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Ireri Hernandez Carballo

Gian Maria Mallarino

Marco Percoco

Università Bocconi
GREEN
Centre for Geography, Resources, Environment, Energy and Networks

The Impact of Green Policies on Local Economic Performance: Evidence from the EU ETS

Ireri Hernandez Carballo[1,2], Gian Maria Mallarino[1], and Marco Percoco[1]

[1]Department of Social and Political Sciences, Bocconi University

[2]RFF-CMCC European Institute on Economics and the Environment (EIEE)

Abstract

Environmental policies such as the European Union Emissions Trading System (EU ETS) raise concerns about their impact on local employment and competitiveness. Yet, existing EU ETS studies focus on firm-level outcomes during the initial phases of the program. We construct a panel dataset of about 900 European provinces across 2008 to 2020 to assess the effects of a significant policy change in Phase 3 of the EU ETS. Specifically, we investigate how the changes in the allocation of free allowances affected local economies in terms of employment, gross value added (GVA) and productivity. By assembling a novel dataset and measuring the net change of paid emissions from Phase 2 to Phase 3 we construct a measure of exposure to the policy change at the NUTS-3 level. Using synthetic difference-in-differences, we find that being more exposed to the EU ETS is associated with a statistically significant contraction of employment and GVA in the more carbon-intensive industries. Our results are complemented with evidence on a sizeable reduction in carbon emissions and mild impact in terms of regional disparities in the European Union.

Keywords: EU ETS, Carbon policies, CO2 Emissions, Regional Economics, Economic Geography

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1 Introduction

As the climate crisis becomes more pressing, governments and firms adopt policies to contain carbon emissions. Among the many instruments to curb greenhouse gases, carbon pricing has gained momentum as 23% of global greenhouse gas emissions are covered by a considerable variety of carbon pricing schemes, including emission trading systems (World Bank, 2022). Despite their potential environmental benefits, green policies also have potential costs in terms of economic and inequality backlash. The yellow vest protests in France are tangible example of the effects of the social and political discontent associated with public policies aiming to decarbonize economies (Colantone et al., 2024; Douenne and Fabre, 2022). The unrest in the French case was generated by a major increase in the carbon tax on car fuel that disproportionately affected low-income workers. In this paper, we aim to make a further step into the growing literature on the economic costs of green policies by considering explicitly their spatial variation. More specifically, we aim to estimate the impact of the European Union Emission Trading System (EU-ETS) on the European (NUTS3) regions.

Inaugurated in 2005, the European Union Emission Trading System (EU ETS) is a carbon pricing mechanism and the main pillar of the European Union's strategy to decarbonize its economy. With currently 31 countries participating, the EU ETS covers 45% of the EU's greenhouse gases (GHG) emissions. Designed to reduce emissions while stimulating heavy emitting companies to innovate their production systems, the EU ETS has raised concerns about its impact on employment, firm competitiveness and subsequent carbon leakage (Commins et al., 2011; Costantini and Mazzanti, 2012; Reinaud, 2008; Colmer et al., 2024; Dechezleprêtre et al., 2023).

On the one hand the Porter hypothesis suggests that carbon pricing policies may lead to improved competitiveness by enabling new production methods could result in the EU ETS having improved economic outcomes (Porter and van der Linde, 1995). On the other hand, negative competitiveness impacts may arise if production is shifted to countries with weaker environmental stringency, as predicted by the pollution haven hypothesis (Levinson and Taylor, 2008). In a detailed literature review of the EU ETS on firm productivity and carbon leakage, Verde (2020) concludes that while the policy has been widely studied to test for eventual economic effects, there is weak empirical evidence of any positive or negative impacts on competitiveness. This wealth of this evidence has mainly focused on the sectorial implication of EU-ETS as it is enforced only in specific sectors. A few more recent studies with more robust research designs analyze firm-level outcomes, also finding limited economic impacts, but mainly focus either on a limited set of countries, on specific sectors or on emissions alone (Dechezleprêtre et al., 2023; Colmer et al., 2024; Bayer and Aklin, 2020;

Jaraitė and Maria, 2016; Marin et al., 2018).

Previous literature has almost neglected the spatial dimension of the EU-ETS despite the intuition of possible heterogeneous effects arising from the concentration of regulated emissions in a limited number of regions (Robaina and Goncalves, 2019; Roseta-Palma et al., 2011). In this paper, we aim to fill this gap by employing a novel measure of policy exposure at the local and industry level to estimate the causal impact of EU-ETS on regional economies. Contrary to previous studies, that have focused on the first phases of the carbon pricing mechanism, we analyze the impact of Phase 3 which led to a substantial contraction in the free allowances on a subsequent surge into carbon prices and hence in the compliance costs of firms. By employing Synthetic Difference-in-Difference methods, our research design takes advantage of an exogenous variation into policy exposure to estimate the impact of EU-ETS enforcement on a battery of economic indicators.

We find that provinces with the largest changes between Phase 2 and Phase 3 in the quantity of allowances that must be purchased, reduced their employment, GVA, and productivity per employees in targeted industries relative to provinces that were less impacted by the changes between Phase 2 and 3. We find the highest impacts on mining and quarrying, electricity, gas, steam and air conditioning supply, water supply, and construction. We find limited impact on manufacturing outcomes, in line with findings of previous studies. Furthermore, we find a strong reduction on emissions of regulated industries. Finally, we find mild evidence of the impact of the policy change in terms of regional disparities, although there are differences across outcomes in specific sectors.

The rest of the paper is organized as follows: Section 2 provides some background on the EU Emission Trading System and the main innovations introduced in Phase 3 of the policy; Section 3 outlines the research design and the data sources used for the analysis; Section 4 presents and discuss the results and Section 5 summarizes and concludes the study.

2 Background: EU Emission Trading System

The European Union Emissions Trading System (EU ETS), established by Directive 2003/87/EC and launched in 2005, is the cornerstone of the EU's strategy to reduce emissions cost-effectively and incentivize decarbonization. As the world's first and largest international cap-and-trade system for greenhouse gas (GHG) emissions, the system operates by setting a cap on total emissions, which is reduced annually, and issuing Emission Unit Allowances (EUA) that companies can use to cover their emissions. These allowances can be traded on the market, enabling firms to buy or sell them depending on their emission levels. This limit is progressively lowered each year to align with the EU's climate objectives, ensuring a steady decline in overall emissions. The cap, initially set at the national level during the first two trading phases, became EU-wide starting in Phase 3 (2013–2020). The linear reduction factor, initially 1.74% annually, was increased to 2.2% for Phase 4 (2021–2030), in line with the EU's objective to achieve a 62% reduction in emissions by 2030 compared to 2005 levels. By 2023, the system contributed to a reduction of approximately 47% in emissions from European power plants and industrial facilities compared to 2005 levels.

