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

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Carbon pricing is a central instrument of climate policy, but its effects on local economies remain insufficiently understood. The costs of decarbonization are unlikely to be distributed evenly across industries and space, and regions that depend heavily on carbon-intensive production may face concentrated losses, even when climate policies are efficient in aggregate. We examine this issue in the context of the European Union Emissions Trading System, focusing on the Phase 3 reform introduced in 2013, which reduced the allocation of free allowances and increased the share of emissions that firms had to cover by purchasing permits. We link installation-level EU ETS data to regional data on employment, gross value added, productivity, and emissions for about 1,000 European NUTS-3 regions from 2008 to 2020. We measure regional exposure to the reform using the change in net paid emission allowances between Phase 2 and Phase 3, and estimate its effects using syntetic difference-in-differences. Regions facing larger increases in purchased emission allowances experienced declines in employment, gross value added, and producvtiy in carbon-intensive sectors, specifically mining and utilities. Manufacturing was less affected: employment declined modestly, while output and producvtiy did not change significantly. We find little evidence of broad regional economic decline or widening regional inequality. Importantly, the reform was also associated with sizeable emissions reductions. Overall, the results point to a specific pattern: the Phase 3 reform reduced emissions while generating economic costs concentrated in a limited set of sectors and regions. This highlights the importance of targeted transition policies for the design of climate policy that is both effective and regionally equitable.

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 a 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.

The burden of decarbonization, even in the form of carbon pricing, is not only sector-specific but also geographically uneven. Provinces more exposed to European and nation-level policies may experience significant declines in key economic indicators relative to less affected regions, alongside measurable reductions in emissions. If regions more exposed to those space-blind policies are also the ones with lower levels of development, then green policies may exacerbate spatial disparities. These considerations underscore the importance of incorporating economic geography into the design and evaluation of climate policies. As the EU accelerates its Green Deal and prepares for an expanded carbon pricing framework, understanding the spatial distribution of economic impacts is essential to crafting policies that are both effective and equitable. In this vein, we contribute to 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 economic outcomes in the European (NUTS3) regions.

Inaugurated in 2005, the 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 improve competitiveness by enabling new production methods (Porter and van der Linde, 1995) and could result in the EU ETS having improved economic outcomes. 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 evidence has mainly focused on sector-level implications of the 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 these 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 Aklın, 2020; Jaraite and Maria, 2016; Marin et al., 2018).

Despite mounting concern on the geography of discontent, the spatial distribution of the impacts of green policies in general and of EU-ETS in particular remains unclear (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 plausibly exogenous variation in exposure to the Phase 3 reform to estimate the impact of the 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 in the most regulated industries relative to provinces that were less impacted by the changes between Phase 2 and 3. These impacts are concentrated in specific sectors: the highest impacts are concentrated in mining and quarrying, electricity, gas, steam and air conditioning supply, water supply, and evidence of spillovers to 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 evidence that the negative economic effects associated with large and concentrated reductions in free allowances were often attenuated in poorer regions, although the magnitude of this mitigation varies across outcomes and 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 noncompliance increased to €100 per

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).

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 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

