

Frattini, Federico Fabio; Vona, Francesco; Bontadini, Filippo; Colantone, Italo

**Working Paper**

## The Local Job Multipliers of Green Industrialization

CESifo Working Paper, No. 11939

**Provided in Cooperation with:**

Ifo Institute – Leibniz Institute for Economic Research at the University of Munich

*Suggested Citation:* Frattini, Federico Fabio; Vona, Francesco; Bontadini, Filippo; Colantone, Italo (2025) : The Local Job Multipliers of Green Industrialization, CESifo Working Paper, No. 11939, CESifo GmbH, Munich

This Version is available at:

<https://hdl.handle.net/10419/322501>

**Standard-Nutzungsbedingungen:**

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

**Terms of use:**

*Documents in EconStor may be saved and copied for your personal and scholarly purposes.*

*You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.*

*If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.*

## The Local Job Multipliers of Green Industrialization

*Federico Fabio Frattini, Francesco Vona, Filippo Bontadini, Italo Colantone*

## **Impressum:**

CESifo Working Papers

ISSN 2364-1428 (electronic version)

Publisher and distributor: Munich Society for the Promotion of Economic Research - CESifo GmbH

The international platform of Ludwigs-Maximilians University's Center for Economic Studies and the ifo Institute

Poschingerstr. 5, 81679 Munich, Germany

Telephone +49 (0)89 2180-2740, Telefax +49 (0)89 2180-17845, email [office@cesifo.de](mailto:office@cesifo.de)

Editor: Clemens Fuest

<https://www.ifo.de/en/cesifo/publications/cesifo-working-papers>

An electronic version of the paper may be downloaded

· from the SSRN website: [www.SSRN.com](http://www.SSRN.com)

· from the RePEc website: [www.RePEc.org](http://www.RePEc.org)

· from the CESifo website: <https://www.ifo.de/en/cesifo/publications/cesifo-working-papers>

# The Local Job Multipliers of Green Industrialization.\*

Federico Fabio Frattini<sup>†</sup>    Francesco Vona<sup>‡</sup>    Filippo Bontadini<sup>§</sup>    Italo Colantone<sup>¶</sup>

June 5, 2025

## Abstract

What are the job multipliers of the green industrialization? We tackle this question within EU regions over the period 2003-2017, building a novel measure of green manufacturing penetration that combines green production and regional employment data. We estimate local job multipliers of green penetration in a long-difference model, using a shift-share instrument that exploits plausibly exogenous changes in non-EU green innovation. We find that a 3-years change in green penetration per worker increases the employment-to-active population ratio by 0.11 pp. The effect is: persistent both in manufacturing and outside manufacturing; halved by agglomeration effects that increase the labour market tightness; stronger for workers with high and low-education; and present also in regions specialized in polluting industries. When focusing on large shocks in a staggered DiD design, we find ten times larger effects, particularly in earlier periods.

*Keywords:* Green industrialisation, Local job multipliers, Employment effects of the green transition, Shift-share IV design, Difference-in-differences.

*JEL:* J21, O14, R11.

---

\*We wish to thank Mattia Guerini, David Hémous, Giovanni Marin, Aurélien Saussay and all the participants at the EAERE, IAERE, 13<sup>th</sup> edition of the MCEE, FEEM in-house workshop and SEEDS workshop. We thank Giovanni Manica and Luqman Shamsudin for excellent research assistance. We acknowledge financial support from the project GREESCO (“Green Specialization and Circularity: Constraints and Opportunities”), funded by the European Union Next-GenerationEU, NATIONAL RECOVERY AND RESILIENCE PLAN (NRRP)– MISSION 4 COMPONENT 2 INVESTMENT 1.1, Fondo per il Programma Nazionale di Ricerca e Progetti di Rilevante Interesse Nazionale (PRIN)-CUP G53D23006810001. Views and opinions expressed are however those of the authors only and do not necessarily reflect those of the European Union or the European Commission. Neither the European Union nor the granting authority can be held responsible for them.

<sup>†</sup>FEEM; .federico.frattini@feem.it

<sup>‡</sup>University of Milan, FEEM and OFCE Sciences-Po; francesco.vona@unimi.it

<sup>§</sup>Luiss University, SPRU – University of Sussex; fbontadini@luiss.it

<sup>¶</sup>Bocconi University, GREEN Research Center, Baffi Research Centre, CESifo and FEEM; italo.colantone@unibocconi.it

# 1 Introduction

In the aftermath of the Covid crisis, green deal plans became popular around the world to reconcile employment growth and the transition to carbon neutrality through coordinated investments in infrastructures, skills and specific industries (Rodrik, 2014; Tagliapietra & Veugelers, 2020). A key element of this new strategy is to foster green industrial productions, e.g., electric vehicles, batteries and PV panels, also leveraging a re-shoring of the associated value chains through local content requirements. Although the logic of green deal plans is clear and resonates with that of a so-called “Big Push” (Murphy et al., 1989; Rosenstein-Rodan, 1943), there is not enough evidence in support of the claim that green industrialization creates a large number of well-paid jobs. EU countries are an interesting case to study the effect of green industrialization on local labour markets. On the one hand, European countries gradually lost their comparative advantage in specific green productions in favour of China. On the other hand, EU governments are planning to implement a combination of trade tariffs, local content requirement and industrial subsidies to re-shore green productions, for example through the Net Zero Industry Act (NZIA). Against this backdrop, a trade-off emerges between creating green jobs through industrial policies and making green goods more affordable to achieve carbon neutrality. Investigating the extent to which green productions boost job creation, and thus allow to gain political support for the green transition (Bergquist et al., 2020; Cavallotti et al., 2025; Vona, 2023), is a first crucial step to assess the potential effects of green industrial policies.

This paper is the first to contribute to this debate providing new evidence on the effect of green industrialization on employment growth for EU NUTS2 regions over the period 2003-2017. Because the local effects of manufacturing activities are widespread, we estimate both a direct effect of green industrialization on local manufacturing employment and an indirect job multiplier effect (Moretti, 2010). The second key contribution of our paper is to rely on a novel measure of green regional penetration that combines granular country-product data on green industrial production (Bontadini & Vona, 2023; Frattini et al., 2024) with regional employment shares disaggregated at the level of 2-digit manufacturing industries. Similarly to the literature on the China shock (Autor et al., 2013), we allocate green production shocks, at various time frequencies, to regions using their lagged industrial structure. We use a shift-share instrumental variable (SSIV) design to mitigate endogeneity concerns (Borusyak et al., 2022; Goldsmith-Pinkham et al., 2020). Specifically, our SSIV design leverages technology improvements in non-EU countries to identify plausibly exogenous variation in the opportunity to produce green goods locally. The intuition is that regions with stronger initial green capabilities can better exploit global improvements in green technologies to activate or expand green productions.<sup>1</sup> To

---

<sup>1</sup>This strategy is conceptually aligned with SSIVs that leverage exposure to technological shocks to study long-term

identify the labour market effects of the green transition, we use technology, supply-side shocks that may potentially lead to different results compared to an analysis exploiting policy shocks. However, this approach is commonly used to circumvent data limitations by a few recent studies evaluating the labour market impacts of renewable energy generation (Fabra et al., 2024; Scheifele & Popp, 2025). The third key novelty of our paper is to evaluate supply-side green shocks for the much larger manufacturing sector, where green innovations are produced and multiplier effects are more likely to emerge.

Our study on the local employment effect of green productions can be framed as a test of recent theoretical models revisiting the job creation and destruction effects of new technologies (Acemoglu & Restrepo, 2019; Autor et al., 2022; Gregory et al., 2022). The main argument of these models is that new technologies are mainly labour-saving on existing tasks, where a learning process towards standardization has been accomplished, and labour-augmenting on new tasks, that are, by definition, ill-structured and less routinised. Previous research shows that the bulk of employment in green activities requires new tasks, either within established occupations or through the emergence of new occupations (Elliott et al., 2024; Saussay et al., 2022; Vona et al., 2018, 2019). Thus, we expect green industrial production to be more labour-intensive than other kinds of production within the manufacturing sector.<sup>2</sup> The economic geography literature provides additional reasons to expect positive local multipliers of green production. First, high and medium-tech activities, such as green ones, pay higher wages that boost local employment through pecuniary externalities (Moretti, 2011). Second, new work and innovative activities, such as green ones, are more likely to attract complementary upstream and downstream activities locally (Carlino & Kerr, 2015; Lin, 2011). In the green economy, for instance, Popp et al. (2021) and Fabra et al. (2024) show that job creation effects on construction activities are particularly important as building new infrastructures is an essential element of green industrialization.

Our favourite shift-share specification reveals that, conditional on pre-existing industrial and country-specific trends as well as on time-invariant regional characteristics, green industrialization increases the employment-to-(economically) active population ratio. New jobs are created both in manufacturing (the “treated sector”) and in non-manufacturing activities (the pure multiplier effects). However, while the former effect is as expected persistent, the latter fades away in the long-run, i.e., after five years, and it is heterogeneous across sub-sectors, being positive for construction and utilities and negative on the service sector. However, inspecting the time profile of the multiplier effect more closely, the muted long-term effect of green industrialization on the employment-to-active population masks posi-

---

employment dynamics in local labour markets (Acemoglu & Restrepo, 2020; Acemoglu et al., 2022; Autor & Dorn, 2013).

<sup>2</sup>Although not directly examining green activities, the recent paper of Autor et al. (2022) finds that several new job titles, a measure of new task, are related to the green economy. The related paper of Saussay et al. (2025) combines the rich textual description of job vacancy data and patent abstracts to show that green technologies are more labour augmenting than other technologies, but also that, over time, they are becoming more labour-saving.

tive effects on both total employment and the active population, resulting in agglomeration effects that eventually increase the tightness of local labour markets. When netting out such agglomeration effect, estimates reveal that green industrialization affects both total and non-manufacturing employment also in the long-term. Moreover, in line with previous research (Popp et al., 2021; Vona et al., 2018), we find that greening of labour markets exacerbates job polarization, as the positive effect of green production is concentrated on workers with tertiary education, especially those employed in STEM -Science, Technology, Engineering and Math (STEM) jobs, and basic education (lower-secondary or less), particularly in the construction sector.

Interpreting our effects as Local Average Treatment Effect (LATE), we quantify their economic relevance using the variation in green production explained by SSIV. In doing so, we find that the historical increase in green industrialization accounted for by the plausibly exogenous technological shocks accounts for approximately one-tenth of a percentage point of the increase in the local employment-to-active population after three years. This effect is twice as large when we purge the total employment effect from the induced agglomeration effects.

A legitimate threat to the plausibility of our identification strategy is the violation of the parallel trend assumption, which is difficult to detect in a SSIV design where the instrument is a linear combination of multiple instruments (Goldsmith-Pinkham et al., 2020). Violations of the parallel trend assumptions are a key issue in the related paper of Popp et al. (2021), where regions receiving more green subsidies under the American Recovery and Reinvestment Act were also growing faster before the policy. Following Goldsmith-Pinkham et al. (2020), we apply the most recent diagnostic tests for SSIV designs to detect the potential presence of pre-trends for the whole instrument and its components, i.e., the baseline employment shares of the 2-digit NACE sectors that receive the highest weights in the SSIV.<sup>3</sup> Overall, these diagnostic tests exclude that severe pre-trends undermine the credibility of our favourite specifications. This is corroborated also by checking the sensitivity of our results to the inclusion of different sets of controls, such as automation exposure, population density and demographic characteristics. Finally, we lend further credibility to our research design providing formal testing about the relevance of the SSIV (Lee et al., 2022) and the validity of the monotonicity assumption.<sup>4</sup>

We then extend our main results in two directions of paramount importance for the green transition. In our first extension, we simulate what could happen with a policy-driven big push by investigating

---

<sup>3</sup>Within the framework of Goldsmith-Pinkham et al. (2020), these correspond to the sectors with the highest Rotemberg weights.

<sup>4</sup>Lending further support to the monotonicity assumption is necessary in our setting because green innovation shocks in other countries can both increase green production in EU countries with better green technological capabilities (the main assumption behind our identification strategy) or decrease them due to a competitiveness effect.

the effect of large green production shocks, which serve as proxies for a policy-driven fiscal stimulus, in a staggered difference-in-differences (DiD) design (Roth et al., 2023). We find that the effect on total employment is approximately ten times larger than the LATE effect, which is not surprising given the larger size of the shocks and the fact that we estimate an Average Treatment Effect (ATT) rather than a LATE. Moreover, the effect of large green industrialization shocks are persistent on non-manufacturing employment, even without purging from induced agglomeration effects. These effects seem not invalidated by the presence of pre-trends. Remarkably, by decomposing the ATT in cohort-specific effects (Callaway & Sant’Anna, 2021), we find that early shocks have significantly larger employment effects. Overall, this resonates with the facts that green production has become more labour-saving over time (Saussay et al., 2025), and that Europe lost his comparative advantage in critical green products, making large shocks less frequent.

In our second extension, we investigate the differential effect of the green industrialization shock for regions more vulnerable to the green transition. In fact, it is critical to consider how the green transition would affect regions that may be poorly equipped for it. We identify such “brown” regions using the regional employment share in polluting industries at baseline. We find that green multipliers are not statistically different for browner regions. Indeed, while browner regions may have less green technological capabilities, they are usually poorer (Weber, 2020) and thus characterised by higher labour supply elasticity (Austin et al., 2018). This finding lends support to green industrial policies as a place-based policy for distressed communities in the context of the green transition (Bartik et al., 2019; Iammarino et al., 2019; Vona, 2023).

This paper contributes to the voluminous literature that evaluates job multiplier effects of various activities, exploiting either fiscal or supply-side shocks (Chodorow-Reich, 2019; Moretti, 2010; Nakamura & Steinsson, 2014; Wilson, 2012). A burgeoning literature evaluates the job multiplier effects of the green transition. The seminal study of Vona et al. (2019) follows the empirical strategy of Moretti (2010), estimating the indirect job creation effects of a new green job in US metropolitan areas. The main finding is that the green job multiplier is large compared to other sectors and in line with job multipliers of high-tech activities. Popp et al. (2021) uses similar data, but concentrates on a fiscal push, i.e. the green subsidies within the American Recovery and Reinvestment Act (ARRA). Green job multipliers appear more uncertain in this case, due to the presence of pre-trends, and become large and persistent only for regions with a greater prevalence of green skills, mostly technical and engineering ones.<sup>5</sup> Taken together, these findings suggest that green job multipliers are expected to be

---

<sup>5</sup>Another recent evaluation of the labour market impact of green subsidies is the paper of Wald et al. (2024), which evaluates job multipliers of the French Energy Efficiency Obligations scheme, a large-scale energy retrofit program, finding a modest job multiplier. Their results are, however, difficult to compare with ours as they focus on short-term effects and on the construction sector.

larger for regions with better pre-existing green capabilities. We build on these findings by exploiting differential exposure to green technology shocks as a function of the initial regional capabilities. We also complement US-based studies considering different countries, the entire EU, and isolating the effects of large green production shocks.

Another strand of literature focuses on the energy sector within the green transition, covering different geographies: Spanish (Fabra et al., 2024) and Brazilian municipalities (Scheifele & Popp, 2025), NUTS3 regions in four EU countries (Cappa et al., 2024) and the US commuting zones (Chan & Zhou, 2024).<sup>6</sup> Like us, these studies use a supply-side shock, such as the building of a wind farm or renewable energy penetration, to identify local labour market effects, either in an event study setup or exploiting the local suitability to wind or solar as an instrument. While the size and the persistence of effects are mixed, the two peer-reviewed papers suggest that job creation effects are probably short-lived, stronger for solar and concentrated in the construction phase of the plant (Fabra et al., 2024; Scheifele & Popp, 2025). Our research complements this work focusing on a larger, yet overlooked, part of the energy transition: green manufacturing production. Because green goods are tradable and high-tech, we expect larger and more persistent job multipliers than those related to the renewable energy generation – although a precise comparison of the effect remains difficult.

Lastly, this paper contributes to the literature on the so-called just transition. Several papers focus on the decline of coal (Hanson, 2023; Haywood et al., 2024; Rud et al., 2024; Weber, 2020), highlighting its persistent negative effects on both workers and regions. Rather than focusing on the consequences of the decline of polluting industries, we focus on the potential solutions by examining the extent to which a green industrial push can alleviate the consequences of job losses in left-behind regions hosting pollution-intensive industries. As shown by a few recent papers in political science (Bergquist et al., 2020; Bolet et al., 2024; Cavallotti et al., 2025), giving new green opportunities to left-behind brown workers and regions is essential to enhance the political acceptability of the green transition. Our results are encouraging on the feasibility of this strategy within the EU context.

The rest of the paper is organized as follows. Section 2 describes the data used and shows a few descriptive facts. Section 3 discusses the empirical framework associated with the SSIV. Section 4 presents the main results, the validation of the SSIV, and the sensitivity of the results to different specifications. Section 5 presents the results of the two extensions. Section 6 concludes.

---

<sup>6</sup>A parallel strand of literature focuses on the local job creation effect of fossil fuel energy (Black et al., 2005; Feyrer et al., 2017; Marchand, 2012; Weber, 2012), finding modest employment effects.

## 2 Data and descriptives

### 2.1 Measuring green production

We measure green manufacturing production using granular product-level data from the PRODCOM dataset by Eurostat. For the manufacturing sector, the PRODCOM dataset provides detailed information on the value of production for around 4,000 products annually from 1995 to 2017. We then follow Bontadini and Vona (2023) to identify a list of products that reduce harmful environmental impacts in their usage, e.g., bicycles and wind turbines. This list is obtained by excluding double-usage products from a list of 902 green products contained either the OECD’s Combined List of Environmental Goods (CLEG) or the German Statistical Office’s list of green goods, which follows Eurostat’s criteria for defining environmental goods (Eurostat, 2016). Because PRODCOM data are only available in Eastern European countries from 2003 on, we start our analysis in 2003.

For this paper, we slightly revise the list of green goods by applying the following changes. First, we expand the list to include a set of new products whose environmental benefits are now established.<sup>7</sup> Second, we include batteries, which were excluded in the original list due to their double usage, given their growing importance in energy transition. Third, we include nuclear energy and biofuels as they are considered part of the broad portfolio of low-carbon technologies in the official EU taxonomy.<sup>8</sup> Fourth, we addressed and corrected prior ambiguities in the previous classification.<sup>9</sup> Lastly, we broadened the scope to include not only final green products, but also their constituent components, with particular attention to those used in energy-efficient building.<sup>10</sup> This slightly revised list contains 188 green products for each country.<sup>11</sup> We then aggregate the green production of each product at the 2-digit NACE-by-country level, and deflate green and non-green production using the price indexes provided by the 2019 release of EUKLEMS.

### 2.2 Green regional penetration

While data on green production are available at the industry-by-country level, our goal is to estimate the impact of green industrialization on local EU labour markets, both directly (on manufacturing

---

<sup>7</sup>Examples of these goods are: 2720235 Lithium-ion accumulators (excl. spent); Indicator panels incorporating light emitting diodes (LED).

<sup>8</sup>See, for instance, here.

<sup>9</sup>For example excluding goods such as 33204100 - Installation of medical and surgical equipment - and 33204200 - Installation services of professional electronic equipment.

<sup>10</sup>For example including goods such as 23991930 - Mixtures and articles of heat/sound-insulating materials n.e.c. - and 26405190 - LED backlight modules for LCDs of headings 8525 to 8528 (excl. for computer monitors).

<sup>11</sup>The reason why the number of green goods in the current list (188) is lower than the lists of Bontadini and Vona (2023) and Frattini et al. (2024) (221) has to do with the fact that we employ newly raw PRODCOM data which Eurostat harmonized up to 2007, hence aggregating directly quite a few green goods. More details on the data cleaning process as well as the full list of green products (Table A21) can be found in the Appendix A.6.

jobs) and indirectly (on other sectors' jobs). Similarly to the approach followed by the China shock literature (Autor et al., 2013), we allocate country-sector green production to regions using information of the regional employment structure. Specifically, we exploit the Structural Business Statistics (SBS) data by Eurostat, which provides NUTS2 manufacturing employment by 2-digit NACE sector, and the EU Labour Force Survey (LFS) that provides NUTS2 total employment. The measure of green regional penetration reads as follows:

$$GRP_{rt} = \sum_j \frac{L_{rjt}}{L_{cjt}} \cdot \frac{GP_{cjt}}{L_{rt}}, \quad (1)$$

where  $GP_{cjt}$  is green production in country  $c$ , manufacturing industry  $j$  at time  $t$ .  $\frac{L_{rjt}}{L_{cjt}}$  are the employment shares of manufacturing industry  $j$  in region  $r$  and country  $c$  at time  $t$ . Note that within-country, cross-regional differences in green production for industry  $j$  (e.g., bicycles) stem uniquely from variation in these shares. Finally, we compute green industrialization shocks relative to the size of the local economy rescaling for the regional employment ( $1/L_{rt}$ ) and hence obtaining a measure of green regional penetration per worker (GRP henceforth).

We explore the time profile of the effect of green industrialization by taking time differences of Equation 1 at various intervals of length  $k$ :

$$\Delta GRP_{rt_k} = \sum_j \frac{L_{rjt-k}}{L_{cjt-k}} \cdot \frac{\Delta GP_{cjt_k}}{L_{rt-k}}, \quad (2)$$

where  $\Delta GP_{cjt_k}$  refers to the change of green production in country  $c$ , industry  $j$ , between  $t$  and  $t - k$ . To capture initial exposure to green shocks, the employment shares, as well as the total regional employment, refer to the initial period  $t - k$ .

### 2.3 Green patents

We seek to isolate arguably exogenous variation in green production exploiting improvements in green technology in non-EU countries. For this purpose, we build a measure of initial exposure to green innovations using patent applications in the European Patent Office (EPO).<sup>12</sup> Information on patent applications are retrieved from the PATSTAT dataset, and we treat as green all patents that contain at least one green technology class, i.e. the so-called Y02 tag under the Cooperative Patent Classification (CPC). To smoothen yearly fluctuations in patent activities and obtain an accurate proxy of green technological exposure, we construct the stock of green patent applications until year  $t$  using the

---

<sup>12</sup>See Popp (2019) for a recent review on the use of patents to measure green innovation.

perpetual inventory method (Verdolini & Galeotti, 2011).<sup>13</sup> We assign green patents to country-NACE industry pairs using the crosswalk provided by PATSTAT.

## 2.4 Final dataset

We gather data from the EU Labour Force Survey (LFS) to construct measures of regional employment (our dependent variable) for specific sectors (manufacturing, utilities, construction, services) and skill categories (by educational attainment). We divide employment measures by the active population to account for the effect of green industrialization on both job creation and labour force participation. We use LFS data for our dependent variables as SBS data -which are used to map green production shocks in manufacturing to region- do not contain information on the service sector. Moreover, we collect various data on NUTS2 characteristics to control for confounders in the econometric analyses, e.g., population density, share of female, foreign-born and population by educational attainment. As an additional control, in an extension, we also use data on regional exposure to automation from Anelli et al. (2021).

Our final dataset is a balanced panel of 278 NUTS2 regions for 28 countries that spans from 2003 to 2017 and contains information on the variables discussed above.<sup>14</sup> Table A4 provides basic statistics related to the main data, while Appendix A.6 provides extensive details on the construction of the final dataset.

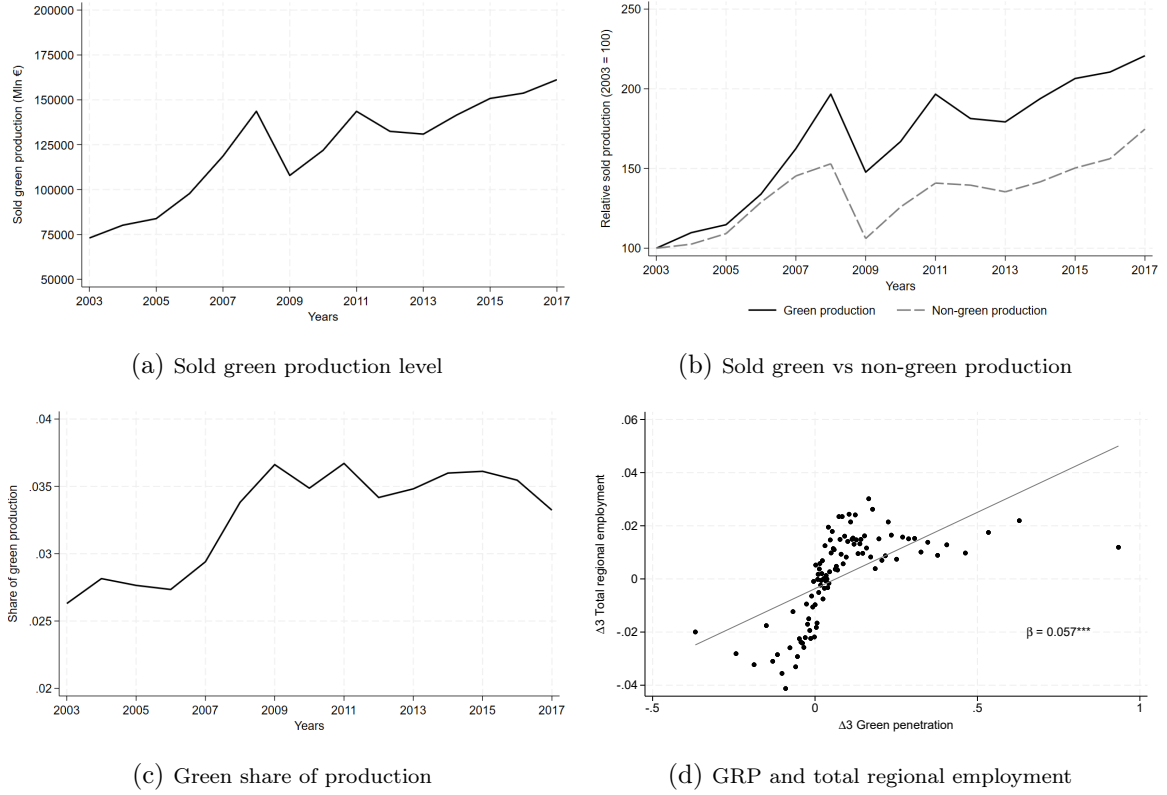
## 2.5 Descriptive evidence

Figure 1 shows that EU green production exhibits an upward trend during the period of our analysis (panel a). A similar upward trend is also observed for the green regional penetration (Table A4 in the Appendix). Importantly, the long-term growth rate of green production (+120%) outperformed that of non-green production (+74%), particularly so after the 2008 financial crisis (panel b). However, regions attracting green productions do not do so at the detriment of non-green production (see Figure A1). Consistently with previous findings on the size of the green economy (Elliott & Lindley, 2017; Saussay et al., 2022; Vona et al., 2019), the share of green over total production remained quite small, accounting for just 3.3% in 2017 (panel c). Lastly, a three-year change in GRP positively correlates with that of regional employment (panel d). This positive unconditional correlation between green industrialization shocks and employment growth further motivates the econometric analysis of the next section.

<sup>13</sup>The formula is  $K_{i,t} = PAT_{i,t} + (1 - \delta)K_{i,t-1}$ , where  $\delta = 0.1$  is the depreciation rate,  $PAT_{i,t}$  is the number of green patents in CPC class  $i$  at time  $t$ . The initial stock (1991) is calculated as  $K_{i,t_0} = PAT_{i,t_0}(1 - \delta)$ .

<sup>14</sup>The countries in the analysis are: AT, BE, BG, CY, CZ, DE, DK, EL, ES, FI, FR, HR, HU, IE, IS, IT, LU, LV, MT, NL, NO, PL, PT, RO, SE, SI, SK, UK. We exclude EE and LT for data availability. Further, we exclude the following regions: FRY1 (Guadalupe); FRY2 (Martinique); FRY3 (Guayane); FRY4 (Reunion); FRY5 (Mayotte); ES70 (Canarias); PT20 (Azores); PT30 (Madeira). A full list of the NUTS2 regions in the dataset is listed in Table A22.

Figure 1: Green and total production over time



*Notes.* These plots show the evolution over time of total and green production in absolute levels in panel (a), in relative levels in panel (b), and of the share of green production in panel (c).