The EU ETS operates in four distinct trading phases. Phase 1 (2005–2007) was a three-year pilot phase designed to test the system's framework and prepare for Phase 2. The inclusion of installations in the EU ETS is determined based on their activity level. This phase covered only CO_2 emissions from power generators and energy-intensive industries. Nearly all allowances were distributed for free to businesses based on historical emissions, a method known as "grandparenting." and the penalty for non-compliance was set at €40 per tonne of CO_2 equivalent. Due to the lack of reliable emissions data, the caps in Phase 1 were determined based on estimates. This led to the issuance of allowances that exceeded actual emissions, resulting in a significant oversupply (Ellerman et al., 2010)[1]. Consequently, in 2007, the surplus caused allowance prices to drop to zero, as unused Phase 1 allowances could not be carried over into Phase 2.

Phase 2 (2008-2012) was the first full implementation phase of the EU ETS, with a tighter emissions cap (6% lower than Phase 1), the introduction of banking for unused allowances into Phase 3 and the introduction of international credits from the Kyoto Protocol's Clean Development Mechanism (CDM) and Joint Implementation (JI) as an option for companies to offset a portion of their emissions. The system's geographical scope expanded to include Norway, Iceland, and Liechtenstein, while aviation emissions were added in 2012 for flights within, to, and from the European Economic Area (EEA). Although allowances were still predominantly allocated for free, their overall quantity was reduced. The penalty for non-compliance increased to €100 per tonne of CO_2 equivalent. However, the 2008 financial crisis reduced industrial activity, resulting in lower-than-expected emissions and a surplus of allowances, which negatively impacted the price that fell to around 5 Euros per EUA by the end of the phase.

Phase 3 introduced major reforms to harmonize and strengthen the EU ETS. The cap was set at the EU level, declining annually by 1.74%, and auctioning became the primary method of allowance allocation (Mirzaee Ghazani and Jafari, 2021), with free allowances reduced to 43% by 2020. Free allocation was based on benchmarks reflecting the top 10% most efficient installations, with revenues from auctions used for renewable energy and energy efficiency

[1]Ellerman et al., (2010) provide a comprehensive overview of the design of the EU ETS and a thorough analysis of the first phase of this policy (2005-2007).

projects. The scope expanded to include additional sectors and gases, such as nitrous oxide (N_2O) and perfluorocarbons (PFCs), while aviation remained partially covered. To address surplus allowances, the Market Stability Reserve (MSR) was introduced in 2019, with the mandate of stabilizing the market by reducing oversupply. By 2020, emissions from covered sectors had dropped by 35% compared to 2005 levels.

As anticipated in the introduction, in this paper, we take advantage of the major changes in the policy between Phase 2 and Phase 3 to estimate the impact of emission trading on regional economies by using data and an econometric design that are discussed in the next sections.

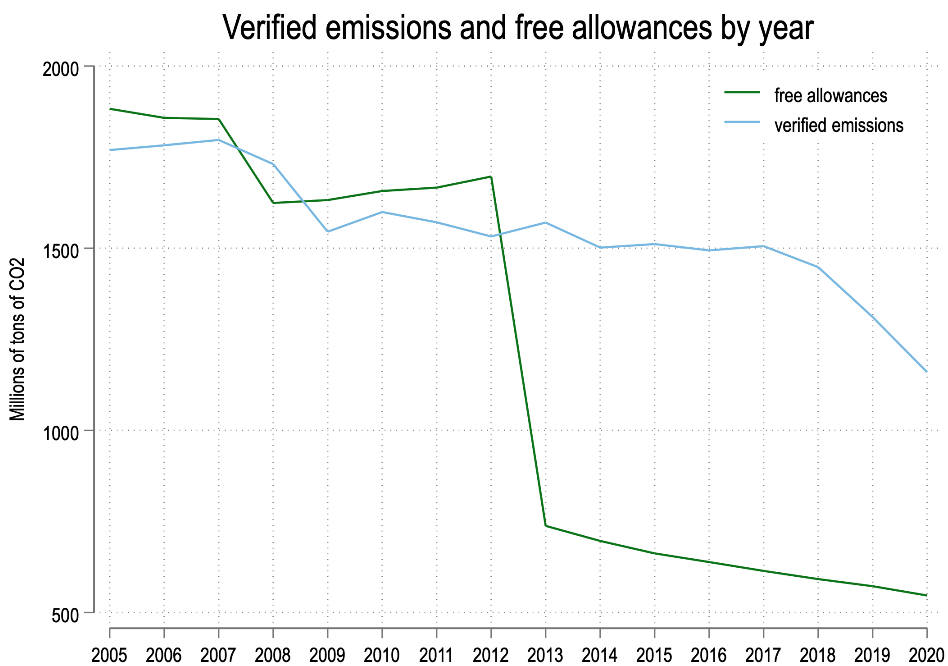


Figure 1: Cumulative Verified emissions and free allowances by year. source: own elaboration

Figure 1 plots the overall levels of free allowances and verified emissions over time, showing the sharp drop in free allowances starting in 2013. Third, the phase encompassed the implementation of a European-wide cap subject to a linear reduction factor of 1.74% per year until 2020.

3 Data and descriptive statistics

3.1 Sources of data and construction of main variables

The econometric analysis on the impact of EU-ETS is conducted by using data from two main sources: the European Union Transaction Log (EUTL) and the Eurostat Regions and Cities Database. The EUTL is the central mandatory reporting and monitoring tool for the EU-ETS, serving as a transaction log for the registration, issuance, transfer, and cancellation of allowances (European Council, 2023). This log is a platform for the European Commission to share public information on the compliance of regulated entities, the active participants in the system and their transactions. We obtain the EUTL data through a publicly available and accessible relational database (Abrell, 2024)[2]. We begin with this rich installation-level data, which contains a unique installation id, address, longitude and latitude, industry classification (NACE), year of compliance, number of certificates allocated for free, number of verified emissions, and numbered of surrendered certificates, among other information.

We employ the EUTL data to build a measure of local exposure to the changes in allocation rules starting in Phase 3 of the EU ETS. Each installation in the EUTL registry is assigned to its corresponding NUTS-3 province using latitude, longitude, and zip code. For each year, we calculate the total verified CO_2 emissions and freely allocated allowances by summing these values across all installations within each NUTS-3 province.

In order to measure total emissions for the NUTS-3 provinces for both regulated and unregulated activities, we use data from the Emissions Database for Global Atmospheric Research (EDGAR) provided by the European Commission. [3]. We use the annual grid maps at the 0.1degree x 0.1 degree level and aggreagate to the NUTS-3 level.

To assess the impact of the regulatory changes, we focus on changes in 2013, the first year of Phase 3. Specifically, we compute the net paid emissions in 2013 by subtracting the total freely allocated allowances from the total verified emissions for each NUTS-3 province. This gives us the total net paid emissions in each province. To capture the cost implications of the policy changes, we compared the 2013 net paid emissions with the average net paid emissions during Phase 2 (2008-2012). This difference provides a measure of the increased costs arising from the sharp reduction in free allowance allocations in Phase 3. The higher this number, the higher the costs for the provinces starting in 2013 relative to phase 2. Finally, we divide these differences across provinces into quintiles and assign each NUTS-3 province a variable indicating the quintile it falls into. This categorization allows for a comparative analysis of the varying degrees of exposure to changes across provinces.

