0.000*	*0.001*	*0.000*	*0.001*	*0.002*
GDPPC	7.3939	−9.962	6.2444	40.849***	7.7672	−2.8388	−2.8223	37.282**
	0.575	*0.351*	*0.668*	*0.002*	*0.554*	*0.782*	*0.88*	*0.036*
Country, sector and year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N.obs	6191	6137	6631	6626	5533	5499	4460	4447
Model test	82.21***	10.92***	86.75***	21.06***	74.12***	9.72***	57.83***	14.90***
Chow test	18.16***	4.04**			9.2***	1.48		
R2	0.36	0.13	0.34	0.20	0.36	0.13	0.33	0.20

For the description of the variables, see Table A.1 in the Appendix. *p*-values are reported in italics. Superscripts ***, ** and * denote statistical significance at the 1, 5 and 10% level, respectively. SIZE, AGE, SALES and GDPPC are in logarithmic form. Model test is the test of joint significance of all explanatory variables. The Chow test checks whether estimated coefficients over different groups of data are statistically different.

Table 6
Interacting GVC with moderating factors.

	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
	Interacting with YOUNG		*Interacting with SME*		*Interacting with TRAIN*		*Interacting with RATIO*		*Interacting with IQ*	
	EMI	REI	EMI	REI	EMI	REI	EMI	REI	EMI	REI
GVC	5.3620***	3.8402***	9.1817***	4.0646***	5.3610***	2.6715***	5.8475***	3.6036***	4.9627***	3.6162***
	0.000	*0.000*	*0.000*	*0.01*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*
GVC*Enabling Conditions	−4.2037*	−5.5608***	−4.6231***	−0.6179	−0.5673	2.0631*	−3.2757**	−0.3729	1.7973**	1.6181**
	0.063	*0.001*	*0.005*	*0.709*	*0.607*	*0.052*	*0.012*	*0.752*	*0.034*	*0.042*
YOUNG	2.1729**	1.5219**								
	0.017	*0.016*								
SME			5.8074***	0.2171						
			0.000	*0.822*						
IQ									33.9034**	34.7045***
									0.029	*0.009*
SIZE	1.7415***	1.0174***	2.2593***	1.0380***	1.7627***	1.0359***	1.7709***	1.0325***	1.7181***	0.9283***
	0.000	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*
AGE	1.6406***	0.9875***	1.1957***	0.7449***	1.1913***	0.7423***	1.1917***	0.7467***	1.2150***	0.8274***
	0.000	*0.001*	*0.000*	*0.001*	*0.000*	*0.001*	*0.000*	*0.001*	*0.000*	*0.000*
SALES	1.4511***	0.4329***	1.4339***	0.4241***	1.4380***	0.4317***	1.4366***	0.4247***	1.4801***	0.4768***
	0.000	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*
FAMILY	0.0401***	0.0164***	0.0402***	0.0166***	0.0402***	0.0167***	0.0405***	0.0166***	0.0409***	0.0162***
	0.000	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*
TRAIN	8.3612***	3.0786***	8.3465***	3.0747***	8.4859***	2.5992***	8.3356***	3.0750***	8.0729***	2.9963***
	0.000	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*
MANENV	13.7720***	9.0184***	13.9217***	9.0599***	13.8351***	9.0240***	13.8162***	9.0704***	13.8658***	9.0254***
	0.000	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*
REQCERT	16.8612***	8.6042***	16.8271***	8.6001***	16.8760***	8.5774***	16.8957***	8.6103***	16.9138***	8.5985***
	0.000	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*
RATIO	−0.1571	−1.4113***	−0.192	−1.4211***	−0.1767	−1.4172***	0.2915	−1.3680***	−0.3249	−1.4880***
	0.728	*0.000*	*0.671*	*0.000*	*0.695*	*0.000*	*0.543*	*0.000*	*0.475*	*0.000*
ETAX	9.4319***	3.2987***	9.3998***	3.3037***	9.4503***	3.2881***	9.4481***	3.3045***	9.1445***	3.1368***
	0.000	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*
GDPPC	2.7423	12.061**	2.1248	12.003**	2.6585	11.708**	2.7291	12.0025**	−4.5184	5.2869
	0.675	*0.014*	*0.744*	*0.014*	*0.684*	*0.017*	*0.676*	*0.014*	*0.534*	*0.318*
Country, sector and year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N.obs	19,878	19,704	19,878	19,704	19,878	19,704	19,878	19,704	19,472	19,281
Model test	136.03***	26.11***	137.08***	26.08***	137.49***	26.41***	137.56***	26.37***	137.62***	26.41***
R2	0.32	0.16	0.33	0.16	0.32	0.16	0.32	0.16	0.33	0.16

For the description of the variables, see Table A.1 in the Appendix. *p*-values are reported in italics. Superscripts ***, ** and * denote statistical significance at the 1, 5 and 10% level, respectively. SIZE, AGE, SALES and GDPPC are in logarithmic form. Model test is the test of joint significance of all explanatory variables.

value chain partners can imply domino effects for the domestic economy. Therefore, policymakers are confronted with the challenge to properly regulate, and strengthen GVC linkages so that they can promote technology transfer while at the same time ensuring a country's economic resilience. Moving beyond a minimalist state intervention, several GVC scholars advocate more potent trade, industrial and innovation policies to engender social and environmental upgrading and economic resilience (Pietrobelli et al., 2022). Moreover, they call for a fine grained microeconomic focus. Recognizing the crucial role that lead firms play in defining the terms and conditions of GVC participation, governments could stimulate partnerships through which policymakers collaborate with GVC lead firms to upgrade local suppliers, make them adopt sustainable practices, and build resiliency.