Green industrial production is known to be highly concentrated in a few high-to-medium tech manufacturing sectors (Bontadini & Vona, 2023; Frattini et al., 2024).<sup>15</sup> An analogous pattern, although less pronounced, is observed across regions. Figure 2 provides a visual insight on the high concentration of green productions across regions (panel a). Out of 278 NUTS2 regions, only 102 have an average GRP value higher than the mean (0.503). Using a standard locational Gini coefficient, the spatial concentration of green activities is 0.444, compared to a concentration of non-green manufacturing activities of 0.413. In line with the cross-country evidence of Bontadini and Vona (2023), the darkest green regions are observed in Denmark (Midtjylland, Syddanmark and Nordjylland among others) and Germany (Oberpfalz, Mittelfranken and Tübingen among others). In other countries, some green industrial regions are also observed in Austria (Oberösterreich and Steiermark), Spain (País Vasco), Sweden (Småland med öarna and Östra Mellansverige) and Italy (Friuli-Venezia Giulia, Emilia-Romagna and Lombardia).<sup>16</sup>

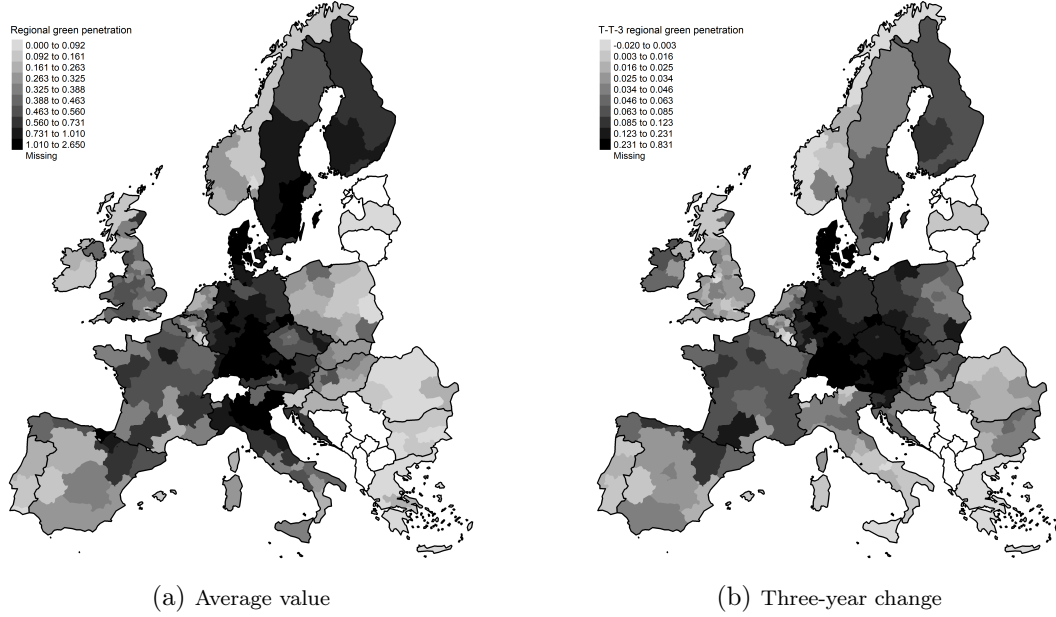
Finally, green production shocks disproportionately occur in regions that are already green (panel

<sup>15</sup>Table A1 shows that, at 2-digit NACE level, only 7 sectors (33 - Repair and installation of machinery and equipment; 26 Manufacture of computer, electronic and optical products; 30 Manufacture of other transport equipment; 27 Manufacture of electrical equipment; 28 Manufacture of machinery and equipment n.e.c.; 16 Manufacture of wood and of products of wood and cork; 29 Manufacture of motor vehicles) out of 24 produce green goods without being identified as polluting.

<sup>16</sup>See Table A2 for details.

b of Figure 2). The largest increases are indeed observed in Denmark, Austria and Germany, and in a few regions of Spain, France and Poland (see Table A3 for details). The path-dependency in green production is captured by a high and statistically significant correlation between the three-year change in GRP and its initial level (0.311, significant at the 1% level), conditional on year fixed effects. As a result, pre-existing differences in green regional penetration could contaminate the estimated effects of green industrialization shocks on local employment growth.

Figure 2: Green penetration by NUTS2 region, levels and three years change



*Notes.* These maps show the average green penetration (panel (a)) and its five-year change (panel (b)) by NUTS2 regions in the EU. The average refers to the whole period, from 2003 to 2017. Levels correspond to deciles. Average values are weighted by the share of the regional population over the EU one.

### 3 Empirical strategy

We adopt the following specification to estimate the local labour market effects of green industrialization shocks:

$$\Delta L_{rt_k} = \alpha + \beta \Delta GRP_{rt_k} + \gamma \mathbf{X}'_{rt_0} \times \tau_t + \tau_t + \eta_c + \epsilon_{rt}. \quad (3)$$

$\Delta L_{rt_k}$  is the change between  $t$  and  $t - k$  (with  $k = 3$  in our favourite specification) in regional employment over the active population.  $\Delta GRP_{rt_k}$  is the change in the green regional penetration per worker defined in Equation 2.  $\tau_t$  and  $\eta_c$  are, respectively, time and country dummies that control for global shocks and country-specific time trends.  $\epsilon_{rt}$  is the error term. To improve the representativeness of our estimates, we weight the regressions using the baseline shares of the regional population over the EU one.

$\mathbf{X}'_{rt_0}$  is a vector of key control variables, which are taken at baseline  $t_0$  (the average value between 2000 and 2003) and interacted with year dummies to allow for non-linear effects of initial conditions on employment dynamics.<sup>17</sup> In our favourite specification, these controls are the share of employment in manufacturing and the non-green regional penetration, constructed as in Equation 1 for the whole manufacturing sector. The first accounts for the so-called missing share component identified as a key confounding factor by the recent literature on shift-share instrumental variable design (Borusyak et al., 2022). Without controlling for the initial degree of industrialization, sector-specific industrial shocks, such as those used in our work, could mechanically capture differential employment trends for regions at different stage of industrial development. Likewise, the latter accounts for the size of industrial production in the region. In some robustness checks, we expand the set of controls to other potential confounders (see Section 4.2).

In Equation 3, the effect of green production shocks on employment growth is identified net of country and industry-specific trends. Yet, it is difficult to believe that GRP shocks are as good as randomly assigned (Borusyak et al., 2022). First, GRP is subject to measurement error because, within 2-digit NACE sectors, green production is also highly concentrated in a handful of 4-digit sectors (Bontadini & Vona, 2023), for which we cannot observe the employment shares at the NUTS2 level. This classical measurement error typically results in attenuation bias of the OLS estimates. Secondly, omitted variable bias is a common issue in analyses where labour market outcomes are regressed on indicators of structural transformations (Acemoglu & Restrepo, 2020; Autor et al., 2013). Specifically to the green transition, regions hosting green production facilities tend to be high-tech and have a solid skill base, thus already positioned on robust economic paths (Popp et al., 2021; Vona et al., 2019). Meanwhile, green investments may be jointly undertaken with automation investments, which reduce labor demand (Acemoglu & Restrepo, 2020, 2022; Graetz & Michaels, 2018). Due to these intricacies, it is difficult to determine a clear direction of the bias due to omitted variables.

To tackle these potential sources of endogeneity, we instrument the change in GRP with a shift-share instrumental variable (SSIV) leveraging differences in the regional green patent exposure.

$$\Delta IVGpat_{rt_k} = \sum_j \frac{L_{rj,t_0}}{L_{cjt_0}} \times \frac{\Delta Gpat_{cjt}^{NonEU}}{L_{rt_0}}. \quad (4)$$

$\frac{L_{rjt_0}}{L_{cjt_0}}$ , the share component, are the employment shares of manufacturing industry  $j$  in region  $r$  and country  $c$  at time  $t_0$  (avg. between 2000 and 2003).  $\Delta Gpat_{cjt}^{NonEU}$ , the shift component, is the change in the stock of EPO green patents by non-EU based inventors between  $t$  and  $t_k$  allocated to country-sector

---

<sup>17</sup>We take the controls at baseline to avoid “bad control” problems (Angrist & Pischke, 2009).

pair  $(c, j)$ .<sup>18</sup> The shift is allocated to a country-sector pair  $(c, j)$  proportionally to the initial patent stock of that country in this sector over the EU green patent stock at time  $t_0$  (2002).<sup>19</sup> Therefore:  $\Delta Gpat_{cjt}^{NonEU} = \Delta Gpat_{jt}^{NonEU} \times Gpat_{cjt_0} / \sum_c Gpat_{cjt_0}$ , where  $\Delta Gpat_{tj}^{NonEU}$  is the change in the stock of green patents by non-EU based inventors in sector  $j$ .

The intuition behind this instrument is that regions with stronger green technological capabilities are able to benefit relatively more from a global green technology push.<sup>20</sup> Note that this instrument is similar to a shift-share design that leverages variation in the baseline exposure to new technologies of the workforce (Acemoglu & Restrepo, 2020; Acemoglu et al., 2022). The main difference is that here capabilities are measured using patents rather than workforce skills. Our instrument is also in line with models and empirical evidence highlighting path-dependency in green knowledge creation (Acemoglu et al., 2012; Aghion et al., 2016; Popp, 2002). In our setup, the use of third-country inventions helps navigating the trade-off between instrument strength, as implied by path-dependency, and exogeneity.

To give a first insight on the instrument’s relevance, Figure 3 shows the raw correlation between the three-year change in the green patent SSIV and the three-year change in GRP. As one could expect, the correlation is quite strong and positive. This result is corroborated by a formal test of the strength of the excluded instrument in the full two-stage least square model based on Equation 3 (i.e., Kleibergen-Paap F-statistic = 53.4, see for example Table 1).

Modern treatment of SSIV requires a careful validation of the plausibility of the underlying identifying assumptions (Borusyak et al., 2022; Goldsmith-Pinkham et al., 2020). Section 4.1 is dedicated to the discussion and testing of such identifying assumptions, supporting the validity of our empirical strategy.

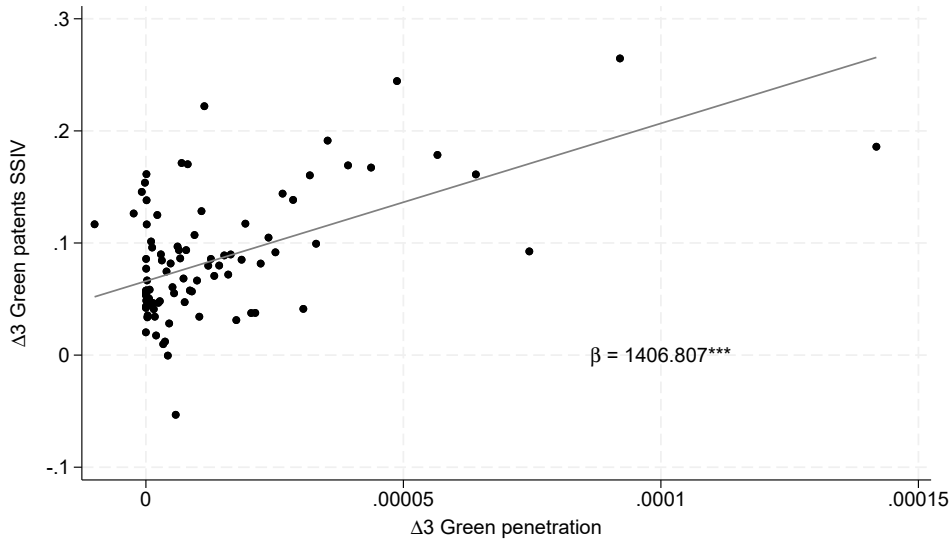
---

<sup>18</sup>We take all inventors that do not reside in the EU and further exclude cross-countries patents if one of the inventors is based in the EU.

<sup>19</sup>In recent research using shift-share instruments, the use of baseline shares is recommended to mitigate endogeneity concerns (Borusyak et al., 2022; Goldsmith-Pinkham et al., 2020).

<sup>20</sup>For a practical example consider the following. A new patent application related to wind technologies filed by Chinese inventors, the shift, is deemed to positively benefit regions that already have a relative advantage in wind patents, such as Danish ones, through various channels. First, foreign competition typically stimulates domestic inventors closer to the technological frontier (e.g., Vestas????), while selecting out those farther away (Acemoglu et al., 2006). Second, it can complement domestic invention if patents result from broad international collaborations, making local producers more productive. Third, even if invention abroad are destructive to local producers, regions with a pre-existing technological advantage are more likely to perform relatively better than regions without it.

Figure 3: Correlation between green penetration and green patents SSIV in three-year changes.



*Notes.* This graph shows the raw correlation between the average three-year change in regional green penetration and the average three-year change in the green patents SSIV. We weight the two variables by the share of regional population over the EU one.

## 4 Main results

Table 1 reports the OLS (odd columns) and 2SLS (even columns) estimates of the relationship between regional employment in different macro sectors and green manufacturing penetration. Panel A presents results for total, manufacturing and non-manufacturing regional employment, while Panel B focuses on construction, services and agriculture plus mining regional employment.<sup>21</sup> For almost all macro-sectors, our estimates show a positive and highly statistically significant effect of the triennial change in green regional penetration on the three-year change in the employment-to-active population ratio. Estimated coefficients are almost an order of magnitude larger in our favourite 2SLS specification, where technology shocks are used to instrument production shocks. The lower OLS coefficient stems from an attenuation bias due to measurement error, but also reflects stronger employment effects on compliers. That is: a stronger effect on regions where higher green technological capabilities at baseline attract green production shocks.

The estimated coefficients can be interpreted as the effects of a 1'000€ three-year increase in green production per worker on the employment-to-the active population. However, the median three-year increase in green production per worker is only 46€ in our data (see Table A4), thus the coefficients should be multiplied by 0.046 to obtain a reasonable range of variation. In our favourite 2SLS specification of column 2, a three-year change in green regional penetration implies a change in the employment-to-population share of 0.008 ( $0.046 \times \hat{\beta}$ ). Still, this quantification is inconsistent with an

<sup>21</sup>Non-manufacturing is the sum of employment in construction, services and utilities. Given its small size and for the sake of space, we do not report here the results related to utilities, but we discuss them in the next sub-sections.

Table 1: Green penetration on regional employment

|                     | (1)                 | (2)                 | (3)                  | (4)                 | (5)                      | (6)                 |
|---------------------|---------------------|---------------------|----------------------|---------------------|--------------------------|---------------------|
| <i>Panel A:</i>     | <i>Total</i>        |                     | <i>Manufacturing</i> |                     | <i>Non-manufacturing</i> |                     |
| $\Delta GRP_{r,t3}$ | 0.028***<br>(0.007) | 0.166***<br>(0.038) | 0.010***<br>(0.003)  | 0.053***<br>(0.015) | 0.022***<br>(0.008)      | 0.126***<br>(0.036) |
| <i>Panel B:</i>     | <i>Construction</i> |                     | <i>Services</i>      |                     | <i>Agric. + Min.</i>     |                     |
| $\Delta GRP_{r,t3}$ | 0.007***<br>(0.002) | 0.076***<br>(0.014) | 0.016**<br>(0.007)   | 0.039<br>(0.030)    | -0.004<br>(0.007)        | -0.013<br>(0.030)   |
| <i>N</i>            | 3336                | 3336                | 3336                 | 3336                | 3336                     | 3336                |
| Estimator           | OLS                 | 2SLS                | OLS                  | 2SLS                | OLS                      | 2SLS                |
| FS coeff.           |                     | 1658.106***         |                      | 1658.106***         |                          | 1658.106***         |
| KP F-Stat           |                     | 53.4                |                      | 53.4                |                          | 53.4                |
| CD F-Stat           |                     | 79.4                |                      | 79.4                |                          | 79.4                |
| Controls            | ✓                   | ✓                   | ✓                    | ✓                   | ✓                        | ✓                   |
| Country FE          | ✓                   | ✓                   | ✓                    | ✓                   | ✓                        | ✓                   |
| Year FE             | ✓                   | ✓                   | ✓                    | ✓                   | ✓                        | ✓                   |

*Notes:* Dependent variables: the three-year change in regional employment over active population in: total; manufacturing; non-manufacturing (utilities, construction, services); construction; services; agriculture + mining. The endogenous variable,  $\Delta GRP_{r,t3}$ , refers to the change in the green penetration measure in region  $r$  between  $t$  and  $t-3$ . The instrumental variable refers to the shift-share instrumental variable related to green patents. Columns (1), (3) and (5) show OLS estimates, while columns (2), (4) and (6) show the ones related to the green patents instrument. Columns (2), (4) and (6) report the Kleibergen-Paap (KP) and the Cragg-Donald (CD) F statistic for weak identification, as well as the first stage coefficient. Controls include the share of employment in manufacturing and the regional non-green penetration, interacted with year fixed effects. All the controls are taken at baseline, that is their average value between 2000 and 2003. We include country and year fixed effects. Estimates are weighted by the share of regional population over the EU one, at baseline. Region clustered standard errors in parentheses. Number of regions: 278. \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

accurate LATE interpretation of the 2SLS coefficients. Indeed, only part of the median three-year increase in green production is accounted for by exogenous green technology shocks. This part can be quantified using the first-stage coefficient and is equal to 0.007 (7€).<sup>22</sup> Using only the three-year change in GRP explained by the instrument, our favourite specification implies an effect of green industrialization shocks on the share of employment-to-active population of 0.0011, or slightly more than one tenth of a percentage point if compared to the median employment-to-active population (0.0011/0.923).<sup>23</sup>

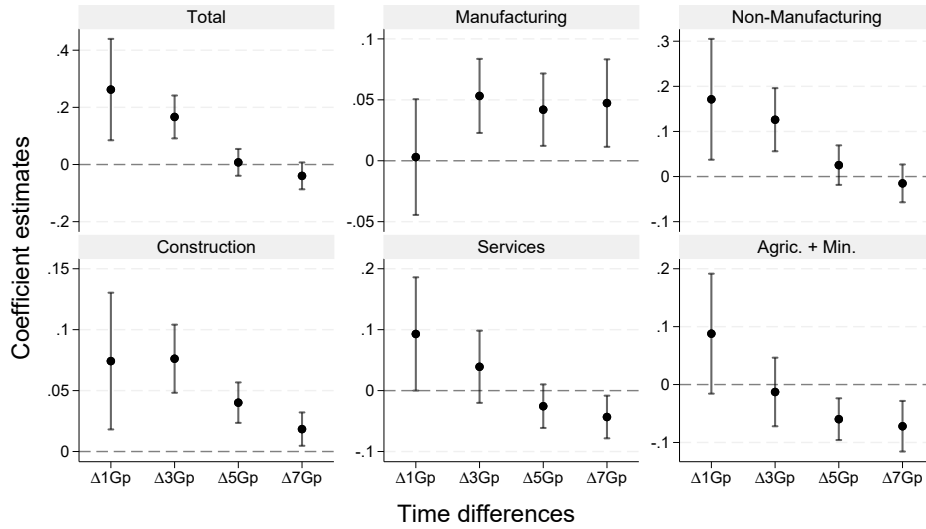
Moving to specific EU sectors in the rest of Table 1, we observe a similar employment effect in terms of magnitude in both the manufacturing sector, which receives the positive green industrialization shocks, and the non-manufacturing sector, which benefits indirectly from these shocks through the multiplier effect. Outside manufacturing, we observe additional job creation especially in the construction sector, in line with previous literature (Cappa et al., 2024; Fabra et al., 2024; Popp et al., 2021). We interpret

<sup>22</sup>This number is obtained multiplying the median value of the green patents SSIV (0.0000041) by the first-stage coefficient of the SSIV instrument (1658.106).

<sup>23</sup>Note that the bias of the OLS becomes smaller when using this accurate quantification. For the OLS regression, the effect should be quantified using the median three-year change in green regional penetration (0.046), thus the implied change in the employment-to-population is 0.0013.

this result as the additional multiplier effect of infrastructural investments complementary to the green transition. Another interesting result is that the overall effect in column 2 of Panel A is smaller than the sum of the effects in manufacturing (col. 4) and non-manufacturing (col. 6). This is because total employment also includes primary industries (mining and agriculture), for which the estimated effect of green industrialization is negative and statistically significant (Panel B col. 6). This result suggests that green industrialization accelerates the secular reallocation of labour from primary sectors to manufacturing and construction.

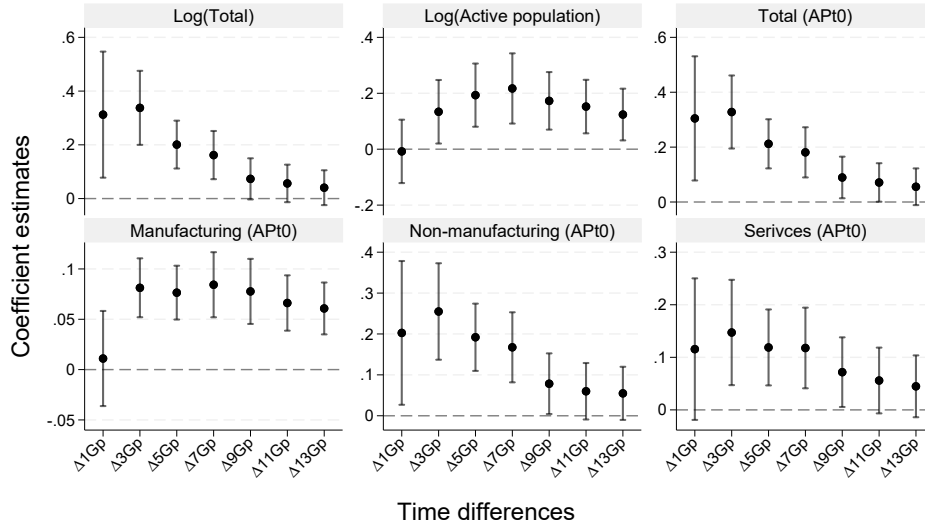
Figure 4: 2SLS estimates of green penetration on regional employment. Green patents SSIV.



*Notes.* These graphs replicate and extend the 2SLS estimation based on Equation 3 and on Equation 4 by looking at one-, three-, five- and seven-year changes. KP F-stats: 11.0; 53.4; 140.3; 160.7. CD F-stats: 14.9; 79.4; 174.8; 191.8.

Next, we explore the time profile of the green industrialization effect estimating the model of Equation 3 varying the time difference  $t - t_k$ . Figure 4 plots the main coefficients of the favourite 2SLS specification. Specifically, each sub-plot reports the time-varying coefficients for each of the macro-sectors. For total employment over active population, the effect is at the peak after one-year and then gradually declines to become statistically insignificant at the five-years difference. Not surprisingly, this pattern is driven by the non-manufacturing sector, which represents the bulk of the local employment in most regions. Outside manufacturing, the effects on construction employment remain statistically significant up to seven-years, although decreasing in magnitude. On the other hand, services employment effects are more short-lived and achieve statistical significance only at the one-year difference, become insignificant at the three- and five-years differences, to then turn negative at seven-years. In contrast, we observe a stable job creation effect in manufacturing, implying that green industrial policy may be able to create stable manufacturing jobs in the local economy. Lastly, the effects on primary activities quickly become negative, reinforcing the reallocation hypothesis.

Figure 5: 2SLS estimates of green penetration on regional employment and active population. Green patents SSIV. Longer time horizon and decomposition.



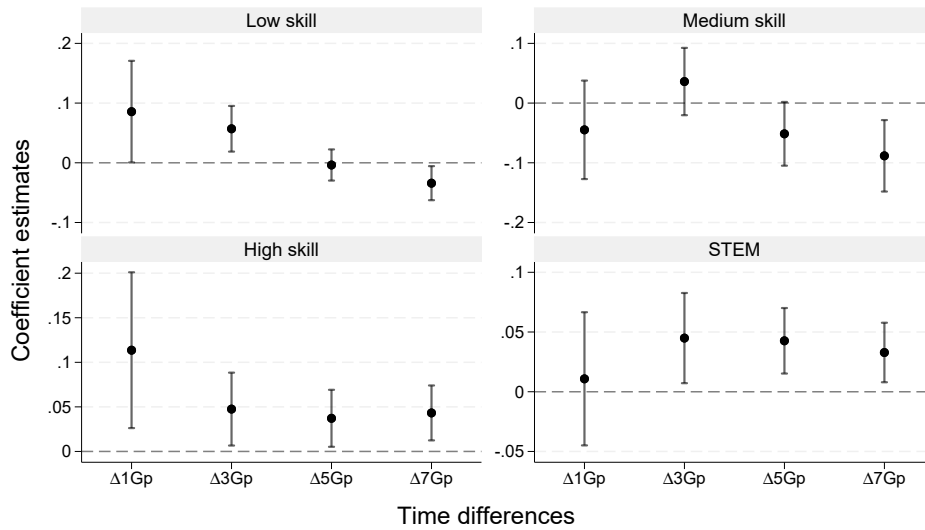
*Notes.* These graphs replicate and extend the 2SLS estimation based on Equation 3 and on Equation 4 by looking at three-, five-, seven-, nine-, eleven- and thirteen- year changes. KP F-stats: 11.0; 53.4; 140.3; 160.7; 129.7; 176.0; 232.5. CD F-stats: 14.9; 79.4; 174.8; 191.8; 324.3; 333.9; 234.2.

To shed further light on the time profile of multiplier effects, we decompose the effect of the green industrialization on the numerator (total or sectoral employment) and the denominator (active population) of our dependent variable. While doing so, we extend the inspected time horizon, looking up until thirteen-year changes. Figure 5 shows the outcome related to this exercise. The top-left and top-centre figures show that, in the short term, green manufacturing penetration impacts more on total employment rather than on active population. However, in the long-term the effect of green industrialization on active population becomes stronger and more persistent, while the one on total employment gradually declines. The former dynamic (i.e., an agglomeration effect) eventually exceeds the latter accounting for the negative seven-year effect on total employment-to active population found in Figure 4. The top-right figure lends further support to this finding, using as dependent variable the change in total employment over an active population fixed at baseline. Quantitatively, the size of the three-year effect on total employment doubles when keeping the active population at baseline. Purging the effect of agglomeration by sector, the three bottom figures show that the multiplier effects remain positive in the long-term, although vanishing over time in the services sector. Moreover, it is remarkable the stability of the coefficients associated with manufacturing employment, which are consistently positive and significant after thirteen years. Overall, green industrialization triggers agglomeration effects that increase the population in search of employment and thus the tightness of the local labour market. Net of these induced agglomeration effects, local job multipliers persist in the long-run, differently from what was found in studies estimating the local employment effect

of renewable energy generation (Fabra et al., 2024; Scheifele & Popp, 2025). This is not surprising as green industrial production is a tradable activity, typically creating supply-side linkages and local spillovers (Moretti, 2011).

Finally, we investigate the quality of the jobs created, using Equation 3 to estimate the skill-biased effect of green industrialization. The caveat here is that, due to data limitations, we can only measure skills using educational attainments. We look at the effect on low- (lower secondary education and less), middle- (higher secondary education) and high- (tertiary education) skill workers. Given the documented importance of Science, Technology, Engineering and Math (STEM) skills for the green transition (Popp et al., 2024; Vona et al., 2018), we define STEM employees as the number of workers employed in science and technology activities and with tertiary education. Figure 6 and Table A13 in the Appendix align with previous findings in the literature showing a positive and persistent impact of green industrialization, especially on college graduate and STEM workers. Despite declining over time, the job creation effect is also strong on workers with basic education, which is again consistent with findings of Popp et al. (2021) for the US and the high low-skill intensity of construction jobs. In contrast, we find no significant effect on middle skill workers. Figure A6 in the Appendix confirms these results even when netting out agglomeration effects.

Figure 6: 2SLS estimates of green regional penetration on regional skill level. Green patents SSIV.



*Notes.* These graphs replicate and extend the 2SLS estimation based on Equation 3, including additional the interaction with the regional skill level, and on Equation 4 by looking at one-, two-, three-, five- and seven-year changes. KP F-stats: 11.0; 53.4; 140.3; 160.7. CD F-stats: 14.9; 79.4; 174.8; 191.8.

To summarize, we observe a modest multiplier effect of green industrialization in the medium-term that gradually disappears in the long-run. Medium-term multipliers are mostly concentrated in the construction sector. In turn, the service sector positively benefits from short-term multipliers, which

then fade away because green industrialization increases the labour supply and thus the tightness of local labour market. As a long-term pay-off of green industrialization, more exposed regions remain endowed with a larger base of manufacturing and construction activities, as well as of STEM and college graduate workers.

#### 4.1 Validation of shift-share instrument

In this sub-section, we discuss the identifying assumptions that support our SSIV design. Moreover, we present the results associated to the validity of this research design.

The credibility of our instrument rests on the exclusion restriction that, conditional on industry-specific and country trends, pre-existing green technological capabilities affect regional employment dynamics only through green production shocks. Because shift-share instruments are implicitly a linear combination of multiple instruments (Goldsmith-Pinkham et al., 2020), the exogeneity assumption (and the related parallel trend assumption) can be violated both for the whole instrument and for each of the shares used to build it. More specifically, Goldsmith-Pinkham et al. (2020) suggest to decompose SSIV into a weighted average of just-identified estimates derived from individual instruments. The resulting weights, known as Rotemberg weights, quantify the contribution of each instrument to the overall 2SLS estimate and allow testing for plausible violations of the parallel trend assumption not only for the whole instrument, but also for components identified as more important by the decomposition.

Following Goldsmith-Pinkham et al. (2020), we rely on the identifying assumption that the initial sectoral shares used to assign the green technology shocks to regions are exogenous. In doing so, we begin by showing the top-five industries that, according to the Rotemberg weights (Goldsmith-Pinkham et al., 2020), contribute more to the overall 2SLS coefficient. Table A5 shows that three of the top-five industries are among the highest in terms of green production (28, 27, and 26 - see Table A1), while two only have marginal green production (20 and 29). The top five industries receive more than three quarters of the absolute weight in the estimator (0.771). In particular, the first two (28 and 27) account for about half of it (0.551/1). This is consistent with the high-degree of concentration in green production (Table A1. Table A5 also shows the baseline (avg. 2000-2003) employment share within manufacturing of these sectors and reports example of green goods that fall within these sectors.

Based on this finding, we assess the plausibility of the parallel trend assumption for the whole SSIV instrument as well as for the top-five sectors identified by the Rotemberg weights. As in Goldsmith-Pinkham et al. (2020), we regress the pre-sample (from 2000 to 2003) dependent variables in levels either on the green patents-SSIV at  $t_0$  or on one of the 2-digit employment shares of top-five sectors at  $t_0$ , interacted with year fixed effects. To mimic the main specification of equation 3, we include in these

regressions region and year fixed effects, country linear trends, and the previously discussed controls interacted with year fixed effects. We weight estimates by the share of baseline regional population. The reference year is 2000.