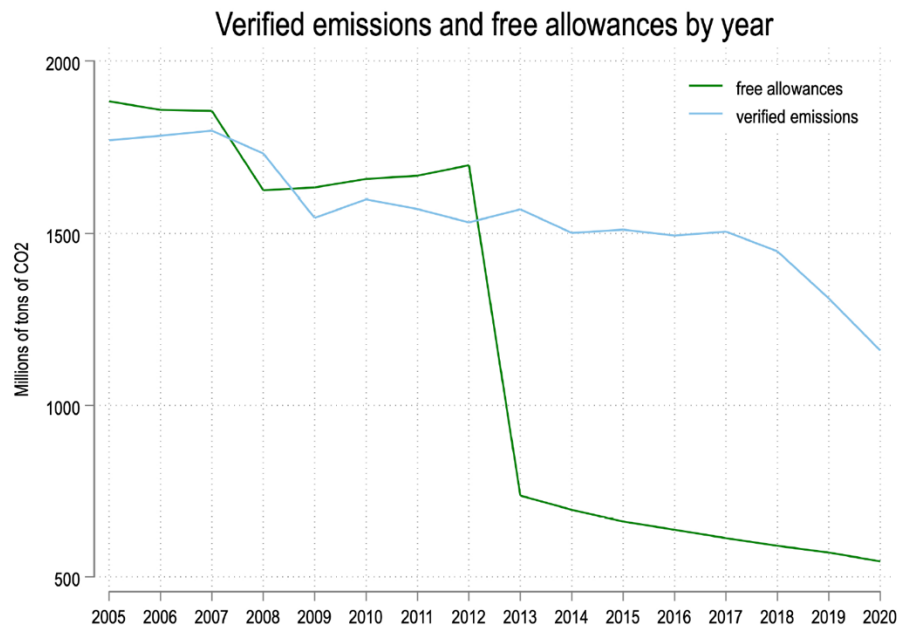


Figure 1 plots the overall levels of free allowances and verified emissions over time, showing the sharp drop in free allowances starting in 2013. Third, the phase encompassed the implementation of a European-wide cap subject to a linear reduction factor of 1.74% per year until 2020.

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 number 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 aggregated 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 change in compliance 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

² This data is available from <https://www.euets.info/>

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

it falls into. This categorization allows for a comparative analysis of the varying degrees of exposure to changes across provinces.