To complete the discussion of our results, some caveats are in order. First, although the dataset we employ provides information on a rich series of firms' characteristics, we lack information on the amount invested in energy-related practices and the share of renewable energy produced and used by the firms on the total amount of energy deployed. Moreover, we had to discard questions included in the Enterprise Surveys on the environmental impact of the establishment, as they had too many missing values. Thus, although our study suggests a robust relationship between GVC involvement and green energy practices, it is not possible to gauge whether greener energy management leads to relevant abatement of pollution. Moreover, given the lack of a longitudinal dimension, we cannot control for the latent heterogeneity of firms or assess whether our results are consistent over time. Finally, we lack information about the origin of imports and destination of exports, and therefore we do not know which countries firms are trading with. This hinders an assessment of the (possibly heterogeneous) impact that trading partners based in different countries may have in terms of positive externalities related to technologies, management practices, and production standards, leading to environmentally friendly practices.

In light of our findings, we believe that a promising avenue for further research is to investigate whether ESPs driven by GVC participation translate into higher energy efficiency and lower emissions at the firm level. As the energy efficiency concept is ambiguous, future investigations should start by appraising different measures of efficiency, focusing on total-factor energy efficiency, which takes into account not only energy but also other inputs, thereby controlling for different productive structures. An interesting matter is whether the results pertaining to energy efficiency will be consistent with the positive relationship recorded between GVC involvement and overall technical efficiency (Agostino et al., 2020).

Credit author statement

The paper "Global value chains and energy-related sustainable practices. Evidence from Enterprise Survey data" has been jointly written by Mariarosaria Agostino, Anna Giunta, Sabrina Ruberto, and Domenico Scalera.

Declaration of Competing Interest

None.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.eneco.2023.107068.

Appendix

Table A.1
List of variables and summary statistics.

Variable	Description	Mean	Std. Dev.	Min	Max	Obs
EMI(a)	Energy Management Index, based on practices to monitor/make more efficient energy use	38.56	33.46	0	100	23,883
REI(a)	Renewable Energy Index, based on the production and use of renewable energy	9.04	22.86	0	100	23,656
GVC	Dummy = 1 if the firm is a two-way trader	0.18	0.38	0	1	25,840
SIZE	Number of employees	65	108.20	1	515	26,910
AGE(b)	Current year minus firm's year of establishment	20.22	15.66	1	205	26,856
SALES (c)	Firm total annual sales	4,335,829	9,723,583	13,279.46	49,150,917	24,347
FAMILY(d)	Percentage of firm shares owned by the same family	43.78	47.29	0	100	26,592
TRAIN	Dummy = 1 if employees have experienced formal training programs	0.29	0.45	0	1	26,940
MANENV	Dummy = 1 if the firm has a manager responsible for environmental or climate issues	0.10	0.30	0	1	26,674
REQCERT	Dummy = 1 if customers require certifications or adherence to environmental standards	0.13	0.34	0	1	26,542
RATIO	Dummy = 1 if the firm was denied financing, or did not apply because discouraged	0.28	0.45	0	1	26,463
ETAX	Dummy = 1 if the firm pays an energy tax or levy	0.21	0.41	0	1	26,006
GDPPC(c)	Per capita gross domestic product	8705.57	6872.69	221.31	29,230.70	27,141
GVC2	Dummy = 1 if the firm exports and imports more than the median values of exports (share on total sales) and imports (share on total inputs)	0.14	0.34	0	1	25,840
YOUNG	Dummy = 1 if the firm age is lower than the first decile of the age distribution (6 years)	0.1	0.3	0	1	26,856
SME	Dummy = 1 if the firm has less than 250 employees	0.93	0.25	0	1	26,910
IQ	Worldwide Governance Indicator (average of the five elementary indexes)	−0.08	0.64	−1.31	1.34	26,528
FORE_TEC	Dummy = 1 if the firm has employed technology licensed from a foreign owned company	0.16	0.36	0	1	26,900
INNO	Dummy = 1 if the firm has introduced product or process innovations	0.29	0.45	0	1	27,061
MP	Dummy = 1 if the firm monitors performance indicators	0.65	0.48	0	1	14,107
IQC	Dummy = 1 if the firm has internationally-recognized quality certifications	0.26	0.44	0	1	26,479

(a) based on PCA. For convenience, we rescaled the variable within a 0–100 range by subtracting to each value the sample minimum and dividing the difference for the maximum-minimum distance; (b) in years; (c) in Euros; (d) in percentage.