Figure A4 shows the results of this empirical exercise. For the aggregate instrument, we detect some signs of positive pre-trends in total employment, particularly in 2002, which may lead to an upward bias in our estimates. However, inspecting the plots for each sector individually, these pre-trends do not arise in the sector where the shock originates (manufacturing), but are concentrated in the construction sector. Indeed, manufacturing, services and, to a lesser extent, the primary sector all exhibit parallel employment trends before 2003. Inspecting the five sectors with the highest Rotemberg weights further mitigates concerns regarding the violation of the parallel trend assumption. Across the board, most sub-figures show rather flat pre-trends. A few notable exceptions are sectors 20 (Manufacture of chemicals and chemical products, which is only marginally green) and 26 (Manufacture of computer, electronic and optical products), which show negative pre-trends in services employment, possibly leading to a downward bias in our estimates. To be sure that these key sectors do not drive our main results, we further validate our SSIV design by excluding them one-by-one from the instrument and replicating the main analysis accordingly. Tables A7, A8, A9, A10 and A11 reassure us that our main results are not driven by any of these key sectors, as the estimates remain qualitatively in line with the main ones.

We also assess the balance of the aggregate SSIV and each employment share identified by the Rotemberg weights along the two key controls present in the estimating equation: the share of employment in manufacturing and the non-green regional penetration. Specifically, we regress the baseline value of the green patents-SSIV (or of each of the 2-digit manufacturing employment shares of top-5 sectors by Rotemberg weights) on the baseline value of the employment share in manufacturing and the regional non-green manufacturing penetration, including country fixed effects and weighting for the share of regional population over the EU one. Table A6 highlights that both the aggregate SSIV and most shares (excluding 26, 28 and 29) positively correlate with the employment share in manufacturing. On the other hand, only the aggregate SSIV and sector 29 positively correlate with non-green manufacturing penetration. This supports our choice of including these controls non-parametrically in Equation 3.

We further assess the relevance of our instrument by applying the methodology of Lee et al. (2022) to adjust the t-statistics of the second-stage coefficients.<sup>24</sup> Table A12 shows that almost all the coefficients of interest of Table 1 have high enough adjusted t-statistics to preserve statistical significance at the

---

<sup>24</sup>Lee et al. (2022) address the issue of invalid inference in IV estimations caused by weak instruments, challenging the reliance on arbitrary thresholds like  $F\text{-stat} > 10$ . Lee et al. (2022) introduce the  $tF$  procedure, a robust inferential method for instrumental variable regressions that adjusts t-statistics and confidence intervals using the first-stage F-statistic. The resulting procedure usually leads to more demanding t-statistics.

1% level. The only exception is the one related to non-manufacturing employment, which, however, does so at a 5% level.

Another issue concerns the interpretation of the IV estimates as Late Average Treatment Effects (LATE, Imbens and Angrist, 1994). To interpret SSIV estimates as LATEs, the monotonicity assumption must hold. In our specific case, it requires that the SSIV variable has a positive effect on green production on all the regions. This is not obvious as, for example, a green invention in China could reduce green production in Europe through a business stealing effect. Although this assumption cannot be tested directly, we perform a Monte Carlo simulation where we re-estimate 1,000 times our main coefficient of Table 1 by redrawing regions with repetition and thus implicitly excluding a few regions at the time. We then plot the estimated first-stage coefficients obtained for each sub-sample to detect large deviations from the central value that we estimated for the whole sample. Figure A5 shows that the distribution of the coefficients of the first stage is consistently positive - thus excluding large violations of the monotonicity assumption - and roughly centred around the baseline estimated value of the first-stage coefficient. Overall, these pieces of evidence provide solid support to the credibility of our identification strategy.

## 4.2 Robustness checks

In this subsection, we assess the robustness of our main estimated effects (Table 1) to different versions of the main specification. These additional results are included in the Appendix for the sake of space.

Table 1 does not report the results related to utilities. Despite being a small sector in terms of employment (average 0.7%), the utilities sector contains activities that are linked to green manufacturing, such as the production, transmission and distribution of electricity. Hence, we would expect to find positive multipliers of GRP on utilities employment. Figure A7 shows that this is actually the case. Remarkably, the time profile of the effects is similar to that of manufacturing employment, suggesting that greener regions experience long-term job growth in the utilities sector as well.

Next, we augment our main specification of Equation 3 including a richer set of potential confounders that were identified as important by the related literatures on the China shock (Autor et al., 2013) and local job multipliers (Chodorow-Reich, 2019; Moretti, 2010; Vona et al., 2019). More specifically, we include the following variables at baseline: population density, median age, the share of female population, the share of foreign population, and the share of the population with at least secondary and tertiary education. Table A14 shows that the estimated coefficients remain quantitatively in line with the main ones.

Our main specification controls for time-invariant regional characteristics, country-level and broad

industry-level trends, but not for pre-existing regional trends unrelated to green industrialization. To assess whether our results survive the inclusion of such trends, Table A15 replaces the country-level fixed effects either with NUTS1 or NUTS2 region fixed effects.<sup>25</sup> We find that the estimated coefficients remain statistically significant at conventional level and increase with respect to our favourite specification with country fixed effects.

As discussed before, one source of bias in the OLS estimates is that green investments may be carried out jointly with automation investments that reduce labour demand (Acemoglu & Restrepo, 2020; Graetz & Michaels, 2018). Hence, controlling for automation investment in our main specification can help avoid a potential source of omitted variable bias. To do so, we measure the exposure to automation at the regional level as in Anelli et al. (2021) and include it as a control variable.<sup>26</sup> Table A16 shows that the main estimates are robust the inclusion of this control, which, as expected, is negatively associated with employment growth.

Lastly, we change the level of clustering of the standard errors from NUTS2 to NUTS1. This accounts for possibly larger interdependencies between local labour markets (Manning & Petrongolo, 2017). Table A18 shows that the significance level of the regional green manufacturing penetration coefficients remains within accepted ranges, except for the construction sector.

## 5 Extensions

This final section extends our analysis into two policy-relevant directions. First, we concentrate on large shocks in green industrial production that more closely resemble the case of a sudden push in green industrial policy. Second, we assess the effect of green industrialization in regions that are specialized in pollution-intensive activities and thus may also experience substantial job losses from the green transition.

### 5.1 Large shocks to green manufacturing penetration

While our data show an upward trend in green productions, higher than the trend in non-green ones (Figure 1), the green industrialization expansion studied so far cannot be considered a “big push” (Murphy et al., 1989; Rosenstein-Rodan, 1943). Indeed, our study spans a historical period where EU countries lost their initial comparative advantage in some key green products, notably solar PV.

---

<sup>25</sup>Specifically, in a first-difference model, this demanding specification allows employment to follow a different linear trend in each region, independently on green industrialization.

<sup>26</sup>It is worth mentioning that there is no perfect overlap of NUTS2 regions between the main data and the automation exposure one. See Appendix A.6 for details. For consistency, we re-estimate the main results restricting the sample to those NUTS2 regions for which we have automation data and show it in Table A17. Estimates are in line with the main ones.

In this context, creating local jobs out of green activities may be easier due to the absence of general equilibrium effects associated, for instance, to the increased tightness of local labour markets, especially for workers with green-specific skills.

Taking stock from the related paper of Aghion et al. (2023) on the local labour market effect of automation in France, we mimic the effect of a big green push in a staggered difference-in-difference (DiD) design, where the treatment is a large positive shock to the local green economy. More formally, we estimate the following two-way fixed effects model.

$$L_{rt} = \alpha + \sum_{p=-5}^7 \beta_p GP_{rp} + \gamma \mathbf{X}'_{rt_0} \times \tau_t + \tau_t + \eta_r + \sigma_c \times year + \epsilon_{rt}, \quad (5)$$

where  $L_{rt}$  and  $\mathbf{X}'_{rt_0}$  are, respectively, one of the outcome variables and of the controls already discussed in Equation 3.  $\tau_t$  and  $\eta_r$  are year and region fixed effects, and  $\epsilon_{r,t}$  is the error term.

$GP_{rp}$  is a dummy variable equal to 1 for treated regions, defined as regions  $r$  experiencing an increase in green regional penetration between  $t$  and  $t - 1$  above the 90<sup>th</sup> percentile. We assume that, once a region experiences such a shock, is treated thereafter and we exclude always treated units (Callaway & Sant'Anna, 2021). As in an DiD event study design, the effect of the treatment is decomposed in a series of leads (up to five years) and lags (up to seven years) relative to the region's year of exposure.<sup>27</sup> Figure A8 provides a sense of the staggered design, showing the fraction of treated regions by cohort. Around 2/3 of large green shocks are observed between 2006 and 2008, before Chinese competition in green production deteriorates the pre-existing EU advantage.

Importantly, this staggered DiD approach does not rely on the technologically-driven source of identifying variation of the SSIV, and hence does not need to be interpreted as a LATE. Assuming that large shocks to green manufacturing penetration are plausibly exogenous, a DiD set-up can be interpreted as an Average Treatment effects on the Treated (ATT). The plausibility of the ATT interpretation rests on the assumption of conditional parallel trends, that can be indirectly tested in an event study design.

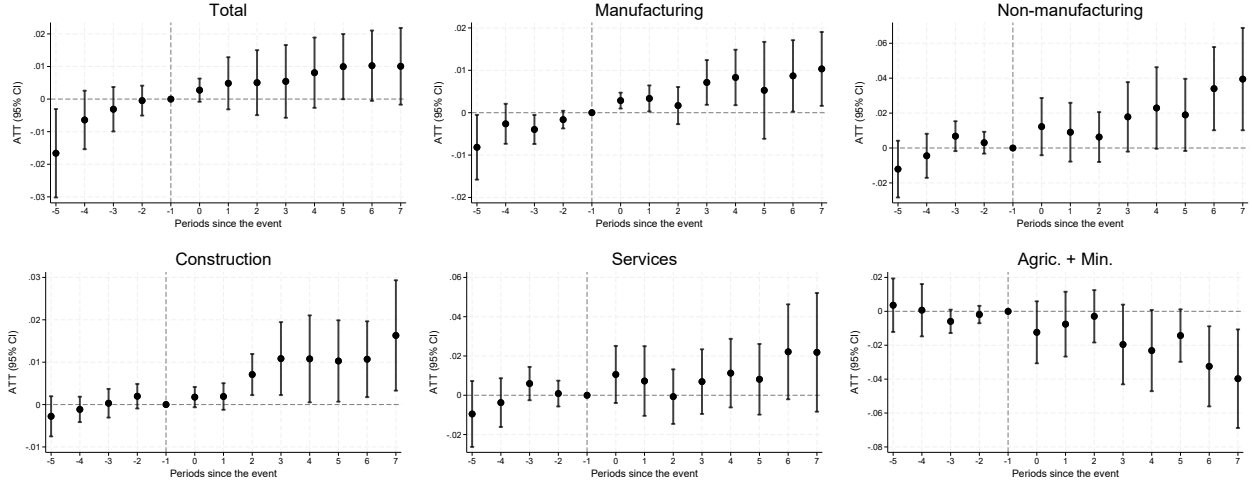
Recent DiD literature has shown that, within a staggered design, the two-way fixed effects (TWFE) models may not yield a transparent weighted average of treatment effects when these effects are heterogeneous (see Roth et al. (2023) for an excellent review). To account for this issue, we choose the regression adjustment framework proposed by Callaway and Sant'Anna (2021) (CS henceforth), where the outcome variable is depurated by the controls included in the main specification of Equation 3. As an additional advantage, the CS estimator relaxes the assumption of treatment homogeneity and

---

<sup>27</sup>Note that, since our sample starts in 2003 and we define treatment based on shocks in regional green manufacturing penetration between  $t$  and  $t - 1$ , the first non-missing year in the estimating sample is 2004.

thus allows to estimate group-time ATTs, with groups determined by the initial treatment time of each unit, before aggregating the results. In the main results, we use never-treated regions as the control group, but changing the control group with not-yet-treated regions does not substantially affect our results (Figure A9 in the Appendix).

Figure 7: Large shocks to green manufacturing penetration. Event study estimates.

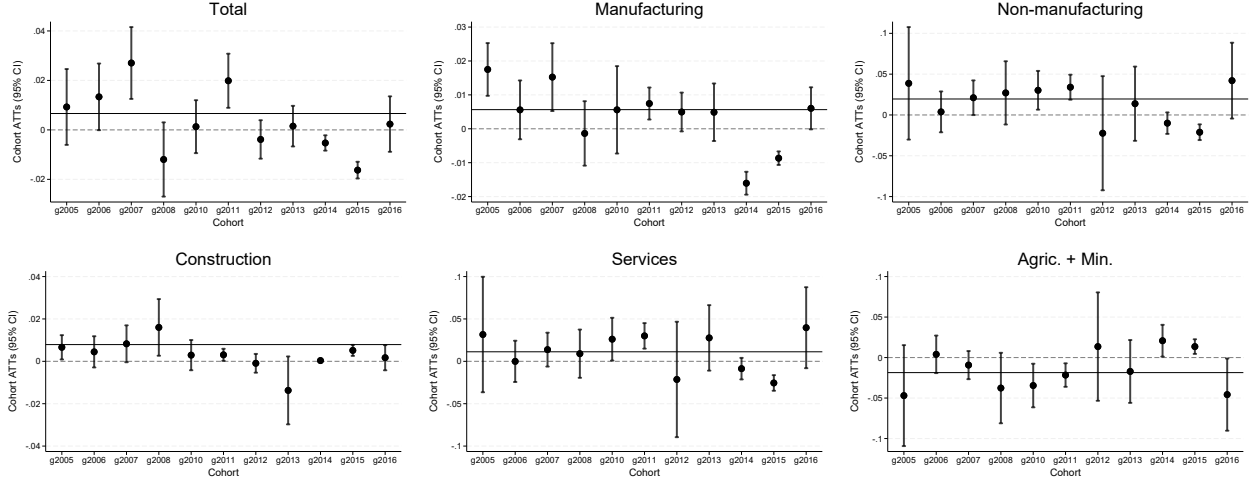


*Notes.* These plots show the results of the event study specification for several outcomes employing a regression adjustment from Callaway and Sant’Anna (2021). The positive spike in green regional penetration is defined as a change higher than the 90<sup>th</sup> percentile in the one-year change of green regional penetration. The first spike identifies the beginning of treatment. Standard errors are clustered at the NUTS2 level.

We display the results of our favourite CS estimator in Figure 7. The results are qualitatively in line with those of the main specification, but the effects are as expected larger, slower to emerge and more persistent also outside manufacturing. More specifically, the coefficients become statistically significant only after five-years, pointing to increases the total employment-to active population ratio by 1.1 pp (0.01/0.092) - an effect ten times larger than the LATE one. Moreover, we do not observe a decline in the employment-to-active population in the services sector and, netting out the agglomeration effect as in Section 4, we find long-term statistically significant effects on all sectors (Figure A11). Reassuringly, most of the sub-plots show no signs of the presence of pre-trends or, for total employment, a negative pre-trend for regions receiving large green shocks, making us confident that violations of the conditional parallel trends assumption are not severe in our setup. Finally, both the TWFE and CS estimators show somewhat similar patterns (Figure A10), consistent with the fact that negative weights account for a small fraction of the total ATTs in our case (Table A19).

Further, exploiting the properties of the CS estimator, we decompose the ATT into cohort-specific ATTs. Figure 8 reveals that the earliest-treated groups mostly exhibit positive ATT, driving the bulk of the aggregate impact. In contrast, later-treated cohorts display more volatile ATTs: some still show positive ATT estimates, while others show estimates that hover around zero or even negative.

Figure 8: Large shocks to green manufacturing penetration. Cohort-specific ATTs.



*Notes.* These figures show the ATT by cohort, with cohort being identified by the year of exposure to treatment, a positive shock in regional green manufacturing penetration between  $t$  and  $t - 1$  above the 90th percentile. The solid black line represents the aggregate ATT.

This evidence suggests that it may be more difficult to reconcile future efforts to promote green industrialization with job creation. This evidence also aligns with the gradual loss of EU’s advantage in green products and with the fact that most recent green technologies are becoming more labour-saving (Saussay et al., 2025).

## 5.2 Evaluating the impacts on vulnerable regions

One of the main goals of the EU green deal is to achieve a so-called “just transition”. That is: the policy-driven green transition must not exacerbate regional inequalities, especially on regions more dependent on polluting industries. Place-based policies for left-behind regions are usually advocated by economists on the ground of their high labour supply elasticity (Austin et al., 2018; Bartik et al., 2019). Regions hosting polluting industries and coal mines can be a good target for such policies as they are usually poorer and already on a declining trajectory (Hanson, 2023; Vona, 2023; Weber, 2020). Recent political-economy research suggests that providing opportunities in the green economy to communities that depend on polluting industries helps mitigate their opposition to the green transition (Bergquist et al., 2020; Bolet et al., 2024; Cavallotti et al., 2025).

Inspired by these considerations, we construct a measure of the potential disadvantages created by the green transition which relies on the degree of specialization in polluting industries at baseline (2000-2003). More specifically, we measure brown exposure as the ratio between regional employment in polluting industries and the total regional employment:  $BP_{r,t_0} = \sum_j \frac{L_{r,j=poll,t_0}}{L_{r,t_0}}$ .<sup>28</sup> The average value

<sup>28</sup>In line with Bontadini and Vona (2023) and the literature cited there, the polluting industries are: 24 - manufacture of basic metals; 25 - manufacture of fabricated metal products; 21 - manufacture of basic pharmaceutical products; 20 - manufacture of chemicals and chemical products; 23 - manufacture of other non-metallic mineral products; 19 -

of  $BP_{r,t_0}$  is 0.044, signalling that the average share of employment in polluting industries is rather small (see Table A4). We measure elevated brown penetration by identifying those NUTS2 regions that have  $BP_{r,t_0}$  above the 75<sup>th</sup> percentile.

Figure A13 shows NUTS2 regions by brown exposure (a) and those identified as having a high degree of brown exposure (b). Notable clusters emerge in the West of France, North of Italy and Czech Republic. Table A20 shows balancing tests between brown and non-brown NUTS2 regions. Brown-specialized regions tend to have lower population density, slightly higher median age, and a higher (lower) share of low (high) skill workers. They also have higher employment in manufacturing and non-green regional penetration at baseline, while they do not show differences in terms of three-year changes in green regional penetration and regional green patents exposure. Lastly, and somehow unexpectedly, brown-specialized regions have a higher probability of being exposed to large shocks to regional green penetration.

Econometrically, we assess the differential effect of green industrialization on brown regions by adding the interaction between the high-brown exposure dummy variable and the three years change in GRP to our main specification of Equation 3. Table 2 shows the results of this empirical exercise, where almost none of the interaction coefficients are statistically significant. For instance, the effect of green industrialization on total employment growth is slightly lower in brown specialized regions, but the coefficient associated to the interaction term is far from being statistically significant. The only exception to this pattern is the more pronounced negative reallocation effect of green penetration in brown regions on agriculture and mining employment.

When restricting the sample to brown-exposed regions and expanding to other time differences (Figure A14), estimates are in line with the main sample although job creation effects on manufacturing are less precisely estimated (Figure 4). However, netting out agglomeration effects makes the estimated coefficients statistically significant also for brown regions (Figure A15- except in the very long-term (after nine-years)). The result that brown-exposed and non-brown exposed regions equally benefit from green industrialization shocks is confirmed using the DiD-large shock specification (see Figure A16), where we estimate the ATT separately for the two groups of regions against the common control group of never treated. In brown-exposed regions, although the ATTs are estimated less precisely due to decrease in sample size, a weaker effect in manufacturing is offset by a stronger effect outside manufacturing.

The main policy implication of these results is that brown exposed regions can still benefit from the green industrialization. Large job creation effects outside manufacturing can be accounted for by

---

manufacture of coke and refined petroleum products and the entire mining sector (i.e. sectors from 05 to 08, excluding sector 09 which pertains services related to the mining sector).

Table 2: Green penetration and brown specialization interaction on regional employment

|                     | (1)                 | (2)                 | (3)                  | (4)                | (5)                      | (6)                 |
|---------------------|---------------------|---------------------|----------------------|--------------------|--------------------------|---------------------|
| <i>Panel A:</i>     | <i>Total</i>        |                     | <i>Manufacturing</i> |                    | <i>Non-manufacturing</i> |                     |
| $\Delta GRP_{r,t3}$ | 0.023***<br>(0.007) | 0.211***<br>(0.066) | 0.007**<br>(0.003)   | 0.044**<br>(0.021) | 0.022**<br>(0.009)       | 0.067<br>(0.079)    |
| * $BP SPEC_{r,t0}$  | 0.019<br>(0.012)    | -0.046<br>(0.087)   | 0.010***<br>(0.003)  | 0.011<br>(0.025)   | 0.000<br>(0.012)         | 0.094<br>(0.106)    |
| <i>Panel B:</i>     | <i>Construction</i> |                     | <i>Services</i>      |                    | <i>Agric. + Min.</i>     |                     |
| $\Delta GRP_{r,t3}$ | 0.006***<br>(0.002) | 0.069**<br>(0.030)  | 0.017**<br>(0.008)   | -0.011<br>(0.065)  | -0.006<br>(0.008)        | 0.100<br>(0.070)    |
| * $BP SPEC_{r,t0}$  | 0.004<br>(0.005)    | 0.015<br>(0.044)    | -0.003<br>(0.008)    | 0.076<br>(0.074)   | 0.008<br>(0.008)         | -0.151**<br>(0.070) |
| <i>N</i>            | 3336                | 3336                | 3336                 | 3336               | 3336                     | 3336                |
| Estimator           | OLS                 | 2SLS                | OLS                  | 2SLS               | OLS                      | 2SLS                |
| KP F-Stat           |                     | 11.1                |                      | 11.1               |                          | 11.1                |
| CD F-Stat           |                     | 16.6                |                      | 16.6               |                          | 16.6                |
| Controls            | ✓                   | ✓                   | ✓                    | ✓                  | ✓                        | ✓                   |
| Country FE          | ✓                   | ✓                   | ✓                    | ✓                  | ✓                        | ✓                   |
| Year FE             | ✓                   | ✓                   | ✓                    | ✓                  | ✓                        | ✓                   |

*Notes:* Dependent variables: the three-year change in regional employment over active population in: total; manufacturing; non-manufacturing (utilities, construction, services); construction; services; agriculture + mining. The endogenous variable,  $\Delta GRP_{r,t3}$ , refers to the change in the green penetration measure in region  $r$  between  $t$  and  $t-3$ . The instrumental variable refers to the shift-share instrumental variable related to green patents. The endogenous and instrumental variable are interacted with a dummy variable equal to 1 if a NUTS2 has a value of brown exposure higher than the 75<sup>th</sup> percentile at baseline (avg. 2000-2003). Columns (1), (3) and (5) show OLS estimates, while columns (2), (4) and (6) show the ones related to the green patents instrument. Columns (2), (4) and (6) report the Kleibergen-Paap (KP) and the Cragg-Donald (CD) F statistic for weak identification. Controls include the share of employment in manufacturing and the regional non-green penetration, interacted with year fixed effects. All the controls are taken at baseline, that is their average value between 2000 and 2003. We include country and year fixed effects. Estimates are weighted by the share of regional population over the EU one, at baseline. Region clustered standard errors in parentheses. Number of regions: 278. \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

the larger labour supply elasticity of more vulnerable regions (Austin et al., 2018). This result is also in line with evidence that green and brown activities utilize a similar set of skills (Saussay et al., 2022; Vona et al., 2018)

## 6 Conclusions

This paper offers new insights on the effects of green industrialization on local labour markets in EU countries. While previous work focused on green energy (Cappa et al., 2024; Chan & Zhou, 2024; Fabra et al., 2024; Scheifele & Popp, 2025) or on green fiscal policies (Popp et al., 2021; Wald et al., 2024), we are, to the best of our knowledge, the first to estimate the local multiplier effect of green industrialization. Within a causal empirical framework, we show that regional green manufacturing penetration creates jobs in the local economy and such effect is more persistent than those estimated

for renewable energy generation. Importantly, we show that the effect is less likely to be contaminated by pre-existing trends, which were an issue in the related study of Popp et al. (2021).

The aggregate effect on the employment-to-active population masks various structural changes in the local economy. First, we observe a strong and persistent effect on manufacturing employment. Green manufacturing production also increases the share of STEM workers in the local labour market, enhancing the general attractiveness of greener regions. Second, the multiplier effect outside manufacturing is more evident and persistent on construction and utilities, while it is short-lived in the services sector. This finding underscores the crucial role of infrastructural investments for the green transition. Third, green industrialization accelerates labour reallocation away from the primary sector and triggers agglomeration forces that increase the tightness of local labour markets. Both reallocation and agglomeration effects are in line with the fact that greener regions become more attractive locations to live and work. Fourth, we observe a skill-bias of green industrial activities in favour of high- (especially STEM) and low-skilled workers, which aligns with previous research (Marin and Vona, 2019; Vona et al., 2018). The change in the skill composition is partly driven by induced changes in the local industrial structure. On the one hand, green industries are high-to-medium tech and thus their expansion increases the demand of STEM workers. On the other hand, the expansion of construction allows to absorb workers laid off from the primary sector and the inflow of new workers.

Although we do not exploit specific green policies to identify local labour market effects, our findings can be used to improve the design of green industrial policies. In particular, the two main extensions of our analysis provide further food for thought for policy makers. On the positive side, our results suggest that green industrialization can be a promising part of place-based policies for left-behind brown regions. On the negative side, large green industrialization shocks are less frequent in recent years and, when they occur, create less jobs. This implies that green subsidies, possibly combined with local content requirement, are less likely to be effective in creating local jobs in the future. What remains unclear is whether a lower effectiveness is due to the lack of competitiveness of EU countries in green industries or to the fact that green technologies are becoming more labour-saving. These issues certainly deserve further research.

## References

- Acemoglu, D., Aghion, P., Bursztyn, L., & Hémous, D. (2012). The environment and directed technical change. *American Economic Review*, 102, 131–66.
- Acemoglu, D., Aghion, P., & Zilibotti, F. (2006). Distance to frontier, selection, and economic growth. *Journal of the European Economic association*, 4(1), 37–74.
- Acemoglu, D., Autor, D., Hazell, J., & Restrepo, P. (2022). Artificial intelligence and jobs: Evidence from online vacancies. *Journal of Labor Economics*, 40(S1), S293–S340.
- Acemoglu, D., & Restrepo, P. (2019). Automation and new tasks: How technology displaces and reinstates labor. *Journal of Economic Perspectives*, 33(2), 3–30.
- Acemoglu, D., & Restrepo, P. (2020). Robots and jobs: Evidence from us labor markets. *Journal of political economy*, 128(6), 2188–2244.
- Acemoglu, D., & Restrepo, P. (2022). Demographics and automation. *The Review of Economic Studies*, 89(1), 1–44.
- Aghion, P., Antonin, C., Bunel, S., & Jaravel, X. (2023). The local labor market effects of modern manufacturing capital: Evidence from france. *AEA Papers and Proceedings*, 113, 219–223.
- Aghion, P., Dechezleprêtre, A., Hémous, D., Martin, R., & Reenen, J. V. (2016). Carbon Taxes, Path Dependency, and Directed Technical Change: Evidence from the Auto Industry. *Journal of Political Economy*, 124(1), 1–51.
- Anelli, M., Colantone, I., & Stanig, P. (2021). Individual vulnerability to industrial robot adoption increases support for the radical right. *Proceedings of the National Academy of Sciences*, 118(47), e2111611118.
- Angrist, J. D., & Pischke, J.-S. (2009). *Mostly harmless econometrics: An empiricist's companion*. Princeton university press.
- Austin, B., Glaeser, E., & Summers, L. (2018). Jobs for the heartland: Place-based policies in 21st-century america. *Brookings Papers on Economic Activity*, 2018(1), 151–255.
- Autor, D., Chin, C., Salomons, A. M., & Seegmiller, B. (2022). *New frontiers: The origins and content of new work, 1940–2018* (tech. rep.). National Bureau of Economic Research.
- Autor, D., & Dorn, D. (2013). The growth of low-skill service jobs and the polarization of the us labor market. *American economic review*, 103(5), 1553–1597.
- Autor, D., Dorn, D., & Hanson, G. (2013). The china syndrome: Local labor market effects of import competition in the united states. *American economic review*, 103(6), 2121–68.

- Bartik, A. W., Currie, J., Greenstone, M., & Knittel, C. R. (2019). The local economic and welfare consequences of hydraulic fracturing. *American Economic Journal: Applied Economics*, 11(4), 105–155.
- Bergquist, P., Mildenerger, M., & Stokes, L. C. (2020). Combining climate, economic, and social policy builds public support for climate action in the us. *Environmental Research Letters*, 15(5), 054019.
- Black, D., McKinnish, T., & Sanders, S. (2005). The economic impact of the coal boom and bust. *The Economic Journal*, 115(503), 449–476.
- Bolet, D., Green, F., & Gonzalez-Eguino, M. (2024). How to get coal country to vote for climate policy: The effect of a “just transition agreement” on spanish election results. *American Political Science Review*, 118(3), 1344–1359.
- Bontadini, F., & Vona, F. (2023). Anatomy of green specialisation: Evidence from eu production data, 1995–2015. *Environmental and Resource Economics*, 1–34.
- Borusyak, K., Hull, P., & Jaravel, X. (2022). Quasi-experimental shift-share research designs. *The Review of Economic Studies*, 89(1), 181–213.
- Callaway, B., & Sant’Anna, P. H. (2021). Difference-in-differences with multiple time periods. *Journal of econometrics*, 225(2), 200–230.
- Cappa, E., Lamperti, F., & Pallante, G. (2024). *Creating jobs out of the green: The employment effects of the energy transition* (tech. rep.). LEM Working Paper Series.
- Carlino, G., & Kerr, W. R. (2015). Agglomeration and innovation. *Handbook of regional and urban economics*, 5, 349–404.
- Cavallotti, E., Colantone, I., Stanig, P., & Vona, F. (2025). Green collars at the voting booth: Material interest and environmental voting.
- Chan, R., & Zhou, Y. C. (2024). *Charged up: Impacts of green energy transition on local labor markets* (tech. rep.). Unpublished.
- Chodorow-Reich, G. (2019). Geographic cross-sectional fiscal spending multipliers: What have we learned? *American Economic Journal: Economic Policy*, 11(2), 1–34.
- De Chaisemartin, C., & d’Haultfoeuille, X. (2020). Two-way fixed effects estimators with heterogeneous treatment effects. *American economic review*, 110(9), 2964–2996.
- Elliott, R. J., Kuai, W., Maddison, D., & Ozgen, C. (2024). Eco-innovation and (green) employment: A task-based approach to measuring the composition of work in firms. *Journal of Environmental Economics and Management*, 127, 103015.

