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EXPLORING THE ROLE OF ENVIRONMENTAL REGULATIONS AND GREEN PRACTICES IN GLOBAL VALUE CHAINS (GVCS) PARTICIPATION: EVIDENCE FROM FIRMS IN THE EURO-MEDITERRANEAN REGION

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CONTENTS

ABSTRACT

The main objective of this study is to examine the association between environmental regulation, green practices, and GVCs participation, while also assessing the moderating and mediating roles of energy innovation and energy management. By using the EBRD-EIB-WB's enterprise surveys 2018-2020, we focus on 16894 private firms in 23 Euro-Mediterranean (Euro-Med) countries operating in the manufacturing and service, and retail industries. We employ the GTP-FRM, a two-step Heckman correction and an instrumental variable (IV) approach to account for the endogeneity bias due to reverse causality and the self-selection problem. The main findings show that environmental regulations and energy management practices are more effective than energy innovation in advancing GVCs integration in line with the PH. The driving forces of environmental regulation and energy management are more pronounced for firms that are weakly integrated in GVCs and for EU firms, whereas the positive effects of energy innovation and energy management prevail more for firms in energy-efficient sectors. This could be explained by the fact that firms operating in energy-intensive sectors are highly reliant on the existence of a well-enforced regulatory framework that incentivizes their adoption of green practices, which enhance their integration in value chains. By contrast, firms operating in the energy-efficient section are already adopting pro-active measures and are able to benefit from these green practices to improve their GVCs integration. Also, while there is no evidence for a moderating role of green practices, a good quality energy management can have a full or partial mediating effect for different levels of GVCs integration, and to a lesser extent energy innovation.

Keywords: Global value chains (GVC), innovation, energy, environmental regulations, firm level

JEL classification: F10 ; F14 ; O32 ; Q40 ; Q48 ; Q56

RÉSUMÉ

L'objectif principal de cette étude est d'examiner l'association entre la réglementation environnementale, les pratiques vertes et la participation aux chaînes de valeur mondiales (CVM), tout en évaluant les rôles modérateur et médiateur de l'innovation énergétique et de la gestion de l'énergie. En utilisant les enquêtes auprès des entreprises menées par la BERD, la BEI et la Banque mondiale entre 2018 et 2020, nous nous concentrons sur 16 894 entreprises privées dans 23 pays euro-méditerranéens (Euro-Med), opérant dans les secteurs de l'industrie manufacturière, des services et du commerce de détail.

Nous employons le modèle GTP-FRM, une correction en deux étapes de Heckman ainsi qu'une approche par variable instrumentale (VI) afin de corriger les biais d'endogénéité dus à la causalité inversée et au problème d'auto-sélection. Les principaux résultats montrent que la réglementation environnementale et les pratiques de gestion de l'énergie sont plus efficaces que l'innovation énergétique pour favoriser l'intégration dans les CVM, conformément à l'hypothèse du Portier (PH). Les moteurs que constituent la réglementation environnementale et la gestion de l'énergie sont particulièrement importants pour les entreprises faiblement intégrées aux CVM et pour les entreprises de l'Union européenne, tandis que les effets positifs de l'innovation énergétique et de la gestion de l'énergie prédominent davantage pour les entreprises opérant dans des secteurs à haute efficacité énergétique.

Cela peut s'expliquer par le fait que les entreprises des secteurs à forte intensité énergétique dépendent fortement de l'existence d'un cadre réglementaire bien appliqué qui les incite à adopter des pratiques écologiques, renforçant ainsi leur intégration dans les chaînes de valeur. En revanche, les entreprises opérant dans des secteurs déjà efficaces sur le plan énergétique adoptent généralement des mesures proactives et sont donc mieux placées pour tirer parti de ces pratiques vertes afin d'améliorer leur participation aux CVM.

Par ailleurs, bien qu'il n'existe pas de preuve d'un rôle modérateur des pratiques vertes, une bonne gestion de l'énergie peut exercer un effet médiateur partiel ou total selon les niveaux d'intégration aux CVM, tandis que l'innovation énergétique joue ce rôle dans une moindre mesure.

الملخص

الهدف الرئيسي من هذه الدراسة هو فحص العلاقة بين التنظيم البيئي، والممارسات الخضراء، والمشاركة في سلاسل القيمة العالمية، مع تقييم الأدوار المعدلة والوسيطة لكل من الابتكار في مجال الطاقة وإدارة الطاقة. وباستخدام بيانات مسوح الشركات التي أجرتها كل من البنك الأوروبي لإعادة الإعمار والتنمية، وبنك الاستثمار الأوروبي، والبنك الدولي خلال الفترة 2018–2020، تركز الدراسة على 16,894 شركة خاصة في 23 دولة من دول منطقة الأورو-متوسط، تعمل في قطاعات الصناعة التحويلية، والخدمات، والتجزئة.

تعتمد الدراسة على نموذج GTP-FRM، الذي يجمع بين تصحيح هيكمان من مرحلتين ونهج المتغيرات الآلية، وذلك للتعامل مع التحيز الناتج عن التسبب العكسي ومشكلة الاختيار الذاتي.

تُظهر النتائج الرئيسية أن التنظيمات البيئية وممارسات إدارة الطاقة أكثر فاعلية من الابتكار في مجال الطاقة في تعزيز الاندماج في سلاسل القيمة العالمية، بما يتماشى مع فرضية الميناء (PH). وتكون القوى الدافعة للتنظيم البيئي وإدارة الطاقة أكثر وضوحًا لدى الشركات ذات الاندماج الضعيف في سلاسل القيمة العالمية، ولدى الشركات الأوروبية، في حين أن الآثار الإيجابية للابتكار في الطاقة وإدارة الطاقة تظهر بشكل أوضح لدى الشركات العاملة في القطاعات ذات الكفاءة العالية في استخدام الطاقة.

ويمكن تفسير ذلك بأن الشركات العاملة في القطاعات كثيفة الاستهلاك للطاقة تعتمد بشكل كبير على وجود إطار تنظيمي صارم يشجع على تبني الممارسات البيئية، مما يعزز اندماجها في سلاسل القيمة. أما الشركات العاملة في القطاعات ذات الكفاءة الطاقية العالية، فهي تتبنى بالفعل إجراءات استباقية وتتمكن من الاستفادة من هذه الممارسات البيئية لتحسين اندماجها في سلاسل القيمة العالمية.

وعلى الرغم من عدم وجود دليل على الدور المعدل للممارسات البيئية، فإن إدارة الطاقة ذات الجودة العالية يمكن أن تلعب دورًا وسيطًا جزئيًا أو كليًا في مستويات مختلفة من الاندماج في سلاسل القيمة العالمية، بدرجة أقل نسبيًا من الابتكار في مجال الطاقة

INTRODUCTION

In recent decades, global value chains (GVCs) have grown in prominence and have transformed the landscape of international trade, with approximately 70% of international trade now involving GVCs (Antràs & de Gortari, 2020; Marvasi, 2022; OECD, 2024). The rise of GVCs has led to a global fragmentation of production processes with firms lowering their costs of production by delocalizing production stages in different locations (Siewers et al., 2024). A firm is said to be participating in a GVC if it produces at least one stage in a GVC (Antràs, 2020). With the increasing number of countries and firms participating in GVCs, the role of GVCs in fostering positive effects on productivity, efficiency, job creation, and economic growth has become more evident.

Nowadays, as concerns about climate change problems and the significant risk it poses to the global economy continue to gain attention (Cevik & Miryugin, 2022), understanding the implications of higher GVCs participation on environmental quality has become crucial. The rapid expansion of GVCs is associated with higher pollution and massive greenhouse gas (GHG) emissions at the upstream level and in more energy-intensive production stages in different countries (Meng et al., 2023b). Therefore, the concept of greening GVCs has emerged along with the urgency to enhance its sustainability and resilience against climate change (Messerli et al., 2019). The greening of GVCs is a process that results in the reduction of their ecological footprint, namely, their impact on GHG emissions, biodiversity loss, and overexploitation of existing natural resources (De Marchi et al., 2019; Gentile et al., 2023).

Furthermore, firms participating in GVCs are required to make key environmental decisions involving the adoption of different sustainability strategies and green measures, and more specifically energy-related sustainability measures that are considered key drivers for the green transformation of GVCs (Burki, 2018; Agostino et al., 2023). Thereupon, firms must develop their green resources and culture as a foundation for their green performance by implementing environmental managerial practices and developing green innovations (Rehman et al., 2023). Besides, other external stakeholders, namely governments, could play a central role in reducing firms' environmental impact through the enactment and enforcement of environmental regulations[1].

Hence, the main objective of this study is to explore the association between environmental regulations, green practices and participation of firms from the Euro-Mediterranean (Euro-Med) region in GVCs. More specifically, the analysis focuses on the nexus between energy regulations, green energy practices and firm-level GVCs participation. In addition, we assess the direct and indirect (moderating and mediating) roles of green practices, namely energy innovation and energy management practices, in

[1] Governments 'intervention is theoretically justified by the absence of markets for environmental services, the poor enforcement (or even the lack) of private property rights, and the lack of pricing of environmental resources, resulting in inevitable excessive demands on the assimilative capacity of the environment" (Baumol and Oates, 1988, p.1).

promoting GVCs participation. The importance of the study stems from the following. Firstly, while the rapid expansion of GVCs foster many positive outcomes for firms and countries, they generate many environmental problems due to lengthier shipping routes and over-exploitation of natural resources and energy in countries with poor institutions resulting in higher GHG emissions (De Melo, 2014; World Bank, 2020; Meng et al., 2023a). And with the increasing vulnerability of firms to climate change disasters, researchers and policymakers demonstrate great interest in analysing the sustainability and resilience of firms and GVCs by focusing on the role of environmental regulations and green practices (Marvasi, 2022; Chatterjee et al., 2024). Secondly, enhancing Euro-Med firms' participation in GVCs is crucial to promote their export dynamics, to attract foreign investors, and to boost regional integration (Zaki, 2019). Thirdly, when compared to their European Union (EU) counterparts, the Southern and Eastern Mediterranean (SEMED) countries are still lagging in the decarbonization of their energy and manufacturing sectors (European Economic and Social Committee, 2023). Thereby, the imposition of stricter energy regulations would affect firms' participation in GVCs. Fourth, focusing on implementing green practices related to energy should be approached by firms and countries integrated in GVCs because energy accounts for more than 75% of total GHG emissions globally (International Energy Agency, 2024), and because policymakers emphasize the urge to shift away from the massive use of fossil fuels and transit towards more sustainable and efficient energy system due to rising prices of energy inputs and growing concerns about climate crisis (Capozza et al., 2021).

For this purpose, we conducted a firm-level analysis on the nexus between environmental regulations, green practices, and GVCs participation for 16894 private firms in 23 Euro-Med countries[2] operating in manufacturing and service, and retail industries. The study bridges the gap in the literature since most of the empirical studies on GVCs are conducted at the country level (Wang et al., 2021; Liu et al., 2022), and those examining the trade effects of environmental regulations at the firm-level focus merely on traditional international trade (Shi & Xu, 2018; Du et al., 2023). The paper is divided into six sections. Section two presents the literature review. Section three describes the data and stylized facts. Section four presents the methodology and identification strategy. Section five discusses the main results. Section six concludes and derives policy implications at the national and regional levels.

[2] We have 7 SEMED countries: Egypt, Jordan, Lebanon, Morocco, Tunisia, Turkey, and West Bank and Gaza, and 16 EU countries: Bulgaria, Croatia, Cyprus, Czechia, Greece, Estonia, Hungary, Italy, Latvia, Lithuania, Malta, Poland, Portugal, Romania, Slovak Republic, and Slovenia.