Table A.2
Robustness checks.

	OLS				*Probit*						
	1	2	3	4	5	6	7	8	9	10	11
	GVC2 instead of GVC		*Changing Dep. Variables*		*EM indicators*					*RE indicators*	
	EMI	REI	N_EM	N_RE	EneMan	EneMoni	EneTarg	HeatCool	Light	GenGreenE	UseGreenE
GVC			0.2547***	0.0706***	0.2046***	0.1586***	0.1629***	0.1119***	0.1612***	0.1659***	0.2139***
			0.000	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*
SIZE	1.8313***	1.0921***	0.0882***	0.0210***	0.0570***	0.0453***	0.0821***	0.0842***	0.0246**	0.0992***	0.0594***
	0.000	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.038*	*0.000*	*0.008*
AGE	1.1893***	0.7483***	0.0586***	0.0150***	0.0408***	0.0924***	0.0597***	0.0025	0.0166	0.0313*	0.0545**
	0.000	*0.000*	*0.000*	*0.001*	*0.005*	*0.000*	*0.000*	*0.862*	*0.228*	*0.091*	*0.036*
SALES	1.4704***	0.4549***	0.0722***	0.0085***	0.0562***	0.0586***	0.0273***	0.0455***	0.0514***	0.0268**	0.0557***
	0.000	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.001*	*0.000*	*0.000*	*0.011*	*0.000*
FAMILY	0.0405***	0.0168***	0.0020***	0.0003***	0.0010***	0.0004*	0.0005**	0.0018***	0.0020***	0.0013***	0.0014***
	0.000	*0.000*	*0.000*	*0.000*	*0.000*	*0.089*	*0.046*	*0.000*	*0.000*	*0.000*	*0.001*
TRAIN	8.4288***	3.1535***	0.4199***	0.0619***	0.2183***	0.2951***	0.2689***	0.2174***	0.2940***	0.1497***	0.1899***
	0.000	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*
MANENV	13.9439***	9.1846***	0.6831***	0.1832***	0.5398***	0.4056***	0.4871***	0.3544***	0.2975***	0.4308***	0.2935***
	0.000	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*
REQCERT	17.0073***	8.7234***	0.8371***	0.1733***	0.5726***	0.5224***	0.5478***	0.4201***	0.3580***	0.4205***	0.4074***
	0.000	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*
RATIO	−0.1897	−1.4374***	−0.0072	−0.0287***	−0.0881***	−0.0035	0.0183	−0.0273	0.0509**	−0.1222***	−0.1303***
	0.674	*0.000*	*0.75*	*0.000*	*0.000*	*0.874*	*0.437*	*0.228*	*0.018*	*0.000*	*0.002*
ETAX	9.4600***	3.3133***	0.4704***	0.0662***	0.2209***	0.5695***	0.4019***	0.1969***	0.1130***	0.1710***	0.3292***
	0.000	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*
GDPPC	2.2303	11.5828**	0.1069	0.2474**	0.5661	−0.5554*	0.5909	0.4189	−1.0566***	1.675***	−1.7350*
	0.733	*0.018*	*0.744*	*0.012*	*0.115*	*0.084*	*0.11*	*0.249*	*0.001*	*0.001*	*0.074*
GVC2	4.4638***	2.5612***									
	0.000	*0.000*									
Country, sector and year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N.obs	19,878	19,704	19,878	19,704	20,726	21,738	21,647	20,611	21,067	20,135	21,136
Model test	138.35***	26.57***	139.46***	26.81***	4022.14***	6675.73***	4505.45***	3388.99***	3985.43***	2352.59***	1644.80***
R2 or Pseudo R2	0.32	0.15	0.32	0.16	0.16	0.22	0.18	0.13	0.14	0.16	0.20

For the description of the variables, see Table A.1 in the Appendix and footnote 3 in the main text. *p*-values are reported in italics. Superscripts ***, ** and * denote statistical significance at the 1, 5 and 10% level, respectively. SIZE, AGE, SALES and GDPPC are in logarithmic form. Model test is the test of joint significance of all explanatory variables.

Table A.3
Balancing tests.

		Mean		t-test	
		Treated	*Control*	*t*	*p > t*
SIZE	U	4.04	3.065	42.79	0.000
	M	4.032	4.011	0.67	0.502
AGE	U	2.979	2.718	19.02	0.000
	M	2.976	2.965	0.65	0.513
SALES	U	14.759	13.192	42.45	0.000
	M	14.744	14.754	−0.21	0.835
FAMILY	U	49.463	43.686	6.67	0.000
	M	49.517	50.559	−0.95	0.342
TRAIN	U	0.459	0.252	25.39	0.000
	M	0.457	0.476	−1.62	0.106
RATIO	U	0.204	0.294	−10.91	0.000
	M	0.205	0.212	−0.77	0.444
GDPPC	U	8.998	8.684	18.52	0.000
	M	8.993	8.991	0.12	0.906

For the description of the variables, see Table A.1.

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