- Elliott, R. J., & Lindley, J. K. (2017). Environmental jobs and growth in the united states. *Ecological Economics*, 132, 232–244.
- Eurostat. (2016). *Environmental goods and services sector accounts manual: 2016 edition*.
- Fabra, N., Gutiérrez, E., Lacuesta, A., & Ramos, R. (2024). Do renewable energy investments create local jobs? *Journal of Public Economics*, 239, 105212.
- Feyrer, J., Mansur, E. T., & Sacerdote, B. (2017). Geographic dispersion of economic shocks: Evidence from the fracking revolution. *American Economic Review*, 107(4), 1313–1334.
- Frattini, F. F., Vona, F., & Bontadini, F. (2024). *Does green re-industrialization pay off? impacts on employment, wages and productivity* (tech. rep.). Nota di Lavoro 23.2024, Milano, Italia: Fondazione Eni Enrico Mattei.
- Goldsmith-Pinkham, P., Sorkin, I., & Swift, H. (2020). Bartik instruments: What, when, why, and how. *American Economic Review*, 110(8), 2586–2624.
- Graetz, G., & Michaels, G. (2018). Robots at work. *Review of economics and statistics*, 100(5), 753–768.
- Gregory, T., Salomons, A., & Zierahn, U. (2022). Racing with or against the machine? evidence on the role of trade in europe. *Journal of the European Economic Association*, 20(2), 869–906.
- Hanson, G. H. (2023). *Local labor market impacts of the energy transition: Prospects and policies* (tech. rep.). National Bureau of Economic Research.
- Haywood, L., Janser, M., & Koch, N. (2024). The welfare costs of job loss and decarbonization: Evidence from germany’s coal phaseout. *Journal of the Association of Environmental and Resource Economists*, 11(3), 577–611.
- Iammarino, S., Rodriguez-Pose, A., & Storper, M. (2019). Regional inequality in europe: Evidence, theory and policy implications. *Journal of economic geography*, 19(2), 273–298.
- Imbens, G. W., & Angrist, J. D. (1994). Identification and estimation of local average treatment effects. *Econometrica*, 62(2), 467–475.
- Lee, D. S., McCrary, J., Moreira, M. J., & Porter, J. (2022). Valid t-ratio inference for iv. *American Economic Review*, 112(10), 3260–3290.
- Lin, J. (2011). Technological adaptation, cities, and new work. *Review of Economics and Statistics*, 93(2), 554–574.
- Manning, A., & Petrongolo, B. (2017). How local are labor markets? evidence from a spatial job search model. *American Economic Review*, 107(10), 2877–2907.
- Marchand, J. (2012). Local labor market impacts of energy boom-bust-boom in western canada. *Journal of Urban Economics*, 71(1), 165–174.

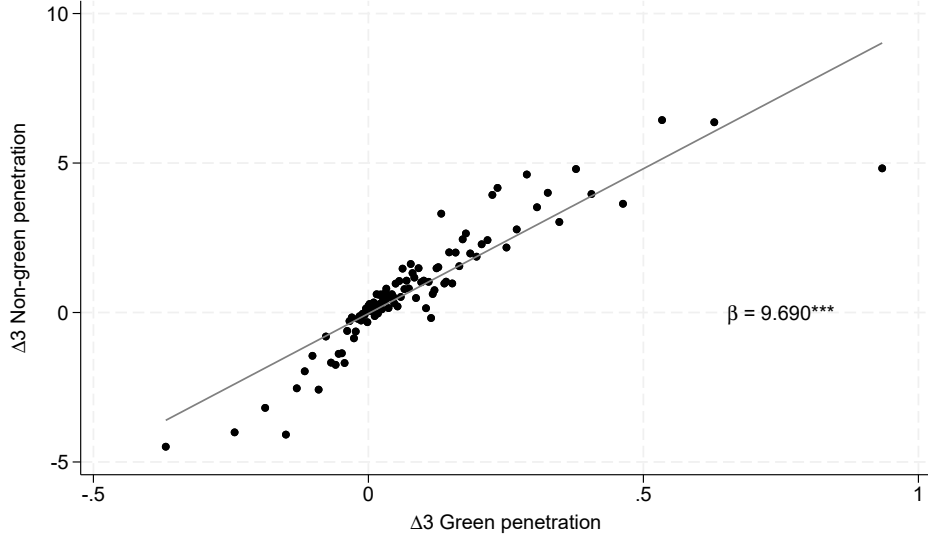
- Marin, G., & Vona, F. (2019). Climate policies and skill-biased employment dynamics: Evidence from eu countries. *Journal of Environmental Economics and Management*, 98, 102253.
- Moretti, E. (2010). Local multipliers. *American Economic Review*, 100(2), 373–377.
- Moretti, E. (2011). Local labor markets. In *Handbook of labor economics* (pp. 1237–1313, Vol. 4). Elsevier.
- Murphy, K. M., Shleifer, A., & Vishny, R. W. (1989). Industrialization and the big push. *Journal of political economy*, 97(5), 1003–1026.
- Nakamura, E., & Steinsson, J. (2014). Fiscal stimulus in a monetary union: Evidence from us regions. *American Economic Review*, 104(3), 753–792.
- Popp, D. (2002). Induced innovation and energy prices. *American Economic Review*, 92(1), 160–180.
- Popp, D. (2019). *Environmental policy and innovation: A decade of research* (tech. rep.). National Bureau of Economic Research.
- Popp, D., Vona, F., Gregoire-Zawilski, M., & Marin, G. (2024). The next wave of energy innovation: Which technologies? which skills? *Review of Environmental Economics and Policy*, 18(1), 45–65.
- Popp, D., Vona, F., Marin, G., & Chen, Z. (2021). The employment impact of a green fiscal push: Evidence from the american recovery and reinvestment act. *Brookings Papers on Economic Activity*.
- Rodrik, D. (2014). Green industrial policy. *Oxford review of economic policy*, 30(3), 469–491.
- Rosenstein-Rodan, P. N. (1943). Problems of industrialisation of eastern and south-eastern europe. *The economic journal*, 53(210-211), 202–211.
- Roth, J., Sant’Anna, P. H., Bilinski, A., & Poe, J. (2023). What’s trending in difference-in-differences? a synthesis of the recent econometrics literature. *Journal of Econometrics*, 235(2), 2218–2244.
- Rud, J.-P., Simmons, M., Toews, G., & Aragon, F. (2024). Job displacement costs of phasing out coal. *Journal of Public Economics*, 236, 105167.
- Saussay, A., Sato, M., & Vona, F. (2025). The social and environmental impacts of the twin technological transition.
- Saussay, A., Sato, M., Vona, F., & O’Kane, L. (2022). Who’s fit for the low-carbon transition? emerging skills and wage gaps in job ad data.
- Scheifele, F., & Popp, D. (2025). Not in my backyard? the local impact of wind and solar parks in brazil. *Energy Economics*, 108481.
- Tagliapietra, S., & Veugelers, R. (2020). *A green industrial policy for europe*. Bruegel Brussels.

- Van Looy, B., Vereyen, C., & Schmoch, U. (2014). Patent statistics: Concordance ipc v8–nace rev. 2. *Eurostat, European Commission*.
- Verdolini, E., & Galeotti, M. (2011). At home and abroad: An empirical analysis of innovation and diffusion in energy technologies. *Journal of environmental economics and management*, 61(2), 119–134.
- Vona, F. (2023). Managing the distributional effects of climate policies: A narrow path to a just transition. *Ecological Economics*, 205, 107689.
- Vona, F., Marin, G., & Consoli, D. (2019). Measures, drivers and effects of green employment: Evidence from us local labor markets, 2006–2014. *Journal of Economic Geography*, 19(5), 1021–1048.
- Vona, F., Marin, G., Consoli, D., & Popp, D. (2018). Environmental regulation and green skills: An empirical exploration. *Journal of the Association of Environmental and Resource Economists*, 5(4), 713–753.
- Wald, G., Cohen, F., & Kahn, V. (2024). *Making jobs out of the energy transition: Evidence from the french energy efficiency obligations scheme* (tech. rep.). IEB Working Paper 2024/01. Institut d’Economia de Barcelona.
- Weber, J. G. (2012). The effects of a natural gas boom on employment and income in colorado, texas, and wyoming. *Energy Economics*, 34(5), 1580–1588.
- Weber, J. G. (2020). How should we think about environmental policy and jobs? an analogy with trade policy and an illustration from us coal mining. *Review of Environmental Economics and Policy*.
- Wilson, D. J. (2012). Fiscal spending jobs multipliers: Evidence from the 2009 american recovery and reinvestment act. *American Economic Journal: Economic Policy*, 4(3), 251–282.

## A Appendix

### A.1 Descriptive statistics

Figure A1: GRP and NGRP



*Notes.* This graph shows the raw correlation between the average three-year change in regional non-green penetration and the average three-year change in regional green penetration. We weight the two variables by the share of regional population over the EU one.

Table A1: Green and polluting production by 2-digit industries

| NACE2D                              | Label                                                    | Share Gp | Tot. Gp    | Mean Gp | SD Gp    | Max Gp    | GHG int. |
|-------------------------------------|----------------------------------------------------------|----------|------------|---------|----------|-----------|----------|
| <i>Potentially green industries</i> |                                                          |          |            |         |          |           |          |
| 33                                  | Repair and installation of machinery and equipment       | 0.1844   | 383554.854 | 711.605 | 1368.634 | 8106.562  | 0.740    |
| 26                                  | Manufacture of computer, electronic and optical products | 0.1804   | 294572.305 | 541.493 | 1432.731 | 11602.843 | 0.300    |
| 30                                  | Manufacture of other transport equipment                 | 0.1764   | 239995.366 | 441.168 | 916.273  | 7482.641  | 0.610    |
| 27                                  | Manufacture of electrical equipment                      | 0.1299   | 383540.545 | 705.038 | 1798.052 | 14265.906 | 0.300    |
| 28                                  | Manufacture of machinery and equipment n.e.c.            | 0.0836   | 524287.359 | 963.764 | 2317.087 | 17440.078 | 0.540    |
| 16                                  | Manufacture of wood and of products of wood and cork     | 0.0015   | 2308.279   | 4.911   | 10.564   | 68.902    | 0.880    |
| 29                                  | Manufacture of motor vehicles                            | 0.0003   | 2422.361   | 4.923   | 25.723   | 251.283   | 0.610    |
| <i>Non-green industries</i>         |                                                          |          |            |         |          |           |          |
| 10                                  | Manufacture of food products                             | 0.0000   | 0.000      | 0.000   | 0.000    | 0.000     | 1.450    |
| 11                                  | Manufacture of beverages                                 | 0.0000   | 0.000      | 0.000   | 0.000    | 0.000     | 1.450    |
| 12                                  | Manufacture of tobacco products                          | 0.0000   | 0.000      | 0.000   | 0.000    | 0.000     | 1.450    |
| 13                                  | Manufacture of textiles                                  | 0.0000   | 0.000      | 0.000   | 0.000    | 0.000     | 0.970    |
| 14                                  | Manufacture of wearing apparel                           | 0.0000   | 0.000      | 0.000   | 0.000    | 0.000     | 0.970    |
| 15                                  | Manufacture of leather and related products              | 0.0000   | 0.000      | 0.000   | 0.000    | 0.000     | 0.970    |
| 17                                  | Manufacture of paper and paper products                  | 0.0000   | 0.000      | 0.000   | 0.000    | 0.000     | 1.180    |
| 18                                  | Printing and reproduction of recorded media              | 0.0000   | 0.000      | 0.000   | 0.000    | 0.000     | 1.180    |
| 22                                  | Manufacture of rubber and plastic products               | 0.0000   | 0.000      | 0.000   | 0.000    | 0.000     | 0.940    |
| 31                                  | Manufacture of furniture                                 | 0.0000   | 0.000      | 0.000   | 0.000    | 0.000     | 0.740    |
| 32                                  | Other manufacturing                                      | 0.0000   | 0.000      | 0.000   | 0.000    | 0.000     | 0.740    |
| <i>Polluting industries</i>         |                                                          |          |            |         |          |           |          |
| 24                                  | Manufacture of basic metals                              | 0.0216   | 63525.056  | 126.544 | 202.420  | 1024.372  | 4.230    |
| 25                                  | Manufacture of fabricated metal products                 | 0.0137   | 75930.470  | 139.578 | 262.518  | 1956.398  | 4.230    |
| 21                                  | Manufacture of basic pharmaceutical products             | 0.0000   | 0.000      | 0.000   | 0.000    | 0.000     | 5.110    |
| 20                                  | Manufacture of chemicals and chemical products           | 0.0163   | 60694.073  | 280.991 | 590.525  | 3945.616  | 5.110    |
| 23                                  | Manufacture of other non-metallic mineral products       | 0.0314   | 95324.577  | 186.545 | 312.939  | 1473.388  | 7.780    |
| 19                                  | Manufacture of coke and refined petroleum products       | 0.0000   | 0.000      | 0.000   | 0.000    | 0.000     | 44.990   |

*Notes:* Authors' elaboration on PRODCOM data. Production values are deflated to have data at constant prices, with 2020 as the base year. Column 1 reports the share that green production of each industry represents in total green production. Column 2 reports total sold green production from 2003 to 2017, with data in million of €. Column 3 and 4 report the mean and standard deviation of green production from 2003 to 2017, with data in million of €. Column 5 reports the maximum value of an industry-year of sold green production, with data in million of €. Columns 6 report the average GHG intensity for each industry computed with WIOD. Polluting industries are identified as the 5 industries with the highest average GHG intensity.

Table A2: Top NUTS2 regions by average green manufacturing penetration.

| Region                          | GRP   | Region                            | GRP   |
|---------------------------------|-------|-----------------------------------|-------|
| DK - Midtjylland                | 2.650 | DE - Sachsen-Anhalt               | 0.771 |
| DK - Syddanmark                 | 2.547 | FR - Alsace                       | 0.771 |
| DE - Oberpfalz                  | 2.141 | DE - Schleswig-Holstein           | 0.759 |
| DE - Mittelfranken              | 2.127 | SE - Västsverige                  | 0.752 |
| DK - Nordjylland                | 2.032 | CZ - Střední Morava               | 0.731 |
| DE - Tübingen                   | 1.805 | AT - Vorarlberg                   | 0.730 |
| DE - Schwaben                   | 1.728 | DE - Münster                      | 0.726 |
| DE - Stuttgart                  | 1.658 | SE - Sydsverige                   | 0.720 |
| DE - Freiburg                   | 1.573 | ES - Aragón                       | 0.720 |
| DE - Bremen                     | 1.510 | DE - Köln                         | 0.712 |
| DE - Karlsruhe                  | 1.498 | AT - Wien                         | 0.704 |
| AT - Oberösterreich             | 1.491 | FI - Etelä-Suomi                  | 0.702 |
| DE - Unterfranken               | 1.473 | FR - Rhône-Alpes                  | 0.700 |
| DE - Hamburg                    | 1.436 | CZ - Moravskoslezsko              | 0.700 |
| DE - Detmold                    | 1.407 | HR - Jadranska Hrvatska           | 0.699 |
| DE - Arnsberg                   | 1.364 | AT - Kärnten                      | 0.689 |
| DE - Dresden                    | 1.300 | FR - Midi-Pyrénées                | 0.681 |
| DE - Oberfranken                | 1.278 | AT - Niederösterreich             | 0.676 |
| DE - Oberbayern                 | 1.237 | DE - Leipzig                      | 0.662 |
| ES - País Vasco                 | 1.231 | DE - Berlin                       | 0.661 |
| DE - Gießen                     | 1.228 | FI - Itä-Suomi                    | 0.640 |
| SE - Småland med öarna          | 1.216 | IT - Toscana                      | 0.636 |
| IT - Friuli-Venezia Giulia      | 1.214 | DE - Brandenburg                  | 0.623 |
| IT - Emilia-Romagna             | 1.185 | ES - La Rioja                     | 0.614 |
| SE - Östra Mellansverige        | 1.148 | AT - Tirol                        | 0.606 |
| IT - Lombardia                  | 1.054 | UK - North Eastern Scotland       | 0.603 |
| DE - Thüringen                  | 1.047 | IT - Umbria                       | 0.601 |
| IT - Veneto                     | 1.021 | IT - Abruzzo                      | 0.599 |
| DE - Kassel                     | 0.999 | DE - Mecklenburg-Vorpommern       | 0.573 |
| DE - Niederbayern               | 0.992 | DE - Trier                        | 0.571 |
| AT - Steiermark                 | 0.986 | CZ - Severovýchod                 | 0.566 |
| DE - Chemnitz                   | 0.977 | FR - Pays de la Loire             | 0.562 |
| FI - Länsi-Suomi                | 0.966 | CZ - Jihovýchod                   | 0.557 |
| ES - Comunidad Foral de Navarra | 0.953 | FR - Limousin                     | 0.557 |
| DK - Sjælland                   | 0.940 | UK - Shropshire and Staffordshire | 0.551 |
| IT - Piemonte                   | 0.931 | ES - Principado de Asturias       | 0.549 |
| SE - Norra Mellansverige        | 0.931 | UK - East Wales                   | 0.548 |
| DE - Saarland                   | 0.931 | FR - Bourgogne                    | 0.547 |
| IT - Marche                     | 0.922 | SE - Övre Norrland                | 0.545 |
| DE - Düsseldorf                 | 0.920 | DE - Lüneburg                     | 0.539 |
| DE - Weser-Ems                  | 0.915 | FR - Centre (FR)                  | 0.539 |
| DE - Braunschweig               | 0.911 | UK - Hampshire and Isle of Wight  | 0.535 |
| DE - Hannover                   | 0.877 | CZ - Jihozápad                    | 0.531 |
| DE - Darmstadt                  | 0.849 | UK - Dorset and Somerset          | 0.529 |
| IT - Liguria                    | 0.847 | HU - Közép-Dunántúl               | 0.528 |
| FR - Ile de France              | 0.825 | FR - Franche-Comté                | 0.521 |
| DE - Rheinhessen-Pfalz          | 0.819 | FR - Haute-Normandie              | 0.514 |
| DK - Hovedstaden                | 0.805 | IT - Campania                     | 0.509 |
| DE - Koblenz                    | 0.788 | ES - Cantabria                    | 0.505 |
| SE - Mellersta Norrland         | 0.783 | CZ - Severozápad                  | 0.504 |
| FI - Etelä-Suomi                | 0.778 | BE - Prov. Hainaut                | 0.503 |

*Notes.* This table shows the NUTS2 regions for which their average green manufacturing penetration from 2003 to 2017 is higher than the average across NUTS regions.

Table A3: Top NUTS2 regions by the average three-year change in green manufacturing penetration.

| Region                | $\Delta_3$ GRP | Region                          | $\Delta_3$ GRP |
|-----------------------|----------------|---------------------------------|----------------|
| DK - Midtjylland      | 0.831          | DE - Saarland                   | 0.152          |
| DK - Syddanmark       | 0.680          | FR - Midi-Pyrénées              | 0.141          |
| DK - Nordjylland      | 0.536          | DE - Schleswig-Holstein         | 0.140          |
| AT - Oberösterreich   | 0.506          | PL - Podkarpackie               | 0.139          |
| AT - Steiermark       | 0.364          | PL - Dolnośląskie               | 0.136          |
| DE - Tübingen         | 0.361          | CZ - Severozápad                | 0.135          |
| DE - Oberpfalz        | 0.352          | CZ - Střední Čechy              | 0.134          |
| DE - Stuttgart        | 0.336          | DE - Koblenz                    | 0.134          |
| DE - Schwaben         | 0.334          | SK - Západné Slovensko          | 0.128          |
| DE - Mittelfranken    | 0.331          | SI - Vzhodna Slovenija          | 0.127          |
| AT - Vorarlberg       | 0.313          | DE - Düsseldorf                 | 0.125          |
| DK - Sjælland         | 0.298          | DE - Darmstadt                  | 0.123          |
| AT - Wien             | 0.296          | ES - Comunidad Foral de Navarra | 0.121          |
| DE - Bremen           | 0.296          | PL - Opolskie                   | 0.119          |
| DE - Freiburg         | 0.290          | DE - Berlin                     | 0.116          |
| DE - Dresden          | 0.286          | PL - Śląskie                    | 0.114          |
| DE - Gießen           | 0.283          | SK - Stredné Slovensko          | 0.114          |
| DE - Unterfranken     | 0.279          | FI - Länsi-Suomi                | 0.113          |
| DE - Hamburg          | 0.278          | DE - Leipzig                    | 0.112          |
| DE - Karlsruhe        | 0.276          | PL - Zachodniopomorskie         | 0.111          |
| AT - Kärnten          | 0.259          | CZ - Praha                      | 0.111          |
| AT - Niederösterreich | 0.249          | DE - Münster                    | 0.109          |
| DE - Detmold          | 0.248          | ES - Aragón                     | 0.109          |
| DE - Oberbayern       | 0.247          | SE - Småland med öarna          | 0.107          |
| CZ - Střední Morava   | 0.238          | DE - Mecklenburg-Vorpommern     | 0.107          |
| DE - Arnsberg         | 0.237          | PL - Wielkopolskie              | 0.105          |
| DK - Hovedstaden      | 0.233          | SI - Zahodna Slovenija          | 0.102          |
| AT - Tirol            | 0.231          | FR - Pays de la Loire           | 0.098          |
| DE - Oberfranken      | 0.231          | DE - Sachsen-Anhalt             | 0.098          |
| CZ - Severovýchod     | 0.209          | DE - Trier                      | 0.098          |
| PL - Pomorskie        | 0.201          | FR - Ile de France              | 0.096          |
| CZ - Jihozápad        | 0.194          | ES - La Rioja                   | 0.093          |
| DE - Kassel           | 0.194          | SK - Bratislavský kraj          | 0.091          |
| DE - Niederbayern     | 0.190          | DE - Köln                       | 0.090          |
| AT - Salzburg         | 0.178          | FI - Etelä-Suomi                | 0.090          |
| DE - Braunschweig     | 0.176          | PL - Lubuskie                   | 0.089          |
| CZ - Jihovýchod       | 0.170          | ES - Principado de Asturias     | 0.088          |
| AT - Burgenland       | 0.170          | DE - Brandenburg                | 0.087          |
| DE - Thüringen        | 0.169          | DE - Lüneburg                   | 0.086          |
| CZ - Moravskoslezsko  | 0.167          | FR - Poitou-Charentes           | 0.084          |
| DE - Hannover         | 0.164          | PL - Kujawsko-pomorskie         | 0.084          |
| DE - Weser-Ems        | 0.161          | FR - Alsace                     | 0.082          |
| ES - País Vasco       | 0.159          | FI - Itä-Suomi                  | 0.082          |
| FR - Alsace           | 0.082          |                                 |                |

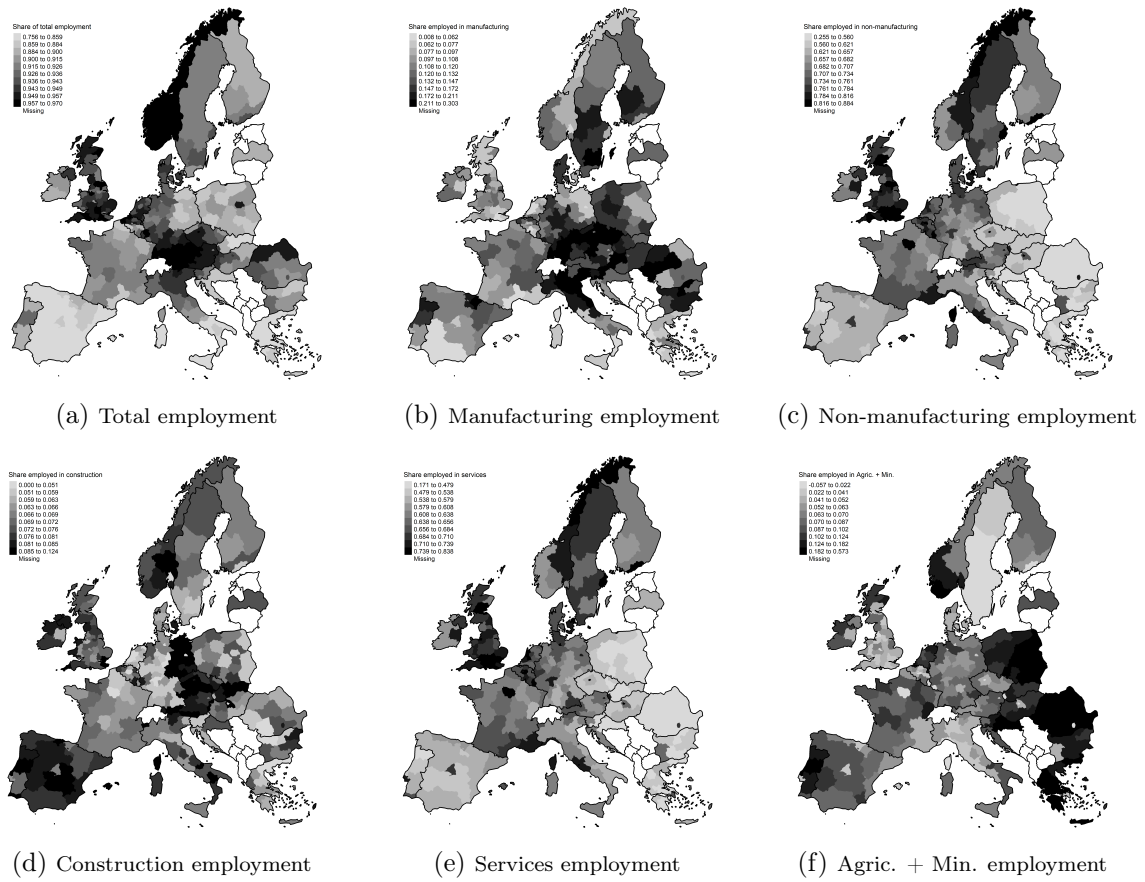
*Notes.* This table shows the NUTS2 regions for which their three-year average green manufacturing penetration from 2003 to 2017 is higher than the average across NUTS regions.