LITERATURE REVIEW AND RESEARCH HYPOTHESIS

Two approaches in the theoretical literature examine the macro- and micro-economic effects of environmental regulation. The first is the neoclassical approach that is based on the conventional pollution haven hypothesis (PHH). The PHH predicts that more stringent regulations reduce the availability of environmental inputs and increase environmental control costs in pollution-intensive sectors. Thus, countries with more stringent regulations turn to have a relative cost disadvantage in the production of pollution-intensive goods and specialize in the production of clean ones, whereas those with less stringent regulations are turned into pollution havens and specialize in the production of pollution-intensive goods (Persson, 2003; Costantini and Mazzanti, 2011). The second is the revisionist approach that is based on the Porter Hypothesis (PH) that defends environmental regulations and makes an invitation for well-designed and stricter ones, which drive private firms and the economy as a whole to become more competitive in international markets (Jaffe et al., 1995). The combination of well-designed and more stringent regulations with appropriate innovation strategies can lead to a win-win situation, entailing that firms will experience productivity gains, enhanced trade performance and international competitiveness on one hand, and higher environmental efficiency on the other hand (Porter & Van der Linde, 1995; Lanoie et al., 2007; Costantini and Mazzanti, 2011; Zhang et al., 2024). Stricter environmental regulations also promote firm-level structural changes, where firms are encouraged to introduce new environmental management systems and practices (environmental accounting, environmental training programs) that may generate information, facilitate efficient investments in environmental R&D, enhance green innovativeness of firms, and finally improving their integration in global markets (Hesse, 2007).

Most empirical studies on the relationship between environmental regulations and international trade are conducted at the country level providing evidence either for PHH (Van Beers & Van den Bergh, 1997; Wilson et al., 2002; Broner et al. (2012) or the PH (Xu, 2000; Lu, 2010; Costantini & Mazzanti, 2011; De Santis, 2011; Fabrizi et al., 2024). By contrast, the empirical evidence on firm-level trade effects of environmental regulations is quite scarce[3]. In line with PHH, scholars argue that more stringent environmental regulations exert a detrimental effect on exports extensive and margins due to the higher fixed cost of exporting, the non-incentivizing design of regulations, higher export prices, the switching to new greener but costly technologies, new products and new destinations, and the higher compliance costs outweighing innovation offsets (Shi & Xu, 2018; Cherniwchan & Najjar, 2019; Zhang et al., 2020). By contrast, other optimistic studies show a U-shaped relationship between environmental regulation and export trade, where the cost of compliance and controlling emissions deters export volume in the short

[3] Empirical studies focus rather on financial performance (Rassier & Earnhard, 2010; Xing et al., 2020; Mu et al.2022; Chomachaei & Golmohammadi, 2023) and total factor productivity (Jaffet et al., 1995; Lanoie et al., 2007; Benatti et al., 2023).

run, and then the PH prevails through the channel of innovative activities offsetting higher production costs, and enhancing trade margins (Huang and Wu, 2022). Moreover, there is evidence that technological innovation acts as the transmission channel through which environmental regulations can promote the cleanliness of firms' exports (Du et al., 2023), and can also drives the export quality upgrading of firms in the manufacturing sector regardless of whether they operate in pollution-intensive or clean industries (Xie et al., 2020).

Regarding the nexus of environmental regulations and green practices, some studies focus on the relationship between environmental regulations and green innovation and support that tightening environmental policies lead to higher innovative activity in environmentally friendly technologies (Benatti et al., 2024), with a special emphasis on market-based instruments such as Chen et al. (2022). Some scholars also find that environmental protection subsidies and environmental management system certification enhance green innovation and that corporate governance and environmental information disclosure positively moderate the relationship (Ying & Jin, 2024). Also, some research highlights mediating role of environmental, social governance (ESG) between environmental taxation and green innovation (Cao et al., 2024), and others provide evidence for the mediating role of proactive environmental strategy in explaining the relationship between green supply chain management (GSCM) practices and green culture on green performance (Rehman et al., 2023). For the specific effect of environmental regulations on energy practices, some studies find that the implementation of environmental regulations improves firm-level energy efficiency (Du et al., 2022) but the effect can exhibit a time lag and the relationship has a U-shape for CAC regulations and an inverse relationship for MBIs (Wang & Liang, 2022).

Empirical studies on the simultaneous association between environmental regulations, green practices, and firms' integration in GVCs are notably scarce (Paschoaleto & Martinez-Zarzoso, 2024). Firstly, most studies on environmental regulations and GVCs nexus are conducted at the country-industry level (Wang et al., 2021; Liu et al., 2022). Secondly, some authors examine how GVCs' integration affects firms' environmental performance (Siewers et al., 2024) or how firms' environmental performance impacts their extensive and intensive participation in GVCs (Paschoaleto & Martinez-Zarzoso, 2024). Thirdly, other studies focus merely on the association between GVCs integration and innovation (Avenyo et al., 2022; Ajide et al., 2023; Eissa &Zaki, 2023a; 2023b) or GVCs integration and the implementation of energy-related sustainable practices (Agostino et al., 2023). Fourth, different studies consider the moderating and mediating effects of green practices such as ESG (Cao et al., 2024; Ying & Jin, 2024), innovation (Xie et al., 2020; Du et al., 2023; Fabrizi et al., 2024), green innovation (Rehman et al., 2023), and energy innovation (Du et al., 2022; Wang & Liang, 2022) but without considering the association between environmental regulations and GVCs participation. Hence, we bridge the gap in the literature and acquire novel firm-level data from the European Bank for Reconstruction and Development (EBRD)-European Investment Bank (EIB)- World Bank (WB) Enterprise Surveys 2018-2020 and focus on 16894 private firms in 23 Euro-Med countries operating in the manufacturing and service industries. Moreover, we explore the moderating effect and the mediating role of two types of green practices, energy innovation and energy management practices. Furthermore, to test the robustness of our results,

we account for the endogeneity sources due to reverse causality and selection bias using two-step Heckman correction and IV approach, and we extend the analysis in two ways. First, we conduct heterogeneity analysis by conducting sub-sample regressions for EU and SEMED countries, and for energy-intensive and energy-efficient industries. Second, we do a sensitivity analysis by extending the model by adding other covariates. For this purpose, we aim at testing three main hypothesis: H1 environmental regulations exert a positive effect on firms' participation in GVCs (PH); H2 energy management and energy innovation play a positive moderating role for the effect of environmental regulations on firms' participation in GVCs; and H3 energy management and energy innovation play a positive mediating role between environmental regulations and firms' participation in GVCs.

DATA AND STYLIZED FACTS

The main research question we want to address is "to what extent environmental regulations and green energy practices matter for firm-level GVCs integration?" For this purpose, we acquire pooled cross-section firm-level data from the European Bank for Reconstruction and Development (EBRD)-European Investment Bank (EIB)- World Bank Enterprise Surveys (WBES) 2018-2020[4] and focus on 16894 private firms in 23 Euro-Med countries (16 EU countries and 7 SEMED countries) operating in manufacturing and service and retail industries.

Data description and sources

Micro-level data is acquired from the EBRD-EIB-WBES. First, for the main dependent variables, we construct different proxies to measure the probability and intensity of GVCs' participation. Following Paschoaleto & Martinez-Zarzoso (2024) and Siewers et al. (2024), we use data related to the shares of direct and indirect exports in total sales (share of foreign materials and supplies (i.e. foreign inputs) in the total purchases of material and supplies and whether any of these foreign inputs was directly imported. In addition, we use data related to foreign ownership and whether the firm owns an internationally recognized quality certification. Following Dovis & Zaki (2020)'s definition of GVCs, we develop four proxies for both the extensive and intensive GVCs participation. For the extensive margins, we have the first Weak GVC1E that is a dummy variable taking the value of 1 if the firm is a two-way trader (exports and imports simultaneously) and zero otherwise; then the second and third intermediate definitions GVC2E and GVC3E both respectively are a dummy variable taking the value of 1 if either the firm is a two-way trader (exports and imports simultaneously) and holds an internationally-recognized quality certification, or is a two-way trade and holds foreign shares, and zero otherwise; and finally the fourth strict definition GVC4E that is a dummy variable taking the value of 1 if the firm is a two-way trader (exports and imports simultaneously), holds an internationally-recognized quality certification, and has foreign shares, and zero otherwise. For the *intensive participation*, we follow Urata and Baek (2020) to construct an index for the intensity of participation calculated as the product of the share of direct exports in total sales, the share of indirect exports in total sales, and the share of foreign inputs in total purchases of materials and supplies. We also develop four main proxies, the first is a weak GVC1I that measured by the intensity index of GVCs participation, the second and third intermediate definitions GVC2I and GVC3I proxied

[4] The main reason for using these surveys is that they contain a specific Green Economy module that gathers data on enterprise actions concerning the environment and climate change. In addition to data related to firms' internal and operational characteristics (e.g. sales revenues, trade, management approach, etc.), the module provides data on the green practices and green investments of firms for a selected pool of 32 countries located in Europe, Central Asia, Middle East, and North Africa for three consecutive years 2018, 2019 and 2020.

by the intensity index of GVCs participation if the firm holds an international certification or has foreign shares respectively, and the fourth strict definition GVC4I that is the intensity of GVCs participation if the firm holds and international certification and has foreign shares. According to the literature on GVCs participation, firms that simultaneously export and import are considered to be larger and more productive, but they are fewer in number. Moreover, having either an international certification or foreign shares serves as a signal for a firm's higher ability to integrate vertically fragmented production processes and to export to foreign markets (Dovis & Zaki, 2020).

Second, for the *main explanatory variables* of our interest, we have environmental regulation and green energy practices. Regarding environmental regulation, we use a dummy variable that takes the value of 1 if the firm is levied an energy tax or energy performance standard, and zero otherwise[5]. Regarding the green energy practices, we construct two proxies for energy innovation and energy management practices[6]. For energy innovation, it is a dummy variable taking the value of 1 if the firm adopts at least any of the following five measures: heating and cooling improvements; lighting system improvements; machinery and equipment upgrades; vehicle upgrades; and more climate-friendly energy generation on site, and zero otherwise. For energy management practices, it is a dummy variable taking the value of 1 if the firm monitors its energy consumption, completes an external audit of its energy consumption, or if the firm sets targets for energy consumption, and zero otherwise.

Third, for other covariates, we use the following variables related to a firm's characteristics based on findings from the determinants of GVCs participation literature. (1) Firm size is a categorical variable equal to 1 for small-sized firms, 2 for medium-sized firms, and 3 for large-sized firms following the WB Classification of firms into small-sized firms with less than 20 employees, medium-sized firms with 20 or more employees and less than 100 employees, and large firms with 100 or more employees. (2) Firm age is defined by the number of years since its establishment. It is calculated as the natural logarithm of the subtracted value of the firm's establishment year from the survey year. (3) Labor productivity is defined as the total amount of sales[7] (delated and converted to US$) over the total number of full-time employees. (4) Access to finance is proxied by a dummy equal to 1 if the firm is financially constrained and zero otherwise[8]. (5) Finally, we account for the level of digitalization, including a dummy variable taking the value of 1 if the firm owns a website and zero otherwise.

[5] Energy taxes are considered as effective tools in environmental policy for combatting climate change. Based on findings from Firtescu et al. (2023), in the long run, an increase in energy taxes can possibly decrease GHG emissions.

[6] Green management is defined as "the firms' managerial, non-productive measures to mitigate their environmental impacts" (Wu, 2023).

[7] It is more accurate to calculate labour productivity as the value added per unit of labour in order to avoid confounding the effect of increasing inputs and materials with productivity (Adviu, 2022). However, the main problem with this approach is the loss of more than the half of observations due to missing data for variables used to calculate value added such as input cost, fuel cost, and electricity cost.