[2] This data is available from https://www.euets.info/

[3] urlhttps://edgar.jrc.ec.europa.eu/dataset_ghg2024

Furthermore, we use data on local economic performance from the Eurostat Regions Database (2021). The Eurostat Regions and Cities Database provides a detailed picture of the diverse EU territories and is used to monitor EU regional policy targets. Data retrieved from this database include different social and economic aspects of European provinces such as demography, economy, employment, and education at the smallest Nomenclature of Territorial Units for Statistics (NUTS-3) levels available. The final dataset presents 1,167 NUTS-3 provinces, containing data on 28 countries[4] located in the European continent over the period 2008-2020[5]. We use the following measurements at the NUTS-3 level:

- Economic performance: data on gross value added (GVA) by sector (according to ISIC Rev. 4 categorizations) and total GVA.
- Employment by sector (according to ISIC Rev. 4 categorizationTable A2 in the Appendix provides a list of the ISIC Rev. 4 codes) and total employment.
- Population levels.
- Education: share of population by education levels according to ISCED 11 categorization: less than primary education (levels 0-2); upper secondary and post-secondary non-tertiary education (levels 3 and 4); and tertiary education (levels 5-8).

3.2 Descriptive Statistics

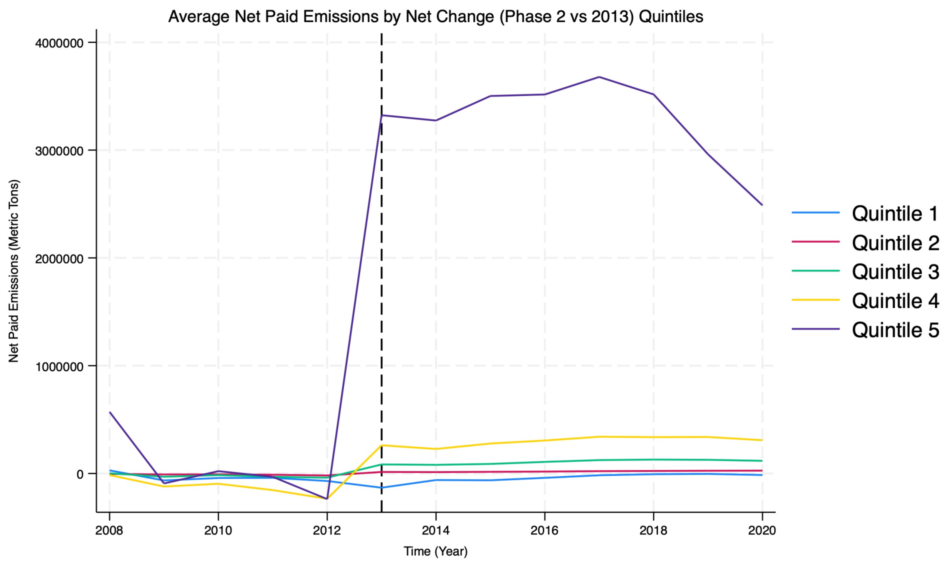
To provide an initial overview of the data, we divide our sample into quintiles based on our measure of exposure: the net change in paid emissions between the average of Phase 2 and 2013, the first year of Phase 3. To examine how net paid emissions vary across regions by quintiles and time, we plot the average yearly net paid emissions for each quintile group, as shown in Figure 2. The figure indicates that quintile 5, and to a moderate extent quintile 4, experienced a significantly higher change in net paid emissions from Phase 2 to phase 3, compared to the rest of the distribution. For subsequent analyses, we group provinces in quintiles 1-3 as this group experienced the least change, and we also group quintiles 4-5 together, as these regions faced the most substantial changes[6].

Table 1 shows the grouped mean and standard deviation for these quintile groups by ETS phase. The table shows that total employment increased slightly from Phase 2 to

[4]Table A1 in the Appendix provides a list of the countries and number of NUTS-3 provinces included in the analysis.

[5]We also provide robustness analyses in the Appendix table A3 omitting the year 2020 to exclude changes that may have been driven by COVID-19

[6]We also provide robustness analyses in the Appendix in which we group together quintiles 1-4 vs 5 and 1-2 vs 3-5



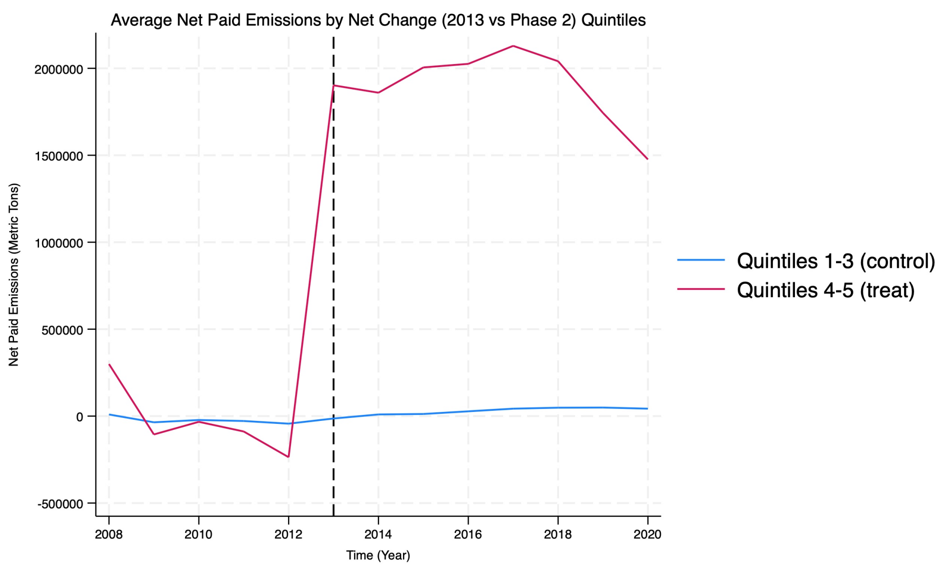


Figure 2: Yearly mean net paid emissions by quintile of net change (Phase 2 vs 2013). All quintiles separately (top) and quintiles 1-3 vs quintiles 4-5 (bottom).

Phase 3 in both groups: for Quintiles 1-3 (Q1-3), employment grew from 115,230 to 118,843, and for Quintiles 4-5 (Q4-5), it rose from 242,990 to 249,493. Similarly, gross value added (GVA) saw growth in both groups of quintiles, with Q1-3 increasing from 5,510 to 6,417 million euros, and Q4-5 rising from 12,958 to 14,865 million euros. Employment in Industry B-E remained stable in Q1-3, while Q4-5 saw a slight decline. GVA in industry B-E grew across both groups. Employment in manufacturing increased slightly in Q1-3 but declined in the highest quintiles, while GVA in manufacturing increased in both groups of quintiles. Additionally, verified emissions decreased in both groups, with Q4-5 experiencing a larger reduction. Overall, GVA seems to have increased across time with a trend toward reduced emission, despite modest employment declines in some sectors like manufacturing and limited growth in employment in industries B-E.