Table A4: Descriptive statistics of main variables

|                                                                   | Mean     | SD       | Min       | p50      | Max       |
|-------------------------------------------------------------------|----------|----------|-----------|----------|-----------|
| <i>Outcomes</i>                                                   |          |          |           |          |           |
| Total employment over active pop.                                 | 0.9104   | 0.0524   | 0.6295    | 0.9224   | 0.9829    |
| t-t <sub>3</sub> Total employment over active pop.                | 0.0011   | 0.0349   | -0.1842   | 0.0032   | 0.1514    |
| Manufacturing employment over active pop.                         | 0.1312   | 0.0583   | 0.0000    | 0.1227   | 0.3332    |
| t-t <sub>3</sub> Manufacturing employment over active pop.        | -0.0057  | 0.0155   | -0.1463   | -0.0054  | 0.0965    |
| Non-manufacturing employment over active pop.                     | 0.6886   | 0.1199   | 0.0573    | 0.7027   | 0.9529    |
| t-t <sub>3</sub> Non-manufacturing employment over active pop.    | 0.0109   | 0.0535   | -0.8496   | 0.0126   | 0.7649    |
| Construction employment over active pop.                          | 0.0675   | 0.0177   | 0.0000    | 0.0663   | 0.1828    |
| t-t <sub>3</sub> Construction employment over active pop.         | -0.0020  | 0.0132   | -0.1020   | -0.0005  | 0.0521    |
| Services employment over active pop.                              | 0.6133   | 0.1214   | 0.0000    | 0.6266   | 0.8678    |
| t-t <sub>3</sub> Services employment over active pop.             | 0.0121   | 0.0497   | -0.8469   | 0.0114   | 0.7648    |
| Agriculture + mining employment over active pop.                  | 0.0906   | 0.1042   | -0.1640   | 0.0661   | 0.8609    |
| t-t <sub>3</sub> Agriculture + mining employment over active pop. | -0.0042  | 0.0494   | -0.7685   | -0.0025  | 0.8489    |
| <i>Green penetration and green patents SSIV</i>                   |          |          |           |          |           |
| Regional green penetration                                        | 0.548829 | 0.468924 | 0.000000  | 0.416036 | 4.595836  |
| t-t <sub>3</sub> regional green penetration                       | 0.082808 | 0.175823 | -0.901374 | 0.046272 | 2.551368  |
| Regional green patents SSIV                                       | 0.000060 | 0.000077 | 0.000000  | 0.000036 | 0.000512  |
| t-t <sub>5</sub> regional green patents SSIV                      | 0.000012 | 0.000021 | -0.000049 | 0.000004 | 0.000187  |
| <i>Controls</i>                                                   |          |          |           |          |           |
| Population density (t0)                                           | 448.4507 | 961.3419 | 2.8500    | 173.4750 | 9519.3584 |
| Median age (t0)                                                   | 38.7253  | 2.6659   | 31.3500   | 38.9750  | 50.1882   |
| Share of female population (t0)                                   | 0.5178   | 0.0084   | 0.4892    | 0.5175   | 0.5545    |
| Share of foreign-born population (t0)                             | 0.0459   | 0.0437   | 0.0015    | 0.0348   | 0.3660    |
| Share of population with lower secondary edu. (t0)                | 0.3977   | 0.1606   | 0.1085    | 0.3690   | 0.8468    |
| Share of population with upper secondary edu. (t0)                | 0.3926   | 0.1373   | 0.0958    | 0.3792   | 0.6943    |
| Share of population with tertiary edu. (t0)                       | 0.1535   | 0.0682   | 0.0497    | 0.1519   | 0.4280    |
| Share employed in manufacturing (t0)                              | 0.1556   | 0.0618   | 0.0102    | 0.1475   | 0.3372    |
| Regional non-green penetration (t0)                               | 8.2605   | 6.7683   | 0.0000    | 6.1283   | 39.7887   |
| Polluting activities exposure (t0)                                | 0.0440   | 0.0205   | 0.0022    | 0.0392   | 0.1188    |

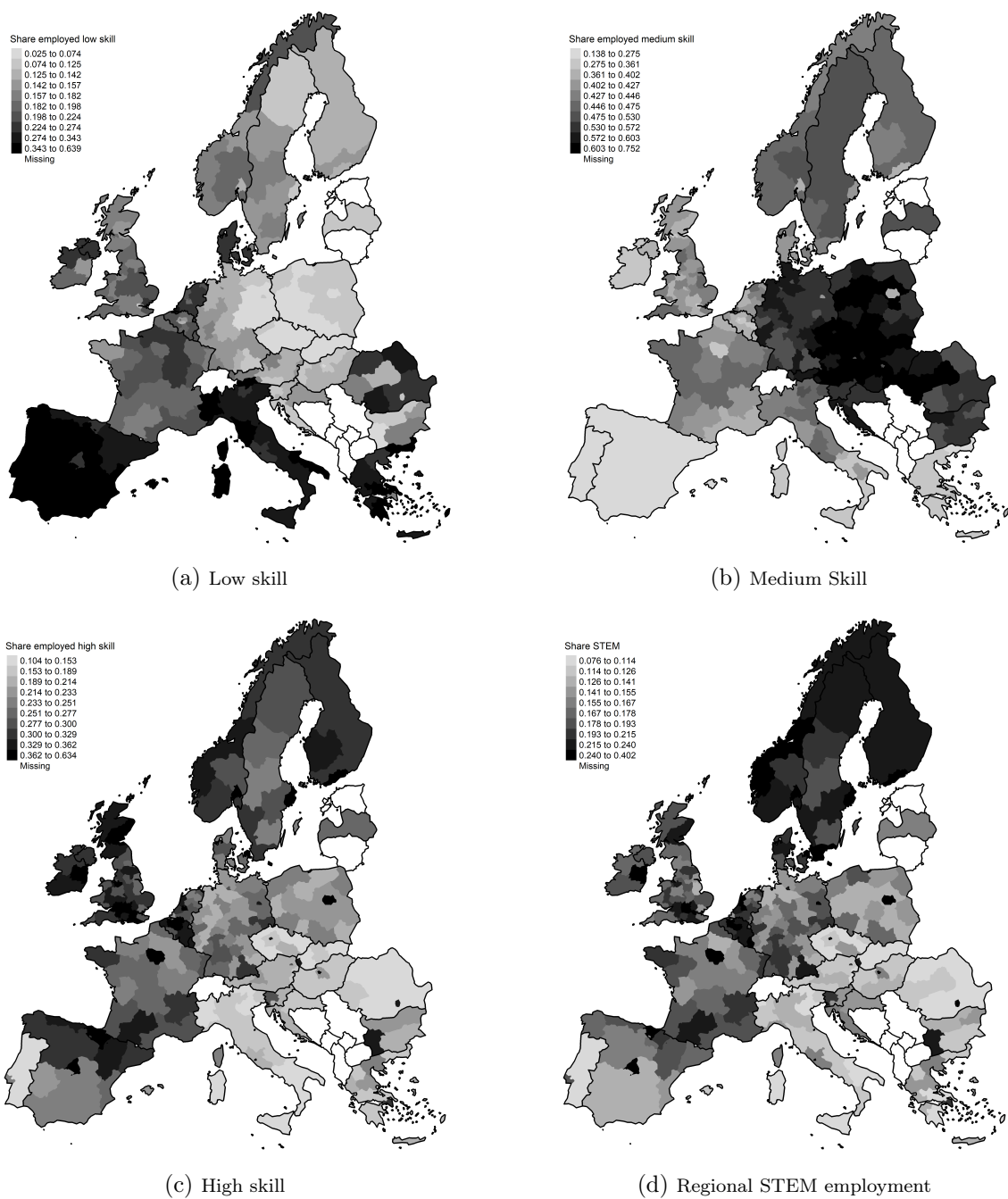
*Notes.* This table shows the descriptive statistics of the main variables used in the analysis.

Figure A2: Regional employment



*Notes.* These maps show the average outcomes inspected by NUTS2 regions in the EU. The average refers to the whole period, from 2003 to 2017. Deciles do the categorization of the variable. Average values are weighted by the share of the regional population over the EU one.

Figure A3: Regional employment by skill level



*Notes.* These maps show the average skill level and STEM employment by NUTS2 regions in the EU. The average refers to the whole period, from 2003 to 2017. Deciles do the categorization of the variable. Average values are weighted by the share of the regional population over the EU one.

## A.2 Green patents SSIV validation

Table A5: Top 5 Rotemberg weights of green patents SSIV

| NACE2    | Label                                                                                | Rotemberg weight | Emp. Share ( $t_0$ ) |
|----------|--------------------------------------------------------------------------------------|------------------|----------------------|
| 28       | Manufacture of machinery and equipment n.e.c.                                        | 0.301            | 0.111                |
| 27       | Manufacture of electrical equipment                                                  | 0.250            | 0.109                |
| 29       | Manufacture of motor vehicles                                                        | 0.091            | 0.090                |
| 20       | Manufacture of chemicals and chemical products                                       | 0.066            | 0.120                |
| 26       | Manufacture of computer, electronic and optical products                             | 0.063            | 0.129                |
| PRODCOM  | Label                                                                                |                  |                      |
| 28211354 | Electric furnaces and ovens (excluding induction- and resistance-heated)             |                  |                      |
| 28251431 | Machinery and apparatus for filtering and purifying gases                            |                  |                      |
| 28112150 | Steam turbines for electricity generation                                            |                  |                      |
| 27201100 | Primary cells and primary batteries                                                  |                  |                      |
| 27902060 | Light-emitting diodes (LEDs)                                                         |                  |                      |
| 27112680 | Photovoltaic AC generators                                                           |                  |                      |
| 29102450 | Motor vehicles, with only electric motor for propulsion                              |                  |                      |
| 29102430 | Motor vehicles, with hybrid propulsion                                               |                  |                      |
| 29104313 | Road tractors for semi-trailers with only electric motor for propulsion              |                  |                      |
| 20595997 | Biofuels (diesel substitute)                                                         |                  |                      |
| 26517015 | Electronic thermostats                                                               |                  |                      |
| 26515313 | Electronic gas or smoke analysers                                                    |                  |                      |
| 26516500 | Hydraulic or pneumatic automatic regulating or controlling instruments and apparatus |                  |                      |

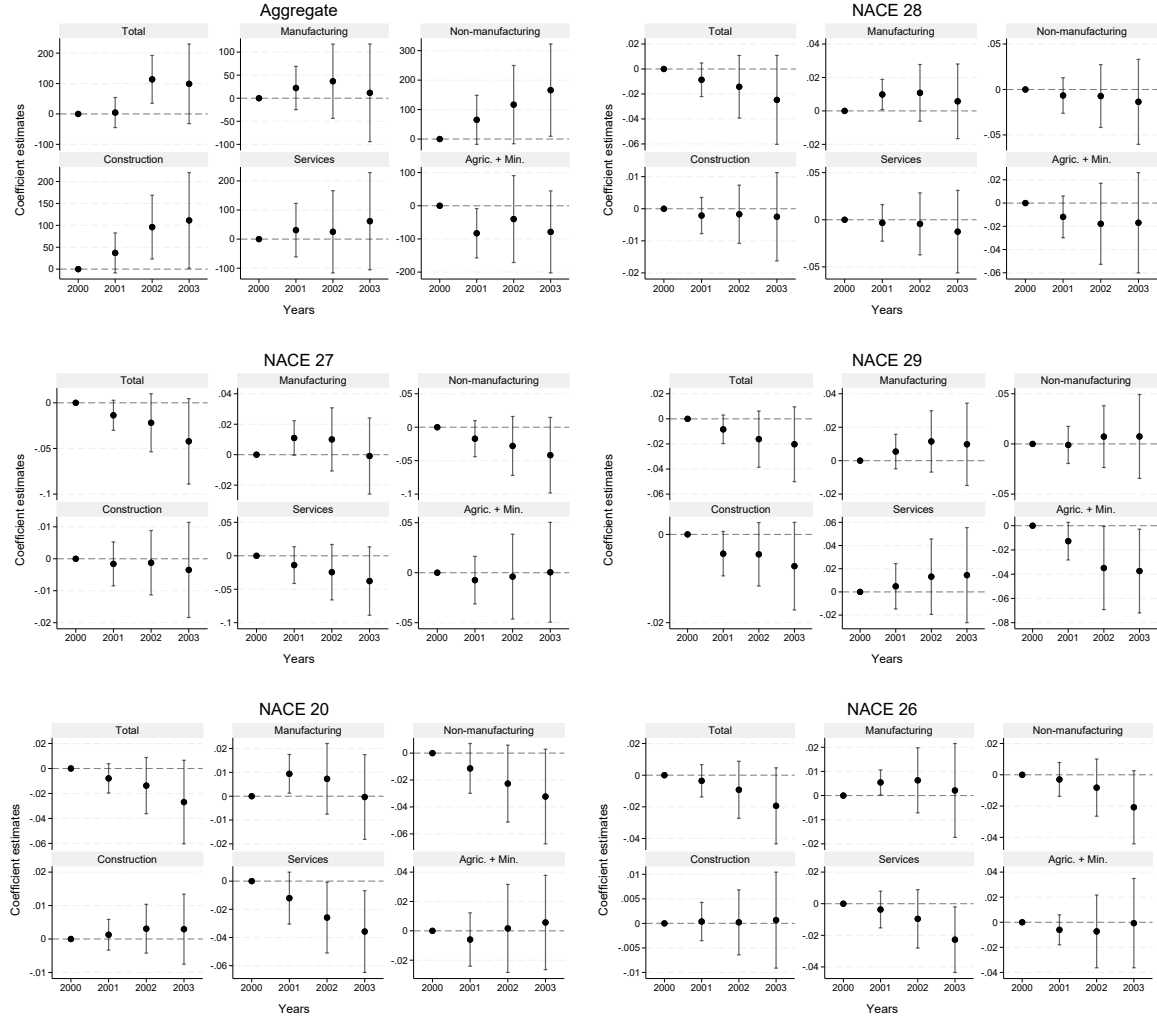
*Notes.* This table reports 2-digit manufacturing sectors with the highest five Rotemberg weights associated to the green patents-SSIV (Goldsmith-Pinkham et al., 2020). Further, it reports the baseline (avg. 2000-2003) employment share within manufacturing of these sectors. Lastly, it reports example of green goods that fall within these sectors.

Table A6: Correlation between green patents SSIV, industry employment shares and controls.

|                           | (1)<br>Green<br>patents | (2)<br>NACE 27        | (3)<br>NACE 26     | (4)<br>NACE 28        | (5)<br>NACE 29      | (6)<br>NACE 20      |
|---------------------------|-------------------------|-----------------------|--------------------|-----------------------|---------------------|---------------------|
| $Share\ emp\ manu_{r,t0}$ | 0.0001*<br>(0.0000)     | 0.7412***<br>(0.2843) | 0.1400<br>(0.5863) | 0.8849***<br>(0.2208) | 0.1467<br>(0.3236)  | 0.6075<br>(0.4454)  |
| $NGRP_{r,t0}$             | 0.0000***<br>(0.0000)   | -0.0019<br>(0.0024)   | 0.0017<br>(0.0071) | -0.0024<br>(0.0023)   | 0.0087*<br>(0.0046) | -0.0030<br>(0.0038) |
| Observations              | 254                     | 254                   | 254                | 254                   | 254                 | 254                 |
| Country FE                | ✓                       | ✓                     | ✓                  | ✓                     | ✓                   | ✓                   |

*Notes:* This table show the balance of the two main covariates for the pre-sample aggregate green patents-SSIV and each of the 2-digit manufacturing employment shares resulting to be within the top 5 Rotemberg weights. We include country fixed effects. Estimates are weighted by the share of regional population over the EU one, at baseline. Region clustered standard errors in parentheses. Number of regions: 254. Due to data availability in baseline employment shares, we exclude the following regions: BG31, BG32, BG33, BG34, BG41, BG42, CY00, HR03, HR04, IS00, LV00, MT00, RO11, RO12, RO21, RO22, RO31, RO32, RO41, RO42, SK01, SK02, SK03, SK04. \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

Figure A4: Parallel trends of the green patents SSIV by industry share



*Notes.* These figures assess the parallel trend assumption by regressing the green patents-SSIV and each top five Rotemberg weight employment share interacted with year fixed effects on outcomes in levels in the pre-sample period, that is from 2000 to 2003. The reference year is 2000. Regressions include employment share in manufacturing and non-green manufacturing penetration at baseline interacted with year fixed effects, as well as region and year fixed effects and country linear trends. We weight estimates by the share of regional population over the EU one.

Table A7: Green penetration on regional employment. Excluding sector 28

|                     | (1)                 | (2)                 | (3)                  | (4)                 | (5)                      | (6)                 |
|---------------------|---------------------|---------------------|----------------------|---------------------|--------------------------|---------------------|
| <i>Panel A:</i>     | <i>Total</i>        |                     | <i>Manufacturing</i> |                     | <i>Non-manufacturing</i> |                     |
| $\Delta GRP_{r,t3}$ | 0.044***<br>(0.010) | 0.418***<br>(0.111) | 0.008*<br>(0.005)    | 0.131***<br>(0.039) | 0.037***<br>(0.012)      | 0.301***<br>(0.088) |
| <i>Panel B:</i>     | <i>Construction</i> |                     | <i>Services</i>      |                     | <i>Agric. + Min.</i>     |                     |
| $\Delta GRP_{r,t3}$ | 0.016***<br>(0.004) | 0.147***<br>(0.038) | 0.022**<br>(0.011)   | 0.136**<br>(0.063)  | -0.002<br>(0.012)        | -0.014<br>(0.060)   |
| <i>N</i>            | 3336                | 3336                | 3336                 | 3336                | 3336                     | 3336                |
| <i>Estimator</i>    | OLS                 | 2SLS                | OLS                  | 2SLS                | OLS                      | 2SLS                |
| <i>FS coeff.</i>    |                     | 944.643***          |                      | 944.643***          |                          | 944.643***          |
| <i>KP F-Stat</i>    |                     | 19.2                |                      | 19.2                |                          | 19.2                |
| <i>CD F-Stat</i>    |                     | 38.3                |                      | 38.3                |                          | 38.3                |
| <i>Controls</i>     | ✓                   | ✓                   | ✓                    | ✓                   | ✓                        | ✓                   |
| <i>Country FE</i>   | ✓                   | ✓                   | ✓                    | ✓                   | ✓                        | ✓                   |
| <i>Year FE</i>      | ✓                   | ✓                   | ✓                    | ✓                   | ✓                        | ✓                   |

*Notes:* Dependent variables: the three-year change in regional employment over active population in: total; manufacturing; non-manufacturing (utilities, construction, services); construction; services; agriculture + mining. The endogenous variable,  $\Delta GRP_{r,t3}$ , refers to the change in the green penetration measure in region  $r$  between  $t$  and  $t-3$ . The instrumental variable refers to the shift-share instrumental variable related to green patents. Columns (1), (3) and (5) show OLS estimates, while columns (2), (4) and (6) show the ones related to the green patents instrument. Columns (2), (4) and (6) report the Kleibergen-Paap (KP) and the Cragg-Donald (CD) F statistic for weak identification, as well as the first stage coefficient. Controls include the share of employment in manufacturing and the regional non-green penetration, interacted with year fixed effects. All the controls are taken at baseline, that is their average value between 2000 and 2003. To assess possible violations of parallel trends as shown in Figure A4, we exclude NACE2 sector 28. We include country and year fixed effects. Estimates are weighted by the share of regional population over the EU one, at baseline. Region clustered standard errors in parentheses. Number of regions: 278. \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

Table A8: Green penetration on regional employment. Excluding sector 27

|                     | (1)                 | (2)                 | (3)                  | (4)               | (5)                      | (6)                |
|---------------------|---------------------|---------------------|----------------------|-------------------|--------------------------|--------------------|
| <i>Panel A:</i>     | <i>Total</i>        |                     | <i>Manufacturing</i> |                   | <i>Non-manufacturing</i> |                    |
| $\Delta GRP_{r,t3}$ | 0.028***<br>(0.007) | 0.239**<br>(0.098)  | 0.012***<br>(0.003)  | 0.063*<br>(0.035) | 0.019***<br>(0.007)      | 0.191**<br>(0.084) |
| <i>Panel B:</i>     | <i>Construction</i> |                     | <i>Services</i>      |                   | <i>Agric. + Min.</i>     |                    |
| $\Delta GRP_{r,t3}$ | 0.006***<br>(0.002) | 0.133***<br>(0.044) | 0.014**<br>(0.005)   | 0.030<br>(0.060)  | -0.002<br>(0.006)        | -0.016<br>(0.058)  |
| <i>N</i>            | 3336                | 3336                | 3336                 | 3336              | 3336                     | 3336               |
| Estimator           | OLS                 | 2SLS                | OLS                  | 2SLS              | OLS                      | 2SLS               |
| FS coeff.           |                     | 1193.462***         |                      | 1193.462***       |                          | 1193.462***        |
| KP F-Stat           |                     | 11.9                |                      | 11.9              |                          | 11.9               |
| CD F-Stat           |                     | 26.0                |                      | 26.0              |                          | 26.0               |
| Controls            | ✓                   | ✓                   | ✓                    | ✓                 | ✓                        | ✓                  |
| Country FE          | ✓                   | ✓                   | ✓                    | ✓                 | ✓                        | ✓                  |
| Year FE             | ✓                   | ✓                   | ✓                    | ✓                 | ✓                        | ✓                  |

*Notes:* Dependent variables: the three-year change in regional employment over active population in: total; manufacturing; non-manufacturing (utilities, construction, services); construction; services; agriculture + mining. The endogenous variable,  $\Delta GRP_{r,t3}$ , refers to the change in the green penetration measure in region  $r$  between  $t$  and  $t-3$ . The instrumental variable refers to the shift-share instrumental variable related to green patents. Columns (1), (3) and (5) show OLS estimates, while columns (2), (4) and (6) show the ones related to the green patents instrument. Columns (2), (4) and (6) report the Kleibergen-Paap (KP) and the Cragg-Donald (CD) F statistic for weak identification, as well as the first stage coefficient. Controls include the share of employment in manufacturing and the regional non-green penetration, interacted with year fixed effects. All the controls are taken at baseline, that is their average value between 2000 and 2003. To assess possible violations of parallel trends as shown in Figure A4, we exclude NACE2 sector 27. We include country and year fixed effects. Estimates are weighted by the share of regional population over the EU one, at baseline. Region clustered standard errors in parentheses. Number of regions: 278. \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

Table A9: Green penetration on regional employment. Excluding sector 29

|                     | (1)                 | (2)                 | (3)                  | (4)                 | (5)                      | (6)                 |
|---------------------|---------------------|---------------------|----------------------|---------------------|--------------------------|---------------------|
| <i>Panel A:</i>     | <i>Total</i>        |                     | <i>Manufacturing</i> |                     | <i>Non-manufacturing</i> |                     |
| $\Delta GRP_{r,t3}$ | 0.028***<br>(0.007) | 0.152***<br>(0.037) | 0.010***<br>(0.003)  | 0.056***<br>(0.015) | 0.022***<br>(0.008)      | 0.113***<br>(0.037) |
| <i>Panel B:</i>     | <i>Construction</i> |                     | <i>Services</i>      |                     | <i>Agric. + Min.</i>     |                     |
| $\Delta GRP_{r,t3}$ | 0.007***<br>(0.002) | 0.073***<br>(0.013) | 0.016**<br>(0.007)   | 0.029<br>(0.033)    | -0.004<br>(0.007)        | -0.017<br>(0.032)   |
| <i>N</i>            | 3336                | 3336                | 3336                 | 3336                | 3336                     | 3336                |
| Estimator           | OLS                 | 2SLS                | OLS                  | 2SLS                | OLS                      | 2SLS                |
| FS coeff.           |                     | 2009.240***         |                      | 2009.240***         |                          | 2009.240***         |
| KP F-Stat           |                     | 55.3                |                      | 55.3                |                          | 55.3                |
| CD F-Stat           |                     | 91.1                |                      | 91.1                |                          | 91.1                |
| Controls            | ✓                   | ✓                   | ✓                    | ✓                   | ✓                        | ✓                   |
| Country FE          | ✓                   | ✓                   | ✓                    | ✓                   | ✓                        | ✓                   |
| Year FE             | ✓                   | ✓                   | ✓                    | ✓                   | ✓                        | ✓                   |

*Notes:* Dependent variables: the three-year change in regional employment over active population in: total; manufacturing; non-manufacturing (utilities, construction, services); construction; services; agriculture + mining. The endogenous variable,  $\Delta GRP_{r,t3}$ , refers to the change in the green penetration measure in region  $r$  between  $t$  and  $t-3$ . The instrumental variable refers to the shift-share instrumental variable related to green patents. Columns (1), (3) and (5) show OLS estimates, while columns (2), (4) and (6) show the ones related to the green patents instrument. Columns (2), (4) and (6) report the Kleibergen-Paap (KP) and the Cragg-Donald (CD) F statistic for weak identification, as well as the first stage coefficient. Controls include the share of employment in manufacturing and the regional non-green penetration, interacted with year fixed effects. All the controls are taken at baseline, that is their average value between 2000 and 2003. To assess possible violations of parallel trends as shown in Figure A4, we exclude NACE2 sector 29. We include country and year fixed effects. Estimates are weighted by the share of regional population over the EU one, at baseline. Region clustered standard errors in parentheses. Number of regions: 278. \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

Table A10: Green penetration on regional employment. Excluding sector 20

|                     | (1)                 | (2)                 | (3)                  | (4)                 | (5)                      | (6)                 |
|---------------------|---------------------|---------------------|----------------------|---------------------|--------------------------|---------------------|
| <i>Panel A:</i>     | <i>Total</i>        |                     | <i>Manufacturing</i> |                     | <i>Non-manufacturing</i> |                     |
| $\Delta GRP_{r,t3}$ | 0.031***<br>(0.007) | 0.118***<br>(0.023) | 0.010***<br>(0.003)  | 0.042***<br>(0.011) | 0.023***<br>(0.008)      | 0.089***<br>(0.025) |
| <i>Panel B:</i>     | <i>Construction</i> |                     | <i>Services</i>      |                     | <i>Agric. + Min.</i>     |                     |
| $\Delta GRP_{r,t3}$ | 0.008***<br>(0.002) | 0.057***<br>(0.008) | 0.016**<br>(0.007)   | 0.023<br>(0.022)    | -0.003<br>(0.008)        | -0.013<br>(0.022)   |
| <i>N</i>            | 3336                | 3336                | 3336                 | 3336                | 3336                     | 3336                |
| Estimator           | OLS                 | 2SLS                | OLS                  | 2SLS                | OLS                      | 2SLS                |
| FS coeff.           |                     | 2225.323***         |                      | 2225.323***         |                          | 2225.323***         |
| KP F-Stat           |                     | 121.6               |                      | 121.6               |                          | 121.6               |
| CD F-Stat           |                     | 132.5               |                      | 132.5               |                          | 132.5               |
| Controls            | ✓                   | ✓                   | ✓                    | ✓                   | ✓                        | ✓                   |
| Country FE          | ✓                   | ✓                   | ✓                    | ✓                   | ✓                        | ✓                   |
| Year FE             | ✓                   | ✓                   | ✓                    | ✓                   | ✓                        | ✓                   |

*Notes:* Dependent variables: the three-year change in regional employment over active population in: total; manufacturing; non-manufacturing (utilities, construction, services); construction; services; agriculture + mining. The endogenous variable,  $\Delta GRP_{r,t3}$ , refers to the change in the green penetration measure in region  $r$  between  $t$  and  $t-3$ . The instrumental variable refers to the shift-share instrumental variable related to green patents. Columns (1), (3) and (5) show OLS estimates, while columns (2), (4) and (6) show the ones related to the green patents instrument. Columns (2), (4) and (6) report the Kleibergen-Paap (KP) and the Cragg-Donald (CD) F statistic for weak identification, as well as the first stage coefficient. Controls include the share of employment in manufacturing and the regional non-green penetration, interacted with year fixed effects. All the controls are taken at baseline, that is their average value between 2000 and 2003. To assess possible violations of parallel trends as shown in Figure A4, we exclude NACE2 sector 20. We include country and year fixed effects. Estimates are weighted by the share of regional population over the EU one, at baseline. Region clustered standard errors in parentheses. Number of regions: 278. \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

Table A11: Green penetration on regional employment. Excluding sector 26

|                     | (1)                 | (2)                 | (3)                  | (4)                 | (5)                      | (6)                 |
|---------------------|---------------------|---------------------|----------------------|---------------------|--------------------------|---------------------|
| <i>Panel A:</i>     | <i>Total</i>        |                     | <i>Manufacturing</i> |                     | <i>Non-manufacturing</i> |                     |
| $\Delta GRP_{r,t3}$ | 0.032***<br>(0.008) | 0.166***<br>(0.044) | 0.010***<br>(0.003)  | 0.040***<br>(0.015) | 0.027***<br>(0.009)      | 0.134***<br>(0.039) |
| <i>Panel B:</i>     | <i>Construction</i> |                     | <i>Services</i>      |                     | <i>Agric. + Min.</i>     |                     |
| $\Delta GRP_{r,t3}$ | 0.009***<br>(0.003) | 0.085***<br>(0.019) | 0.019***<br>(0.007)  | 0.043<br>(0.032)    | -0.005<br>(0.007)        | -0.008<br>(0.031)   |
| <i>N</i>            | 3336                | 3336                | 3336                 | 3336                | 3336                     | 3336                |
| Estimator           | OLS                 | 2SLS                | OLS                  | 2SLS                | OLS                      | 2SLS                |
| FS coeff.           |                     | 1735.026***         |                      | 1735.026***         |                          | 1735.026***         |
| KP F-Stat           |                     | 31.5                |                      | 31.5                |                          | 31.5                |
| CD F-Stat           |                     | 65.2                |                      | 65.2                |                          | 65.2                |
| Controls            | ✓                   | ✓                   | ✓                    | ✓                   | ✓                        | ✓                   |
| Country FE          | ✓                   | ✓                   | ✓                    | ✓                   | ✓                        | ✓                   |
| Year FE             | ✓                   | ✓                   | ✓                    | ✓                   | ✓                        | ✓                   |

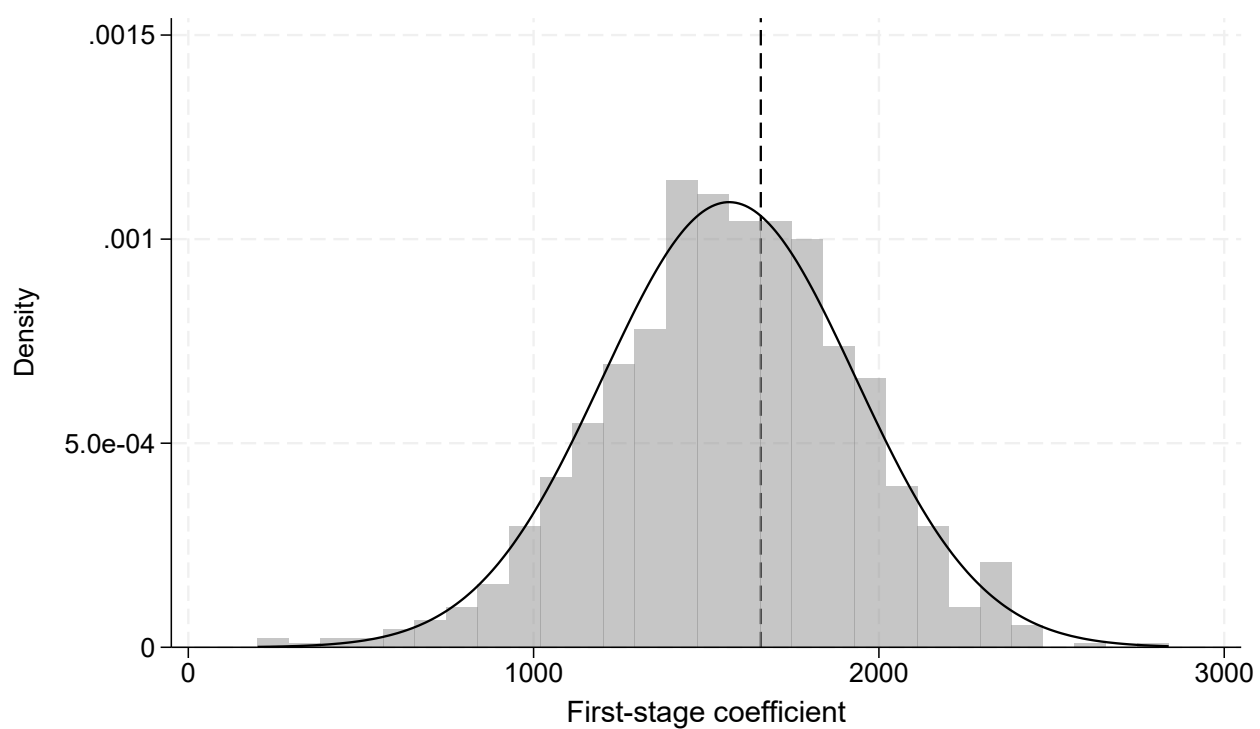
*Notes:* Dependent variables: the three-year change in regional employment over active population in: total; manufacturing; non-manufacturing (utilities, construction, services); construction; services; agriculture + mining. The endogenous variable,  $\Delta GRP_{r,t3}$ , refers to the change in the green penetration measure in region  $r$  between  $t$  and  $t-3$ . The instrumental variable refers to the shift-share instrumental variable related to green patents. Columns (1), (3) and (5) show OLS estimates, while columns (2), (4) and (6) show the ones related to the green patents instrument. Columns (2), (4) and (6) report the Kleibergen-Paap (KP) and the Cragg-Donald (CD) F statistic for weak identification, as well as the first stage coefficient. Controls include the share of employment in manufacturing and the regional non-green penetration, interacted with year fixed effects. All the controls are taken at baseline, that is their average value between 2000 and 2003. To assess possible violations of parallel trends as shown in Figure A4, we exclude NACE2 sector 26. We include country and year fixed effects. Estimates are weighted by the share of regional population over the EU one, at baseline. Region clustered standard errors in parentheses. Number of regions: 278. \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

Table A12: Lee et al. (2022) valid t-ratio inference

| <i>Panel A:</i> | <i>Total</i>        | <i>Manufacturing</i> | <i>Non-manufacturing</i> |
|-----------------|---------------------|----------------------|--------------------------|
| Coefficient     | 0.166               | 0.053                | 0.126                    |
| Unadj SE        | 0.028               | 0.012                | 0.046                    |
| 1% CV of  t     | 3.138               | 3.138                | 3.138                    |
| Adj SE          | 0.034               | 0.015                | 0.056                    |
| Adj UB          | 0.255               | 0.091                | 0.269                    |
| Adj LB          | 0.078               | 0.015                | -0.017                   |
| FS F-stat       | 80.909              | 80.909               | 80.909                   |
| <i>Panel B:</i> | <i>Construction</i> | <i>Services</i>      | <i>Agric. + Min.</i>     |
| Coefficient     | 0.076               | 0.039                | -0.013                   |
| Unadj SE        | 0.012               | 0.042                | 0.042                    |
| 1% CV of  t     | 3.138               | 3.138                | 3.138                    |
| Adj SE          | 0.015               | 0.051                | 0.052                    |
| Adj UB          | 0.115               | 0.171                | 0.12                     |
| Adj LB          | 0.038               | -0.093               | -0.146                   |
| FS F-stat       | 80.909              | 80.909               | 80.909                   |

*Notes:* This table applies the methodology from Lee et al. (2022) to estimate valid t-ratio inference for instrumental variables. The estimates the command works on are even columns of Table 1.