[8] We follow Fowowe (2017), according to who the firm is financially constrained if it has used external sources of finance for working capital and /or investments during the previous fiscal year and /or have a loan outstanding at the time of the survey, and it did not apply for a loan during the previous fiscal year due to complex application procedures, high interest rates, high collateral requirements, insufficient size and maturity of loans, or due to doubts about the loan being approved, or it has applied for a loan but was rejected

Furthermore, since the problem of endogeneity bias is most likely to occur due to the existence of a causal relationship between the likelihood that a firm is levied an environmental regulation and GVCs participation[9] and the existence of selection bias[10]. Hence, an instrumental variables (IVs) approach is employed to tackle reverse causality. For this purpose, we use two instruments[11]. First, we follow Paschoaleto & Martinez-Zarzoso (2024) by using an IV that is the interaction between a country-level variable that denotes a strong environmental regulatory system and a firm-level variable that indicates the greening of the firm performance. For the country-level variable, we use a dummy variable taking the value of 1 if the country's legal origin is French legal origin and zero otherwise. The main reason for using the legal origin is that they are assumed to be strongly correlated with countries' policies and institutions, which would affect their economic performance. At the same level of development, French civil law countries exhibit heavier regulations and greater government intervention (Glaeser and Schleife, 2002). Hence, countries with French civil law are expected to have more stringent regulations and a lower level of emissions. Data about the French legal origin have been obtained from La Porta et al. (1999). For the firm-level data, we use a dummy variable equal to 1 if the firm has adopted at least one of the following green measures: monitoring carbon emissions, targeting carbon emissions, external audit for carbon emissions, monitor water use, external audit for water use, monitor other pollutants levels, target other pollutant levels, external audit other pollutants levels, or adopts energy efficiency measures, and zero otherwise. Second, we instrument for environmental regulation using the shift share variable of environmental regulation aggregated by country-region-sector-year, minus each firm's status in terms of subjection to environmental regulations. The selection bias problem is accounted for by conducting a two-step Heckman correction where we first regress the selection equation on a set of covariates (firm size and firm age) and two excluded instruments, namely political connection and the probability of facing strict regulations[12].

Finally, to test the robustness of our results, we extend the model by adding other covariates. First, we include technological capability is a dummy taking the value of 1 if the firm is spent on R&D within the last three years, if the firm has introduced new products/services over the last three years, or if the firm has introduced new/significantly introduced new processes over the last three years, and zero otherwise. Second, we account for firms' perception of the major obstacles to trade using a dummy variable taking the value of 1 if the firm considers transport and customs, and trade regulations as major or very severe obstacles to its current operations, and zero otherwise.

[9] This causal relationship may cause estimates to be biased downwards since some countries would avoid imposing energy taxes or energy performance standards on firms in order to promote their integration in GVCs.

[10] The selection bias problem is due to the inclusion of the firms' subjection to environmental regulation as the main variable of interest.

[11] In order to test for the validity and the weakness for the IV, we run the two-stage least square (2SLS) and according to the findings of the Kleibergen-Paap rk Wald F statistic test, its value exceeds all stock-yogo critical values, i.e. the IV passes the weak instrument test.

[12] Political connecting is a dummy variable taking the value of 1 if the firm belongs to organized business associations (e.g. trade unions, business support groups) and find provided lobbying services very useful, and zero otherwise. Based on the literature, when if a firm is part of organized sectors and are able to exert lobbying, they are more likely able to regulatory decision-making processing including the imposition of environmental regulations (Aboushady & Zaki, 2024). Strict regulation is a dummy taking the value of 1 if the firm finds that different regulations like occupational safety regulations, health and hygiene regulations, environmental regulations, tax rates, and business licenses and permits as major and very severe obstacles to their operations, and zero otherwise. This is justified by the fact that firms that face different types of strict regulations are more likely to be levied energy taxation or performance standard.

Stylized facts

Table 1 presents the main summary statistics of all the variables used to conduct the analysis. Tables 2 and 3 present respectively the shares of firms that are integrated in GVCs according to the four definitions of the extensive margin, and the shares of firms that face an environmental regulation, and the share of firms that undertake energy innovation and energy management practices for EU and SEMED countries separately. Regarding the GVCs integration, table 2 shows that firms in both regions are less likely to be integrated in GVCs and that the weaker the definition of GVCs participation, the greater the share of firms that are integrated and the stricter the definition, the lower the share of firms that are part of a GVC (Zaki, 2019). Yet, the share of EU firms that are integrated in GVCs is relatively greater than the share of SEMED firms for all GVCs definition, which goes in line with the fact that GVCs participation represent less than 50% of SEMED countries' gross exports (except Turkey), whereas it represents more than 60% of EU gross exports during the period 2000-2018 (European Bank for Reconstruction and Development & European Commission, 2020). Regarding environmental regulation and green energy practices, table (3) shows that the share of firms facing environmental regulation in the SEMED countries is greater than in EU countries. Also, while more EU firms introduce energy innovation, both regions have relatively the same shares of firms undertaking energy management practices.

Tables 1: Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Exporting and importing status of the firms					
Exporting firms	16894	.334	.472	0	1
Importing firms	16894	.558	.497	0	1
Share of direct exports in total sales (%)	16744	11.652	26.072	0	100
Share of indirect exports in total sales (%)	16745	4.337	15.251	0	100
Share of foreign imports in total purchases of raw materials and supplies (%)	16320	28.813	34.966	0	100
Direct imports of inputs	9262	.54	.498	0	1
Extensive participation in GVCs					
Weak GVC1E	16894	.26	.439	0	1
Intermediate GVC2E	16894	.134	.341	0	1
Intermediate GVC3E	16894	.053	.223	0	1
Strict GVC4E	16894	.031	.173	0	1
Intensive participation in GVCs					
Weak GVC1I	16251	.002	.012	0	.25
Intermediate GVC2I	4945	.003	.017	0	.25
Intermediate GVC3I	1325	.006	.023	0	.25
Strict GVC4I	674	.008	.027	0	.25

Environmental regulations, green innovation, and green management practices					
Environmental regulation	16049	.252	.434	0	1
Energy innovation	15869	.661	.473	0	1
Energy management	16242	.493	.5	0	1
Legal origin	16894	.582	.493	0	1
Green measures	16249	.387	.487	0	1
Instrumental variables					
Legal origin*Green measures	16249	.185	.388	0	1
Firms and sectors characteristics					
Small-sized firms	16894	.481	.5	0	1
Medium-sized firms	16894	.322	.467	0	1
Large-sized firms	16894	.197	.398	0	1
Ln firm age	16721	2.876	.717	0	5.308
Ln labor productivity*	15545	5.877	1.438	-1.405	13.277
Digital firms	16864	.634	.482	0	1
Trade obstacles	16894	.315	.465	0	1
Technological capability	16894	.29	.454	0	1
Credit constraints	16894	.925	.263	0	1
Manufacturing industries	9647	1	0	1	1
Service industries	7247	2.67283	.4692122	2	3
Energy intensive sectors	16894	.525	.499	0	1
Energy efficient sectors	16894	.475	.499	0	1

Source: Author's own elaboration using data from the WBES. *Deflated and converted to US $.

Tables 2: Distribution of firms in EU and SEMED countries for the probability of GVCs participation

		%	Std.Err.	[95%_Conf	Interval]
GVCE1					
EU countries					
	No	84.9	0.013	0.821	0.873
	Yes	15.1	0.013	0.127	0.179
SEMED countries					
	No	89.3	0.009	0.875	0.909
	Yes	10.7	0.009	0.091	0.125
GVCE2					
EU countries					
	No	96.6	0.004	0.959	0.973
	Yes	4.4	0.004	0.027	0.041
SEMED countries					
	No	96.8	0.004	0.959	0.974
	Yes	3.2	0.004	0.026	0.041
GVCE3					
EU countries					
	No	99.1	0.001	0.988	0.993
	Yes	0.09	0.001	0.007	0.012
SEMED countries					
	No	98.5	0.003	0.979	0.989
	Yes	1.5	0.003	0.011	0.021

GVCE4					
EU countries					
	No	99.6	0.001	0.994	0.997
	Yes	0.4	0.001	0.003	0.006
SEMED countries					
	No	99.7	0.001	0.994	0.998
	Yes	0.3	0.001	0.002	0.006

Source: Author's own elaboration using data from WBES. Notes: *Weights are used.*

Tables 3: Distribution of firms in EU and SEMED countries for the probability of facing an environmental regulation and of undertaking green practices

		Proportion	**Std.Err.**	**[95%_Conf**	**Interval]**
Env. regulation					
EU countries					
	No	90.8	0.010	0.887	0.925
	Yes	9.2	0.010	0.075	0.113
SEMED countries					
	No	77.1	0.011	0.749	0.792
	Yes	22.9	0.011	0.208	0.251
Energy innovation					
EU countries					
	No	39.2	0.020	0.355	0.432
	Yes	60.8	0.020	0.568	0.645
SEMED countries					
	No	53.7	0.014	0.509	0.565
	Yes	46.3	0.014	0.435	0.491
Energy management					
EU countries					
	No	66.7	0.017	0.632	0.700
	Yes	33.3	0.017	0.300	0.368
SEMED countries					
	No	66.3	0.013	0.637	0.688
	Yes	33.7	0.013	0.312	0.363

Source: Author's own elaboration using data from WBES. Notes: *Weights are used.*

METHODOLOGY

In order to examine the association between environmental regulation, green practices, and GVCs participation, we divide the analysis in two parts. The first part estimates two equations, including the interaction terms to examine the moderating role using the generalized two-part fractional response model (GTP-FRM). In this case, for each equation, we analyse five equations: the baseline equation, the baseline equation with energy innovation, the baseline equation with energy management, and two baselines with interaction terms between environmental regulation and energy innovation and energy management. The second part is the mediating analysis using the generalized structural equation model (GSEM).

The moderating role of energy practices

We estimate two main equations: the probit equation and the fractional response equation[13]. The first equation estimates the impact of environmental regulation and the moderating role of energy practices on the probability of participation in GVCs. The second equation estimates the impact of environmental regulation and the moderating role of energy practices on the intensity of GVCs' participation.

$$\Pr(GVCE_{isct}=1)= \beta 0 + \beta 1\ EnvREG_{isct} + \beta 2\ GreenPractices_{isct} + \beta 3 GreenPractices_{isct} * EnvReg_{isct} + \beta 4\ Firmage_{isct} + \beta 5\ Firmsize_{isct} + \beta 6\ laborproductivity_{isct} + \beta 7\ website_{isct} + \beta 8\ creditconstraint_{isct} + \gamma_s + \alpha_c + \sigma t + \varepsilon_{isct} \quad (Eq1)$$

$$(GVCI_{isct} \mid GVC\ E_{isct}=1)= \beta 0 + \beta 1\ EnvREG_{isct} + \beta 2\ GreenPractices_{isct} + \beta 3 GreenPractices_{isct} * EnvReg_{isct} + \beta 4\ Firmage_{isct} + \beta 5\ Firmsize_{isct} + \beta 6\ laborproductivity_{isct} + \beta 7\ website_{isct} + \gamma_s + \alpha_c + \sigma t + \varepsilon_{isct} \quad (Eq2)$$

where i, s, c, and t represent firm, sector of activity, country, and year, respectively. γs represents industry fixed effects that control for unobserved industrial characteristics such as technological dynamism and industrial policies across different industries. αc indicates country fixed effects that control for country-level unobservable attributes such as institutional and market mechanism differences. σt is year dummies for time-specific attributes, εisct is the error term. Also, errors are clusters at sector, region and country levels.

The dependent variables *GVCE* and *GVCI* are proxied by the four definitions of extensive and intensive GVCs participation. *EnvREG* is a dummy variable taking the value of 1 if the firm is levied an energy tax or performance standard. *GreenPractices* is a dummy variable taking the value of 1 if the firm undertakes an energy innovation or energy management practices. *Firmage* is the natural logarithm of firm age is defined by the number of years since its establishment. It is calculated as the natural logarithm of the subtracted value of the firm's establishment year from the survey year. *Firmsize* is a categorical variable equal to 1 for small-sized firms, 2 for medium-sized firms, and 3 for large-sized firms following the WB

[13] The GVC intensity index is divided by 100 to convert it into a variable between 0 and 1 in order to conduct the FR modelling.

