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The Relationship Between Global Value Chains, Green Technologies, and Air Pollution: Initial Evidence for EU Regions

Federico Colozza and Carlo Pietrobelli

1   Introduction

The 13th goal of the Sustainable Development Goals (SDGs) includes all the "climate actions to combat climate change and its impacts," and to improve the atmospheric conditions. Among all atmospheric pollutants, two of the most dangerous ones are represented by NOx (Nitrogen Oxides) and SOx (Sulfur Oxides) particles (Wang et al., 2021); the latter are the consequences mostly related to industrial processes that have an

F. Colozza (✉)
Department of Economics, Roma Tre University, Rome, Italy
e-mail: federico.colozza@uniroma3.it

C. Pietrobelli
UNESCO Chair at United Nations University UNU-MERIT, Maastricht, The Netherlands

Department of Economics, Roma Tre University, Rome, Italy
e-mail: carlo.pietrobelli@uniroma3.it

impact on a wide range of elements, including the atmosphere and the soil. The literature widely debates these issues (OECD, 2013) and also highlights the possible connection between the environment and the economic development of regions and countries (Dinda, 2004; Georgiev & Mihaylov, 2015; Fujii & Managi, 2016).

In the last three decades, the pursuit of ever-better economic opportunities has pushed industrial organizations to delocalize: this process has built fragmented and functionally integrated chains of production and commercialization, also known as Global Value Chains, in which firms and industries contribute to the final productions by assembling parts and components (Gereffi & Korzeniewicz, 1994). However, along these chains, economies do not only share components and parts, but also knowledge and information (Morrison et al., 2008). In short, the higher the level of integration in these value chains, the greater the benefits of participation might be (Jurowetzki et al., 2018; Lema et al., 2019), often through the possible upgrading opportunities within GVCs (Humphrey & Schmitz, 2002; Pietrobelli & Rabellotti, 2011; Gereffi, 2019). The extent to which this mechanism of knowledge diffusion may work in countries, regions, and, more in general, territories is highlighted in a huge literature (Pietrobelli & Rabellotti, 2011; Jurowetzki et al., 2018; Fagerberg et al., 2018; Colozza et al., 2022) that also stresses the limits that GVC governance, and the context prevailing in host countries, may pose on such processes. More recently, other studies claim that no matter whether on economic development or on complexity (Colozza & Pietrobelli, 2021; Boschma, 2022; Colozza et al., 2022), the participation in higher value-added activities is a positive factor, especially when the knowledge shared is less common. However, there is still little understanding of whether GVCs may work to foster the so-called greening process across EU regions.

To this end, in this chapter, we seek to lay out whether GVC integration and green technologies influence NOx and SOx emissions in EU

NUTS-2 regions.[1] We carry out our analysis in two stages. First, we assess to what extent GVC participation may affect green technologies in EU regions. Second, we study the influence of green patents and GVCs on air pollution. We also examine whether backward and forward participation in GVCs plays different roles in this process.

With this research, we seek to provide preliminary evidence on the mechanisms of environmental upgrading across EU NUTS-2 regions. We examine this process for the period 2005–2007. In particular, we provide some preliminary evidence on the dynamics of green technologies, GVCs, and air pollution in EU NUTS-2 regions, using some precautions (such as, for instance, Perpetual Inventory Method) to provide solid results. Our original findings show that not only the participation in GVCs is increasingly correlated to green patents in EU regions, but also that more and more regions are relying on offshoring productions, at the same time concentrating air pollution in fewer regions.

This chapter is organized as follows. In the next section, we discuss the literature. We then explain the method to construct our variables (Sect. 3). Hence, we present our methods and preliminary results (Sect. 4). Finally, we discuss some preliminary conclusions (Sect. 5).