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 countries⁴ located in the European continent over the period 2008-2020⁵. We use the following measurements at the NUTS-3 level (except for education, which is at the NUTS2-level):

- Economic performance: gross value added (GVA) by sector (according to ISIC Rev. 4 categories) and total GVA.
- Employment: total and sectoral employment (ISIC Rev. 4). Table A2 in the Appendix provides a list of the ISIC Rev. 4 codes).
- Population: total population by province.
- Education: shares 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

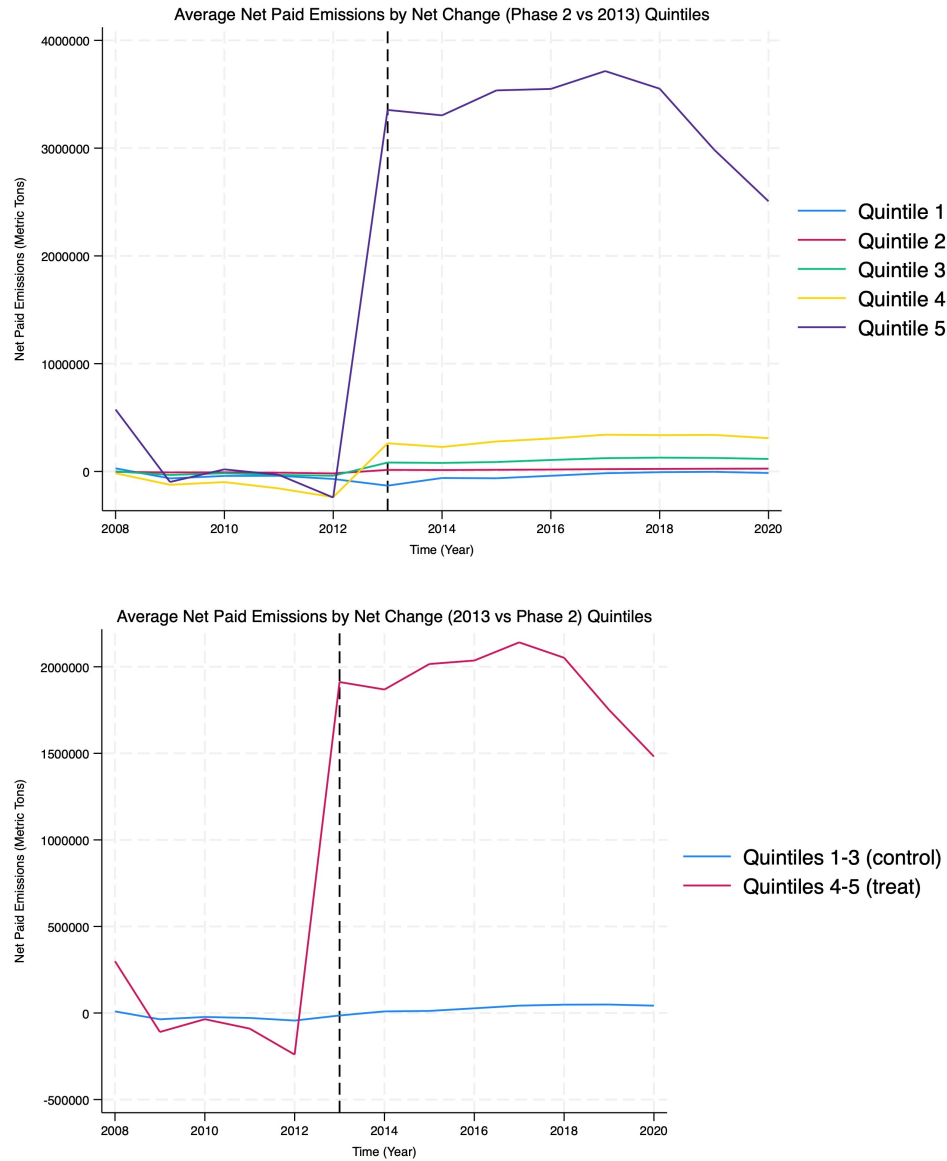
To provide an initial overview of the data, we divide our sample into quintiles based on our measure of exposure: the net change in paid emissions between the average of Phase 2 and 2013, the first year of Phase 3. To examine how net paid emissions vary across regions by quintiles and time, we plot the 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 substantially 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