Classification. *Labourproductivity* is the natural logarithm of labour productivity calculated as the value addded over the total number of full-time employees. $Website_i$ is a dummy variable taking the value of 1 if the firm owns a website and zero otherwise. *Creditconstraint*[14] is a dummy variable for access to finance equal to 1 if the firm is financially constrained. The interaction terms between environmental regulation and energy practices asses the moderating roles of energy innovation and energy management.

Given the binary nature of the dependent variable of the first equation, the probit model should be used, and given the fractional nature of the dependent variable of the second equation, the pooled OLS should be used[15]. However, for the second equation, the dependent variable is a fractional response variable that only takes values between zero and one. Hence, the main drawback of the OLS prediction is that it may fall outside the zero and 1 interval and the prediction become inconsistence (Schwiebert & Wagner, 2015). In this case, as suggested by Paschoaleto & Martinez-Zarzoso, (2024), the fractional probit model should be used, even though the estimation of these two equations separately can lead to biased results for several reasons. Firstly, when estimating the impact of environmental regulation on the probability and the intensity of GVC participation, we should account for the dependency between the two processes; the second process depends on the first (Schwiebert & Wagner, 2015). Second, in the case of excess zeros, there is a large portion of the observations that have an outcome equal to zero, and the fractional probit model might not be the optimal identification strategy since it does not predict zeros. In this case, the solution is to employ the generalized two-part fractional response model (GTP-FRM) to overcome the excess zeros[16] and to deal with the sample selection bias problem when outcomes are non-randomly missing. The GTP-FRM allows the error terms of the probit model and the fractional response model to be correlated. Finally, in order to conduct the GTP-FRM, an exclusion restriction is identified; it needs a variable affecting the participation decision without directly affecting the amount decision (Wulff, 2019). Therefore, we use the credit constraint where we assume that while it highly affects the probability of GVC participation, it affects GVC intensity to a lower extent. This argument is based on findings from trade and credit constraint literature by Egger & Kesina (2014), Hasan &Sheldon (2016), and Regis (2018), according to which higher credit availability in the economy directs resources towards more productive but financially vulnerable sectors and thus the intensive margin of trade of firms already in the export market gets shallow. Thus, once a firm has paid the fixed costs of entry to the export market, they are not credit-constrained in terms of increasing the volume of its exports. Following Roodman (2011) and Wulff (2019), we use the GTP-FRM to estimate the baseline model and its extensions, and for accounting for sources of endogeneity bias such as reverse causality and selection bias.

In order to solve the problem of endogeneity bias due to reverse causality and selection bias, we use the IV approach and a two-step Heckman analysis. The first step consists of regressing the selection

[14] This variable is exclusively included in equation (1) as an exclusion restriction for the GTP-FRM as discussed below.

[15] We have pooled cross-section data of firms that are not necessarily tracked over the three years.

[16] This model assumes different processes for having a non-zero outcome (for the second equation) and, conditionally on having a non-zero outcome for the first equation (Schwiebert & Wagner, 2015)

equation, i.e., the probability of being levied an environmental regulation on firm size, firm age, political connection, and firms' perception of different regulations as major or severe obstacles to their current operations, and the Inverse Mille Ratio (IMR) is predicted. In the second step, we insert the IMR in the main equations that are estimated while instrumenting for environmental regulation by using the interaction term between a country's legal origin and a firm's green strategies as an IV. Then, in order to test the robustness of our results, we instrument using the shift share variable of environmental regulation aggregated by country-region-sector-year minus each firm's own status in terms of subjection to environmental regulations. Moreover, we extend the model to conduct a heterogeneity analysis by estimating sub-sample regressions for firms operating in energy-intensive and energy-efficient sectors[17]and for firms in the EU and SEMED countries. The main objective is to draw inferences on the underlying heterogeneous and moderating factors. Finally, we test the robustness of our model by including additional covariates such as technological capabilities and obstacles to trade.

The mediating role of energy practices

The analysis also extends the previous model by estimating the mediating roles of energy innovation and energy management. Hence, equations (1) and (2) are complemented by the following four equations, and all six equations are estimated using the GSEM technique that is adapted for multilevel generalized (binary) outcomes[18].

$$\Pr(\text{EnergyInnovation}_{isct}=1)= \alpha_{0a}+ \alpha_{1a}\ \text{EnvREG}_{isct} + \alpha_a\ X_{isct}+ \gamma_s+\alpha_c+ \sigma t +\varepsilon_{isct}) \quad \text{(Eq3a)}$$

$$\text{GVC E/I}_{isct}= \rho_{0a}+ \rho 1_a\ \text{EnvREG}_{isct}+ \rho 2_a\ \text{EnergyInnovation}_{isct}+ \rho_a\ X_{isct}++ \gamma_s+\alpha_c+ \sigma t +\varepsilon_{isct} \quad \text{(Eq3b)}$$

$$\Pr(\text{EnergyManagement}_{isct}=1)= \alpha_{0b}+ \alpha_{1b}\ \text{EnvREG}_{isct}+ \alpha_b\ X_{isct}+ \gamma_s+\alpha_c+ \sigma t +\varepsilon_{isct}) \quad \text{(Eq4a)}$$

$$\text{GVC E/I}_{isct}= \rho_{0b}+ \rho_{1b}\ \text{EnvREG}_{isct}+ \rho_{2b}\ \text{EnergyManagement}_{isct}+ \rho b\ X_{isct}++ \gamma_s+\alpha_c+\sigma t +\varepsilon_{isct} \quad \text{(Eq4b)}$$[19]

In equations (1) and (2), the β's coefficients represent the total effect environmental regulations on GVCs integration, in equations 3a and 4a the α's coefficients represent the direct effect of environmental regulations on energy innovation and energy management respectively and in equations 3b and 4b, the ρ's coefficients of energy innovation and energy management represent their mediating effects after controlling for environmental regulations. Hence, $\alpha_{1a}{}^{*}\ \rho_{2a}$ and $\alpha_{1b}{}^{*}\ \rho_{2b}$ represent the indirect effect of environmental regulations transmitted through energy innovation and energy management, respectively. If the α_{1a} , α_{1a}, ρ_{2a} and ρ_{2b} are statistically significant, this means that energy practices have a

[17] In order to calculate the energy intensity of sectors, we divide total energy cost (costs of fuel and electricity) by total annual sales, then we calculate the median value of energy intensity and divide the sector into energy-intensive one if their energy intensity is greater than the median value, and energy efficient sectors if their energy intensity is lower than the median values.

[18] The *gsem* command has been used allowing to estimate the mediating roles of energy innovation and energy management. (probit) and for the proportion variable we use family (Gaussian and link (identity). Then the *gsem, coefleg* and *nlcom* commands have been used to estimate the direct, indirect and total effects.

[19] We use the same notations and fixed effects of the baseline model. X is the list of covariates included in Equations (1) and (2). Also, all errors are clusters at the firm, sector and region levels.

mediating effect, and firms need to adapt to environmental regulations by undertaking rigorous green practices to enhance their GVCs participation. In addition, if the statistical significance of ρ_{1a} and ρ_{1b} decreases compared to β_1 of equations (1) and (2), then we can infer that energy practices *partially mediate* the relationship between environmental regulation and GVCs participation. However, if ρ_{1a} and ρ_{1b} are not statistically significant, we can infer that there is a "*full mediating impact*" of energy practices.

EMPIRICAL RESULTS

BASELINE RESULTS

To examine the impact of environmental regulation, and the impact of green energy practices and their moderating role on the probability of GVCs' participation and intensity, we use the GTP-FRM to estimate five regressions as discussed in section 4.1. Table (4) shows a significant positive association between environmental regulations and both the probability and intensity of GVCs participation but mainly for GVC1E, GVC1I, GVC2E, and GVC2I, in line with the argument of the PH. Similarly to Paschoaleto & Martinez-Zarzoso (2024), the evidence shows that with environmental regulations and improved environmental performance, firms can enhance their GVCs participation at both the extensive and intensive levels. Also, the effect is mostly positive and significant for firms that have a shallow integration in GVCs, and are highly reliant on the enforcement of the regulatory framework to green their practices. In turn, firms would be able to overcome barriers (fixed costs) to integrate value chains, and they would be able to increase the intensity of their participation. Yet, for firms that already own foreign shares or firms that satisfy the four criteria for the strict definition, the effect is insignificant. Moreover, other covariates hold the expected signs in line with the empirical literature. Medium-sized firms have lower probability and lower intensity of GVCs participation compared to large-sized firms. Labor productivity matters for GVCs integration because only highly productive firms can overcome the high fixed costs (e.g. advertising or regulations) for entering foreign markets and for expanding their sales (Melitz, 2003; Urata & Baek, 2020). Hence, these findings show the combination of scale economies that benefit large firms, and the existence of fixed costs of importing and exporting would justify that only firms that are large enough are able to amortize the fixed costs associated with importing and exporting. In line with Antràs (2020), there is a selection into importing associated with firms engaged in backward GVCs' participation, i.e. they are able to import foreign inputs; and a selection into exporting and importing associated with firms engaged in forward GVCs participation. Hence, firms importing their products are likely to be exporters themselves. Firm age has a negative but mostly insignificant effect on GVCs participation because young firms tend to be more agile than old firms in adopting new production systems such as GVCs, in order to survive and grow in the market (Urata & Baek, 2020; Paschoaleto & Martinez-Zarzoso, 2024). Digitalization is also positively associated with the probability of participating in GVCs but to a lesser extent with the intensity of participation (Gopalan et al., 2022). Finally, credit constraints reduce the probability of integrating GVCS with more significant effects on the stricter definitions (Li & Yu, 2009; Manova et al., 2015).

Tables 5 and 6 show that, after including energy innovation and energy management in the same regression, environmental regulation still enhances GVCs' participation, even though their coefficient decreases in magnitude highlighting the mediating effect of new energy variables. Regarding energy innovation, the coefficients of the direct effect on GVCs are mostly insignificant except for GVC2E

and GVC3I whereas those of environmental regulations are significant only for GVC2E, indicating a partial mediating role for energy innovation. The coefficient of environmental regulation is insignificant for GVC3I, indicating a full mediating effect for this definition. These results indicate that innovative efforts undertaken by firms to enhance their energy efficiency have a limited mediation effect. This could be explained by the definition of energy innovation variables referring only to incremental upgrades undertaken by firms to improve the energy efficiency of their lighting systems, machinery and equipment, vehicles, and energy generation processes. Hence, it could be of great importance for firms to climb up the innovation ladder and to move from incremental to radical innovation to enhance its GVCs' participation (Reddy et al., 2021). By contrast, for energy management, its effect on GVCs' participation is more significant than the effect of energy innovation and is relatively greater than the effect of environmental regulation. Coefficients of both environmental regulation and energy management are significant for GVC2E and GVC2I at the 1% and 5% levels, implying a partial mediating effect for the effect of environmental regulations on GVCs participation according to the intermediate definition. Also, while the coefficients of environmental regulation are insignificant for GVC1E, GVC3E, GVC3I, and GVC4E, those of energy management are significant at 5%, 10%, and 1% significance levels respectively, implying a full mediation effect for energy management for these GVCs definitions. Thus, proactive energy management practices matter more for GVCs participation than energy innovation, and they can can partially or fully mediate the relationship between environmental regulation and firm performance (Sendawula et al., 2021; Rehman et al., 2023). Yet, the effect of both environmental regulation and energy management practices is also more pronounced for firms that are weekly integrated in GVCs.

Table 7 depicts the fact that both energy innovation and energy management do not play any moderating role between environmental regulation and GVCs' participation[20]. Also, surprisingly, the results show a negative and significant role of energy management on the intensive margin of the strictest definition of GVCs participation. These findings suggest that energy innovation is ineffective in either mediating or moderating the relationship between environmental regulation and GVCs participation. Also, firms rely on environmental regulations to adopt energy management practices, which would improve their GVCs' participation, but proactive energy management practices do not moderate the relationship.