2 Global Value Chains, Green Technologies, and Air Pollution

Nowadays, there is compelling evidence on the importance of countries' and regions' integration in GVCs to receive knowledge and information, and trigger economic upgrading processes (Colozza et al., 2022). Besides, in addition to the general influence that GVCs may have on knowledge diffusion (Jona-Lasinio et al., 2019), and on the ensuing opportunities for learning and development, this mechanism may work also for sharing

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[1] The Nomenclature of Territorial Units for Statistics (NUTS) was established by Eurostat to provide a single uniform breakdown of territorial units for the production of regional statistics for the European Union. The NUTS is a five-level hierarchical classification (three regional levels and two local levels). Specifically, the NUTS subdivides each Member State into a whole number of NUTS 1 regions, each of which is in turn subdivided into a whole number of NUTS 2 regions and so on (Eurostat, "Reference and Management of Nomenclatures").

"green" knowledge. This may occur both directly, in terms of technologies (Glachant et al., 2013), or indirectly, by fostering competition in green strategies (De Marchi et al., 2013; De Marchi et al., 2020). Essentially, while GVC integration may lead some economies to upgrade production techniques to become more competitive (De Marchi et al., 2020), other countries may exploit these channels to learn and adopt green technologies (Dechezleprêtre et al., 2013). For instance, De Marchi et al. (2013) suggest that the presence of opportunities embodied in GVCs is likely to help economies share green techniques and support industrial companies in keeping or gaining new competitive advantages.

An additional perspective is highlighted by Poulsen et al. (2018), which suggest that participation in GVCs would reduce emissions of air pollutants (in the case study of the maritime sector), through an upgrading mechanism that involves new adaptations of techniques and methods in firms to improve their reputation, and also providing incentives for buyers and suppliers to do the same (Nadvi, 2008). Glachant et al. (2013) also offer new evidence on the mechanism of green technologies diffusion across world economies. The literature argues that this would be especially true for economies that internalize their productions, leveraging channels of knowledge transfer that may facilitate investments in R&D (Castellani & Pieri, 2013).

A new contribution that is especially relevant to our present aims is the paper by Wang et al. (2021), who find that when OECD economies increase their productivity, they reduce pollutants emissions not only through green patents but also by exploiting GVC connections. However, despite a great deal of advantages, it goes without saying that GVCs also imply various substantial environmental limitations.[2] These are related to the claims of the "pollution haven" hypothesis (Duan et al., 2021), which demonstrates a negative impact of GVC participation on the emissions of pollutants in the atmosphere: indeed, polluting activities might be offshored in other places, rather than in the territories that participate in GVCs (Ponte, 2020).

In contrast, there are no doubts about the effect of green patents on air pollution. Here, for a long time the literature has underlined the role of

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[2] See among the many, Lopez & Islam (2008); Yasmeen et al. (2019); Ponte (2019); Duan et al. (2021).

environment-related technologies as elements of air pollution abatement (Jaffe et al., 2003), in specific sector-sector relations[3] (Nameroff et al., 2004), in specific countries (Shen et al., 2020), and in assessing the quality of such technologies (Töbelmann & Wendler, 2020). Within a supply-chain approach, Costantini et al. (2017) also examine the role of green technologies in reducing air pollutants emissions in EU regions. Their research produces evidence not only on the effects of green technologies in the sector-sector relationship, but also on the presence of spill-over mechanisms. Moreover, Sarfraz (2021) shows how green technologies tackle down emissions of air pollutants and discuss in-depth the several opportunities related to green knowledge.

To the best of our knowledge, no study yet exists that analyzes the connection between GVCs, green technologies, and air pollutants emissions for the EU NUTS-2 regions. In sum, the purpose of this preliminary study is to answer the following questions: (1) Does participation in GVCs allow EU economies to share green knowledge? Is there a relationship between GVCs and green patents? (2) Is integration in GVCs related to the emissions of air pollutants? Does backward participation have a special role in this regard?

3   Variables Construction

This chapter builds on a novel dataset for EU NUTS-2 regions, especially for GVC participation and emissions of NOx and SOx particles. We collect data from the Regional Input-Output Database (RIOD) tables (Thissen et al., 2018) for the calculation of the GVCs participation indicators, from the European Environmental Agency (EEA) and Structural Business Statistics (SBS) datasets (Eurostat) to calculate respectively the emissions of air pollutants and manufacturing specialization, and the OECD dataset for green patents (y2 category). We compute these variables for the period 2005–2007.