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

experienced the least change, and we also group quintiles 4-5 together, as these regions faced the most substantial changes⁶⁷.

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).



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

⁷ -2 vs 3-5

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 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 emissions, despite modest employment declines in some sectors like manufacturing and relatively flat growth in employment in industries B-E.

We next map the quintiles across NUTS-3 provinces. Figure 3 shows the spatial heterogeneity in changes of net paid emissions (phase 2 vs 2013) across NUTS-3 regions in levels (left), per capita (center), and per GVA (right). 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.

Figure 3: EU ETS 2013 Net Change in Paid Emissions (L) per Capita (M) and per GVA (R)B-E (Mining, Manuf., Utilities)

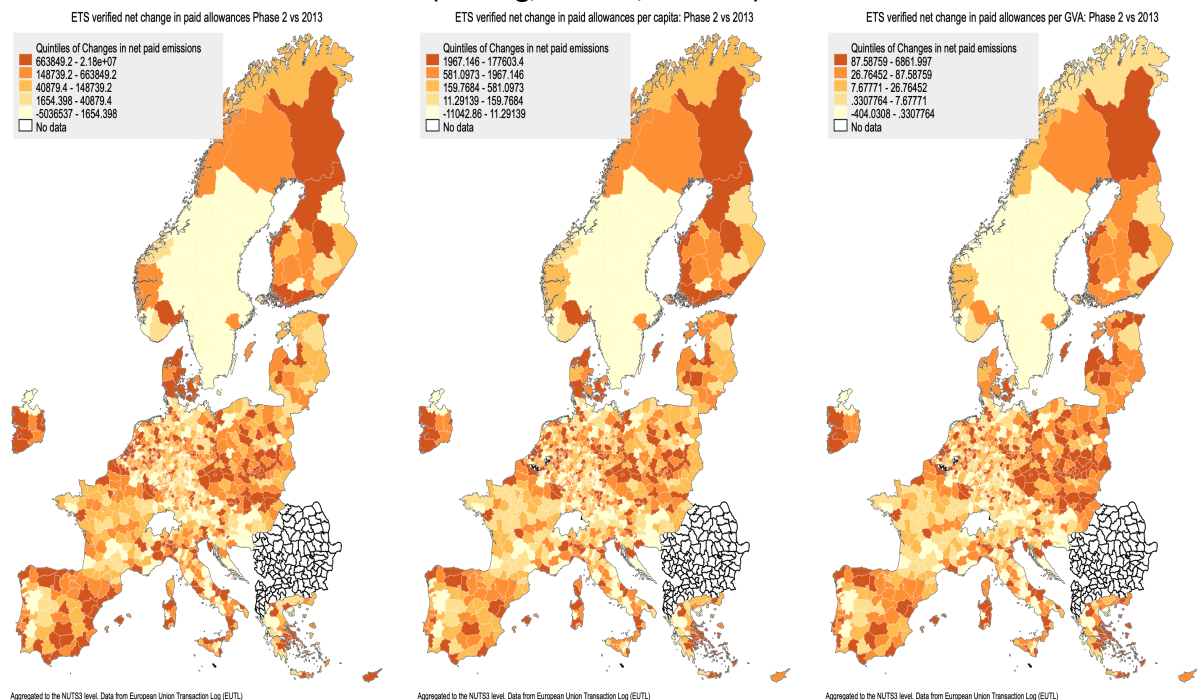


Table 1: Summary Statistics. Quintile 1-3 vs Quintile 4-5: Phase 2 and Phase 3

	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)	111,300.48 (136,635.38)	235,130.38 (281,814.88)	114,457.49 (144,526.52)	240,707.20 (291,700.55)
GVA total (all industries)	5,536.53 (10,073.17)	12,068.41 (18,431.57)	6,388.84 (11,735.06)	13,830.73 (21,182.88)
PPE total (all industries)	0.05 (0.02)	0.05 (0.02)	0.05 (0.02)	0.05 (0.02)
Employment industry B-E	20,134.33 (20,239.39)	38,262.95 (36,713.10)	20,141.94 (20,266.40)	37,313.10 (35,132.55)
GVA industry B-E (million euros)	1,130.38 (1,403.82)	2,339.83 (2,783.29)	1,327.73 (1,665.31)	2,666.06 (3,460.18)
PPE industry B-E	0.06 (0.03)	0.06 (0.04)	0.07 (0.03)	0.07 (0.05)
Employment in manufacturing	18,537.11 (19,003.96)	34,021.01 (33,498.39)	18,478.98 (18,952.14)	33,064.55 (31,754.33)
GVA in manufacturing	971.03 (1,232.43)	1,884.01 (2,312.33)	1,144.45 (1,479.32)	2,187.74 (3,034.77)
PPE in manufacturing	0.05 (0.02)	0.06 (0.03)	0.06 (0.03)	0.07 (0.05)
Employment in construction	7,901.01 (8,358.35)	16,630.75 (20,205.87)	7,626.39 (8,199.75)	14,850.55 (16,127.58)
GVA in construction	336.26 (468.73)	703.93 (1,060.18)	373.88 (542.29)	694.62 (906.08)
PPE in construction	0.04 (0.02)	0.04 (0.02)	0.05 (0.02)	0.05 (0.02)
verified emissions	264212.12	2.78e+06	248136.47	2.51e+06

	(1.12e+06)	(4.76e+06)	(950288.75)	(4.54e+06)
population (thsd)	256.24 (254.30)	515.90 (566.02)	257.95 (261.83)	521.09 (581.59)
education up to upper secondary (share)	52.41 (12.74)	49.97 (15.55)	52.43 (11.13)	49.87 (13.84)
education tertiary and above (share)	24.04 (6.52)	23.85 (7.84)	28.03 (7.39)	28.38 (8.78)
Observations	3095.00	2795.00	4952.00	4472.00

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. We focus on the change in allowance allocation rules introduced in Phase 3 of the EU ETS, when auctioning became the default allocation mechanism. Using the exposure measure defined in Section 3.1, we compare provinces that experienced the largest increases in net paid emissions (quintiles 4–5) to provinces that faced smaller changes (quintiles 1–3).