[20] For the sake of brevity, we report the results of the moderating roles for the weakest and strongest definitions of GVCs.

Table 4: Baseline regressions: Environmental regulation and GVCs participation

VARIABLES	GVC1E	GVC1I	GV2E	GVC2I	GVC3E	GVC3I	GVC4E	GVC4I
Env. Regulation	0.206*	0.248***	0.471***	0.274***	0.214*	-0.0902	0.146	-0.0569
	(0.107)	(0.0737)	(0.115)	(0.0885)	(0.119)	(0.114)	(0.128)	(0.121)
Medium-sized	0.380***	0.117	0.648***	0.153	0.448***	-0.0903	0.637***	0.654***
	(0.103)	(0.0781)	(0.104)	(0.0942)	(0.122)	(0.200)	(0.228)	(0.167)
Large sized	0.622***	0.348***	1.272***	0.536***	1.189***	0.653***	1.491***	1.421***
	(0.146)	(0.0928)	(0.0967)	(0.0902)	(0.110)	(0.206)	(0.148)	(0.145)
Firm age	0.00448	-0.0275	-0.0603	-0.0125	-0.157**	-0.279**	-0.0815	-0.121*
	(0.0802)	(0.0599)	(0.0679)	(0.0605)	(0.0636)	(0.133)	(0.0735)	(0.0680)
Labor productivity	0.114**	0.0511	0.0783***	0.107***	0.150***	0.00753	0.187***	0.106**
	(0.0578)	(0.0468)	(0.0289)	(0.0347)	(0.0407)	(0.0340)	(0.0527)	(0.0425)
Digital firm	0.230**	-0.153	0.340***	0.339**	0.0873	0.108	0.0670	-0.0939
	(0.0905)	(0.129)	(0.0949)	(0.139)	(0.128)	(0.128)	(0.175)	(0.150)
Credit constraint	-0.232		-0.217		-0.415***		-0.328**	
	(0.178)		(0.141)		(0.160)		(0.136)	
Constant	-1.471***	-4.190***	-1.861***	-5.117***	-2.540***	-3.438***	-3.342***	-4.572***
	(0.523)	(0.515)	(0.339)	(0.505)	(0.486)	(0.780)	(0.629)	(0.615)
atanhrho_12	3.518*		3.189***		0.401**		1.221***	
	(2.096)		(0.755)		(0.192)		(0.210)	
Country dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sector dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	14,686	14,686	14,623	14,623	14,639	14,639	14,558	14,558

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1
Notes: Weights are used. Errors are cluster at sector, region and country levels

Table 5: Baseline regressions: Environmental regulations, energy innovation, and GVCs participation

VARIABLES	GVC1E	GVC1I	GV2E	GVC2I	GVC3E	GVC3I	GVC4E	GVC4I
Env. Regulation	0.189	0.257***	0.423***	0.251***	0.199	-0.126	0.138	-0.0612
	(0.115)	(0.0788)	(0.117)	(0.0898)	(0.126)	(0.127)	(0.122)	(0.122)
Energy innovation	0.208	-0.0366	0.261**	0.128	0.164	0.482***	0.0625	0.117
	(0.133)	(0.108)	(0.115)	(0.0878)	(0.120)	(0.169)	(0.202)	(0.177)
Medium-sized	0.388***	0.125	0.638***	0.152	0.458***	-0.0922	0.653***	0.684***
	(0.106)	(0.0787)	(0.105)	(0.0936)	(0.118)	(0.215)	(0.224)	(0.168)
Large sized	0.612***	0.370***	1.249***	0.524***	1.195***	0.653***	1.511***	1.449***
	(0.142)	(0.0927)	(0.100)	(0.0901)	(0.112)	(0.224)	(0.143)	(0.149)
Firm age	0.00122	-0.0661	-0.0735	-0.0188	-0.179***	-0.198***	-0.0952	-0.127*
	(0.0745)	(0.0597)	(0.0666)	(0.0590)	(0.0645)	(0.0589)	(0.0742)	(0.0694)
Labor productivity	0.113*	0.0547	0.0859***	0.109***	0.153***	-0.00202	0.189***	0.108**
	(0.0602)	(0.0423)	(0.0302)	(0.0352)	(0.0428)	(0.0374)	(0.0543)	(0.0462)
Digital firm	0.232**	-0.177	0.331***	0.329**	0.0471	-0.00405	0.0385	-0.126
	(0.0949)	(0.130)	(0.0953)	(0.136)	(0.126)	(0.143)	(0.163)	(0.149)
Credit constraint	-0.235		-0.193		-0.401**		-0.319**	
	(0.181)		(0.149)		(0.158)		(0.136)	
Constant	-1.774***	-4.062***	-2.037***	-5.180***	-2.599***	-4.006***	-3.381***	-4.602***
	(0.516)	(0.517)	(0.359)	(0.519)	(0.507)	(0.568)	(0.718)	(0.676)
atanhrho_12	3.418*		3.496***		0.516***		1.148***	
	(1.870)		(1.182)		(0.190)		(0.191)	
Country dummies	yes	yes	yes	yes	yes	yes	yes	yes
Sector dummies	yes	yes	yes	yes	yes	yes	yes	yes
Year dummies	yes	yes	yes	yes	yes	yes	yes	yes
Observations	14,413	14,413	14,352	14,352	14,367	14,367	14,287	14,287

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1
Notes: weights are used. Errors are cluster at sector, region and country levels

Table 6: Baseline regressions: Environmental regulations, energy management, and GVCs participation

VARIABLES	GVC1E	GVC1I	GV2E	GVC2I	GVC3E	GVC3I	GVC4E	GVC4I
Env. Regulation	0.115	0.219***	0.364***	0.223**	0.165	-0.185	0.0794	-0.0952
	(0.115)	(0.0829)	(0.106)	(0.0877)	(0.124)	(0.125)	(0.122)	(0.129)
Energy management	0.334**	0.102	0.458***	0.240***	0.186**	0.382***	0.273*	0.166
	(0.143)	(0.107)	(0.106)	(0.0873)	(0.0906)	(0.139)	(0.161)	(0.166)
Medium-sized	0.345***	0.107	0.619***	0.136	0.427***	-0.140	0.610***	0.638***
	(0.109)	(0.0818)	(0.104)	(0.0935)	(0.116)	(0.208)	(0.212)	(0.163)
Large sized	0.558***	0.330***	1.201***	0.500***	1.154***	0.570**	1.446***	1.392***
	(0.155)	(0.0964)	(0.0966)	(0.0912)	(0.108)	(0.227)	(0.138)	(0.146)
Firm age	-0.00278	-0.0335	-0.0647	-0.0157	-0.164***	-0.212***	-0.0966	-0.129*
	(0.0751)	(0.0607)	(0.0660)	(0.0601)	(0.0620)	(0.0652)	(0.0689)	(0.0665)
Labor productivity	0.110*	0.0494	0.0766***	0.104***	0.148***	0.00440	0.189***	0.107**
	(0.0588)	(0.0435)	(0.0278)	(0.0338)	(0.0408)	(0.0326)	(0.0542)	(0.0436)
Digital firm	0.217**	-0.158	0.306***	0.316**	0.0817	0.0577	0.0414	-0.111
	(0.0895)	(0.129)	(0.0989)	(0.139)	(0.131)	(0.131)	(0.176)	(0.151)
Credit constraint	-0.221		-0.204		-0.408***		-0.315**	
	(0.180)		(0.150)		(0.155)		(0.135)	
Constant	-1.559***	-4.211***	-2.049***	-5.196***	-2.586***	-3.553***	-3.471***	-4.642***
	(0.527)	(0.515)	(0.332)	(0.498)	(0.489)	(0.635)	(0.668)	(0.636)
atanhrho_12	3.407**		1.279***		0.419**		1.166***	
	(1.737)		(0.315)		(0.173)		(0.185)	
Country dummies	yes	yes	yes	yes	yes	Yes	Yes	Yes
Sector dummies	yes	yes	yes	yes	yes	Yes	Yes	Yes
Year dummies	yes	yes	yes	yes	yes	Yes	Yes	Yes
Observations	14,665	14,665	14,602	14,602	14,618	14,618	14,537	14,537

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1
Notes: Weights are used. Errors are clustered at sector, region, country levels

ADDRESSING SELF-SELECTION PROBLEMS AND ENDOGENEITY BIASES

Since investigating the association between environmental regulation and GVCs could be subjected to endogeneity bias due to reverse causality and self-selection problem from the inclusion of the firms' subjection to environmental regulation as the main variable of interest, we report the results after addressing the endogeneity bias using the IV approach and the self-selection problem using a two-step analysis as discussed in section 4.1[21].

Tables 8-10 report the results after accounting of sources of endogeneity bias by including the IMR[22] and by using the interaction term between countries 'legal origin and firm-level green measures to instrument for environmental regulations. The findings show that instrumented environmental regulations still exert a positive effect on the extensive and intensive participation in GVCs and mostly for the weak and intermediate definitions. Moreover, the coefficients of environmental regulations have increased in magnitude, showing that the previous results were biased downwards due to endogeneity bias. Results after the inclusion of energy innovation and energy management are still robust and show the same evidence of the baseline regressions. While undertaking innovative efforts to improve energy efficiency is ineffective in driving GVCs' participation, adopting managerial practices to control and evaluate energy performance is crucial for integrating value chains. Moreover, these practices fully mediate the relationship for GVC1E and GVC2I and partially mediate it for GVC2E. In addition, we use the IV shift-share method to instrument for environmental regulation using an aggregated variable at country, region, sector and year levels and table 11 reports the results showing that environmental regulations and green practices are positively associated with GVCs participation with a significant mediating role for energy management. Yet, the IV method shows a significant effect also on firms that are deeply integrated in GVCs, but at the extensive level only.

[21] For the sake of brevity, we report the results of GVCs1, GVCs2 and GVCs4.

[22] For the sake of brevity, we report the results of the second step only.

Table 8: Endogeneity and selection bias: Environmental regulation and GVCs participation

VARIABLES	GVC1E	GVC1I	Env. Reg.	GVC2E	GVC2I	Env. Reg.	GVC4E	GVC4I	Env. Reg.
Env. Regulation	1.865**	1.246**		2.583***	0.599		-0.127	1.167	
	(0.799)	(0.613)		(0.711)	(0.805)		(0.842)	(0.895)	
Medium-sized	0.289**	0.0868		0.521***	0.0871		0.668***	0.578***	
	(0.121)	(0.0900)		(0.118)	(0.116)		(0.247)	(0.192)	
Large sized	0.558***	0.321***		1.183***	0.446***		1.508***	1.326***	
	(0.150)	(0.0957)		(0.102)	(0.103)		(0.162)	(0.191)	
Firm age	0.0121	-0.0135		-0.0424	-0.0161		-0.0845	-0.0826	
	(0.0803)	(0.0747)		(0.0646)	(0.0703)		(0.0750)	(0.0704)	
Labor productivity	0.115**	0.0353		0.0809***	0.0871**		0.187***	0.0938**	
	(0.0576)	(0.0509)		(0.0280)	(0.0358)		(0.0529)	(0.0393)	
Digital firm	0.223**	-0.163		0.324***	0.320**		0.0703	-0.0684	
	(0.0892)	(0.160)		(0.0952)	(0.142)		(0.177)	(0.164)	
Credit constraint	-0.221			-0.214			-0.328**		
	(0.174)			(0.142)			(0.136)		
Inverse Mills Ratio	-0.695	-0.363		-0.975**	-0.394		0.248	-0.694	
	(0.431)	(0.295)		(0.421)	(0.320)		(0.480)	(0.500)	
Legorigin*Greenmeasures			0.702***			0.694***			0.689***
			(0.155)			(0.155)			(0.155)
Constant	-1.781***	-4.281***	-1.299***	-2.317***	-4.898***	-1.297***	-3.284***	-4.634***	-1.297***
	(0.522)	(0.436)	(0.0790)	(0.389)	(0.617)	(0.0791)	(0.635)	(0.680)	(0.0791)
Country/sector/ year dummies	yes	yes	yes	Yes	yes	yes	yes	yes	yes
Observations	16,042	16,042	16,042	16,042	16,042	16,042	16,042	16,042	16,042