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[3] Namely, they analyze the relationship between the adoption of green technologies in specific sectors and the emission of air pollutants from the same activities.

3.1   Air Pollutants (AP) Emissions

We consider two of the most dangerous particles: Nitrogen and Sulfur
Oxides (NOx and SOx), being also the subject of other studies (Wang
et al., 2021). We extract the data for the EU NUTS-1 level and for the
period 2005–2007, from Eurostat (Environment European Agency,
EEA). The first step in the construction is to generate a sum-variable of
the air pollution for each country i and time t, and for each sector s
(Eq. 9.1):

$$AP_{i,\,s,\,t} = NOx_{i,s,t} + SOx_{i,s,t} \qquad (9.1)$$

Then, following the intuition of the "Commodity Balance approach"
(Isard, 1953), we assign the yearly values of national air pollution to each
region, matching the source's sector of pollution with the sectors that
contribute to these emissions in each region. To this end, we rely on sec-
toral employment data (Structural Business Statistics) which include data
about 54 sectors and for the period of interest.

Then, we select two different data: (1) National data on air pollutants
emissions, from 78 sectors, which we call source-of-emission (soe); and
(2) Regional data on employment composition, for 27 sectors (selecting
only those connected to the sources of emission), which we call sector-of-
interest (soi) (Table 9.1).

We build our yearly regional data by following the Eq. 9.2:

$$AP_{r,t} = \frac{\sum_{soe=1}^{78} AP_{i,soe,t}}{\sum_{soi=1}^{27} Empl_{i,soi,t}} \qquad (9.2)$$

Where we distribute the AP emissions, at the country level, for
each sector-of-emission following the presence of the same sector in
region i.

As a result, we have data on regional emissions of air pollutants
(NOx+SOx), which indicate, as shown in Fig. 9.1, the highest emissions
of air pollutants from the Spanish east coast to the Italian west coast,

Table 9.1 Composition of Soe and Soi

Group	Kind	Code (*main components*)	# of sectors
Soe	Emissions	NFR1A1A—NFR1A2G8 (*Combustion in man. industries*);	78
		NFR1A3A1_1—NFR1A3A2_2 (*Aviation*);	
		NFR1A3B2—NFR1A3B3 (*Road transport, commercial*);	
		NFR1A3D1_1—NFR1A4A2 (*Commercial transport*);	
		NFR1B1A—NFR2L (*Industrial productions*);	
		NFR5D1—NFR5D3 (*Wastewater handling*).	
Soi	Employment	CA—CB (*Mining and quarrying*);	27
		DA15—DN36 (*Manufacture*);	
		E1—F45 (*Electricity, gas and water supply, construction*);	
		I60—I62 (*Transport: land, water and air*).	
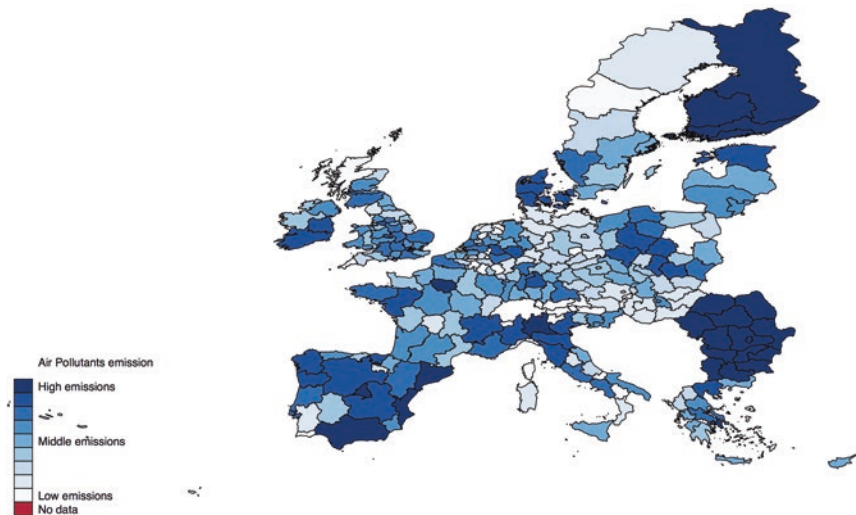
Fig. 9.1 Air pollutants emission for EU regions. (Source: Authors' elaboration)

including Emilia Romagna and Lombardy, Ile-de-France, and some Poland regions.[4]