To construct plausible counterfactuals for treated provinces, we rely on synthetic difference-in-differences (SDID) 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). SDID offers a flexible alternative to traditional difference-in-differences (DID). 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 effects⁸. 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

⁸ 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.

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).

SDID re-weights control provinces (quintiles 1-3) and time periods to match the pre-treatment trajectories 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 posttreatment period. In our application, SDID matches on the outcomes of interest in the pre-treatment period, employment, gross value added (GVA), and productivity per employee (PPE), ensuring that treated and control provinces follow similar dynamics before the policy shock. The estimator therefore places higher weights on control provinces whose pre-2013 trajectories best approximate those of the treated provinces, and on years in Phase 2 (2008–2012) that are most comparable to the treated periods. Since the SDID procedure optimizes pre-treatment balance for each outcome variable, the re-weighting of control provinces is conducted separately for employment, GVA, and PPE. As a result, the effective control sample and time weights may differ across outcomes, ensuring the best possible match for each dependent variable.

Our identification strategy does not require treatment to be independent of pre-treatment characteristics, rather it requires that these characteristics do not induce differential counterfactual trends. We assess this assumption using visual diagnostics. Figures A1 in the Appendix display parallel-trends graphs for employment, GVA, and PPE, separately for treated (quintiles 4–5) and control (quintiles 1–3) provinces, separately for each group of industries. We also show similar trends for the treatment normalized by average pre-treatment GVA (Figure 13 and 14). These plots show that the SDID procedure achieves a close alignment of pre-2013 outcomes across groups, addressing concerns about the comparability of treated and control regions.

In the main analysis, treatment intensity is defined based on the change in net paid emissions from Phase 2 to Phase 3. Provinces with larger increases in net paid emissions are expected to experience greater exposure to the Phase 3 reform. We define a binary treatment indicator equal to one for provinces in the top two quintiles of this distribution and zero for provinces in the bottom three quintiles.

To account for differences in regional economic scale, we also report results using a normalized treatment measure that scales changes in net paid emissions by average pre-treatment GVA. This normalization facilitates comparison across regions of different sizes and can

be interpreted as an emissions cost shock per unit of output. Results using this alternative definition are presented in the Appendix starting with Table 11.

While treatment intensity may be higher in regions with a larger presence of carbon-intensive industries, this reflects the institutional design of the EU ETS, which specifically targets those sectors. Our identification strategy does not require treated and control regions to be similar in levels or industry composition, but rather that, absent the policy change, outcomes would have evolved along similar trends. We assess this directly using pre-treatment parallel trends .

Formally, we observe 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 τ^{sdid} below as in Arkhangelsky et al. (2021).

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

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; E: 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.

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

5 Results

5.1 Baseline estimates

We first 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 and Figure 4 show 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 the first panel of Table 2, industries most heavily regulated, B-E (in NACE nomenclature) in the provinces with highest treatment exposure saw a significant negative treatment effect of the EU ETS Phase 3 on employment and GVA, relative to these industries in the provinces that experienced lower treatment levels. Specifically, we estimate approximately a 1% ($\exp(-0.010) - 1$) * 100) reduction in employment during Phase 3 compared to provinces in the bottom three quintiles of treatment. Similarly, GVA in this group decreased by approximately 1.8% and PPE did not significantly decline in treated provinces relative to the control group.

We find that these negative effects are concentrated in the most regulated industries (mining and utilities, excluding manufacturing, panel 2 of Table 2) 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 supply¹⁰. This group of industries in the highest treated provinces saw significant (at the 1%) decreases in employment, GVA, and PPE of about 3.1%, 8% and 6.1%, 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 (about -1.2%) but no significant impacts in GVA or PPE in this sector. Interestingly, we report negative impacts on employment in the construction industry (about -1.8%), 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 that excludes 2020, the first year of COVID. The results remain similar.