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1
Notes: weights are used Errors are clustered at sector, region, country levels

Table 9: Endogeneity and selection bias: Environmental regulation, energy innovation and GVCs participation

VARIABLES	GVC1E	GVC1I	Env. Reg.	GVC2E	GVC2I	Env. Reg.	GVC4E	GVC4I	Env. Reg.
Env. Regulation	2.158***	1.299***		2.687***	1.074*		-0.0860	1.205	
	(0.670)	(0.484)		(0.691)	(0.645)		(1.043)	(1.012)	
Energy innovation	0.169	0.0279		0.239**	0.110		0.0559	0.231	
	(0.127)	(0.0915)		(0.114)	(0.0911)		(0.205)	(0.196)	
Medium-sized	0.306***	0.0706		0.508***	0.118		0.679***	0.573***	
	(0.116)	(0.0870)		(0.119)	(0.115)		(0.241)	(0.197)	
Large sized	0.529***	0.304***		1.154***	0.489***		1.525***	1.307***	
	(0.135)	(0.0987)		(0.103)	(0.114)		(0.159)	(0.191)	
Firm age	0.00400	-0.0535		-0.0550	-0.0276		-0.0973	-0.0824	
	(0.0690)	(0.0491)		(0.0629)	(0.0577)		(0.0754)	(0.0697)	
Labor productivity	0.110*	0.0752**		0.0879***	0.0997***		0.189***	0.0932**	
	(0.0564)	(0.0315)		(0.0291)	(0.0341)		(0.0546)	(0.0463)	
Digital firm	0.221**	-0.105		0.314***	0.334**		0.0421	-0.199	
	(0.0893)	(0.0963)		(0.0953)	(0.150)		(0.164)	(0.175)	
Credit constraint	-0.220			-0.191			-0.320**		
	(0.170)			(0.150)			(0.137)		
Inverse Mills Ratio	-0.455	-0.143		-0.978**	-0.323		0.213	-0.837	
	(0.408)	(0.281)		(0.434)	(0.345)		(0.477)	(0.513)	
Legorigin*Greenmeasures			0.699***			0.691***			0.689***
			(0.145)			(0.156)			(0.155)
Constant	-2.011***	-4.254***	-1.296***	-2.499***	-5.027***	-1.297***	-3.328***	-4.539***	-1.297***
	(0.485)	(0.432)	(0.0770)	(0.408)	(0.523)	(0.0790)	(0.718)	(0.785)	(0.0791)
Country/sector/ year dummies	yes	yes	yes	Yes	yes	yes	yes	yes	yes
Observations	16,039	16,039	16,039	16,039	16,039	16,039	16,039	16,039	16,039

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1
Notes: weights are used Errors are clustered at sector, region, country levels

Table 10: Endogeneity and selection bias: Environmental regulation, energy management and GVCs participation

VARIABLES	GVC1E	GVC1I	Env. Reg.	GVC2E	GVC2I	Env. Reg.	GVC4E	GVC4I	Env. Reg.
Env. Regulation	1.154	0.308		2.024***	0.937		-0.464	1.023	
	(0.799)	(0.555)		(0.753)	(0.725)		(0.926)	(0.902)	
Energy management	0.323**	0.107		0.437***	0.224***		0.276	0.155	
	(0.144)	(0.106)		(0.110)	(0.0864)		(0.169)	(0.164)	
Medium-sized	0.278**	0.130		0.516***	0.0746		0.650***	0.576***	
	(0.126)	(0.0879)		(0.120)	(0.114)		(0.236)	(0.191)	
Large sized	0.515***	0.321***		1.135***	0.435***		1.472***	1.312***	
	(0.157)	(0.0963)		(0.0987)	(0.107)		(0.154)	(0.195)	
Firm age	0.00340	-0.0272		-0.0501	-0.0146		-0.101	-0.0921	
	(0.0749)	(0.0680)		(0.0643)	(0.0561)		(0.0704)	(0.0688)	
Labor productivity	0.111*	0.0452		0.0778***	0.105***		0.189***	0.0922**	
	(0.0588)	(0.0401)		(0.0272)	(0.0313)		(0.0547)	(0.0401)	
Digital firm	0.214**	-0.138		0.297***	0.283**		0.0455	-0.0857	
	(0.0897)	(0.129)		(0.0989)	(0.133)		(0.179)	(0.170)	
Credit constraint	-0.213			-0.199			-0.316**		
	(0.179)			(0.152)			(0.136)		
Inverse Mills Ratio	-0.529	-0.0398		-0.823*	-0.274		0.310	-0.650	
	(0.421)	(0.292)		(0.424)	(0.315)		(0.486)	(0.497)	
Legorigin*Greenmeasures			0.690***			0.689***			0.689***
			(0.156)			(0.155)			(0.155)
Constant	-1.767***	-4.275***	-1.297***	-2.409***	-5.157***	-1.297***	-3.367***	-4.661***	-1.297***
	(0.516)	(0.406)	(0.0792)	(0.387)	(0.470)	(0.0791)	(0.655)	(0.678)	(0.0791)
Country dummies	yes	yes	yes	Yes	yes	yes	yes	yes	yes
Sector dummies	yes	yes	yes	Yes	yes	yes	yes	yes	yes
Year dummies	yes	yes	yes	yes	yes	yes	yes	yes	yes
Observations	16,036	16,036	16,036	16,036	16,036	16,036	16,036	16,036	16,036

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1
Notes: weights are used Errors are clustered at sector, region, country levels

ANALYSIS EXTENSION[23]

The analysis is further extended by undertaking subsample regressions for firms in the EU and firms in SEMED countries on the one hand, and for firms operating in energy-intensive and firms operating in more energy-efficient sectors. In line with previous results, those in table 12 show that environmental regulations and energy management practices matter more for GVCs' participation and, most importantly, for EU and SEMED firms that are weakly integrated. However, the effect of environmental regulations is more pronounced for EU firms, which could be explained by the relatively weaker enforcement of environmental regulation in SEMED countries and their lower levels of GVCs integration compared to their EU counterparts (meetMed, 2019; European Bank for Reconstruction and Development & European Commission, 2020). Also, energy management practices are less effective in driving GVCs integration for SEMED firms compared to EU ones. This could be explained by the following. On one hand, SEMED countries still lack of awareness with the importance of promoting energy efficiency measures (meetMed, 2019); and on the other hand, with most SEMED firms have being operating in upstream GVCs stages over the last 20 years (European Bank for Reconstruction and Development & European Commission, 2020), it is less likely that energy efficiency is approached when assessing the environmental footprints of these upstream firms in supply chains (Xavier et al., 2024). Also, based on our data, around 53% of SEMED firms operate in energy-intensive sectors whereas 63.3% of EU firms do so and hence the latter are more incentivized to adopt measures to improve their energy performance in order to overcome higher costs of complying with energy regulations and to improve their performance within value chains[24]. Finally, both sub-sample regressions show that energy innovation is ineffective in fostering GVCs' participation.

For energy-intensive and energy-efficient sectors subsample regressions, table 13 shows that firms in both sectors are benefiting from the imposition of environmental regulations and from adopting green energy management since they enhance their GVCs participation. Yet, the effects of environmental regulations are more pronounced for firms operating in energy intensive sector, which goes in line with the PH arguments. Firms operating in energy-intensive sectors can improve their GVCs' integration when faced with energy-related regulations. Moreover, unlike baseline regressions, energy innovation exhibits some positive effects on GVCs' participation, mostly for firms operating in energy-efficient sectors. Likewise, energy management practices exhibit a more important effect on firms in energy-efficient sectors. These findings show that firms that are already adopting proactive measures to improve their energy efficiency are more likely to benefit from these actions, whereas firms operating in energy-efficient sectors are positively affected by the enforcement of green regulations.

Moreover, we test the robustness of our results in table 14 and extend the analysis by including two other covariates: firms' technological capability and obstacles to trade such as transport and customs, and trade regulation. We find that our results are mostly robust and confirm the main findings of the baseline. Environmental regulations matter more for firms that are weakly integrated into GVCs. Also, while energy

[23] For the sake of brevity, we report results of baseline regressions including energy innovation and energy management.

[24] Author's own calculation using data from WBES. Notes: *Weights are used.*

innovation still does not exhibit any effect, energy management exerts a positive and significant effect on GVCs' participation, with a more pronounced effect for firms that follow the shallow GVCs' participation. Also, we find that while technological capability is positively associated with extensive and intensive GVCs' participation regardless of the integration depth, trade obstacles are mostly insignificant.

Table 11: Shift-share IV results: Environmental regulation, energy innovation, energy management, and GVCs participation

VARIABLES	GVC1E	GVC1I	GVC2E	GVC2I	GVC4E	GVC4I
Baseline regression						
Env. Regulation	0.249*	0.245***	0.603***	0.100	0.470**	-0.245
	(0.143)	(0.0852)	(0.188)	(0.363)	(0.223)	(0.306)
Shift Share IV (step1)	3.110***		3.109***		3.110***	
Observations	16,045	16,045	16,045	16,045	16,044	16,045
Baseline regression with energy innovation						
Env. Regulation	0.333*	-0.0161	0.634***	0.531*	0.484**	0.0112
	(0.180)	(0.167)	(0.171)	(0.321)	(0.225)	(0.265)
Energy innovation	0.206	0.00126	0.253**	0.148*	0.0582	0.175
	(0.132)	(0.110)	(0.113)	(0.0891)	(0.203)	(0.171)
Shift Share IV (step1)	3.108***		3.110***		3.110***	
Observations	16,044	16,044	16,044	16,044	16,043	16,043
Baseline regression with energy management						
Env. Regulation	0.0481	-0.0187	0.519***	0.149	0.408*	-0.303
	(0.174)	(0.388)	(0.137)	(0.159)	(0.224)	(0.316)
Energy management	0.334**	0.122	0.457***	0.233***	0.268*	0.260
	(0.143)	(0.0916)	(0.106)	(0.0867)	(0.160)	(0.172)
Shift Share IV (step1)	3.107***		3.109***		3.110***	
Observations	16,044	16,044	16,044	16,044	16,043	16,043
Other covariates	yes	yes	yes	yes	yes	yes
Country/sector/year dummies	yes	yes	yes	yes	yes	yes

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1
Notes: Weights are used. Errors are clustered at sector, region, country levels