It is interesting to know that we exclude the emissions from energy savings, located in power plants, since in our analysis we are interested in the evaluation of the environmental upgrading in production processes from GVCs knowledge.

3.2   Global Value Chain Participation

Following the value-added approach (Montalbano et al., 2018), we evaluate the participation in Global Value Chains by computing the shared value added in forward and backward linkages on gross exports (Borin & Mancini, 2019), based on RIOD tables (Thissen et al., 2018). As Eq. 9.3 shows, we follow established literature (Colozza et al., 2022; Montalbano et al., 2018) and sum the backward and forward linkages, considering the degree of participation as the ratio on gross exports:

$$GVC \text{ index}_{r,t} = \frac{\text{backward } GVCs_{r,t} + \text{forward } GVCs_{r,t}}{\text{Gross Export}_{r,t}} \quad (9.3)$$

Where the backward and forward components are computed as follows (Eqs. 9.4 and 9.5):

$$GVC\_\text{backward}_r = \frac{V_r\left(I - A_{rr}\right)^{-1}\left[\sum_{j\neq r}^{G}A_{rj}B_{jr}E_{rs} + \sum_{t\neq r}^{G}V_tB_{tr}E_{rs}\right]}{u_nE_{rs}} \quad (9.4)$$

$$GVC\text{forward}_r = \frac{V_r\left(I - A_{rr}\right)^{-1}A_{rs}\left(I - A_{ss}\right)^{-1}\left[\sum_{j\neq s,r}^{G}Y_{sj} + \sum_{j\neq s}^{G}A_{sj}\sum_{l\neq r,s}^{G}B_{js}Y_{sl}\right]}{u_nE_{rs}} \quad (9.5)$$

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[4] We compute this variable for the period 2000–2010, although here we analyze only the time span 2005–2007. Interestingly, in the map we represent the geographical distribution (simple average by regions) of air pollution per capita for the complete period 2000–2010.

We use the same notation employed in Borin and Mancini (2017):

- V_r: value added shared from the region r;
- $B_{rr} = (I - A_{rr})^{-1}$: Leontief inverse, that indicates the amount of input that the region *r* needs to produce an additional unit of the good for the same region in this case; an *rs* subscript indicates the amount of input that the region r needs to produce an additional unit of the good for region *s*;
- E_{rs}: export from the region r to the region s;
- Y_{rs}: final goods from the region *r* consumed in region s.

In other words, if on the one hand, the backward component represents the foreign value-added embodied in the intermediate and final exports of region *r,* on the other hand, the forward component represents the domestic value-added embodied in the final exports of the region *r*. As a result, we have participation indexes for the EU NUTS-2 regions.

3.3 Green Technologies

Our third variable of interest is represented by the adoption of green technologies in the EU NUTS-2 regions. The definition of "green patents" is strictly related to the environmental impact of those technologies. Haščič and Migotto (2015) present a list of green technologies, and we rely on their work for defining our measure of "green patents."

We extract data from OECD Reg-Pat for NUTS-3 regions and for three years (2005–2007), and we refer to "applicant's regions" to consider the innovativeness of firms in each region, whatever the location of their research facilities is.

Since green patents are expressed in absolute values, we consider per capita green patents, in order to give a regional weight to each observation. Moreover, following RAMON (Eurostat), we create the NUTS-2 observations. In conclusion, relying on Perpetual Inventory Method (Braun et al., 2010; Costantini et al., 2017; Meinen et al., 1998), we calculate the stock of patents by considering a depreciation rate of 20% and an initial growth rate of 15%. In the next section, we present some descriptive statistics of our dataset.