We next map the quintiles across NUTS-3 provinces. Figure 4 shows the spatial heterogeneity in changes of net paid emissions (phase 2 vs 2013) across NUTS-3 regions in levels (left). To get a sense of the monetary costs of these changes, the average 2013 allowance price was 4.32 euros; the provinces in the highest treated quintile faced an approximate change in costs of between 2.9 million and 94 million Euros. The middle figure shows the regional heterogeneity by net change in paid emissions per capita, while the figure on the right shows the net change per regional GVA in 2013.

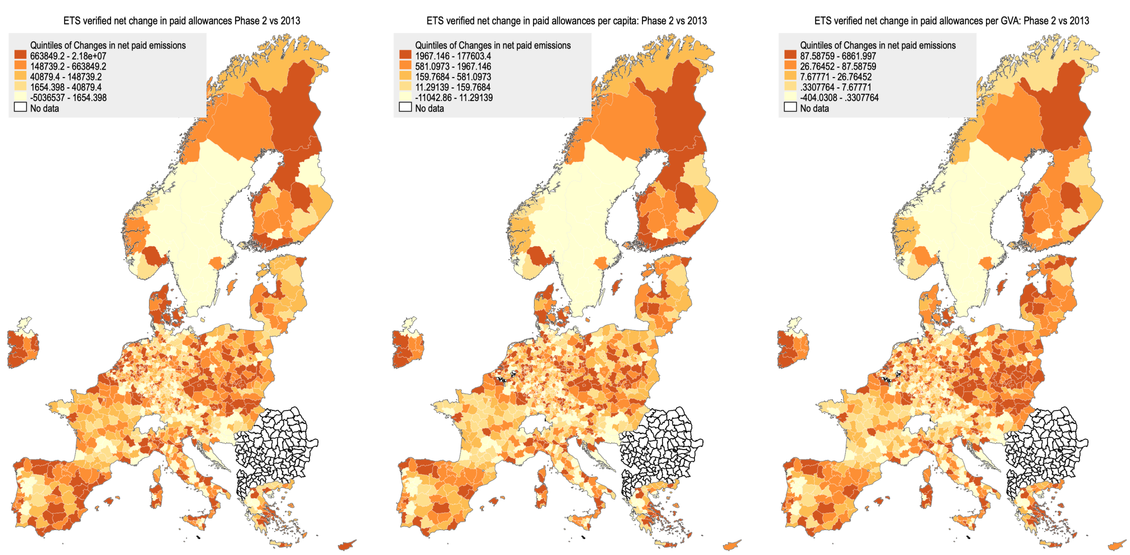


Figure 3: EU ETS 2013 Net Change in Paid Emissions per Capita (L) and per GVA (R)

Table 1: Summary Statistics. Quintile 1-3 vs Quintile 4-5: Phase 2 and Phase 3

	Phase 2 2008-2012 Q1-3	Phase 2 2008-2012 Q4-5	Phase 3 2013-2020 Q1-3	Phase 3 2013-2020 Q4-5
employment total (all industries)	115,230.96	242,990.75	118,843.10	249,493.68
	(125633.35)	(270550.69)	(133532.55)	(283147.67)
GVA total (all industries)	5,510.60	12,958.09	6,417.44	14,865.03
	(7,705.00)	(18,813.11)	(9,093.48)	(21,916.96)
PPE total (all industries)	0.05	0.05	0.05	0.05
	(0.02)	(0.02)	(0.02)	(0.02)
employment industry B-E	21,867.76	39,033.78	21,990.49	38,025.79
	(21,425.87)	(38,155.10)	(21,525.47)	(36,506.78)
GVA industry B-E (million euros)	1,233.01	2,467.42	1,457.39	2,772.61
	(1,469.38)	(2,922.72)	(1,758.05)	(3,287.75)
PPE industry B-E	0.06	0.07	0.07	0.08
	(0.03)	(0.04)	(0.03)	(0.04)
employment in manufacturing	20,195.70	34,558.46	20,262.53	33,557.65
	(20,141.53)	(34,939.80)	(20,179.09)	(33,107.65)
GVA in manufacturing	1,057.55	1,970.54	1,266.12	2,253.14
	(1,319.26)	(2,450.68)	(1,618.86)	(2,820.39)
PPE in manufacturing	0.05	0.06	0.06	0.07
	(0.02)	(0.03)	(0.03)	(0.04)
employment in construction	8,183.36	16,803.22	7,942.85	14,998.95
	(8,604.26)	(18,814.95)	(8,542.65)	(15,438.06)
GVA in construction	333.25	732.37	378.21	728.66
	(429.27)	(994.89)	(513.24)	(909.26)
PPE in construction	0.04	0.04	0.05	0.05
	(0.02)	(0.02)	(0.02)	(0.02)
verified emissions	257433.30	3.46e+06	243296.89	3.14e+06
	(996168.24)	(5.34e+06)	(755334.66)	(5.12e+06)
education up to upper secondary (share)	52.98	50.05	52.79	49.89
	(12.87)	(15.67)	(11.60)	(13.96)
education tertiary and above (share)	24.66	23.92	28.30	28.35
	(6.42)	(7.82)	(7.32)	(8.71)
population (thsds)	266.01	528.18	268.27	535.06
	(270.32)	(536.58)	(277.68)	(553.62)
Observations	2345.00	2050.00	3752.00	3280.00

Note: Mean of group values. Standard deviations in parentheses. GVA in millions of euros.

4 Empirical Strategy

Our research design exploits the variation in the EU-ETS stringency over time as well as the spatial heterogeneity of the policy exposure to estimate the impact of emission trading on regional economic outcomes. To explore the local impact of the EU ETS changes allowance allocation rules, in which auctioning became the default method for distributing allowances starting in 2013, we exploit the differential treatment across provinces as defined above. This allows us to compare provinces that were the most impacted by the new allocation rules (in quintiles 4 and 5 of the net changes) relative to provinces that saw smaller changes in net paid allowances. To find plausible counterfactuals for each province, we rely on synthetic difference-in-differences as formalized by Arkhangelsky et al. (2021). A similar strategy, Generalized Synthetic Control (Xu, 2017), has been used to analyze the impact of the ETS on emissions and pollution (Basaglia et al., 2024; Bayer and Aklin, 2020).

Using synthetic difference-in-differences (SDID) provides a more robust alternative relative to traditional difference-in-differences (DID) methods. Ideally, we would have similar provinces treated with different "doses" of EU ETS changes in free allowances, whose outcomes would have otherwise evolved similarly. DID is typically applied in settings where some units are exposed to a policy and the "parallel trends" assumption is met, often after including time and unit fixed effects to control for selection effects[7]. Synthetic difference-in-differences weakens the reliance on the parallel trends assumption and is a data-driven way to choose control units that match a set of treated units, exploiting variation in treatment over time and groups. This method re-weights control units and time periods to match the pre-exposure trends of treated and control units, ensuring comparability. These weights put more emphasis on units that on average more similar to the treated units and more weight on years that are more similar to the treated periods, making the estimator more robust relative to DID. Furthermore, it has consistency and statistical normality advantages over traditional difference-in-differences (Arkhangelsky et al., 2021).