Figure A5: Distribution of the first stage's coefficients. Monte Carlo simulation.



*Notes.* This figure shows the distribution of the coefficient of the first stage drawn from 1000 different subsamples. The vertical dashed black line correspond to the first-stage coefficient of Table 1.

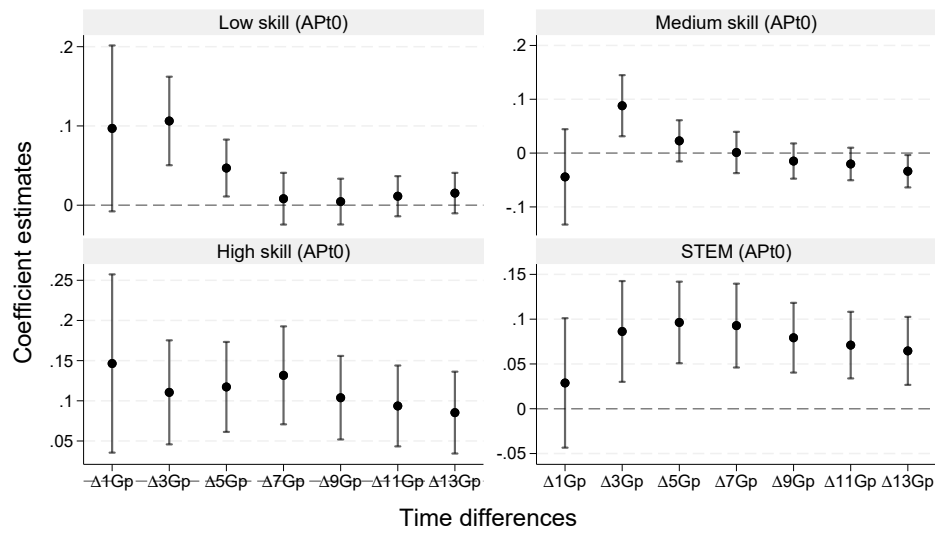
### A.3 Additional specifications

Table A13: Green penetration on regional employment by skill level and STEM employment.

|                     | (1)                 | (2)                 | (3)                | (4)                |
|---------------------|---------------------|---------------------|--------------------|--------------------|
| <i>Panel A:</i>     | <i>Low skill</i>    | <i>Medium skill</i> | <i>High skill</i>  | <i>STEM</i>        |
| $\Delta GRP_{r,t3}$ | 0.057***<br>(0.019) | 0.036<br>(0.029)    | 0.048**<br>(0.021) | 0.045**<br>(0.019) |
| <i>N</i>            | 3336                | 3336                | 3336               | 3336               |
| Estimator           | 2SLS                | 2SLS                | 2SLS               | 2SLS               |
| FS coeff.           | 1658.106***         | 1658.106***         | 1658.106***        | 1658.106***        |
| KP F-Stat           | 53.4                | 53.4                | 53.4               | 53.4               |
| CD F-Stat           | 79.4                | 79.4                | 79.4               | 79.4               |
| Controls            | ✓                   | ✓                   | ✓                  | ✓                  |
| Country FE          | ✓                   | ✓                   | ✓                  | ✓                  |
| Year FE             | ✓                   | ✓                   | ✓                  | ✓                  |

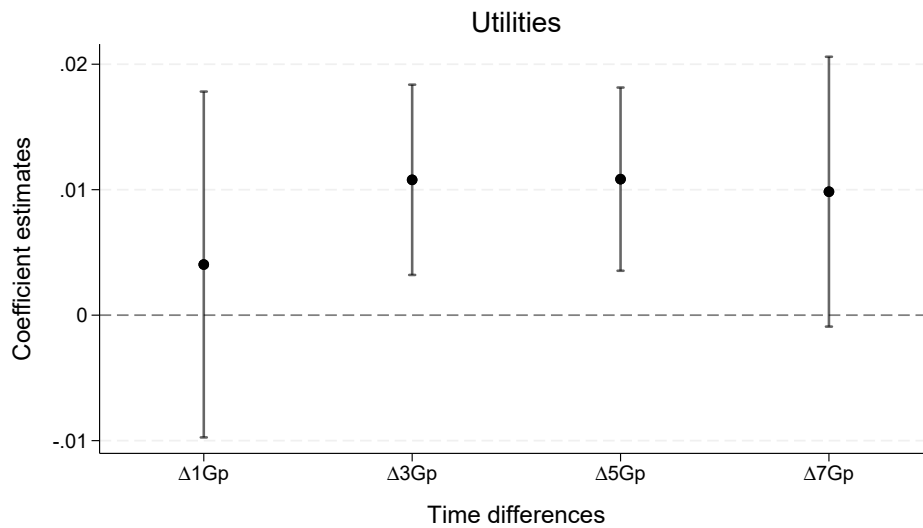
*Notes:* Dependent variables: the three-year change in regional employment over active population by low, medium and high skill and employment in STEM. Employment with low-skill is given by employed people with less than primary, primary and lower secondary education. Employment with medium-skill is given by employed people with upper secondary and post-secondary non-tertiary education. Lastly, employment with high-skill is given by employed people with tertiary education. STEM employment is given by people with tertiary education and employed in science and technology. The endogenous variable,  $\Delta GRP_{r,t3}$ , refers to the change in the green penetration measure in region  $r$  between  $t$  and  $t-3$ . The instrumental variable refers to the shift-share instrumental variable related to green patents. All columns show estimates related to the green patents instrument. All columns report the Kleibergen-Paap (KP) and the Cragg-Donald (CD) F statistic for weak identification, as well as the first stage coefficient. Controls include the share of employment in manufacturing and the regional non-green penetration measure, interacted with year fixed effects. All the controls are taken at baseline, that is their average value between 2000 and 2003. We include country and year fixed effects. Estimates are weighted by the share of regional population over the EU one, at baseline. Region clustered standard errors in parentheses. Number of regions: 278. \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

Figure A6: 2SLS estimates of green regional penetration on regional skill level. Green patents SSIV. Longer time horizon and fixed active population.



*Notes.* These graphs replicate and extend the 2SLS estimation based on Equation 3, including additional the interaction with the regional skill level, and on Equation 4 by looking at one-, two-, three-, five-, seven-, nine-, eleven- and thirteen-year changes. In all graphs active population is kept fixed at baseline (avg. 2000-2003). KP F-Stats: 11.0; 53.4; 140.3; 160.7; 129.7; 176.0; 232.5. CD F-stats: 14.9; 79.4; 174.8; 191.8; 324.3; 333.9; 234.2.

Figure A7: 2SLS estimates of green penetration on regional employment. Green patents SSIV. Utilities employment. Other time differences.



*Notes.* These graphs replicate and extend the 2SLS estimation based on Equation 3 and on Equation 4 by looking at three-, five- and seven-year changes. Results report estimates related to utilities employment. KP F-stats: 11.0 53.4 140.3 160.7 – CD F-stats: 14.9 79.4 174.8 191.8.

Table A14: Green penetration on regional employment. Extended controls.

|                     | (1)                 | (2)                 | (3)                  | (4)                 | (5)                      | (6)                 |
|---------------------|---------------------|---------------------|----------------------|---------------------|--------------------------|---------------------|
| <i>Panel A:</i>     | <i>Total</i>        |                     | <i>Manufacturing</i> |                     | <i>Non-manufacturing</i> |                     |
| $\Delta GRP_{r,t3}$ | 0.029***<br>(0.007) | 0.205***<br>(0.040) | 0.010***<br>(0.003)  | 0.051***<br>(0.014) | 0.023***<br>(0.008)      | 0.149***<br>(0.041) |
| <i>Panel B:</i>     | <i>Construction</i> |                     | <i>Services</i>      |                     | <i>Agric. + Min.</i>     |                     |
| $\Delta GRP_{r,t3}$ | 0.007***<br>(0.002) | 0.081***<br>(0.015) | 0.016**<br>(0.007)   | 0.059<br>(0.036)    | -0.003<br>(0.007)        | 0.005<br>(0.036)    |
| <i>N</i>            | 3336                | 3336                | 3336                 | 3336                | 3336                     | 3336                |
| Estimator           | OLS                 | 2SLS                | OLS                  | 2SLS                | OLS                      | 2SLS                |
| FS coeff.           |                     | 1611.003***         |                      | 1611.003***         |                          | 1611.003***         |
| KP F-Stat           |                     | 49.7                |                      | 49.7                |                          | 49.7                |
| CD F-Stat           |                     | 71.7                |                      | 71.7                |                          | 71.7                |
| Controls            | ✓                   | ✓                   | ✓                    | ✓                   | ✓                        | ✓                   |
| Country FE          | ✓                   | ✓                   | ✓                    | ✓                   | ✓                        | ✓                   |
| Year FE             | ✓                   | ✓                   | ✓                    | ✓                   | ✓                        | ✓                   |

*Notes:* Dependent variables: the three-year change in regional employment over active population in: total; manufacturing; non-manufacturing (utilities, construction, services); construction; services; agriculture + mining. The endogenous variable,  $\Delta GRP_{r,t3}$ , refers to the change in the green penetration measure in region  $r$  between  $t$  and  $t-3$ . The instrumental variable refers to the shift-share instrumental variable related to green patents. Columns (1), (3) and (5) show OLS estimates, while columns (2), (4) and (6) show the ones related to the green patents instrument. Columns (2), (4) and (6) report the Kleibergen-Paap (KP) and the Cragg-Donald (CD) F statistic for weak identification, as well as the first stage coefficient. Controls include population density, median age, share of female population, share of foreign population, share of employed people with secondary education, share of employed people with tertiary education, share of employment in manufacturing and the regional non-green penetration. The share of employment in manufacturing and the regional non-green penetration are interacted with year fixed effects. All the controls are taken at baseline, that is their average value between 2000 and 2003. We include country and year fixed effects. Estimates are weighted by the share of regional population over the EU one, at baseline. Region clustered standard errors in parentheses. Number of regions: 270. \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

Table A15: Green penetration on regional employment. NUTS1 and NUTS2 fixed effects

|                     | (1)                 | (2)                 | (3)                  | (4)                | (5)                      | (6)                 |
|---------------------|---------------------|---------------------|----------------------|--------------------|--------------------------|---------------------|
| <i>Panel A:</i>     | <i>Total</i>        |                     | <i>Manufacturing</i> |                    | <i>Non-manufacturing</i> |                     |
| $\Delta GRP_{r,t3}$ | 0.353***<br>(0.091) | 0.459***<br>(0.148) | 0.059***<br>(0.022)  | 0.069**<br>(0.031) | 0.259***<br>(0.073)      | 0.339***<br>(0.114) |
| <i>Panel B:</i>     | <i>Construction</i> |                     | <i>Services</i>      |                    | <i>Agric. + Min.</i>     |                     |
| $\Delta GRP_{r,t3}$ | 0.131***<br>(0.033) | 0.172***<br>(0.055) | 0.114**<br>(0.053)   | 0.150**<br>(0.073) | 0.035<br>(0.055)         | 0.051<br>(0.072)    |
| <i>N</i>            | 3336                | 3336                | 3336                 | 3336               | 3336                     | 3336                |
| <i>Estimator</i>    | 2SLS                | 2SLS                | 2SLS                 | 2SLS               | 2SLS                     | 2SLS                |
| <i>KP F-Stat</i>    | 17.9                | 10.6                | 17.9                 | 10.6               | 17.9                     | 10.6                |
| <i>CD F-Stat</i>    | 34.3                | 24.2                | 34.3                 | 24.2               | 34.3                     | 24.2                |
| <i>Controls</i>     | ✓                   | ✓                   | ✓                    | ✓                  | ✓                        | ✓                   |
| <i>NUTS1 FE</i>     | ✓                   |                     | ✓                    |                    | ✓                        |                     |
| <i>NUTS2 FE</i>     |                     | ✓                   |                      | ✓                  |                          | ✓                   |
| <i>Year FE</i>      | ✓                   | ✓                   | ✓                    | ✓                  | ✓                        | ✓                   |

*Notes:* Dependent variables: the three-year change in regional employment over active population in: total; manufacturing; non-manufacturing (utilities, construction, services); construction; services; agriculture + mining. The endogenous variable,  $\Delta GRP_{r,t3}$ , refers to the change in the green penetration measure in region  $r$  between  $t$  and  $t-3$ . The instrumental variable refers to the shift-share instrumental variable related to green patents. Columns (1), (3) and (5) show 2SLS estimates related to the green patents instrument including NUTS 1 and year fixed effects, while columns (2), (4) and (6) show the ones related to the green patents instrument including NUTS 2 and year fixed effects. All columns report the Kleibergen-Paap (KP) and the Cragg-Donald (CD) F statistic for weak identification. Controls include the share of employment in manufacturing and the regional non-green penetration, interacted with year fixed effects. All the controls are taken at baseline, that is their average value between 2000 and 2003. Estimates are weighted by the share of regional population over the EU one, at baseline. Region clustered standard errors in parentheses. Number of regions: 278. \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

Table A16: Green penetration on regional employment. Automation controls

|                                    | (1)                 | (2)                  | (3)                  | (4)                  | (5)                      | (6)                 |
|------------------------------------|---------------------|----------------------|----------------------|----------------------|--------------------------|---------------------|
| <i>Panel A:</i>                    | <i>Total</i>        |                      | <i>Manufacturing</i> |                      | <i>Non-manufacturing</i> |                     |
| $\Delta GRP_{r,t3}$                | 0.041***<br>(0.007) | 0.149***<br>(0.048)  | 0.019***<br>(0.003)  | 0.063***<br>(0.021)  | 0.034***<br>(0.008)      | 0.134***<br>(0.044) |
| $\Delta Robot\ penetration_{r,t3}$ | -0.009**<br>(0.004) | -0.016***<br>(0.005) | -0.005**<br>(0.002)  | -0.009***<br>(0.003) | 0.000<br>(0.003)         | -0.007<br>(0.005)   |
| <i>Panel B:</i>                    | <i>Construction</i> |                      | <i>Services</i>      |                      | <i>Agric. + Min.</i>     |                     |
| $\Delta GRP_{r,t3}$                | 0.010***<br>(0.003) | 0.086***<br>(0.023)  | 0.025***<br>(0.006)  | 0.024<br>(0.032)     | -0.012**<br>(0.006)      | -0.049<br>(0.029)   |
| $\Delta Robot\ penetration_{r,t3}$ | 0.001<br>(0.001)    | -0.004*<br>(0.002)   | -0.001<br>(0.003)    | -0.001<br>(0.003)    | -0.004*<br>(0.002)       | -0.001<br>(0.003)   |
| <i>N</i>                           | 2173                | 2173                 | 2173                 | 2173                 | 2173                     | 2173                |
| Estimator                          | OLS                 | 2SLS                 | OLS                  | 2SLS                 | OLS                      | 2SLS                |
| FS coeff.                          |                     | 1207.878***          |                      | 1207.878***          |                          | 1207.878***         |
| KP F-Stat                          |                     | 21.6                 |                      | 21.6                 |                          | 21.6                |
| CD F-Stat                          |                     | 39.3                 |                      | 39.3                 |                          | 39.3                |
| Controls                           | ✓                   | ✓                    | ✓                    | ✓                    | ✓                        | ✓                   |
| Country FE                         | ✓                   | ✓                    | ✓                    | ✓                    | ✓                        | ✓                   |
| Year FE                            | ✓                   | ✓                    | ✓                    | ✓                    | ✓                        | ✓                   |

*Notes:* Dependent variables: the three-year change in regional employment over active population in: total; manufacturing; non-manufacturing (utilities, construction, services); construction; services; agriculture + mining. The endogenous variable,  $\Delta GRP_{r,t3}$ , refers to the change in the green penetration measure in region  $r$  between  $t$  and  $t-3$ . The instrumental variable refers to the shift-share instrumental variable related to green patents. Columns (1), (3) and (5) show OLS estimates, while columns (2), (4) and (6) show the ones related to the green patents instrument. Columns (2), (4) and (6) report the Kleibergen-Paap (KP) and the Cragg-Donald (CD) F statistic for weak identification, as well as the first stage coefficient. Controls include share of employment in manufacturing and the regional non-green penetration, interacted with year fixed effects. The additional control is the 3 years change in regional automation exposure. Besides this last one, all the controls are taken at baseline, that is their average value between 2000 and 2003. We include country and year fixed effects. Estimates are weighted by the share of regional population over the EU one, at baseline. Region clustered standard errors in parentheses. Number of regions: 207. \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

Table A17: Green penetration on regional employment. Balanced sample by automation data

|                     | (1)                 | (2)                 | (3)                  | (4)                 | (5)                      | (6)                 |
|---------------------|---------------------|---------------------|----------------------|---------------------|--------------------------|---------------------|
| <i>Panel A:</i>     | <i>Total</i>        |                     | <i>Manufacturing</i> |                     | <i>Non-manufacturing</i> |                     |
| $\Delta GRP_{r,t3}$ | 0.043***<br>(0.008) | 0.162***<br>(0.037) | 0.018***<br>(0.003)  | 0.057***<br>(0.015) | 0.043***<br>(0.010)      | 0.140***<br>(0.033) |
| <i>Panel B:</i>     | <i>Construction</i> |                     | <i>Services</i>      |                     | <i>Agric. + Min.</i>     |                     |
| $\Delta GRP_{r,t3}$ | 0.011***<br>(0.003) | 0.071***<br>(0.013) | 0.034***<br>(0.008)  | 0.056**<br>(0.025)  | -0.019**<br>(0.008)      | -0.035<br>(0.021)   |
| <i>N</i>            | 2484                | 2484                | 2484                 | 2484                | 2484                     | 2484                |
| Estimator           | OLS                 | 2SLS                | OLS                  | 2SLS                | OLS                      | 2SLS                |
| FS coeff.           |                     | 1708.035***         |                      | 1708.035***         |                          | 1708.035***         |
| KP F-Stat           |                     | 56.1                |                      | 56.1                |                          | 56.1                |
| CD F-Stat           |                     | 99.3                |                      | 99.3                |                          | 99.3                |
| Controls            | ✓                   | ✓                   | ✓                    | ✓                   | ✓                        | ✓                   |
| Country FE          | ✓                   | ✓                   | ✓                    | ✓                   | ✓                        | ✓                   |
| Year FE             | ✓                   | ✓                   | ✓                    | ✓                   | ✓                        | ✓                   |

*Notes:* Dependent variables: the three-year change in regional employment over active population in: total; manufacturing; non-manufacturing (utilities, construction, services); construction; services; agriculture + mining. The endogenous variable,  $\Delta GRP_{r,t3}$ , refers to the change in the green penetration measure in region  $r$  between  $t$  and  $t-3$ . The instrumental variable refers to the shift-share instrumental variable related to green patents. Columns (1), (3) and (5) show OLS estimates, while columns (2), (4) and (6) show the ones related to the green patents instrument. Columns (2), (4) and (6) report the Kleibergen-Paap (KP) and the Cragg-Donald (CD) F statistic for weak identification, as well as the first stage coefficient. Controls include the share of employment in manufacturing and the regional non-green penetration, interacted with year fixed effects. All the controls are taken at baseline, that is their average value between 2000 and 2003. We include country and year fixed effects. Estimates are weighted by the share of regional population over the EU one, at baseline. The sample is restricted depending on availability of automation data at the regional level. Region clustered standard errors in parentheses. Number of regions: 207. \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

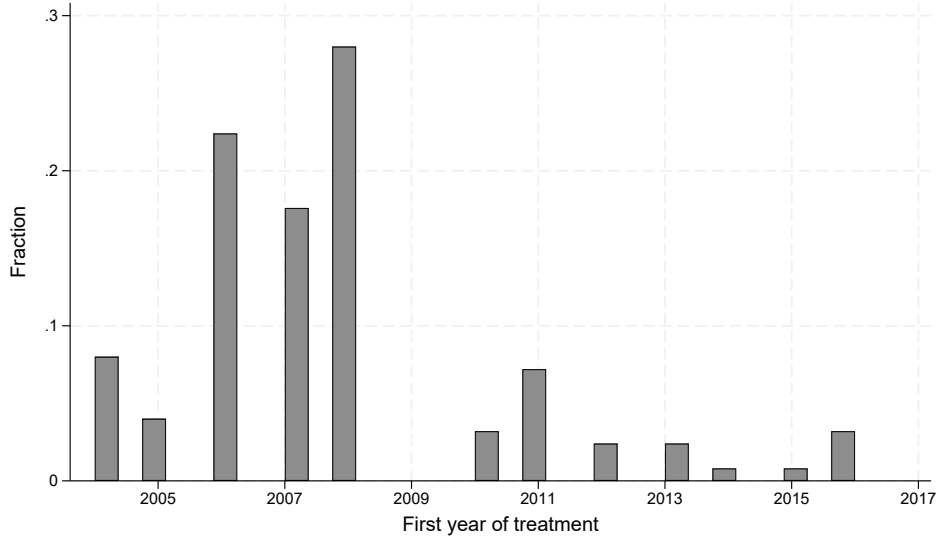
Table A18: Green penetration on regional employment. NUTS 1 clustered standard errors

|                     | (1)                 | (2)                 | (3)                  | (4)                 | (5)                      | (6)                |
|---------------------|---------------------|---------------------|----------------------|---------------------|--------------------------|--------------------|
| <i>Panel A:</i>     | <i>Total</i>        |                     | <i>Manufacturing</i> |                     | <i>Non-manufacturing</i> |                    |
| $\Delta GRP_{r,t3}$ | 0.028***<br>(0.010) | 0.166***<br>(0.053) | 0.010***<br>(0.004)  | 0.053***<br>(0.019) | 0.022**<br>(0.011)       | 0.126**<br>(0.052) |
| <i>Panel B:</i>     | <i>Construction</i> |                     | <i>Services</i>      |                     | <i>Agric. + Min.</i>     |                    |
| $\Delta GRP_{r,t3}$ | 0.007**<br>(0.003)  | 0.076***<br>(0.019) | 0.016*<br>(0.009)    | 0.039<br>(0.040)    | -0.004<br>(0.009)        | -0.013<br>(0.037)  |
| <i>N</i>            | 3336                | 3336                | 3336                 | 3336                | 3336                     | 3336               |
| Estimator           | OLS                 | 2SLS                | OLS                  | 2SLS                | OLS                      | 2SLS               |
| FS coeff.           |                     | 1658.106***         |                      | 1658.106***         |                          | 1658.106***        |
| KP F-Stat           |                     | 38.3                |                      | 38.3                |                          | 38.3               |
| CD F-Stat           |                     | 79.4                |                      | 79.4                |                          | 79.4               |
| Controls            | ✓                   | ✓                   | ✓                    | ✓                   | ✓                        | ✓                  |
| Country FE          | ✓                   | ✓                   | ✓                    | ✓                   | ✓                        | ✓                  |
| Year FE             | ✓                   | ✓                   | ✓                    | ✓                   | ✓                        | ✓                  |

*Notes:* Dependent variables: the three-year change in regional employment over active population in: total; manufacturing; non-manufacturing (utilities, construction, services); construction; services; agriculture + mining. The endogenous variable,  $\Delta GRP_{r,t3}$ , refers to the change in the green penetration measure in region  $r$  between  $t$  and  $t-3$ . The instrumental variable refers to the shift-share instrumental variable related to green patents. Columns (1), (3) and (5) show OLS estimates, while columns (2), (4) and (6) show the ones related to the green patents instrument. Columns (2), (4) and (6) report the Kleibergen-Paap (KP) and the Cragg-Donald (CD) F statistic for weak identification, as well as the first stage coefficient. Controls include the share of employment in manufacturing and the regional non-green penetration, interacted with year fixed effects. All the controls are taken at baseline, that is their average value between 2000 and 2003. We include country and year fixed effects. Estimates are weighted by the share of regional population over the EU one, at baseline. NUTS 1 clustered standard errors in parentheses. Number of regions: 278. Number of NUTS1: 100. \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

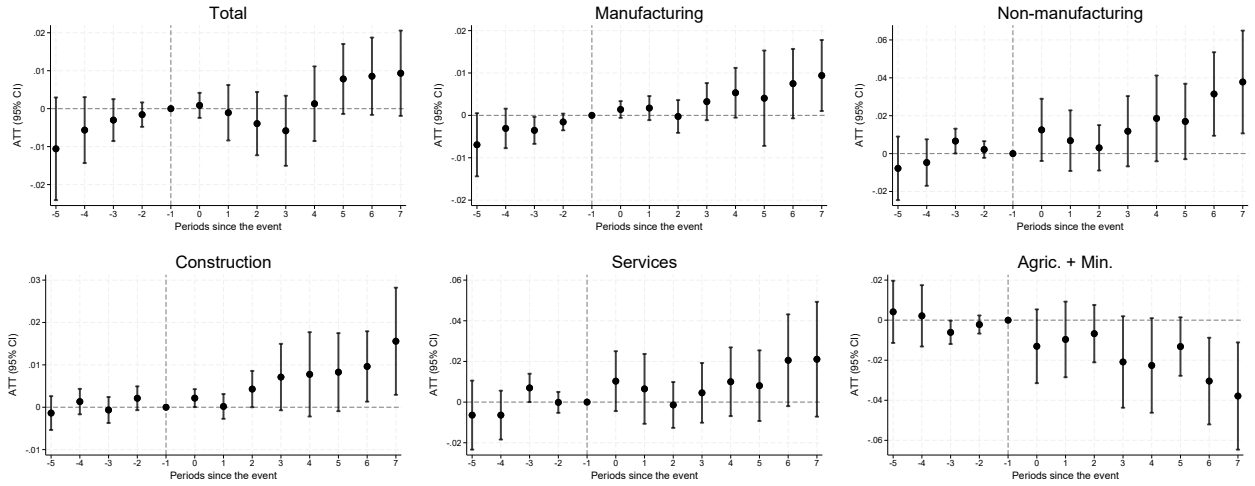
## A.4 Large shocks staggered DiD

Figure A8: Large shocks to green regional penetration - first year of treatment



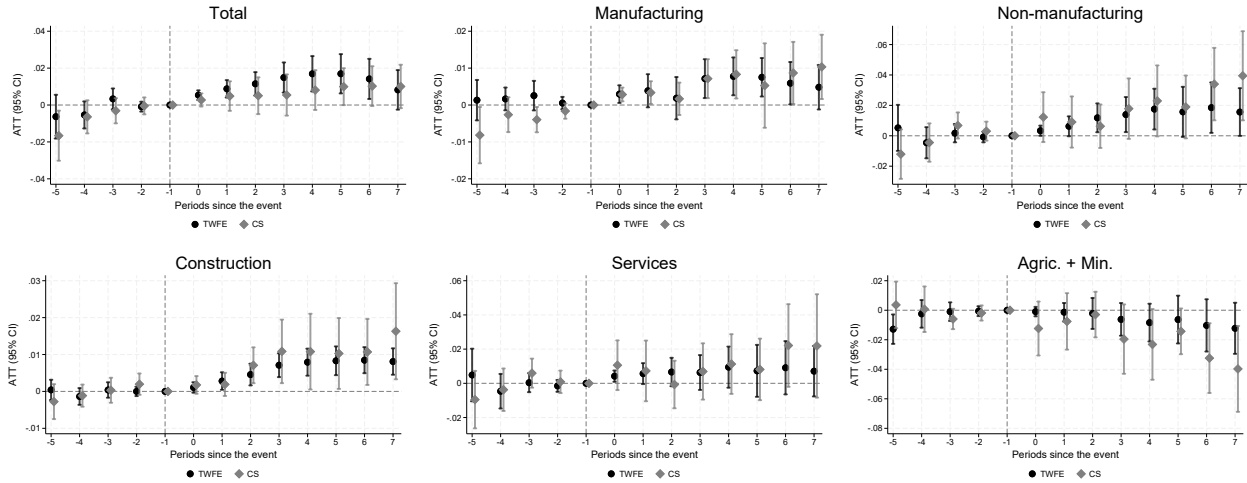
*Notes.* This figure shows the fraction of municipalities that are treated over the total number by year.