Table 9.2 Descriptive statistics

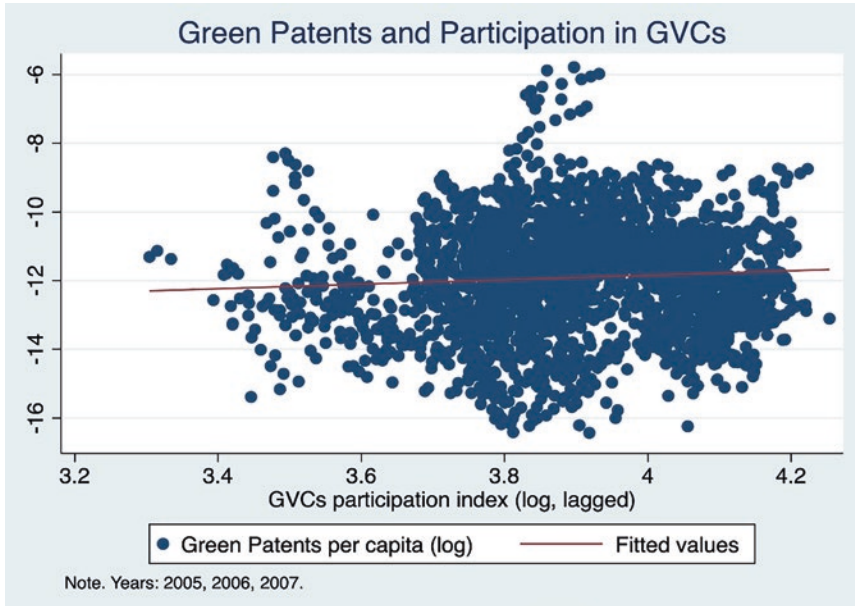| Variable (log)	Mean	Std. dev.	Min	Max	Obs
Air pollution per capita					
Overall	–3.421789	0.5455337	–6.93311	–1.982248	*N* = 729
Between		0.5306808	–5.28666	–2.018354	*n* = 243
Within		0.1290145	–5.233008	–2.500495	*T* = 3
Green patents PIM					
Overall	–11.84842	1.478124	–15.92311	–6.137361	*N* = 654
Between		1.454729	–15.41213	–6.253355	*n* = 218
Within		0.2740324	–13.41966	–10.25563	*T* = 3
GVCs index					
Overall	3.91929	0.1669416	3.412084	4.253636	*N* = 717
Between		0.1662919	3.415358	4.215879	*n* = 239
Within		0.017139	3.856529	4.001922	*T* = 3
Backward GVCs					
Overall	–0.0004946	0.2174042	–0.9307788	0.4912888	*N* = 717
Between		0.2156479	–0.8796115	0.4692047	*n* = 239
Within		0.0298409	–0.1051223	0.1158218	*T* = 3

Source: Authors' elaboration

3.4   Descriptive Statistics

Table 9.2 describes our dataset, with means, standard deviation, minimum and maximum values of our variables, as well as the number of observations (N), regions (n), and years (T).

4   Methods and Some Preliminary Evidence

We propose three different steps in our analysis. First, we address whether GVCs participation allows EU regions to transfer green knowledge, embodied in the adoption of green patents. Second, we examine the simple correlation between air pollution per capita, green patents and participation in GVCs. Third, we test whether these phenomena are increasingly concentrated in specific regions, preliminary testing for a possible sigma convergence, that is, the fall in the dispersion of air pollution and backward GVCs.

Green Patents and Participation in GVCs

Graph showing Green Patents per capita (log) on y-axis (ranging from -16 to -6) versus GVCs participation index (log, lagged) on x-axis (ranging from 3.2 to 4.2), with a scatter of data points and a fitted line.

Legend: ● Green Patents per capita (log)   —— Fitted values

Note. Years: 2005, 2006, 2007.