In our setting, SDID re-weights the least treated NUTS3 regions (quintiles 1-3) to make their time trend before the change in policy regulation (2013) parallel to the trend of the highest exposed treated regions (quintiles 4-5), then applies DID to this reweighted panel. We use Phase 2 (2008-2012) as our pre-treatment period and Phase 3 (2013-2020) as post-treatment period . We exploit NUTS3 variation in regulation intensity under of the EU ETS based on the change in net allowances paid from Phase 2 to Phase 3. Given the regulatory changes, NUTS3 provinces with higher changes in net paid emissions are expected to be

[7] Before adopting the SDID estimator, we have conducted an extensive analysis using the standard DID approach, however, estimates were unreliable as the parallel trend assumption in the pre-treatment period did not hold. Results, although not reported in the paper, are available upon request.

impacted relatively more than provinces with lower changes. For instance, a region that paid for the same amount of emissions in Phase 2 and in Phase 3 experienced no change in net paid emissions and is expected to be relatively less impacted by the regulatory changes than a region experienced an increase in the net paid emissions from Phase 2 to Phase 3. We split provinces according to quintiles of changes. In our main analysis we define a binary treatment, considering quintiles 4 and 5 to be the "treated" quintiles and quintiles 1-3 as the "control group" [8].

In our setup, we have a panel of N NUTS-3 units and T time periods, Where i indexes the NUTS-3 province, i.e., the province and t the years. $Y_{it}$is our economic outcome variable of interest. W_it is the exposure to the binary treatment as 1) a dummy variable equal to 1 if the region belongs to the highest 2 treated quintiles. Specifically, SDID: i) finds weights, $\hat{\omega}_i$, that align pre-exposure trends in the outcome of units in quintiles 1-3 with those for the units in quintiles 4-5, ii) finds $\hat{\lambda}_t$ time weights that balance pre-exposure (2008-2012) time periods with post-exposure ones (2013-2020). It then uses these weights in a basic two-way fixed effects regression to estimate the average causal effect of exposure, denoted by $\hat{\tau}^{sdid}$ below as in Arkhangelsky et al. (2021).:

$$\left(\hat{\tau}^{sdid}, \hat{\mu}, \hat{\alpha}, \hat{\beta}\right) = \arg \min_{\tau,\mu,\alpha,\beta} \left\{ \sum_{i=1}^{N} \sum_{t=1}^{T} \left(Y_{it} - \mu - \alpha_i - \beta_t - W_{it}\tau\right)^2 \hat{\omega}_i^{sdid} \hat{\lambda}_t^{sdid} \right\} \tag{1}$$

Our coefficient of interest is τ which indicates the average treatment effect of the ETS for the change in net paid emissions in the NUTS3 region in 2013 relative to phase 2. Our estimation includes unit fixed effects α_i and time fixed effects β_t as well as a generalized intercept. We estimate the average treatment effect on the following outcomes: employment, GVA, and PPE at the aggregate level across all industries and on the following sub-industry outcomes, grouped according to their availability in Eurostat for the panel of interest: B-E (B: Mining and Quarrying; C: Manufacturing; D: Electricity, Gas, Steam and Air Conditioning Supply; D: Water Supply); B-E excluding manufacturing; C: Manufacturing; F: Construction; and G-J (G: Wholesale and Retail Trade; H: Transportation and Storage; I: Accommodation and Food Service Activities; J: Publishing, Broadcasting, and Content Production and Distribution Activities)[9]. In sub-industry analyses, we re-estimate the quintiles of treatment based on the net changes occurring within industries. That is, for each sub-industry group, we calculate the change in net paid emissions for installations belonging to a particular industry, and define quintiles and treatment based on the industry quintiles.

[8]We also test for robustness to other treatment definitions, e.g. including only quintile 5 in the treatment. Results are shown in Appendix Table A5

[9]We omit results of unregulated industries for which we find no significant impact.

5 Results

5.1 Baseline estimates

We show the set of results comparing the provinces in the highest two quintiles of changes in net paid emissions (treat = 1) with the bottom three quintiles (treat = 0). We estimate the average treatment effect (ATE) including covariates for population and education. Table 2 shows the ATEs with separate results by industry groups within a NUTS-3 region and for the overall NUTS-3 level outcomes across all industries in the bottom panel.

As shown in Table 2, the provinces with the highest treatment exposure experienced a significant negative treatment effect of the EU ETS Phase 3 on employment, GVA, and PPE for the industries most heavily regulated, B-E (in NACE nomenclature), relative to these industries in the provinces that experienced lower treatment levels. Provinces in the highest treatment quintiles experienced a 0.9% reduction in employment during Phase 3 compared to provinces in the bottom three quintiles of treatment (exp(-0.009) -1) * 100). Similarly, GVA in this group decreased by 1.9% and PPE declined by 1.3% in treated provinces relative to the control group.

We find these negative effects are driven by the most regulated industries (mining and utilities) and to a moderate and limited degree by the manufacturing industry. The negative impacts are strongest for the industry groups B Mining and quarrying, D Electricity, gas, steam and air conditioning supply, and E Water supply[10]. This group of industries in the highest treated provinces saw decreases in employment, GVA, and PPE of 3.2%, 8.6% and 6.7%, respectively, in Phase 3 compared to these same industries in provinces in the control group. When focusing on the manufacturing industry, we find smaller decreases in employment (-1%) but no significant impacts in GVA or PPE in this sector. Interestingly, we report negative impacts on employment in the construction industry, indicating potential spillovers to this sector.

Pooling the economic indicators across all industries (A-V) we find no significant effect of the policy change for the provinces in the highest treated quintiles relative to the less treated provinces. This suggests the impacts are concentrated across specific industries, particularly those most highly regulated and with the highest changes in free allowances from Phase 2-3, including electricity generators.

Our results are robust to changes in the timeframe and definition of the treated quintiles. We repeat the analyses using the panel from 2008-2019. The results remain similar.

5.2 Heterogeneity analyses by sub-industry

We next show results using a definition of treatment at the sub-industry level, focusing on sub-industry outcomes. Specifically, we re-define the highest treated provinces based on NUTS3 sub-industry changes in net paid allowances from Phase 2 to Phase 3, instead of total changes

[10] Due to data availability, we are not able to analyze each of these sub-industries B, D, and E separately.