Furthermore, as shown in Appendix Table 11 and Figure 10, our results using a normalized treatment definition show similar patterns. In particular, for industries B-E excluding

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

manufacturing, we find significant declines in employment, GVA, and PPE of approximately 5%, 7.3% and 3.3%, respectively, in Phase 3 compared to these same industries in provinces in the control group. For the broader B–E group, we find significant declines in GVA and PPE, but no statistically significant effect on employment. Using this treatment definition, we find no significant impacts in manufacturing across any outcome, and a modest but statistically significant decrease of about 0.9% in overall employment, accompanied by a significant increase in productivity of around 1.1%, with no corresponding change in aggregate GVA.

Finally, as another robustness check, we use a treatment definition using the share of gross value added coming from the most regulated industries (B-E: mining and utilities, excluding manufacturing) in years 2000-2004, split into quintiles. Similarly, we consider those regions in the top 2 quintiles of share of GVA in these industries as treated, and the remainder as controls. Using this alternative definition, we again find that regions with greater exposure to regulated industries experience significant relative declines in employment, GVA, and productivity in mining and utilities. Manufacturing exhibits smaller declines limited to employment, with no significant effects on output or productivity, consistent with the persistence of free allowances in this sector. These results are found in Appendix Table 14 and Figure 15.

Figure 4: SDID Results by Sub-industry and Total

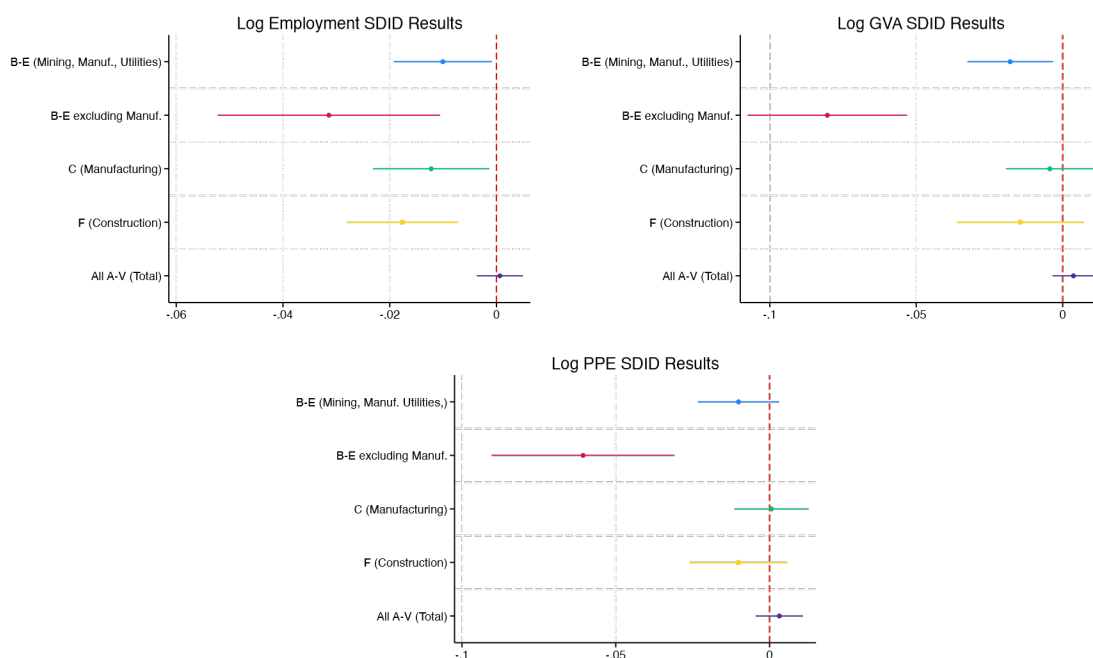


Table 2: SDID Results by Sub-industry and Total

	Log Employment	Log GVA	Log PPE
B Mining and quarrying; C Manufacturing; D Electricity, gas, steam and air conditioning supply; E Water supply			
treat	-0.010** 0.005	-0.018** 0.007	-0.010 0.007
Observations	14391	14391	14391
N NUTS-3	1107	1107	1107
B-E Excluding Manufacturing			
treat	-0.031*** 0.011	-0.080*** 0.014	-0.061*** 0.015
Observations	14092	14092	14092
N NUTS-3	1084	1084	1084
C Manufacturing			
treat	-0.012** 0.006	-0.004 0.008	0.001 0.006
Observations	14417	14417	14417
N NUTS-3	1109	1109	1109
F Construction			
treat	-0.018*** 0.005	-0.014 0.011	-0.010 0.008
Observations	14430	14430	14430
N NUTS-3	1110	1110	1110
Total: All Industries			
treat	0.001 0.002	0.004 0.004	0.003 0.004
Observations	14430	14430	14430
N NUTS-3	1110	1110	1110
Note: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.10			