Figure A9: Large shocks to green manufacturing penetration. Event study estimates. Not-yet treated control group.



*Notes.* These plots show the results of the event study specification for several outcomes employing the regression adjustment estimator from Callaway and Sant'Anna (2021). The positive spike in green regional penetration is defined as a change higher than the 90<sup>th</sup> percentile in the one-year change of green regional penetration. The first spike identifies the beginning of treatment. Standard errors are clustered at the NUTS2 level. Not-yet-treated regions compose the control group.

Figure A10: Large shocks to green manufacturing penetration. Event study estimates. TWFE and CS.



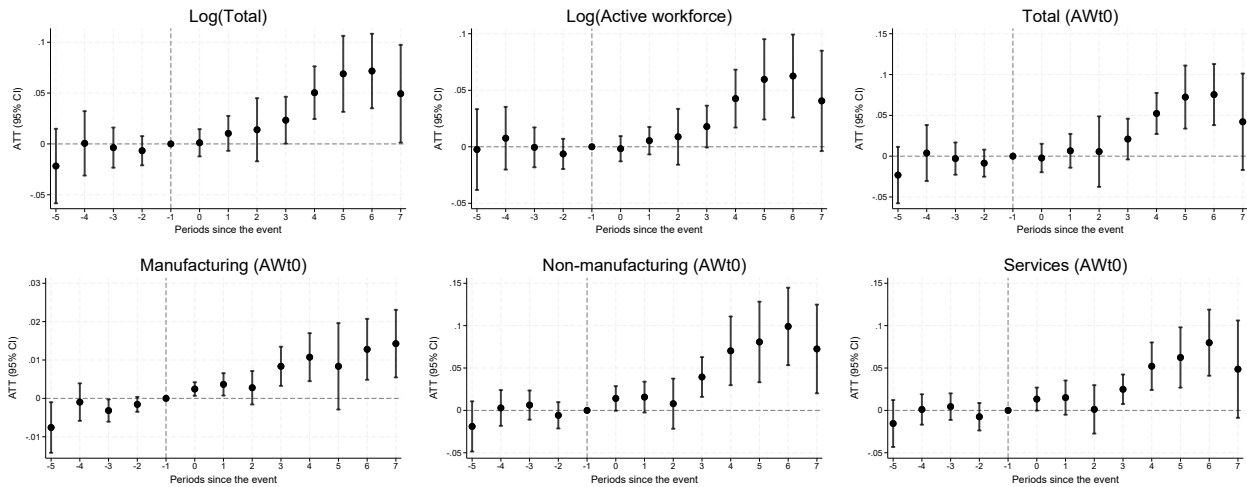
*Notes.* These plots show the results of the event study specification for several outcomes employing both a two-way fixed effects estimator and the regression adjustment one from Callaway and Sant'Anna (2021). The positive spike in green regional penetration is defined as a change higher than the 90<sup>th</sup> percentile in the one-year change of green regional penetration. The first spike identifies the beginning of treatment. Standard errors are clustered at the NUTS2 level.

Table A19: Positive and negative weights from the TWFE regression

|                  | N ATTs | Sum of weights |
|------------------|--------|----------------|
| Positive Weights | 1141   | 1.0614         |
| Negative Weights | 135    | -.0614         |
| Total            | 1276   | 1              |

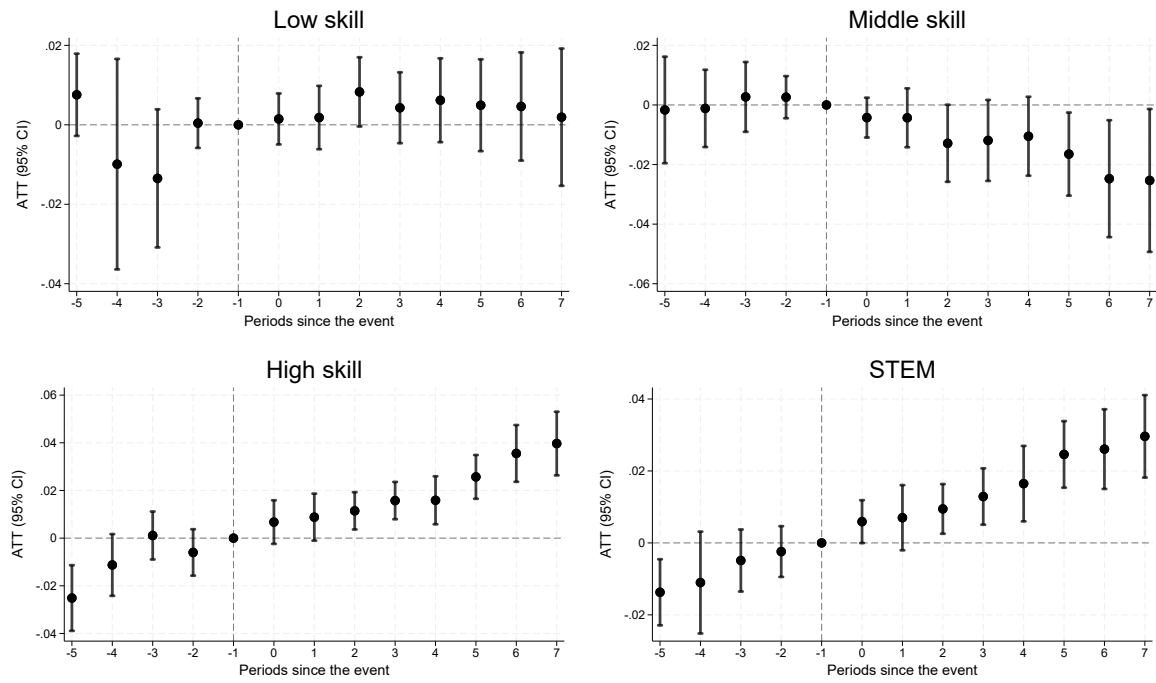
*Notes.* This table shows the weights attached to the two-way fixed effects regressions computed as in De Chaisemartin and d'Haultfoeuille (2020).

Figure A11: Large shocks to green manufacturing penetration. Event study estimates. Agglomeration effects.



*Notes.* These plots show the results of the event study specification for several outcomes employing the regression adjustment estimator from Callaway and Sant'Anna (2021). The positive spike in green regional penetration is defined as a change higher than the 90<sup>th</sup> percentile in the one-year change of green regional penetration. The first spike identifies the beginning of treatment. Standard errors are clustered at the NUTS2 level.

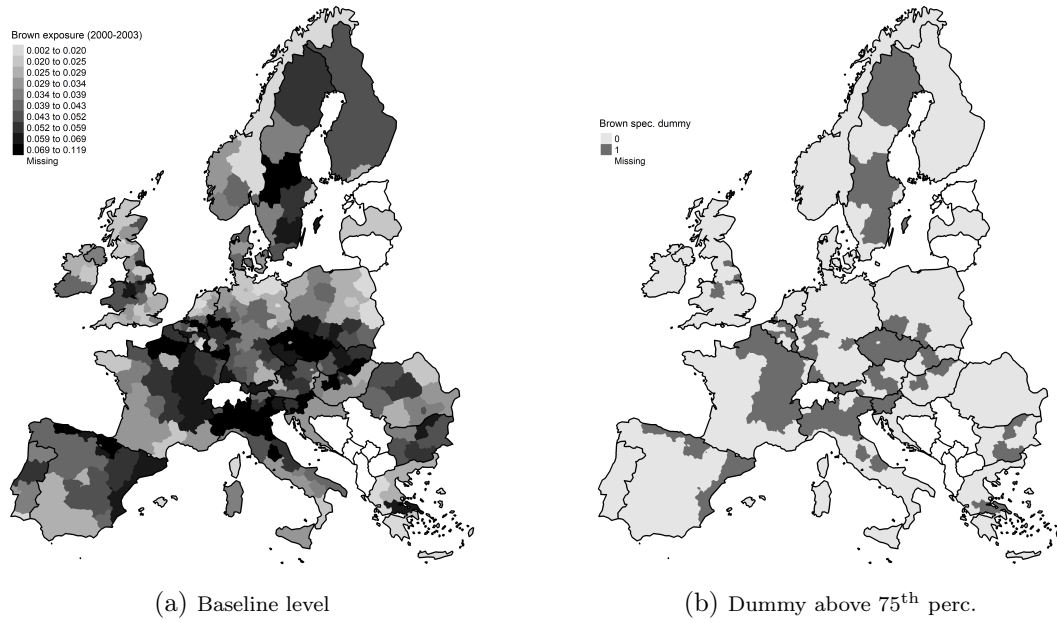
Figure A12: Large shocks to green manufacturing penetration. Event study estimates. Skill-biased employment.



*Notes.* These plots show the results of the event study specification for several outcomes employing the regression adjustment estimator from Callaway and Sant'Anna (2021). The positive spike in green regional penetration is defined as a change higher than the 90<sup>th</sup> percentile in the one-year change of green regional penetration. The first spike identifies the beginning of treatment. Standard errors are clustered at the NUTS2 level.

## A.5 Brown specialization

Figure A13: Baseline brown exposure by NUTS2 region and dummy that identifies specialization



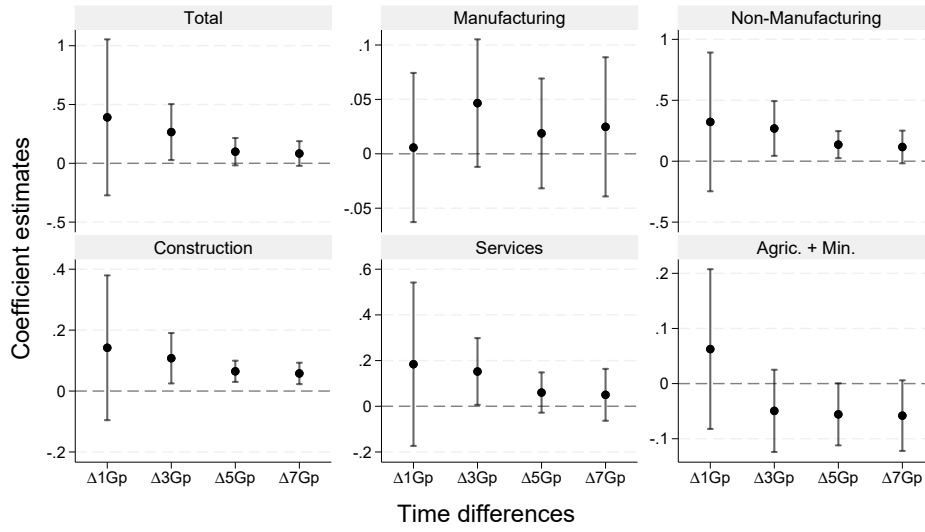
*Notes.* These maps show the baseline brown exposure (panel (a)) and a dummy that identifies values higher than the 75<sup>th</sup> percentile (panel (b)) by NUTS2 regions in the EU. Panel (a) levels correspond to deciles, and are weighted by the share of the regional population over the EU one.

Table A20: Balance table by baseline specialization in brown exposure.

| Variable                                           | Not-BP75               | BP75                  | Diff. (BP75-NBP75)      |
|----------------------------------------------------|------------------------|-----------------------|-------------------------|
| Total employment over active pop.                  | 0.909<br>(0.0543)      | 0.914<br>(0.0462)     | 0.0041<br>(0.0077)      |
| Non-manufacturing employment over active pop.      | 0.694<br>(0.1330)      | 0.673<br>(0.0632)     | -0.0214<br>(0.0131)     |
| Population density (t0)                            | 493.477<br>(1078.0203) | 312.031<br>(422.9457) | -181.4457*<br>(99.5077) |
| Median age (t0)                                    | 38.516<br>(2.7258)     | 39.358<br>(2.3669)    | 0.8414*<br>(0.4711)     |
| Share of female population (t0)                    | 0.518<br>(0.0090)      | 0.517<br>(0.0061)     | -0.0009<br>(0.0010)     |
| Share of foreign-born population (t0)              | 0.044<br>(0.0451)      | 0.052<br>(0.0389)     | 0.0076<br>(0.0069)      |
| Share of population with lower secondary edu. (t0) | 0.385<br>(0.1628)      | 0.437<br>(0.1470)     | 0.0519*<br>(0.0292)     |
| Share of population with upper secondary edu. (t0) | 0.392<br>(0.1325)      | 0.394<br>(0.1509)     | 0.0014<br>(0.0266)      |
| Share of population with tertiary edu. (t0)        | 0.161<br>(0.0715)      | 0.131<br>(0.0513)     | -0.0299***<br>(0.0110)  |
| Share employed in manufacturing (t0)               | 0.136<br>(0.0498)      | 0.217<br>(0.0543)     | 0.0810***<br>(0.0109)   |
| Regional non-green penetration (t0)                | 6.644<br>(5.4745)      | 13.159<br>(7.8702)    | 6.5148***<br>(1.3654)   |
| t-t <sub>3</sub> regional green penetration        | 0.080<br>(0.1671)      | 0.093<br>(0.1997)     | 0.0130<br>(0.0132)      |
| t-t <sub>3</sub> regional green patents SSIV       | 0.000<br>(0.0000)      | 0.000<br>(0.0000)     | 0.0000<br>(0.0000)      |
| Pr. large green shock                              | 0.422<br>(0.4939)      | 0.738<br>(0.4401)     | 0.3158***<br>(0.0831)   |
| Observations                                       | 3195                   | 975                   | 4170                    |

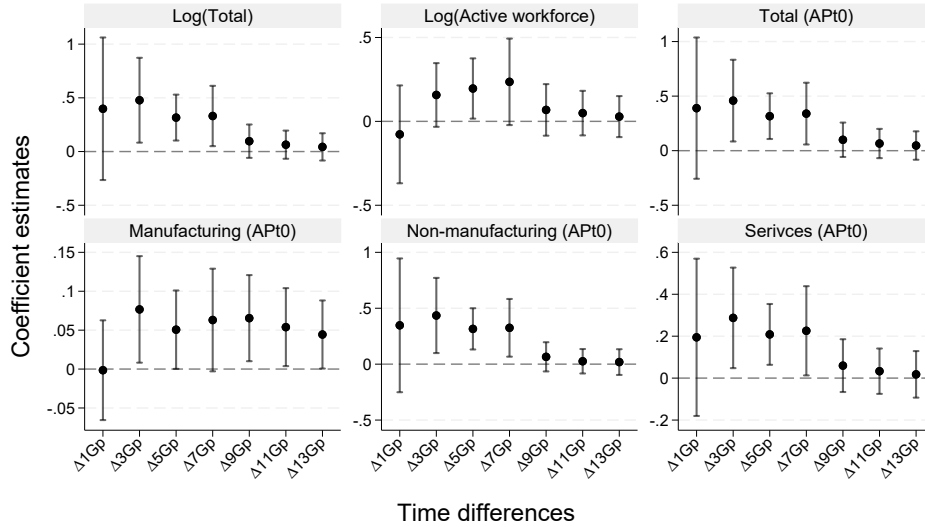
*Notes.* If t0 is present then values are taken at baseline, i.e. an average between 2000 and 2003. \* p<0.10, \*\* p<0.05, \*\*\* p<0.01.

Figure A14: 2SLS estimates of green penetration on brown-exposed regional employment. Green patents SSIV.



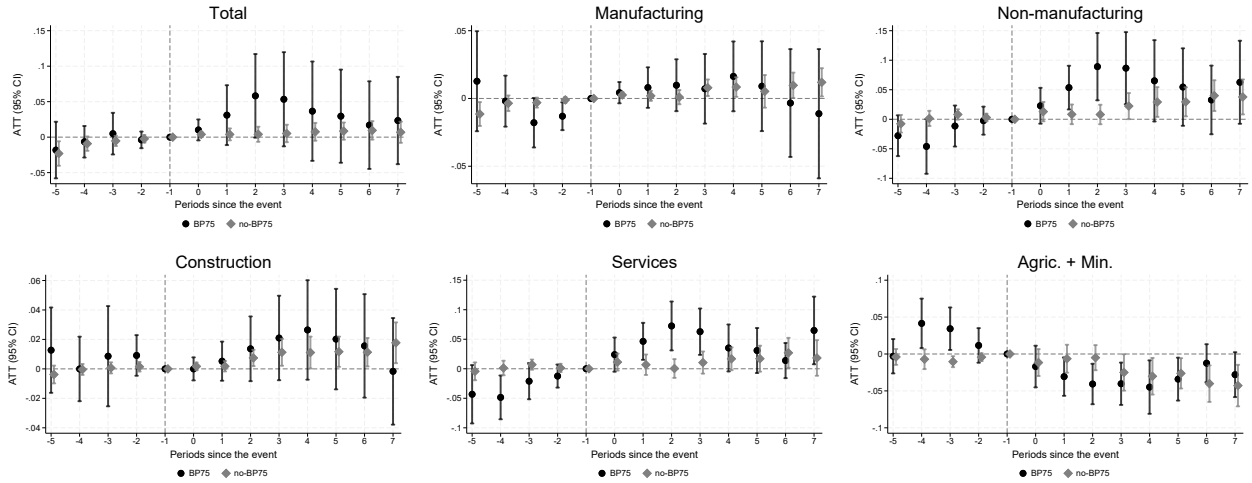
*Notes.* These graphs replicate and extend the 2SLS estimation based on Equation 3 and on Equation 4 by looking at one-, three-, five- and seven-year changes. The sample is restricted to brown-exposed regions as defined in text. KP F-stats: 1.6; 7.3; 22.0; 25.9. CD F-stats: 2.8; 13.8; 31.6; 25.6.

Figure A15: 2SLS estimates of green penetration on brown-exposed regional employment and active population. Green patents SSIV. Longer time horizon and decomposition.



*Notes.* These graphs replicate and extend the 2SLS estimation based on Equation 3 and on Equation 4 by looking at three-, five-, seven-, nine-, eleven- and thirteen- year changes. The sample is restricted to brown-exposed regions as defined in text. KP F-stats: 11.0; 53.4; 140.3; 160.7; 129.7; 176.0; 232.5. CD F-stats: 14.9; 79.4; 174.8; 191.8; 324.3; 333.9; 234.2.

Figure A16: Green regional penetration event study estimates. Splitting by brown exposure.



*Notes.* These plots show the results of the event study specification for several outcomes employing a regression adjustment estimator from Callaway and Sant'Anna (2021). The positive spike in green regional penetration is defined as a change higher than the 90<sup>th</sup> percentile in the one-year change of green regional penetration. The first spike identifies the beginning of treatment. The analysis is split by brown exposure. Standard errors are clustered at the NUTS2 level.

## A.6 Data sources and cleaning

### A.6.1 Main employment data

**Total employment.** Source: Eurostat - LFS (links: NACER 2 - 2008/2017; NACER 1.1 - 2000 -2007). The data concerns total employment levels by NUTS2 and year, from 2000 to 2017. The division in NACER 2 and NACER 1.1 does not imply any harmonization for employment data. We focus on employment for people older than 15 years old, of both sexes. NUTS2 regional codes have been harmonized to the NUTS 2016 changes. This implies harmonizing changes in regions definitions.<sup>29</sup> Employment data are reallocated for regions affected by splits or merges using proportionate coefficients. Remaining missing data has been interpolated and extrapolated using an inverse distance weighted interpolation.

**Manufacturing employment.** Source: Eurostat - SBS (links: NACER 2 - 2008/2017; NACER 1.1 - 2000 -2007). The data concerns manufacturing employment, both aggregate and by 2-digit manufacturing industries, levels by NUTS2 and year, from 1995 to 2017. We map 2-digit employment NACER 1.1 data to 2-digit NACER 2 categories using country-specific weights, proportionally redistributing employment values when multiple mappings exist. These weights are calculated from country-product (PRODCOM) levels that leverage details about the crosswalk provided by Eurostat. For example NACER 1.1 sector 29 - Manufacture of machinery and equipment n.e.c. - is allocated as follows: for the 82% to NACER 2 sector 28 - Manufacture of machinery and equipment n.e.c.; for the 5% to NACER 2 sector 33 (Repair and installation of machinery and equipment); for the 9% to NACER 2 sector 27 (Manufacture of electrical equipment); the remaining 4% is allocated to NACER 2 sectors 25 (Manufacture of fabricated metal products, except machinery and equipment), 26 (Manufacture of computer, electronic and optical products) and 32 (Other manufacturing). Across countries, this allocation is mostly stable. For example, the allocation to NACER 2 sector 28 is at minimum 82.65% and at maximum 83.10%. The rest of the data management is identical to that described for total employment.

**Utilities employment.** Source: Eurostat - SBS (links: NACER 2 - 2008/2017; NACER 1.1 - 2000 -2007). The data concerns utilities employment levels by NUTS2 and year, from 1995 to 2017. The crosswalk between NACER 1.1 and NACER 2 is a simple one-to-one of the NACER 1.1 category E to NACER 2 categories D and E, summed together. The rest of the data management is identical to that described for total employment.

---

<sup>29</sup>For example, in the UK UKM3 was split into UKM8 and UKM9.

**Construction employment.** Source: Eurostat - LFS (links: NACER 2 - 2008/2017; NACER 1.1 - 2000 -2007). The data concerns construction employment levels by NUTS2 and year, from 2000 to 2017. The crosswalk between NACER 1.1 and NACER 2 is a simple one-to-one of the NACER 1.1 category F to NACER 2 category F. The rest of the data management is identical to that described for total employment.

**Services employment.** Source: Eurostat - HTEC (links: NACER 2 - 2008/2017; NACER 1.1 - 2000 -2007). The data concerns services employment levels by NUTS2 and year, from 2000 to 2017. The crosswalk between NACER 1.1 and NACER 2 is a simple one-to-one of the NACER 1.1 categories that identify KIS, summed together, to NACER 2 categories that identify KIS, summed together. KIS identification is defined by Eurostat. The rest of the data management is identical to that described for total employment.

**Agriculture plus mining employment.** Retrieved indirectly by subtracting from total employment employment in manufacturing, utilities, construction and services.

**Employment by educational attainment.** Source: Eurostat - LFS (link: link). The data concerns employment levels by educational attainment levels by NUTS2 and year, from 2000 to 2017. The levels are the following: less than primary, primary and lower secondary education (ISCED 2011 levels 0-2); upper secondary and post-secondary non-tertiary education (ISCED 2011 levels 3 and 4); tertiary education (ISCED 2011 levels 5-8). The rest of the data management is identical to that described for total employment.

**STEM.** Source: Eurostat - HRST (link: link). The data concerns employment levels of people with tertiary education (ISCED 2011) and employed in science and technology by NUTS2 and year, from 2000 to 2017. The rest of the data management is identical to that described for total employment.

### **A.6.2 Green production**

**Green goods list.** Bontadini and Vona (2023) and Frattini et al. (2024) PRODCOM list of green potential goods is the union of the CLEG list and the German list, net of manually inspected goods with double usage.<sup>30</sup> As we discussed in the main text, we refine this list by: including newly items whose environmental benefits are now established; including all batteries, that were excluded due to their potential for double usage; including nuclear energy and biofuels, that enter as part of a

---

<sup>30</sup>The CLEG list is itself the union of the following lists: the Plurilateral Environmental Goods and Services (PEGS) list developed by the OECD itself, the list suggested by the Asian Pacific Economic Cooperation (APEC) forum and the list stipulated by the WTO Friends group.

broader low-carbon energy portfolio; excluding ambiguities in the classification arising from dual-use cases; including not only final green products but also their constituent components, with particular attention to those used in energy-efficient housing solutions. Table A21 shows the full list of green goods. The reason why the number of green goods in the current list (188) is lower than the original one (221) has to do with the fact that Eurostat harmonized PRODCOM codes up to 2007. From 2008 we do not harmonize product codes as none of them changes classification up to 2-digit manufacturing industry. Hence, we effectively include more products.

**Production.** Source: Eurostat - PRODCOM (link: PRODCOM). 8-digit country-product level data is aggregated to country-2-digit industries data from 1995 to 2017. The data is then deflated using 2019 EUKLEMS value added deflators (link all but UK: all; link UK: UK). Non-green production is retrieved by subtracting green production from total production.

### A.6.3 Patent data

Patent data panel is retrieved from PATSTAT Online database (link: PATSTAT), which is provided by the European Patent Office (EPO). We obtained access by subscription that costs around EUR700/year. For each patent application, the patent office assigns NACE codes associated with it following Van Looy et al. (2014). We classify a patent as green if at least one CPC code associated with it starts with Y.

### A.6.4 Economic-Socio-demographic data

**Active population.** Source: Eurostat - LFS (link: link). The data concerns active population levels of the local population older than 15 years by NUTS2 and year, from 2000 to 2017. The data management is identical to that described for total employment.

**Population density.** Source: Eurostat - DEMS (link: link). The data concerns population density levels by NUTS2 and year, from 2000 to 2017.

**Median age.** Source: Eurostat - DEMS (link: link). The data concerns the median age of the population by NUTS2 and year, from 2000 to 2017.

**Population by educational attainment.** Source: Eurostat - LFS (link: link). The data concerns population by educational attainment levels by NUTS2 and year, from 2000 to 2017. The levels are the following: less than primary, primary and lower secondary education (ISCED 2011 levels 0-2); upper

secondary and post-secondary non-tertiary education (ISCED 2011 levels 3 and 4); tertiary education (ISCED 2011 levels 5-8).

### A.6.5 Automation exposure data

Data on automation exposure comes from Anelli et al. (2021). Anelli et al. (2021) estimate regional time-varying exposure to automation as  $Robot\ Exp_{r,t} = \sum_j \frac{L_{rj,t_0}}{L_{cj,t_0}} \cdot \frac{\Delta Robot_{cj,t_k}}{L_{r,t_0}}$ , where  $\Delta Robot_{cj,t_k}$  is the change in the operational stock of industrial robots between year  $t$  and  $t - k$ .

### A.6.6 Brown employment data

To measure regional brown exposure, we use 2-digit selected manufacturing and mining employment levels at the NUTS2, at baseline (average between 2000 and 2003). The 2-digit manufacturing sectors are: 4 - manufacture of basic metals; 25 - manufacture of fabricated metal products; 21 - manufacture of basic pharmaceutical products; 20 - manufacture of chemicals and chemical products; 23 - manufacture of other non-metallic mineral products; 19 - manufacture of coke and refined petroleum products. These sectors are identified as polluting from Table A1. The 2-digit mining sectors are: 05 - mining of coal and lignite; 06 - Extraction of crude petroleum and natural gas; 07 - mining of metal ores; 08 - other mining and quarrying. The 2-digit mining sector 09 - mining support service activities are not included. Then, regional brown employment is computed as  $BP_{r,t_0} = \sum_j \frac{L_{r,j=poll,t_0}}{L_{r,t_0}}$ . We then measure elevated regional brown exposure by identifying those NUTS2 regions that have values of this ratio above the 75th percentile.