Table 2: SDID Results by Sub-industry and Total

	log Employment	log GVA	log PPE
B Mining and quarrying; C Manufacturing; D Electricity, gas, steam and air conditioning supply; E Water supply			
treat	-0.009**	-0.019**	-0.013*
	0.004	0.009	0.007
Observations	14391	14391	14391
N NUTS-3	1107	1107	1107
B-E Excluding Manufacturing			
treat	-0.033***	-0.090***	-0.069***
	0.011	0.015	0.015
Observations	14092	14092	14092
N NUTS-3	1084	1084	1084
C Manufacturing			
treat	-0.010*	0.002	0.002
	0.005	0.010	0.008
Observations	14391	14391	14391
N NUTS-3	1107	1107	1107
F Construction			
treat	-0.018**	-0.011	-0.011
	0.007	0.014	0.011
Observations	14404	14404	14404
N NUTS-3	1108	1108	1108
Total: All Industries			
treat	0.003	0.001	-0.002
	0.003	0.005	0.004
Observations	14404	14404	14404
N NUTS-3	1108	1108	1108

Note: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.10

across all industries. For example, for manufacturing, the highest treated provinces are those whose changes in net paid allowances in the manufacturing sector are in the top 2 quintiles, and similarly for each of the industry groups B-E and B-E excluding manufacturing. The results are shown in Table 3.

Table 3: SDID Results by Sub-industry and Total. Treatment Defined at the Industry Level.

	log Employment	log GVA	log PPE
B Mining and quarrying; C Manufacturing; D Electricity, gas, steam and air conditioning supply; E Water supply			
treat	-0.009**	-0.016*	-0.010*
	0.004	0.010	0.006
Observations	14391	14391	14391
N NUTS-3	1107	1107	1107
B-E Excluding Manufacturing			
treat	-0.040***	-0.077***	-0.051***
	0.013	0.016	0.019
Observations	14092	14092	14092
N NUTS-3	1084	1084	1084
C Manufacturing			
treat	-0.009*	0.003	0.008
	0.005	0.008	0.006
Observations	14417	14417	14417
N NUTS-3	1109	1109	1109

Note: Standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.10$

The results show similar results for industries B-E, with negative treatment effects on employment and GVA and negative impacts on productivity per employee in sectors B-E when excluding manufacturing. Specifically, provinces in quintiles 4-5 saw a treatment effect on employment of -0.9% in Phase 3, relative to provinces in the bottom 3 quintiles of treatment. Similarly, GVA in this group decreased by 1.6% in Phase 3 relative to the control group, while there was a decreas of 1% on PPE. When focusing on the industries in mining and utilities (B, D, E), we find larger decreases in employment, GVA and PPE (-3.9%, -7.4%, and -5% , respectively).

When focusing on manufacturing-level changes due to the regulatory impacts of Phase 3, the treatment impact is -0.9% significant at the 10% level. This smaller and less significant effect is in line with the literature on firm-level studies focused on the manufacturing sector, which typically find no significant impacts on manufacturing employment (Colmer et al., 2024; Dechezleprêtre et al., 2023).

5.3 Heterogeneity by level of regional development

One of the main concerns of the EU ETS is that the policy might generate regional disparities as the most polluting industries are located in less developed regions. In order to explore the impact of the EU ETS's changes in allocation rules starting in Phase 3, we analyze treatment effects on separate sub-samples of provinces by level of output per capita. We split regions into terciles according to their GVA per capita in 2012, representing different levels of economic development. Figure 5 below shows a map of the categorization. We run the SDID analyses on each separate sample of level of development, comparing those provinces in the 4th and 5th quintile of net changes in allowances with those that had smaller changes, as before. Table 4 below shows the average treatment effect for each sub-sample of development. This table presents the results of the SDID analyses that estimate the treatment effects of changes in the allocation rules of the EU ETS starting in Phase 3. We estimate treatment effects across various sub-industries and also on the aggregated results.

In the sample in the first tercile, employment is largely unaffected across industries, with exceptions in the Construction (-0.028**) and agriculture which sees a positive impact on employment (0.03*), where significant effects are found relative to less treated provinces in this group. However, industries B-E excluding manufacturing experience a decline in GVA and PPE.

In the second tercile, we find the strongest impacts in sectors B-E excluding manufacturing, where treated provinces experienced decreases across employment, GVA, and PPE. No other industry group in this tercile experienced employment decreases (although we find increases in agricultural employment). We also find a significant impact on total PPE when we aggregate across all industries. Furthermore, we find negative treatment effects in PPE for industries B-E, construction, agriculture, and on the aggregate levels across all industries.

Finally, in the highest tercile of economic development, we find negative impacts on employment in industries B-E, including manufacturing (which was not impacted in other terciles). We also find negative impacts on GVA and PPE of industries B-E excluding manufacturing but no significant impact on all other outcomes and industry groups. Across most sectors, we find no evidence that productivity and output were affected in the most economically developed regions.

While all terciles experienced a negative treatment impact on employment of industries in mining and utilities (electricity, gas, steam and air conditioning supply, water supply), only the first and second terciles experienced negative impacts on GVA and PPE. Furthermore, the second tercile appears to be the most impacted in terms of GVA and PPE in industries B-E, while the third tercile sees consistent negative effects on employment in these industries.

Overall, our results indicate mild evidence of the impact of EU ETS on regional disparities in