Graph 9.1 Green Patents and GVCs participation (period: 2005–2007, authors elaboration)

Does participation in GVCs allow EU economies to share green knowledge? Is the haven hypothesis met? Are pollutant emissions concentrated in same contexts? In Graph 9.1, we plot on the y-axis the number of green patents per capita and on the x-axis the participation in GVCs, during the period 2005–2007.

As the distribution in Graph 9.1 shows, in the period 2005–2007, GVCs appear to be positively related to green technologies. This scatterplot demonstrates that EU regions that strengthen their participation in GVCs, in year t-1, are more likely to adopt green technologies in year t. The second element of interest concerns the distribution of participation rates in GVCs: all things considered, EU regions experienced quite homogeneous participation, with values between 3.3 and 4.2.

However, the hypothesis of pollution haven, as briefly mentioned in the introduction, could imply an offshoring process of pollution activities, creating areas selling final goods with low levels of pollutants, but

Table 9.3 Correlations of per capita air pollution

| Variables (log, lagged)	Year 2005	Year 2006	Year 2007
Green patents per capita	–0.0894	–0.0885	–0.0823
GVCs index	–0.1421	–0.2095	–0.2544
Backward GVCs index	–0.0599	–0.1187	–0.1519

Source: Authors elaboration

relying on components and goods produced in other places, with higher environmental impacts.

We seek to find some early proof on whether this "offshoring" mechanism occurred also in EU regions for the period 2005–2007, and whether green technologies play a role in this process as well. In Table 9.3, we examine the evolution of correlations between green patents per capita, overall GVCs participation, and backward GVC indexes with air pollution per capita.

Table 9.3 suggests interesting patterns in the EU regions. First of all, we notice an expected negative and stable correlation between green patents and per capita air pollution (first row), suggesting that green patents are more numerous when per capita air pollution is lower. Moreover, when we analyze the correlation between GVCs and per capita air pollution (second row), we find a negative and increasing correlation between these two phenomena, that is, participation in GVCs is larger as per capita air pollution decreases, and this trend is growing. In addition, the third row allows us to examine the relationship between backward participation (the dependence of economies on productions delocalized in other places) and per capita air pollution. Again, the correlation coefficient suggests a negative relation between backward participation and per capita air pollution, and this negative relationship has become increasingly stronger in these years.

What is more, to provide further signals on the pollution haven hypothesis, we examine the territorial dispersion of air pollution per capita and backward GVCs across EU regions. In doing so, we study this aspect through the analysis of the presence of sigma convergence: that is, considering the pattern of the average standard deviation for both air pollution and backward GVCs.