Table A21: Green goods list

| Code     | Label                                                                                      |
|----------|--------------------------------------------------------------------------------------------|
| 16101010 | Railway or tramway sleepers (cross-ties) of wood, not impregnated                          |
| 16101300 | Railway or tramway sleepers (cross-ties) of wood, not impregnated                          |
| 16103200 | Railway or tramway sleepers (cross-ties) of impregnated wood                               |
| 20595990 | Biofuels (diesel substitute), other chemical products, n.e.c.                              |
| 20595997 | Biofuels (diesel substitute)                                                               |
| 23121330 | Multiple-walled insulating units of glass                                                  |
| 23991930 | Mixtures and articles of heat/sound-insulating materials n.e.c.                            |
| 24107500 | Railway material (of steel)                                                                |
| 24333000 | Structures, solely or principally of iron or steel sheet comprising two walls of profil... |
| 25112200 | Iron or steel towers and lattice masts                                                     |
| 25301150 | Vapour generating boilers (including hybrid boilers) (excluding central heating hot wat... |
| 25301230 | Auxiliary plant for use with boilers of HS 8402 or 8403                                    |
| 25301330 | Parts of vapour generating boilers and super-heater water boilers                          |
| 25302100 | Nuclear reactors                                                                           |

Continued on next page

Table A21 – continued from previous page

| Code     | Label                                                                                      |
|----------|--------------------------------------------------------------------------------------------|
| 25302200 | Parts of nuclear reactors                                                                  |
| 25991131 | Sanitary ware and parts of sanitary ware of iron or steel                                  |
| 25992910 | Railway or tramway track fixtures and fittings and parts thereof                           |
| 26112220 | Semiconductor light emitting diodes (LEDs)                                                 |
| 26112240 | Photosensitive semiconductor devices; solar cells, photo-diodes, photo-transistors, etc.   |
| 26114070 | Parts of diodes, transistors and similar semiconductor devices, photosensitive semicond... |
| 26405190 | LED backlight modules for LCDs of headings 8525 to 8528 (excl. for computer monitors)      |
| 26511200 | Theodolites and tachymeters (tachometers); other surveying, hydrographic, oceanographic... |
| 26511215 | Electronic rangefinders, theodolites, tacheometers and photogrammetrical instruments an... |
| 26511235 | Electronic instruments and apparatus for meteorological, hydrological and geophysical p... |
| 26511239 | Other electronic instruments, n.e.c.                                                       |
| 26511270 | Surveying (including photogrammetrical surveying), hydrographic, oceanographic, hydrolo... |
| 26511280 | Non electronic surveying (including photogrammatrical surveying), hydrographic, oceanog... |
| 26514100 | Instruments and apparatus for measuring or detecting ionising radiations                   |
| 26514200 | Cathode-ray oscilloscopes and cathode-ray oscillographs                                    |
| 26514300 | Instruments for measuring electrical quantities without a recording device                 |
| 26514310 | Multimeters without recording device                                                       |
| 26514330 | Electronic instruments and apparatus for measuring or checking voltage, current, resist... |
| 26514355 | Voltmeters without recording device                                                        |
| 26514359 | Non-electronic instruments and apparatus, for measuring or checking voltage, current, r... |
| 26514530 | Instruments and apparatus, with a recording device, for measuring or checking electric ... |
| 26514555 | Electronic instruments and apparatus, without a recording device, for measuring or chec... |
| 26514559 | Non-electronic instruments and apparatus, without a recording device, for measuring or ... |
| 26515110 | Thermometers, liquid-filled, for direct reading, not combined with other instruments (e... |
| 26515135 | Electronic thermometers and pyrometers, not combined with other instruments (excluding ... |
| 26515139 | Thermometers, not combined with other instruments and not liquid filled, n.e.c.            |
| 26515235 | Electronic flow meters (excluding supply meters, hydrometric paddle-wheels)                |
| 26515239 | Electronic instruments and apparatus for measuring or checking the level of liquids        |
| 26515255 | Non-electronic flow meters (excluding supply meters, hydrometric paddle-wheels)            |
| 26515313 | Electronic gas or smoke analysers                                                          |
| 26515319 | Non-electronic gas or smoke analysers                                                      |
| 26515330 | Spectrometers, spectrophotometers... using optical radiations                              |
| 26515350 | Instruments and apparatus using optical radiations, n.e.c.                                 |
| 26515381 | Electronic ph and rh meters, other apparatus for measuring conductivity and electrochem... |
| 26515390 | Other instruments and apparatus for physical or chemical analysis n.e.c.                   |
| 26516350 | Liquid supply or production meters (including calibrated) (excluding pumps)                |
| 26516370 | Electricity supply or production meters (including calibrated) (excluding voltmeters, a... |
| 26516500 | Hydraulic or pneumatic automatic regulating or controlling instruments and apparatus       |
| 26516620 | Test benches                                                                               |
| 26516650 | Electronic instruments, appliances and machines for measuring or checking geometrical q... |
| 26516683 | Other instruments, appliances,... for measuring or checking geometrical quantities         |
| 26516689 | Non-electronic measuring machines and instruments (excluding test benches, optical inst... |
| 26517015 | Electronic thermostats                                                                     |
| 26517019 | Non-electronic thermostats                                                                 |

Continued on next page

Table A21 – continued from previous page

| Code     | Label                                                                                            |
|----------|--------------------------------------------------------------------------------------------------|
| 26518200 | Parts and accessories for the goods of 26.51.12, 26.51.32, 26.51.33, 26.51.4 and 26.51....       |
| 26518550 | Parts and accessories for automatic regulating or controlling instruments and apparatus          |
| 26702450 | Other instruments and apparatus using optical radiation (UV, visible, IR)                        |
| 26702490 | Exposure meters, stroboscopes, optical instruments, appliances and machines for inspect...       |
| 27111010 | Electric motors of an output $\leq 37,5$ W (including synchronous motors $\leq 18$ W, univers... |
| 27111095 | Photovoltaic DC generators of an output not exceeding 50 W                                       |
| 27111096 | Photovoltaic DC generators of an output exceeding 50 W                                           |
| 27112680 | Photovoltaic AC generators                                                                       |
| 27115023 | Polycrystalline semiconductors                                                                   |
| 27116110 | Parts suitable for use solely or principally with electric motors and generators, elect...       |
| 27123130 | Numerical control panels with built-in automatic data-processing machine for a voltage ...       |
| 27123150 | Programmable memory controllers for a voltage $\leq 1$ kV                                        |
| 27123170 | Other bases for electric control, distribution of electricity, voltage $\leq 1\ 000$ V           |
| 27201100 | Primary cells and primary batteries                                                              |
| 27201110 | Manganese dioxide cells and batteries, alkaline, in the form of cylindrical cells (excl...       |
| 27201115 | Other manganese dioxide cells and batteries, alkaline (excl. spent, and cylindrical cells)       |
| 27201120 | Manganese dioxide cells and batteries, non-alkaline, in the form of cylindrical cells (...)      |
| 27201125 | Other manganese dioxide cells and batteries, non-alkaline (excl. spent, and cylindrical...       |
| 27201130 | Mercuric oxide primary cells and primary batteries (excl. spent)                                 |
| 27201140 | Silver oxide primary cells and primary batteries (excl. spent)                                   |
| 27201150 | Lithium primary cells and primary batteries, in the form of cylindrical cells (excl. sp...       |
| 27201155 | Lithium primary cells and primary batteries, in the form of button cells (excl. spent)           |
| 27201160 | Lithium primary cells and primary batteries (excl. spent, and in the form of cylindrica...       |
| 27201170 | Air-zinc primary cells and primary batteries (excl. spent)                                       |
| 27201175 | Dry zinc-carbon primary batteries of a voltage of $\geq 5,5$ V but $\leq 6,5$ V (excl. spent)    |
| 27201190 | Other primary cells and primary batteries, electric (excl. spent, dry zinc-carbon batte...       |
| 27201200 | Parts of primary cells and primary batteries (excluding battery carbons, for rechargeab...       |
| 27202300 | Nickel-cadmium, nickel metal hydride, lithium-ion, lithium polymer, nickel-iron and oth...       |
| 27202350 | Lithium-ion accumulators (excl. spent)                                                           |
| 27401250 | Tungsten halogen filament lamps for motorcycles and motor vehicles (excluding ultraviol...       |
| 27401293 | Tungsten halogen filament lamps, for a voltage $> 100$ V (excluding ultraviolet and infr...      |
| 27401295 | Tungsten halogen filament lamps for a voltage $\leq 100$ V (excluding ultraviolet and infr...    |
| 27401510 | Fluorescent hot cathode discharge lamps, with double ended cap (excluding ultraviolet l...       |
| 27401530 | Fluorescent hot cathode discharge lamps (excluding ultraviolet lamps, with double ended...       |
| 27402200 | Electric table, desk, bedside or floor-standing lamps                                            |
| 27403090 | Electric lamps and lighting fittings, of plastic and other materials, of a kind used fo...       |
| 27403200 | Lighting sets for Christmas trees                                                                |
| 27403930 | Electric lamps and lighting fittings, of plastic and other materials, of a kind used fo...       |
| 27512690 | Other electric space heaters                                                                     |
| 27521400 | Non-electric instantaneous or storage water heaters                                              |
| 27902050 | Indicator panels incorporating light emitting diodes (LED)                                       |
| 27902060 | Light-emitting diode (LED) modules and lamps                                                     |
| 27904200 | Fuel cells                                                                                       |
| 279900Z1 | Parts suitable for use solely or principally with electric motors and generators, elect...       |

Continued on next page

Table A21 – continued from previous page

| Code     | Label                                                                                      |
|----------|--------------------------------------------------------------------------------------------|
| 28112130 | Steam turbines and other vapour turbines (excluding for electricity generation)            |
| 28112150 | Steam turbines for electricity generation                                                  |
| 28112160 | Steam turbines and other vapour turbines                                                   |
| 28112200 | Hydraulic turbines and water wheels                                                        |
| 28112400 | Generating sets, wind-powered                                                              |
| 28113100 | Parts for steam turbines and other vapour turbines                                         |
| 28113200 | Parts for hydraulic turbines and water wheels (including regulators)                       |
| 28211354 | Electric furnaces and ovens (excluding induction- and resistance-heated); equipment for... |
| 28211362 | Dielectric furnaces and ovens, electron beam furnaces, plasma and vacuum arc furnaces, ... |
| 28211470 | Parts for industrial or laboratory electric, induction or dielectric furnaces and ovens... |
| 28221130 | Pulley tackle and hoists powered by an electric motor (excluding of the kind used for r... |
| 28221250 | Winches and capstans powered by an electric motor or internal combustion piston engines... |
| 28221513 | Self-propelled works trucks fitted with lifting or handling equipment, powered by an el... |
| 28221515 | Self-propelled works trucks fitted with lifting or handling equipment, powered by an el... |
| 28241150 | Grinders, sanders and planers, for working in the hand, with self-contained electric mo... |
| 28241185 | Electromechanical hand tools, with self-contained electric motor operating with an exte... |
| 28251130 | Heat exchange units                                                                        |
| 28251380 | Heat pumps other than air conditioning machines of HS 8415                                 |
| 28251410 | Machinery and apparatus for filtering or purifying air (excluding intake filters for in... |
| 28251420 | Machinery and apparatus for filtering or purifying gases by a liquid process (excluding... |
| 28251430 | Machinery and apparatus for filtering and purifying gases (other than air and excluding... |
| 28251431 | Machinery and apparatus for filtering and purifying gases (other than air and excluding... |
| 28251440 | Machinery and apparatus for filtering or purifying gases by catalytic process (excludin... |
| 28251441 | Machinery and apparatus for filtering or purifying gases by catalytic process (excludin... |
| 28251442 | Catalytic converters or particulate filters, whether or not combined, for purifying or ... |
| 28251450 | Machinery and apparatus for filtering and purifying gases with stainless steel housing,... |
| 28251470 | Machinery and apparatus for filtering or purifying gases including for filtering dust f... |
| 28253070 | Parts of refrigerating or freezing equipment and heat pumps, n.e.s.                        |
| 28291100 | Producer gas or water gas generators; acetylene gas generators and the like; distilling... |
| 28291230 | Machinery and apparatus for filtering or purifying water                                   |
| 28291270 | Machinery and apparatus for solid-liquid separation/ purification excluding for water a... |
| 28298250 | Parts for filtering and purifying machinery and apparatus, for liquids or gases (exclud... |
| 28304010 | Electric mowers for lawns, parks, golf courses or sports grounds                           |
| 28992020 | Machines and apparatus used solely or principally for the manufacture of semiconductor ... |
| 28992060 | Machines and apparatus used solely or principally for the manufacture of flat panel dis... |
| 28993945 | Machines and apparatus used solely or principally for (a) the manufacture or repair of ... |
| 29102410 | Motor vehicles, with both spark-ignition or compression-ignition internal combustion re... |
| 29102430 | Motor vehicles, with both spark-ignition or compression-ignition internal combustion re... |
| 29102450 | Motor vehicles, with only electric motor for propulsion                                    |
| 29104142 | Motor vehicles for the transport of goods with both compression-ignition internal combu... |
| 29104212 | Motor vehicles for the transport of goods with both spark-ignition internal combustion ... |
| 29104213 | Motor vehicles for the transport of goods with only electric motor for propulsion          |
| 29104311 | Road tractors for semi-trailers with both compression-ignition internal combustion pist... |
| 29104312 | Road tractors for semi-trailers with both spark-ignition internal combustion piston eng... |

Continued on next page

Table A21 – continued from previous page

| Code     | Label                                                                                      |
|----------|--------------------------------------------------------------------------------------------|
| 29104313 | Road tractors for semi-trailers with only electric motor for propulsion                    |
| 29105200 | Motor vehicles specially designed for travelling on snow, golf cars and similar vehicles   |
| 29312310 | Electrical or battery operated lighting or visual signalling of a kind used on bicycles    |
| 30201100 | Rail locomotives powered from an external source of electricity                            |
| 30201200 | Diesel-electric locomotives                                                                |
| 30201300 | Other rail locomotives; locomotive tenders                                                 |
| 30202000 | Self-propelled railway or tramway coaches, vans and trucks, except maintenance or servi... |
| 30203100 | Railway or tramway maintenance or service vehicles (including workshops, cranes, ballas... |
| 30203200 | Rail/tramway passenger coaches; luggage vans, post office coaches and other special pur... |
| 30203300 | Railway or tramway goods vans and wagons, not self-propelled                               |
| 30204030 | Parts of locomotives or rolling-stock                                                      |
| 30204050 | Mechanical or electromechanical signalling, safety or traffic control equipment for roa... |
| 30204070 | Fixtures and fittings and mechanical signalling, safety or traffic control equipment fo... |
| 30209100 | Reconditioning of railway and tramway locomotives and rolling-stock                        |
| 30921000 | Bicycles and other cycles (including delivery tricycles), non-motorised                    |
| 30921030 | Non-motorized bicycles and other cycles, without ball bearings (including delivery tric... |
| 30921050 | Non-motorized bicycles and other cycles with ball bearings (including delivery tricycles)  |
| 30923010 | Frames and forks, for bicycles                                                             |
| 30923030 | Parts of frames, front forks, brakes, coaster braking hubs, hub brakes, pedals crank-ge... |
| 30923060 | Parts and accessories of bicycles and other cycles, not motorised (excl. frames, front ... |
| 30923070 | Parts and accessories for invalid carriages                                                |
| 30923090 | Other parts and accessories of bicycles and other cycles, not motorised                    |
| 33141120 | Repair and maintenance of electric motors, generators and transformers                     |
| 33141150 | Repair and maintenance of electricity distribution and control apparatus                   |
| 33141900 | Repair and maintenance of electrical equipment (excluding electricity distribution and ... |
| 33171100 | Repair and maintenance of railway and tramway locomotives and rolling-stock and of mech... |
| 33205020 | Installation of electric motors, generators and transformers                               |
| 33205050 | Installation of electricity distribution and control apparatus                             |
| 33205090 | Installation of other electrical equipment, excluding electrical signalling equipment f... |

Table A22: NUTS2 regions in the sample list

| Code | Label                                                            |
|------|------------------------------------------------------------------|
| AT11 | AT - Burgenland                                                  |
| AT12 | AT - Niederösterreich                                            |
| AT13 | AT - Wien                                                        |
| AT21 | AT - Kärnten                                                     |
| AT22 | AT - Steiermark                                                  |
| AT31 | AT - Oberösterreich                                              |
| AT32 | AT - Salzburg                                                    |
| AT33 | AT - Tirol                                                       |
| AT34 | AT - Vorarlberg                                                  |
| BE10 | BE - Région de Bruxelles-Capitale/Brussels Hoofdstedelijk Gewest |

Continued on next page

Table A22 – continued from previous page

| Code | Label                       |
|------|-----------------------------|
| BE21 | BE - Prov. Antwerpen        |
| BE22 | BE - Prov. Limburg (BE)     |
| BE23 | BE - Prov. Oost-Vlaanderen  |
| BE24 | BE - Prov. Vlaams-Brabant   |
| BE25 | BE - Prov. West-Vlaanderen  |
| BE31 | BE - Prov. Brabant wallon   |
| BE32 | BE - Prov. Hainaut          |
| BE33 | BE - Prov. Liège            |
| BE34 | BE - Prov. Luxembourg (BE)  |
| BE35 | BE - Prov. Namur            |
| BG31 | BG - Severozapaden          |
| BG32 | BG - Severen tsentralen     |
| BG33 | BG - Severoiztochen         |
| BG34 | BG - Yugoiztochen           |
| BG41 | BG - Yugoizapaden           |
| BG42 | BG - Yuzhen tsentralen      |
| CY00 | CY - Kýpros                 |
| CZ01 | CZ - Praha                  |
| CZ02 | CZ - Střední Čechy          |
| CZ03 | CZ - Jihozápad              |
| CZ04 | CZ - Severozápad            |
| CZ05 | CZ - Severovýchod           |
| CZ06 | CZ - Jihovýchod             |
| CZ07 | CZ - Střední Morava         |
| CZ08 | CZ - Moravskoslezsko        |
| DE11 | DE - Stuttgart              |
| DE12 | DE - Karlsruhe              |
| DE13 | DE - Freiburg               |
| DE14 | DE - Tübingen               |
| DE21 | DE - Oberbayern             |
| DE22 | DE - Niederbayern           |
| DE23 | DE - Oberpfalz              |
| DE24 | DE - Oberfranken            |
| DE25 | DE - Mittelfranken          |
| DE26 | DE - Unterfranken           |
| DE27 | DE - Schwaben               |
| DE30 | DE - Berlin                 |
| DE40 | DE - Brandenburg            |
| DE50 | DE - Bremen                 |
| DE60 | DE - Hamburg                |
| DE71 | DE - Darmstadt              |
| DE72 | DE - Gießen                 |
| DE73 | DE - Kassel                 |
| DE80 | DE - Mecklenburg-Vorpommern |

Continued on next page

Table A22 – continued from previous page

| Code | Label                            |
|------|----------------------------------|
| DE91 | DE - Braunschweig                |
| DE92 | DE - Hannover                    |
| DE93 | DE - Lüneburg                    |
| DE94 | DE - Weser-Ems                   |
| DEA1 | DE - Düsseldorf                  |
| DEA2 | DE - Köln                        |
| DEA3 | DE - Münster                     |
| DEA4 | DE - Detmold                     |
| DEA5 | DE - Arnsberg                    |
| DEB1 | DE - Koblenz                     |
| DEB2 | DE - Trier                       |
| DEB3 | DE - Rheinhessen-Pfalz           |
| DEC0 | DE - Saarland                    |
| DED2 | DE - Dresden                     |
| DED4 | DE - Chemnitz                    |
| DED5 | DE - Leipzig                     |
| DEE0 | DE - Sachsen-Anhalt              |
| DEF0 | DE - Schleswig-Holstein          |
| DEG0 | DE - Thüringen                   |
| DK01 | DK - Hovedstaden                 |
| DK02 | DK - Sjælland                    |
| DK03 | DK - Syddanmark                  |
| DK04 | DK - Midtjylland                 |
| DK05 | DK - Nordjylland                 |
| EL30 | EL - Attiki                      |
| EL41 | EL - Voreio Aigaio               |
| EL42 | EL - Notio Aigaio                |
| EL43 | EL - Kriti                       |
| EL51 | EL - Anatoliki Makedonia, Thraki |
| EL52 | EL - Kentriki Makedonia          |
| EL53 | EL - Dytiki Makedonia            |
| EL54 | EL - Ipeiros                     |
| EL61 | EL - Thessalia                   |
| EL62 | EL - Ionia Nisia                 |
| EL63 | EL - Dytiki Ellada               |
| EL64 | EL - Sterea Ellada               |
| EL65 | EL - Peloponnisos                |
| ES11 | ES - Galicia                     |
| ES12 | ES - Principado de Asturias      |
| ES13 | ES - Cantabria                   |
| ES21 | ES - País Vasco                  |
| ES22 | ES - Comunidad Foral de Navarra  |
| ES23 | ES - La Rioja                    |
| ES24 | ES - Aragón                      |

Continued on next page

Table A22 – continued from previous page

| Code | Label                           |
|------|---------------------------------|
| ES30 | ES - Comunidad de Madrid        |
| ES41 | ES - Castilla y León            |
| ES42 | ES - Castilla-La Mancha         |
| ES43 | ES - Extremadura                |
| ES51 | ES - Cataluña                   |
| ES52 | ES - Comunitat Valenciana       |
| ES53 | ES - Illes Balears              |
| ES61 | ES - Andalucía                  |
| ES62 | ES - Región de Murcia           |
| ES63 | ES - Ciudad de Ceuta            |
| ES64 | ES - Ciudad de Melilla          |
| FI19 | FI - Länsi-Suomi                |
| FI1B | FI - Etelä-Suomi                |
| FI1C | FI - Etelä-Suomi                |
| FI1D | FI - Itä-Suomi                  |
| FI20 | FI - Åland                      |
| FR10 | FR - Ile de France              |
| FRB0 | FR - Centre (FR)                |
| FRC1 | FR - Bourgogne                  |
| FRC2 | FR - Franche-Comté              |
| FRD1 | FR - Basse-Normandie            |
| FRD2 | FR - Haute-Normandie            |
| FRE1 | FR - Nord-Pas-de-Calais         |
| FRE2 | FR - Picardie                   |
| FRF1 | FR - Alsace                     |
| FRF2 | FR - Champagne-Ardenne          |
| FRF3 | FR - Lorraine                   |
| FRG0 | FR - Pays de la Loire           |
| FRH0 | FR - Bretagne                   |
| FRI1 | FR - Aquitaine                  |
| FRI2 | FR - Limousin                   |
| FRI3 | FR - Poitou-Charentes           |
| FRJ1 | FR - Languedoc-Roussillon       |
| FRJ2 | FR - Midi-Pyrénées              |
| FRK1 | FR - Auvergne                   |
| FRK2 | FR - Rhône-Alpes                |
| FRL0 | FR - Provence-Alpes-Côte d'Azur |
| FRM0 | FR - Corse                      |
| HR03 | HR - Jadranska Hrvatska         |
| HR04 | HR - Kontinentalna Hrvatska     |
| HU11 | HU - Közép-Magyarország         |
| HU12 | HU - Közép-Magyarország         |
| HU21 | HU - Közép-Dunántúl             |
| HU22 | HU - Nyugat-Dunántúl            |

Continued on next page

Table A22 – continued from previous page

| Code | Label                                 |
|------|---------------------------------------|
| HU23 | HU - Dél-Dunántúl                     |
| HU31 | HU - Észak-Magyarország               |
| HU32 | HU - Észak-Alföld                     |
| HU33 | HU - Dél-Alföld                       |
| IE04 | IE - Border, Midland and Western      |
| IE05 | IE - Southern and Eastern             |
| IE06 | IE - Southern and Eastern             |
| IS00 | IS - Iceland                          |
| ITC1 | IT - Piemonte                         |
| ITC2 | IT - Valle d'Aosta/Vallée d'Aoste     |
| ITC3 | IT - Liguria                          |
| ITC4 | IT - Lombardia                        |
| ITF1 | IT - Abruzzo                          |
| ITF2 | IT - Molise                           |
| ITF3 | IT - Campania                         |
| ITF4 | IT - Puglia                           |
| ITF5 | IT - Basilicata                       |
| ITF6 | IT - Calabria                         |
| ITG1 | IT - Sicilia                          |
| ITG2 | IT - Sardegna                         |
| ITH1 | IT - Provincia Autonoma Bolzano/Bozen |
| ITH2 | IT - Provincia Autonoma Trento        |
| ITH3 | IT - Veneto                           |
| ITH4 | IT - Friuli-Venezia Giulia            |
| ITH5 | IT - Emilia-Romagna                   |
| ITI1 | IT - Toscana                          |
| ITI2 | IT - Umbria                           |
| ITI3 | IT - Marche                           |
| ITI4 | IT - Lazio                            |
| LU00 | LU - Luxembourg                       |
| LV00 | LV - Latvia                           |
| MT00 | MT - Malta                            |
| NL11 | NL - Groningen                        |
| NL12 | NL - Friesland (NL)                   |
| NL13 | NL - Drenthe                          |
| NL21 | NL - Overijssel                       |
| NL22 | NL - Gelderland                       |
| NL23 | NL - Flevoland                        |
| NL31 | NL - Utrecht                          |
| NL32 | NL - Noord-Holland                    |
| NL33 | NL - Zuid-Holland                     |
| NL34 | NL - Zeeland                          |
| NL41 | NL - Noord-Brabant                    |
| NL42 | NL - Limburg (NL)                     |

Continued on next page

Table A22 – continued from previous page

| Code | Label                             |
|------|-----------------------------------|
| NO01 | NO - Oslo og Akershus             |
| NO02 | NO - Innlandet                    |
| NO03 | NO - Sør-Østlandet                |
| NO04 | NO - Agder og Rogaland            |
| NO05 | NO - Vestlandet                   |
| NO06 | NO - Trøndelag                    |
| NO07 | NO - Nord-Norge                   |
| PL21 | PL - Małopolskie                  |
| PL22 | PL - Śląskie                      |
| PL41 | PL - Wielkopolskie                |
| PL42 | PL - Zachodniopomorskie           |
| PL43 | PL - Lubuskie                     |
| PL51 | PL - Dolnośląskie                 |
| PL52 | PL - Opolskie                     |
| PL61 | PL - Kujawsko-pomorskie           |
| PL62 | PL - Warmińsko-mazurskie          |
| PL63 | PL - Pomorskie                    |
| PL71 | PL - Łódzkie                      |
| PL72 | PL - Świętokrzyskie               |
| PL81 | PL - Lubelskie                    |
| PL82 | PL - Podkarpackie                 |
| PL84 | PL - Podlaskie                    |
| PL91 | PL - Mazowieckie                  |
| PL92 | PL - Mazowieckie                  |
| PT11 | PT - Norte                        |
| PT15 | PT - Algarve                      |
| PT16 | PT - Centro (PT)                  |
| PT17 | PT - Área Metropolitana de Lisboa |
| PT18 | PT - Alentejo                     |
| RO11 | RO - Nord-Vest                    |
| RO12 | RO - Centru                       |
| RO21 | RO - Nord-Est                     |
| RO22 | RO - Sud-Est                      |
| RO31 | RO - Sud-Muntenia                 |
| RO32 | RO - București-Ilfov              |
| RO41 | RO - Sud-Vest Oltenia             |
| RO42 | RO - Vest                         |
| SE11 | SE - Stockholm                    |
| SE12 | SE - Östra Mellansverige          |
| SE21 | SE - Småland med öarna            |
| SE22 | SE - Sydsverige                   |
| SE23 | SE - Västsverige                  |
| SE31 | SE - Norra Mellansverige          |
| SE32 | SE - Mellersta Norrland           |

Continued on next page

Table A22 – continued from previous page

| Code | Label                                                 |
|------|-------------------------------------------------------|
| SE33 | SE - Övre Norrland                                    |
| SI03 | SI - Vzhodna Slovenija                                |
| SI04 | SI - Zahodna Slovenija                                |
| SK01 | SK - Bratislavský kraj                                |
| SK02 | SK - Západné Slovensko                                |
| SK03 | SK - Stredné Slovensko                                |
| SK04 | SK - Východné Slovensko                               |
| UKC1 | UK - Tees Valley and Durham                           |
| UKC2 | UK - Northumberland and Tyne and Wear                 |
| UKD1 | UK - Cumbria                                          |
| UKD3 | UK - Greater Manchester                               |
| UKD4 | UK - Lancashire                                       |
| UKD6 | UK - Cheshire                                         |
| UKD7 | UK - Merseyside                                       |
| UKE1 | UK - East Yorkshire and Northern Lincolnshire         |
| UKE2 | UK - North Yorkshire                                  |
| UKE3 | UK - South Yorkshire                                  |
| UKE4 | UK - West Yorkshire                                   |
| UKF1 | UK - Derbyshire and Nottinghamshire                   |
| UKF2 | UK - Leicestershire, Rutland and Northamptonshire     |
| UKF3 | UK - Lincolnshire                                     |
| UKG1 | UK - Herefordshire, Worcestershire and Warwickshire   |
| UKG2 | UK - Shropshire and Staffordshire                     |
| UKG3 | UK - West Midlands                                    |
| UKH1 | UK - East Anglia                                      |
| UKH2 | UK - Bedfordshire and Hertfordshire                   |
| UKH3 | UK - Essex                                            |
| UKI3 | UK - Inner London                                     |
| UKI4 | UK - Inner London                                     |
| UKI5 | UK - Outer London                                     |
| UKI6 | UK - Outer London                                     |
| UKI7 | UK - Outer London                                     |
| UKJ1 | UK - Berkshire, Buckinghamshire and Oxfordshire       |
| UKJ2 | UK - Surrey, East and West Sussex                     |
| UKJ3 | UK - Hampshire and Isle of Wight                      |
| UKJ4 | UK - Kent                                             |
| UKK1 | UK - Gloucestershire, Wiltshire and Bristol/Bath area |
| UKK2 | UK - Dorset and Somerset                              |
| UKK3 | UK - Cornwall and Isles of Scilly                     |
| UKK4 | UK - Devon                                            |
| UKL1 | UK - West Wales and The Valleys                       |
| UKL2 | UK - East Wales                                       |
| UKM5 | UK - North Eastern Scotland                           |
| UKM6 | UK - Highlands and Islands                            |

Continued on next page

**Table A22 – continued from previous page**

| <b>Code</b> | <b>Label</b>                |
|-------------|-----------------------------|
| UKM7        | UK - Eastern Scotland       |
| UKM8        | UK - South Western Scotland |
| UKM9        | UK - South Western Scotland |
| UKN0        | UK - Northern Ireland (UK)  |