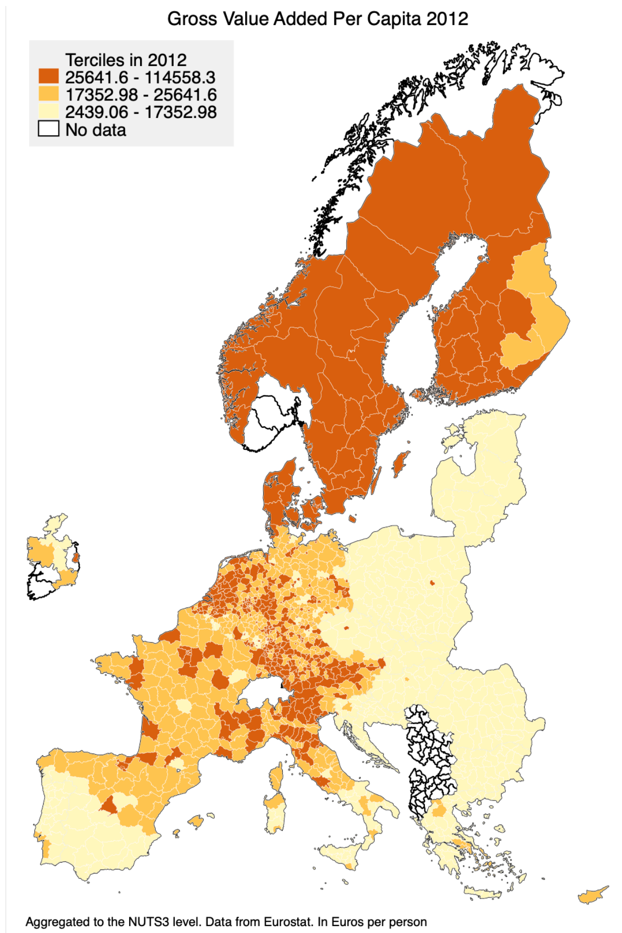


Figure 4: Terciles of GVA per Capita in 2012

Table 4: SDID Results by Tercile of GVA per capita: Sub-industry and Total

	Tercile 1			Tercile 2			Tercile 3		
	log Emp.	log GVA	log PPE	log Emp.	log GVA	log PPE	log Emp.	log GVA	log PPE
B Mining and quarrying; C Manufacturing; D Electricity, gas, steam and air conditioning supply; E Water supply									
treat	-0.002	-0.020	-0.012	-0.009	-0.022*	-0.019*	-0.017***	-0.011	0.002
	0.008	0.015	0.012	0.007	0.013	0.011	0.006	0.011	0.010
Observations	4797	4797	4797	4797	4797	4797	4797	4797	4797
N NUTS-3	369	369	369	369	369	369	369	369	369
B-E Excluding Manufacturing									
treat	-0.027	-0.122***	-0.095***	-0.027*	-0.071***	-0.057**	-0.038**	-0.072***	-0.043**
	0.019	0.033	0.032	0.015	0.023	0.022	0.016	0.021	0.021
Observations	4706	4706	4706	4693	4693	4693	4693	4693	4693
N NUTS-3	362	362	362	361	361	361	361	361	361
C Manufacturing									
treat	-0.001	0.013	0.013	-0.010	-0.014	-0.012	-0.019***	0.005	0.015
	0.008	0.016	0.013	0.007	0.013	0.010	0.006	0.013	0.010
Observations	4797	4797	4797	4797	4797	4797	4797	4797	4797
N NUTS-3	369	369	369	369	369	369	369	369	369
F Construction									
treat	-0.028**	-0.011	0.012	-0.018	-0.023	-0.028**	-0.012	-0.011	-0.018
	0.014	0.028	0.027	0.016	0.015	0.013	0.009	0.016	0.012
Observations	4810	4810	4810	4797	4797	4797	4797	4797	4797
N NUTS-3	370	370	370	369	369	369	369	369	369
A Agriculture, Forestry and Fishing									
treat	0.030*	0.026	0.004	0.025**	-0.024*	-0.043**	-0.003	-0.001	0.010
	0.016	0.018	0.022	0.010	0.014	0.018	0.014	0.022	0.020
Observations	4784	4784	4784	4784	4784	4784	4771	4771	4771
N NUTS-3	368	368	368	368	368	368	367	367	367
Total: All Industries									
treat	0.006	0.003	-0.004	0.004	-0.007	-0.014**	-0.003	-0.003	-0.004
	0.006	0.009	0.011	0.005	0.007	0.006	0.003	0.005	0.004
Observations	4810	4810	4810	4797	4797	4797	4797	4797	4797
N NUTS-3	370	370	370	369	369	369	369	369	369
Total Excluding B-E									
treat	0.008	0.009	-0.001	0.004	-0.008	-0.014***	-0.002	-0.004	-0.004
	0.007	0.009	0.011	0.005	0.005	0.005	0.004	0.006	0.005
Observations	4810	4810	4810	4797	4797	4797	4797	4797	4797
N NUTS-3	370	370	370	369	369	369	369	369	369

Note: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.10.

terms of loss of output and productivity in terciles 1-2, particularly in industries B-E.

5.4 Emissions

We now turn to study the impact of the EU ETS Phase 3 changes in allowance allocation on emissions. Since the main objective of the EU ETS program is to reduce emissions, it is important to consider whether the changes in the program reached this objective. We repeat the SDID analysis, using log emissions of regulated industries as our outcome of interest. The results are shown in Table 5. We find large and significant negative impacts on total emissions of regulated firms and on emissions of regulated firms in industries B-E. Provinces in the highest treated quintiles saw reductions of about 10% in regulated emissions (on total regulated emissions and on emissions of industries B-E) in Phase 3, relative to provinces in the bottom 3 quintiles of treatment. When focusing on overall provincial emissions, including those of unregulated entities, we also find significant decreases in emissions. Table 6 show the results on the total provincial CO2 emissions using the EDGAR data. Relative to quintiles 1-3, provinces in the highest treated quintiles saw a reduction of about 5% in total provincial emissions.

Table 5: SDID Results on Emissions of Regulated Installations

	log Emissions Total	log Emissions B-E
treat	-0.107***	-0.100***
	(0.036)	(0.037)
Observations	12558	12441
N NUTS-3	966	957

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
Note: Balanced sample.

Table 6: SDID Results on Total CO2 Emissions

	log Emissions Total
treat	-0.050***
	(0.006)
Observations	14404
N NUTS-3	1108

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
Note: Balanced sample. Data from the JRC EDGAR database.

The implementation of EU ETS Phase 3 led to a significant reduction in carbon emissions but came at a measurable economic cost. Our analysis estimates that the policy resulted in a 10% decrease in emissions from regulated industries in the most highly regulated provinces compared to the least impacted ones, amounting to approximately 24,299 tons of CO reduced from regulated entities. However, this reduction was accompanied by about a 1% decline in employment, translating to the loss of about 2,187 jobs, and a 1.9% drop in Gross Value Added (GVA) equating to approximately €246.2 million in lost economic output. When assessing the cost per ton of CO abated, we find that for every ton of emissions reduced, there was an associated loss of 0.09 jobs (or roughly 1 job lost per 11.1 tons of CO) and €10,132 in economic output. These results highlight the trade-offs of stringent emissions regulations, underscoring the need for complementary policies to mitigate the economic burden while achieving environmental goals.

6 Discussion and conclusion

Our findings indicate that while provinces with the largest increases in net paid allowances achieved significant emissions reductions, this was accompanied by decreases in economic outcomes of mining, electricity, and utility supply industries. When focusing on the manufacturing industry, we find moderate decreases in employment (-1%) but no significant impacts on GVA or PPE in this sector. Furthermore, we report evidence for some potential spillover effects, particularly as we find negative impacts on employment in the construction industry.

While we find impacts on the regulated industries, we find no evidence of a significant decrease in total economic activity. Pooling economic indicators across all industries (A-V) we find no evidence of significant overall treatment effects for the provinces in the highest treated quintiles relative to the less treated provinces. These results suggest that the impacts of are concentrated across specific industries, particularly those most highly regulated and with the highest changes in free allowances from Phase 2-3, including electricity generators.

When focusing on manufacturing-level changes and outcomes, the treatment impact is no longer significantly different than zero for GVA and PPE, despite a small decrease in employment. This is in line with the literature studying firm-level outcomes focused on the manufacturing sector, which typically finds no significant impacts on employment (Colmer et al., 2024; Dechezleprêtre et al., 2023).

While EU ETS Phase 3 effectively reduced emissions, its economic costs highlight the need for complementary policies to mitigate adverse labor and economic effects. Policies supporting worker retraining, investment in cleaner technologies, and transition support for affected industries could help balance environmental goals with economic sustainability.