Table 12: Subsample regressions for firms in EU and SEMED countries

	With energy innovation						With energy management					
For EU countries												
VARIABLES	**GVC1E**	**GVC1I**	**GV2E**	**GVC2I**	**GVC4E**	**GVC4I**	**GVC1E**	**GVC1I**	**GV2E**	**GVC2I**	**GVC4E**	**GVC4I**
Env. Regulation	0.231	0.241**	0.480***	0.183	0.00234	-0.152	0.158	0.205**	0.416***	0.157	-0.0475	-0.185
	(0.155)	(0.0948)	(0.151)	(0.116)	(0.121)	(0.125)	(0.154)	(0.0981)	(0.138)	(0.113)	(0.131)	(0.133)
Energy innovation	0.192	-0.0571	0.346**	0.0822	0.117	0.112						
	(0.159)	(0.126)	(0.147)	(0.103)	(0.275)	(0.218)						
Energy management							0.410**	0.105	0.529***	0.236**	0.291	0.201
							(0.169)	(0.123)	(0.128)	(0.0937)	(0.199)	(0.216)
Constant	-2.501***	-3.650***	-3.388***	-5.141***	-4.647***	-9.533***	-2.591***	-3.726***	-3.344***	-5.234***	-4.745***	-9.296***
	(0.608)	(0.481)	(0.389)	(0.562)	(0.866)	(0.711)	(0.601)	(0.467)	(0.334)	(0.514)	(0.802)	(0.699)
atanhrho_12	2.895***		1.298***		15.20		1.547**		1.146***		11.48	
	(0.859)		(0.276)		(0)		(0.653)		(0.182)		(0)	
Observations	7,944	7,944	7,942	7,942	7,919	7,919	8,073	8,073	8,071	8,071	8,048	8,048
For SEMED countries												
VARIABLES	**GVC1E**	**GVC1I**	**GV2E**	**GVC2I**	**GVC4E**	**GVC4I**	**GVC1E**	**GVC1I**	**GV2E**	**GVC2I**	**GVC4E**	**GVC4I**
Env. Regulation	0.170	0.291***	0.317***	0.255	0.435***	-1.501	0.184	0.191	0.285**	0.129	0.353**	-0.0376
	(0.152)	(0.112)	(0.120)	(0.157)	(0.147)	(1.049)	(0.147)	(0.120)	(0.124)	(0.148)	(0.148)	(0.364)
Energy innovation	0.192	-0.222	-0.00524	-0.0894	-0.184	1.060						
	(0.136)	(0.137)	(0.173)	(0.197)	(0.160)	(0.695)						
Energy management							-0.0627	0.160	0.161	0.270*	0.153	-0.543
							(0.132)	(0.156)	(0.141)	(0.147)	(0.203)	(0.362)
Constant	-0.733	-4.551***	-2.262***	-5.007***	-3.144***	-14.56***	0.000829	-4.963***	-2.331***	-5.266***	-3.268***	-9.890
	(0.486)	(0.520)	(0.587)	(0.580)	(0.616)	(1.631)	(0.507)	(0.623)	(0.580)	(0.587)	(0.618)	(0)
atanhrho_12	3.879**		3.638**		6.137***		2.937***		3.813*		7.410	
	(1.902)		(1.805)		(1.814)		(0.755)		(2.026)		(77.94)	
Observations	6,162	6,162	6,093	6,093	5,268	5,268	6,283	6,283	6,212	6,212	5,371	5,371
Country/sector/year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Other Covariates	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Notes: Weights are used. Errors are clustered at sector, region, country levels

Table 13: Subsample regressions for firms in energy-intensive and energy-efficient sector

	With energy innovation						With energy management					
Energy-intensive sectors												
VARIABLES	**GVC1E**	**GVC1I**	**GV2E**	**GVC2I**	**GVC4E**	**GVC4I**	**GVC1E**	**GVC1I**	**GV2E**	**GVC2I**	**GVC4E**	**GVC4I**
Env. Regulation	0.170	0.353***	0.455***	0.422***	0.349**	0.0770	0.152	0.277**	0.366**	0.335**	0.267	0.000878
	(0.167)	(0.113)	(0.144)	(0.142)	(0.157)	(0.163)	(0.166)	(0.115)	(0.144)	(0.134)	(0.165)	(0.160)
Energy innovation	0.363**	-0.106	0.287*	-0.0805	-0.0741	-0.0922						
	(0.159)	(0.119)	(0.153)	(0.135)	(0.234)	(0.262)						
Energy management							0.226*	0.146	0.503***	0.162	0.143	0.293
							(0.131)	(0.0933)	(0.129)	(0.130)	(0.140)	(0.182)
Constant	-2.754***	-4.192***	-3.459***	-4.754***	-3.337***	-5.089***	-2.583***	-3.918***	-3.475***	-4.790***	-3.323***	-5.141***
	(0.392)	(0.375)	(0.346)	(0.463)	(0.900)	(0.833)	(0.399)	(0.342)	(0.316)	(0.437)	(0.831)	(0.736)
atanhrho_12	1.737***		1.614***		2.154***		4.022		1.850***		2.079***	
	(0.124)		(0.476)		(0.647)		(0)		(0.147)		(0.290)	
Observations	7,606	7,606	7,606	7,606	7,606	7,606	7,748	7,748	7,748	7,748	7,748	7,748
Energy-efficient sectors												
VARIABLES	**GVC1E**	**GVC1I**	**GV2E**	**GVC2I**	**GVC4E**	**GVC4I**	**GVC1E**	**GVC1I**	**GV2E**	**GVC2I**	**GVC4E**	**GVC4I**
Env. Regulation	0.225	0.307**	0.446**	0.177	0.145	-0.310*	0.144	0.263**	0.353*	0.139	0.0684	-0.333**
	(0.165)	(0.120)	(0.186)	(0.165)	(0.170)	(0.163)	(0.170)	(0.122)	(0.187)	(0.166)	(0.170)	(0.164)
Energy innovation	0.235	0.0954	0.386**	0.427**	0.335*	0.216						
	(0.219)	(0.173)	(0.151)	(0.214)	(0.201)	(0.158)						
Energy management							0.390**	0.224	0.700***	0.517***	0.545***	0.186
							(0.177)	(0.154)	(0.129)	(0.194)	(0.211)	(0.169)
Constant	-1.723***	-2.839***	-3.916***	-4.471***	-4.324***	-5.227***	-1.605***	-2.831***	-3.826***	-4.424***	-4.273***	-5.237***
	(0.522)	(0.309)	(0.319)	(0.348)	(0.580)	(0.737)	(0.474)	(0.305)	(0.310)	(0.354)	(0.549)	(0.759)
atanhrho_12	1.801***		1.689***		1.082**		1.863***		1.418***		1.023**	
	(0.126)		(0.549)		(0.515)		(0.124)		(0.455)		(0.421)	
Observations	6,807	6,807	6,807	6,807	6,807	6,807	6,917	6,917	6,917	6,917	6,917	6,917
Country/sector/year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Other Covariates	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. Notes: Weights are used and errors are clustered at sector, region, country levels.

Table 14: Robustness check

	With energy innovation						With energy management					
VARIABLES	**GVC1E**	**GVC1I**	**GV2E**	**GVC2I**	**GVC4E**	**GVC4I**	**GVC1E**	**GVC1I**	**GV2E**	**GVC2I**	**GVC4E**	**GVC4I**
Env. Regulation	0.139	0.213***	0.384***	0.226**	0.126	-0.1000	0.0578	0.174**	0.324***	0.201**	0.0698	-0.137
	(0.111)	(0.0720)	(0.125)	(0.0893)	(0.125)	(0.119)	(0.111)	(0.0762)	(0.114)	(0.0869)	(0.124)	(0.130)
Energy innovation	0.115	-0.105	0.196	0.0942	0.0365	0.127						
	(0.146)	(0.0944)	(0.119)	(0.0956)	(0.195)	(0.189)						
Energy management							0.311**	0.0696	0.416***	0.215**	0.261*	0.189
							(0.136)	(0.0841)	(0.108)	(0.0919)	(0.155)	(0.185)
Medium-sized	0.395***	0.131	0.636***	0.145	0.642***	0.538***	0.351***	0.116	0.618***	0.131	0.602***	0.500***
	(0.110)	(0.0834)	(0.112)	(0.0941)	(0.215)	(0.164)	(0.113)	(0.0852)	(0.110)	(0.0941)	(0.203)	(0.162)
Large sized	0.592***	0.345***	1.233***	0.502***	1.495***	1.277***	0.536***	0.308***	1.187***	0.480***	1.434***	1.235***
	(0.151)	(0.101)	(0.0998)	(0.0908)	(0.142)	(0.148)	(0.168)	(0.103)	(0.0981)	(0.0931)	(0.138)	(0.147)
Firm age	0.0384	-0.0339	-0.0542	-0.0101	-0.0949	-0.0807	0.0304	-0.00475	-0.0488	-0.00849	-0.0969	-0.0830
	(0.0721)	(0.0604)	(0.0681)	(0.0612)	(0.0721)	(0.0596)	(0.0721)	(0.0618)	(0.0681)	(0.0621)	(0.0655)	(0.0579)
Labor productivity	0.111**	0.0501	0.0840***	0.107***	0.190***	0.119**	0.108**	0.0444	0.0762***	0.103***	0.190***	0.122***
	(0.0558)	(0.0404)	(0.0310)	(0.0350)	(0.0545)	(0.0468)	(0.0545)	(0.0414)	(0.0289)	(0.0340)	(0.0549)	(0.0443)
Digital firm	0.176*	-0.224*	0.280***	0.298**	0.0124	-0.128	0.165*	-0.199	0.260***	0.289**	0.0226	-0.109
	(0.102)	(0.131)	(0.0947)	(0.135)	(0.157)	(0.138)	(0.0944)	(0.130)	(0.0980)	(0.139)	(0.169)	(0.140)
Credit constraint	-0.207		-0.177		-0.322**		-0.191		-0.184		-0.315**	
	(0.182)		(0.147)		(0.134)		(0.182)		(0.148)		(0.133)	
Tech. capability	0.458***	0.325***	0.344***	0.183**	0.120	0.223**	0.429***	0.305***	0.325***	0.168*	0.0929	0.206*
	(0.152)	(0.0888)	(0.103)	(0.0882)	(0.126)	(0.114)	(0.150)	(0.0865)	(0.103)	(0.0891)	(0.115)	(0.107)
Trade obstacles	0.195	0.173	0.132	0.0395	-0.0612	0.217	0.227	0.188	0.136	0.0503	-0.0385	0.227
	(0.152)	(0.135)	(0.124)	(0.0836)	(0.170)	(0.154)	(0.145)	(0.137)	(0.113)	(0.0817)	(0.167)	(0.155)
Constant	-2.103***	-4.277***	-2.222***	-5.224***	-3.407***	-4.904***	-1.912***	-4.432***	-2.255***	-5.249***	-3.497***	-5.003***
	(0.472)	(0.446)	(0.397)	(0.546)	(0.664)	(0.656)	(0.493)	(0.437)	(0.368)	(0.517)	(0.626)	(0.642)
	3.758		1.277***		1.179***		3.514*		1.176***		1.194***	
	(2.757)		(0.273)		(0.207)		(2.031)		(0.191)		(0.219)	
Country/sector/year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	14,413	14,413	14,352	14,352	14,287	14,287	14,665	14,665	14,602	14,602	14,537	14,537

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. Notes: Weights are used Errors are clustered at sector, region, country levels.

THE MEDIATING EFFECTS ANALYSIS

This section presents the main results of the GSEM technique that is employed to examine the mediating roles of energy innovation and energy practices. Table 15 reports the main direct, indirect, and total effects of environmental regulation for all definitions of the probability and intensity of GVCs participation. The findings mainly show that energy management exerts a mediating effect only for GVC1E, GVC1I, GVC2E, GVC2I, GVC3E, and GVC4I. For GVC1E, GVC2I, GVC4I, since only the indirect effect is significant, whereas the direct effect is insignificant, this implies that energy management has a full mediation effect of energy management on the probability of GVCs' integration and the intensity of GVCs' participation. For GVC1I, GVC2E, GVC3E, since both the direct and indirect effects are statistically significant, this indicates a partial mediating role for energy management. This finding shows that regardless of the degree of integration in GVCs and regardless of whether environmental regulation directly affects energy management, the latter has a good potential for fully mediating the effect of environmental regulation on GVCs. Hence, firms are encouraged to green their management practices by developing their environmental accounting practices, namely by monitoring their energy consumption levels, by setting targets for an efficient threshold for energy consumption, and by undergoing an external audit for energy consumption. For energy innovation, it has a limited mediating role compared to energy management. For GVC1E, GVC1I, GVC2I, and GVC3E, since only the direct effect is significant, whereas the indirect effect is non-significant, indicating no mediating effect. Energy innovation plays a partial mediating role only for GVC2E, where both the direct and indirect effects are statistically significant. Despite the limited mediating effect for energy innovation, firms are encouraged to adapt to environmental regulations by undertaking R&D efforts in energy-related fields to develop energy-saving technologies on one hand, and to adopt renewable energy on the other hand. By improving their energy performance, firms would be able to align to international standards of green performance and improve their GVCs participation. Finally, the evidence highlights the fact that while energy innovation plays a limited mediating role for firms that are weakly integrated, energy management is more effective regardless of the depth of GVCs integration. All firms need to enhance their energy management since quality energy management lays the foundation for an energy efficiency improvement for all firms in the value chains.