The above Graphs 9.2 and 9.3 show two different patterns of dispersion across EU regions. If, on the one hand, the dispersion in per capita
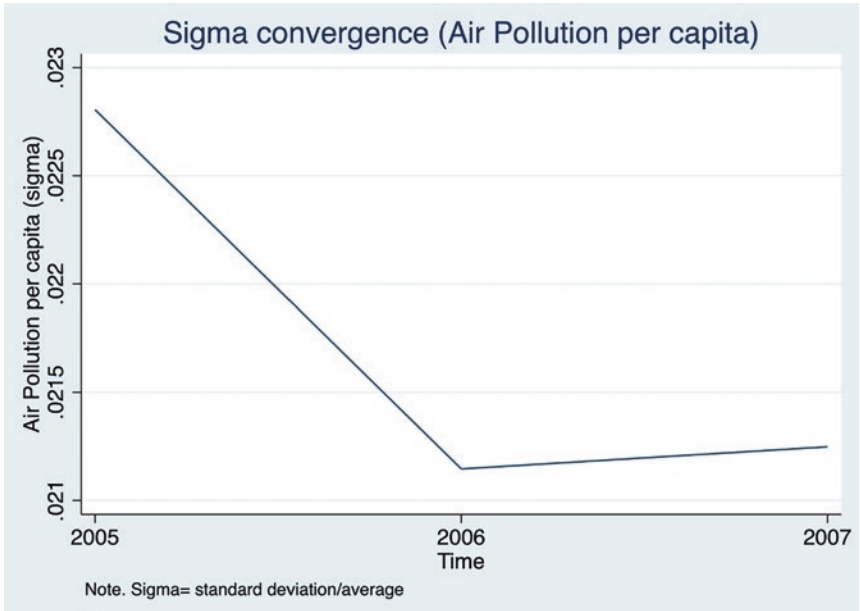
Graph 9.2 Sigma convergence AP per capita
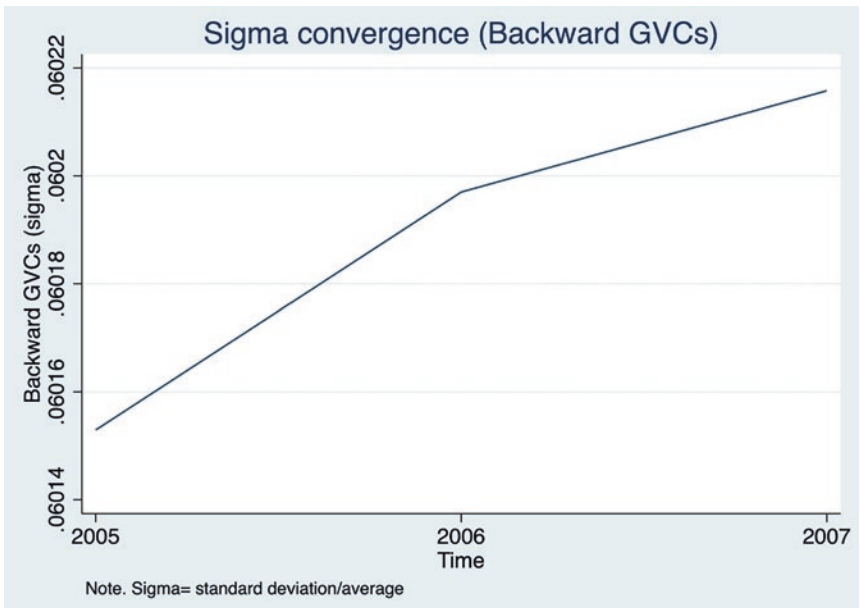
Graph 9.3 Sigma convergence backward GVCs (authors' elaboration)

air pollution falls during the period 2005–2007 (Graph 9.2), on the other the dispersion in participation in GVC backward participation increases (Graph 9.3). In other words, these two graphs demonstrate the presence of sigma convergence for air pollution, and sigma divergence for participation in backward GVCs—namely, while the pollution is increasingly concentrated in fewer regions, the number of regions that leverage offshore productions increases.

5   Interpretation and Concluding Remarks

The mechanism of green-upgrading along Global Value Chains has been hardly evaluated for EU NUTS-2 regions so far (De Marchi et al., 2020). In a broader context, the GVCs literature has been stressing how this process may work, even though the empirical evidence is scant, let alone policy recommendations.

In this chapter we make an early attempt to shed new light on the relationship between Global Value Chains, green technologies, and air pollutants emissions. We select the period 2005–2007 to provide early evidence on how and whether this mechanism works for EU regions. First, we analyze the positive relation between GVCs and green technologies, showing that GVCs confirm their role as green knowledge pipelines. Then, after analyzing the correlation between per capita air pollution, green technologies, and backward participation in GVCs, we find that backward participation is negatively related to air pollution. To this end, we analyze sigma convergence to show that while AP is more concentrated in some EU regions, backward participation is more widespread. In other words, while few regions suffer from increasing pollution, the number of regions dependent on offshoring productions is also growing.

This initial evidence paves the way for additional, more rigorous econometric work that will be carried out soon and for a larger number of years. Up to now, research leads us to suggest the idea that GVCs represent today an exclusive "green-island" for economies that have the chance to enter these international channels, but their access is unevenly distributed, also in Europe. Moreover, our initial findings appear to

suggest the hypothesis of "pollution haven," which, however, should be confirmed through a more appropriate econometric analysis.

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