As with all studies, our analysis is subject to some limitations. Given the current availability of data, we cover the period ending in 2020 leaving de facto out the last years in which the price of the CO_2 allowances has dramatically increased, remaining stably above 50 euros per tonne since August 2021 and surpassing 95 euros per tonne in February and August 2022. The effects of the policy might be even more accentuated in these last two years, pointing to a potential lower-bound of the reported impact. In the future, we hope to further study the mechanisms driving our outputs and make several robustness checks to our methods and measurements.

Notwithstanding, our study sheds light on the local economic impacts of the EU ETS, and includes data on Phase 3, a previously understudied phase. Following the growing literature focusing on the heterogeneous effects and the social externalities of the so-called green policies, this paper finds that the changes in the EU ETS allocation method decreased economic outcomes on some provinces and sectors, but had limited overall impact across all sectors. Our findings have relevant implications for both researchers and policy makers. From an academic perspective, this evidence raises several questions related to the mechanisms through which local economies have been able to react to the EU ETS.

7 Appendix

Table A1: List of countries in the analysis

Country	**Number of NUTS-3 provinces in the analysis**
Austria (AT)	35
Belgium (BE)	44
Bulgaria (BG)	28
Cyprus (CY)	1
Czech Republic (CZ)	14
Germany (DE)	401
Denmark (DK)	11
Estonia (EE)	5
Greece (EL)	52
Spain (ES)	59
Finland (FI)	19
France (FR)	100
Croatia (HR)	21
Hungary (HU)	20
Ireland (IE)	5
Italy (IT)	107
Lithuania (LT)	10
Luxembourg (LU)	1
Latvia (LV)	6
Malta (MT)	2
Netherlands (NL)	40
Norway (NO)	5
Poland (PL)	73
Portugal (PT)	25
Romania (RO)	42
Sweden (SE)	21
Slovenia (SI)	12
Slovakia (SK)	8
Total	**1,167**

Table A2: Industry Classifications

ISIC Rev. 4 Industry Code	**Description**
A	Agriculture, Forestry and Fishing
B	Mining and Quarrying
C	Manufacturing
D	Electricity, Gas, Steam and Air Conditioning Supply
E	Water Supply
F	Construction
G	Wholesale and Retail Trade
H	Transportation and Storage
I	Accommodation and Food Service Activities
J	Publishing, Broadcasting, and Content Production and Distribution Activities
K	Telecomm., Computer Programming, Consulting, Computing Infrastructure, and Other Information Service Activities
L	Financial and Insurance Activities
M	Real Estate Activities
N	Professional, Scientific and Technical Activities
O	Administrative and Support Service Activities
P	Public Administration and Defence, Compulsory Social Security
Q	Education
R	Human Health and Social Work Activities
S	Arts, Sports and Recreation
T	Other Service Activities
U	Activities of Households as Employers and Undifferentiated Goods and Service-Producing Activities of Households for Own Use
V	Activities of Extraterritorial Organisations and Bodies

Note: GVA and employment are available at the following aggregate levels:
A; B-E; C; F; G-I; G-J; J; K; K-N; L; M-N; O-U; R-U.

Table A3: SDID Results by Sub-industry and Total. Panel 2008-2019

	log Employment	log GVA	log PPE
B Mining and quarrying; C Manufacturing; D Electricity, gas, steam and air conditioning supply; E Water supply			
treat	-0.010**	-0.019***	-0.012*
	0.005	0.007	0.006
Observations	9972	9972	9972
N NUTS-3	831	831	831
B Mining and quarrying; C Manufacturing; D Electricity, gas, steam and air conditioning supply; E Water supply			
treat	-0.010**	-0.019***	-0.012*
	0.005	0.007	0.006
Observations	9972	9972	9972
N NUTS-3	831	831	831
B-E Excluding Manufacturing			
treat	-0.037***	-0.075***	-0.052***
	0.009	0.016	0.016
Observations	9756	9756	9756
N NUTS-3	813	813	813
C Manufacturing			
treat	-0.012**	0.001	0.002
	0.006	0.008	0.007
Observations	9972	9972	9972
N NUTS-3	831	831	831
F Construction			
treat	-0.019***	-0.027*	-0.028**
	0.006	0.015	0.011
Observations	9984	9984	9984
N NUTS-3	832	832	832
Total: All Industries			
treat	-0.000	-0.003	-0.005
	0.003	0.005	0.005
Observations	9984	9984	9984
N NUTS-3	832	832	832

Note: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.10

Table A4: SDID Results by Sub-industry and Total. Treatment defined as Q5

	log Employment	log GVA	log PPE
B Mining and quarrying; C Manufacturing; D Electricity, gas, steam and air conditioning supply; E Water supply			
treat	-0.008*	-0.015*	-0.010
	0.004	0.008	0.007
Observations	13284	13284	13284
N NUTS-3	1107	1107	1107
B-E Excluding Manufacturing			
treat	-0.031***	-0.084***	-0.066***
	0.010	0.014	0.014
Observations	13008	13008	13008
N NUTS-3	1084	1084	1084
C Manufacturing			
treat	-0.009*	0.005	0.005
	0.005	0.009	0.008
Observations	13284	13284	13284
N NUTS-3	1107	1107	1107
F Construction			
treat	-0.017***	-0.008	-0.007
	0.007	0.013	0.010
Observations	13296	13296	13296
N NUTS-3	1108	1108	1108
Total: All Industries			
treat	0.003	0.001	-0.001
	0.002	0.004	0.004
Observations	13296	13296	13296
N NUTS-3	1108	1108	1108

Note: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.10. Control quinitles are 1-4.

Table A5: SDID Results by Sub-industry and Total. Treatment defined as Q5.

	log Employment	log GVA	log PPE
B Mining and quarrying; C Manufacturing; D Electricity, gas, steam and air conditioning supply; E Water supply			
treat	-0.006	-0.028***	-0.025***
	0.005	0.010	0.008
Observations	14391	14391	14391
N NUTS-3	1107	1107	1107
B Mining and quarrying; C Manufacturing; D Electricity, gas, steam and air conditioning supply; E Water supply			
treat	-0.006	-0.028***	-0.025***
	0.005	0.010	0.008
Observations	14391	14391	14391
N NUTS-3	1107	1107	1107
B-E Excluding Manufacturing			
treat	-0.047***	-0.111***	-0.078***
	0.013	0.018	0.020
Observations	14092	14092	14092
N NUTS-3	1084	1084	1084
C Manufacturing			
treat	-0.004	0.001	-0.004
	0.006	0.010	0.008
Observations	14391	14391	14391
N NUTS-3	1107	1107	1107
F Construction			
treat	-0.014	-0.003	-0.007
	0.009	0.017	0.013
Observations	14404	14404	14404
N NUTS-3	1108	1108	1108
Total: All Industries			
treat	0.003	-0.003	-0.006
	0.003	0.006	0.005
Observations	14404	14404	14404
N NUTS-3	1108	1108	1108

Note: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.10. Control quinitles are 1-4. Full sample.

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GREEN
Centre for Geography, Resources, Environment, Energy and Networks
via Röntgen, 1
20136 Milano - Italia

www.green.unibocconi.eu