Table 15: Mediation analysis results

	Mediating role of energy innovation			Mediating role of energy management		
	Direct effect	**Indirect effect**	**Total effect**	**Direct effect**	**Indirect effect**	**Total effect**
GVC1E	0.178	0.087	0.265	0.118	0.252	0.369
(p-value)	*0.091*	*0.114*	*0.012*	*0.273*	*0.018*	*0.003*
GVC1I	0.001	0.000	0.001	0.001	0.001	0.002
(p-value)	*0.012*	*0.215*	*0.008*	*0.025*	*0.054*	*0.001*
GVC2E	0.456	0.155	0.611	0.359	0.478	0.836
(p-value)	*0.000*	*0.007*	*0.000*	*0.003*	*0.000*	*0.000*
GVC2I	0.002	0.000	0.002	0.001	0.001	0.003
(p-value)	*0.072*	*0.296*	*0.029*	*0.168*	*0.028*	*0.005*

GVC3E	0.306	0.071	0.377	0.254	0.221	0.475
(p-value)	*0.006*	*0.148*	*0.000*	*0.034*	*0.013*	*0.000*
GVC3I	-0.004	0.000	-0.003	-0.005	0.006	0.001
(p-value)	*0.284*	*0.935*	*0.345*	*0.190*	*0.113*	*0.720*
GVC4E	0.188	0.032	0.220	-0.037	-0.013	-0.050
(p-value)	*0.179*	*0.691*	*0.148*	*0.287*	*0.710*	*0.330*
GVC4I	-0.038	-0.013	-0.051	0.106	0.294	0.400
(p-value)	*0.261*	*0.587*	*0.274*	*0.458*	*0.030*	*0.019*

Source: Author's own elaboration using findings from the *nlcom* results to report direct, indirect and total effects of environmental regulations on GVCs
Notes: Weights are use, errors are clustered, and country, year, and sector dummies are included.

CONCLUSION

This study examines the impact of environmental regulation on firm-level extensive and intensive participation in GVC, and it also assesses the moderating and mediating roles of energy innovation and energy management. We focus on 16894 private firms in 23 Euro-Med countries operating in the manufacturing and service industries. We employ the GTP-FRM, a two-step Heckman correction analysis, and the IV approach to account for the endogeneity bias. The main findings show that environmental regulations and energy management practices are more effective than energy innovation in advancing GVCs' integration in line with the PH. The driving forces of environmental regulation and energy management are more pronounced for firms that are weakly integrated in GVCs and for EU firms, whereas the positive effects of energy innovation and energy management prevail more for firms in energy-efficient sectors. This could be explained by the fact that firms operating in energy-intensive sectors are highly reliant on the existence of a well-enforced regulatory framework that incentivizes the adoption of green practices, and which enhances their integration in value chains. By contrast, firms operating in the energy-efficient sector are already adopting proactive measures and can benefit from these green practices to improve their GVCs' integration. Also, while there is no evidence for a moderating role of green practices, a good quality energy management can have a full or partial mediating effect for different levels of GVCs' integration, and to a lesser extent, energy innovation.

POLICY IMPLICATIONS AND RECOMMENDATIONS

From a policy standpoint, results show that the implementation of environmental regulation and greening practices in energy-related fields is crucial for boosting firm-level GVCs' participation through better alignment with the green requirements of foreign trade partners. Hence, Euro-Med governments need to prioritize the implementation of strategies for greening their value chains. Thereby, the implementation of a well-enforced regulatory framework based on the use of market-based instruments is highly required to incentivize the adoption of green innovation and management practices. Special attention should be paid to firms that have a shallow integration in GVCs since they are the most benefited from regulations and green practices.

Thus, governments could also intervene through complementary public policies (tax credits, tax reductions, green subsidies) to encourage R&D in energy-related fields and to help firm establish their environmental accounting systems, especially SMEs.

Also, easing access to finance is very important in order to help firms finance the decarbonization of their production processes, and it is crucial to provide them with capacity building for using green technologies.

When it comes to firms, while they can benefit from stricter regulations to undertake green practice, they must be conscious enough about the importance of undertaking voluntary and pro-active actions for environmental self-regulation. Hence, they need to develop their environmental accounting system and approach their energy performance when evaluating their environmental footprint.

This finding is crucial for SEMED firms that are mostly operating in upstream stages and are less likely to integrate energy management strategies despite being energy-intensive sectors. This is an important step for the decarbonization of the supply chains. (Xavier et al., 2024). Hence, a better management for energy performance is an economic objective that entails the maximization of energy-cost savings and the minimization of waste generation without affecting production volume and quality.

To this end, governments can complement the regulatory framework with the supervisory role of voluntary public environmental actions such as eco-auditing, and to assist firms in the capacity building for their workforce and for helping them in introducing measure, reporting, and verification (MRV) system to track emissions for all firms in the value chains.

Moreover, governments in the SEMED countries need to account for the main challenges that impede a deep integration in GVCs, especially since more firms in the region are located in upstream stages and are mostly involved in forward linkages.

Ensuring a business-friendly environment by cutting red tapes, enhancing governance, enforcing property rights, removing discriminatory policies, and facilitating investments in services (transports and logistics)

is key to attract foreign investments and to enhance their GVCs' integration and to move towards more downstream stages (European Bank for Reconstruction and Development & European Commission, 2020).

Finally, SEMED governments need to promote their firms' integration in higher-value-added activities within GVCs since most of them operate in upstream stages of GVCs and receive investments in the oil sector (Zaki, 2019), which limits the potential of creating deep regional integration in GVCs. It is crucial for governments to upgrade their industrial policies and to couple them with trade policies because is a great opportunity for SEMED countries to diversify their manufacturing production and to increase their GVCs' integration in higher value-added sectors.

At the regional level, harmonizing environmental regulations is important for addressing related problems and for boosting regional value chains. To this end, SEMED governments must consider the establishment of voluntary carbon markets, especially since the Carbon Border Adjustment Mechanism has already entered into force since October 2023. The establishment of regional carbon markets would allow the exchange of carbon credits in foreign exchange markets, which would generate secured revenues for assisting firms in developing their green practices and adopting energy-saving technologies. The establishment of a regional voluntary carbon market is more recommended than developing a regional energy market since the latter is not well developed and still lacks the regulatory and technical guidelines for its establishment. Hence, it is more efficient for governments to rely on voluntary carbon markets to promote the development of energy-efficient technologies.

Also, in order to foster regional cooperation between EU and SEMED firms for easy access to energy-related sustainability practices and different green technologies, policymakers are encouraged to develop and harmonize their innovation policies (IPRs) to facilitate access to foreign green technologies.

Most of SEMED firms operate in oil and gas, horticulture, chemical, manufactured, and textile products. Given the low level of industrial complexity and higher vulnerability to external shocks such as wars and pandemic crises, there is a need to assess the ability of firms in these sectors to pay the high fixed costs of complying with environmental regulations and to adapt their operational strategies to environmental upgrading within GVCs.

Moreover, regional trade agreements must be revised to increase the legal enforceability of environmental provisions, and more specifically, those related to energy efficiency for all trading partners.

Given the lack of harmonization between EU and SEMED regulations and standards (e.g. environmental standards, technical barriers to trade and sanitary and phytosanitary standards) and inability of firms in SEMED countries to comply with all EU market conditions, SEMED governments need to work on better harmonization aspects to attract more foreign direct investments in the manufacturing sector and to be able to integrate EU markets.

Finally, it is important to create a regional platform for a green dialogue to allow the exchange of information and knowledge about best practices related to energy innovation and the development of energy management on one hand, and to promote energy-saving technology from the EU to their SEMED neighbours.

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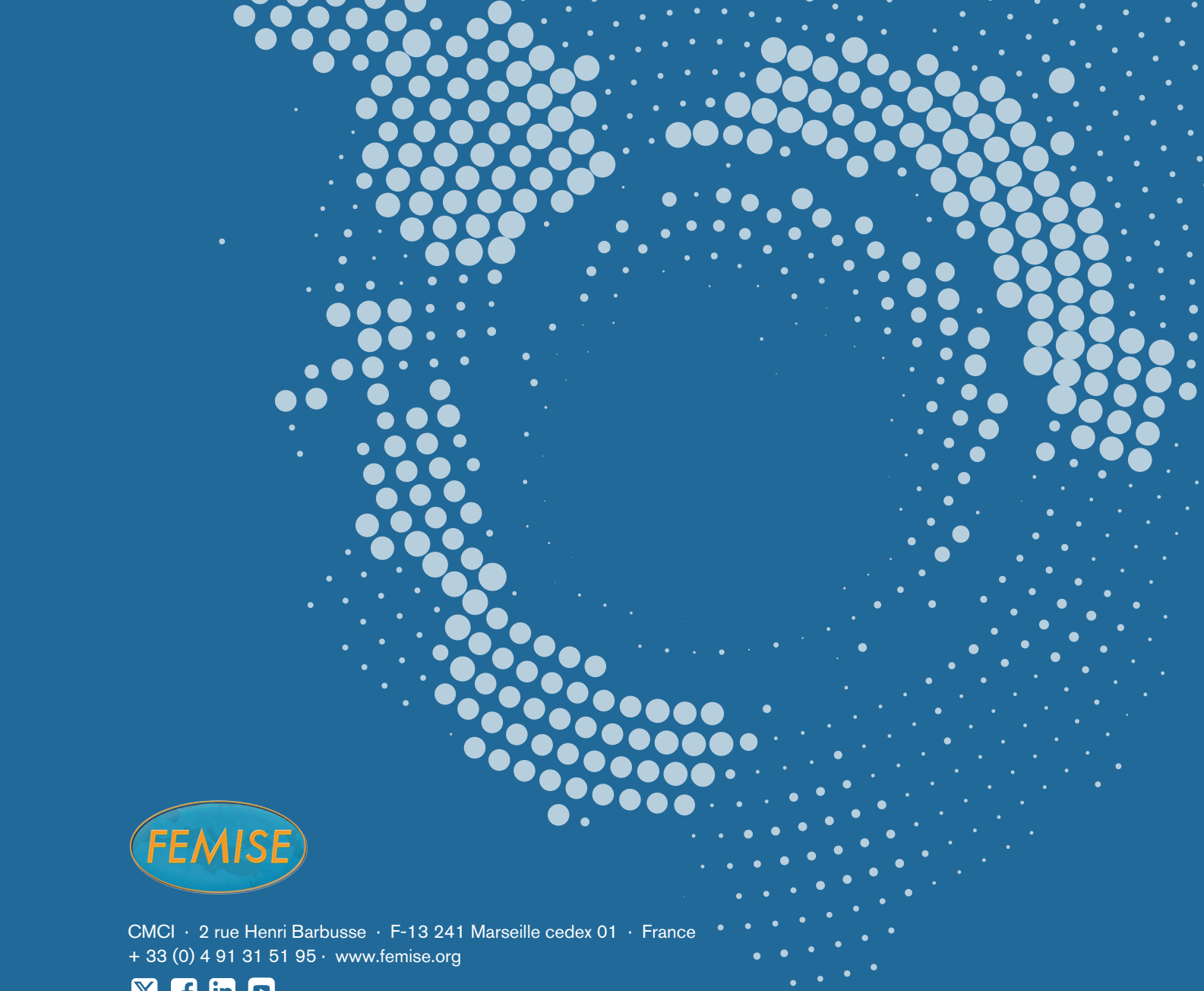

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