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 regional sub-industry changes in net paid allowances from Phase 2 to Phase 3 instead of total regional changes. This approach allows treatment intensity to vary across industries within regions, rather than being driven by aggregate regional exposure. The results are shown in Figure 5 and Table 3.

Figure 5: SDID Results by Sub-industry and Total. Treatment Defined at the Industry Level

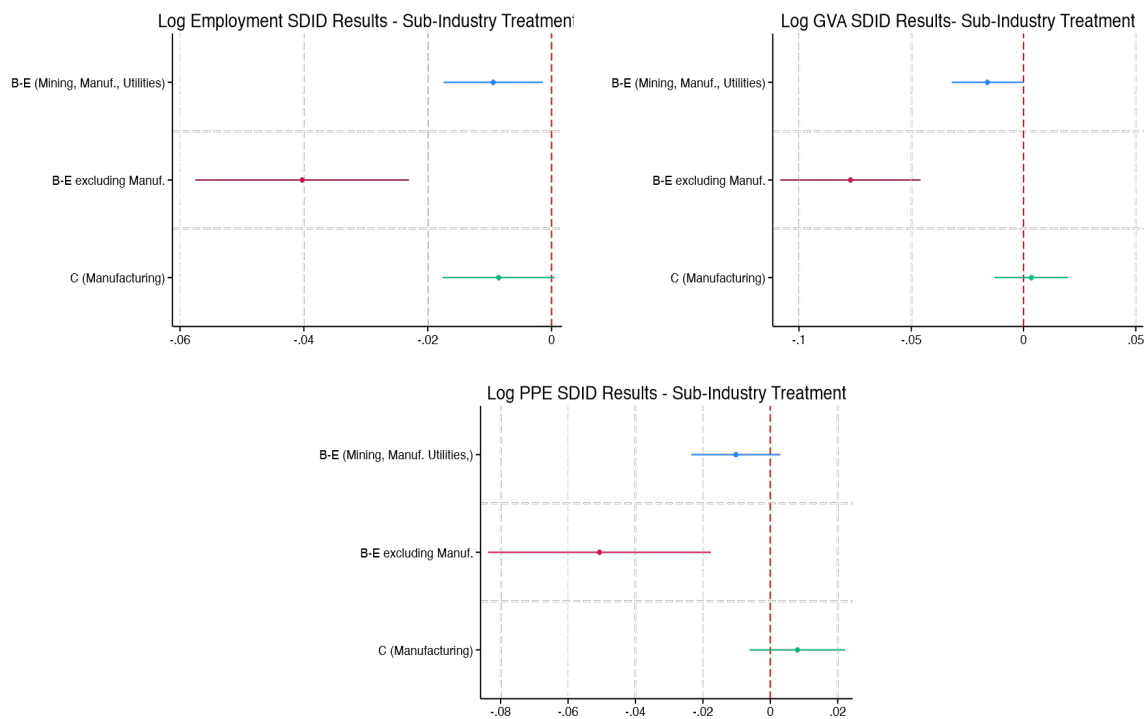


Table 3: SDID Results by Sub-industry and Total. Treatment Defined at the Industry Level.

	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** 0.004	-0.016* 0.010	-0.010* 0.006
Observations	14391	14391	14391
N NUTS-3	1107	1107	1107
B-E Excluding Manufacturing			
treat	-0.040*** 0.013	-0.077*** 0.016	-0.051*** 0.019
Observations	14092	14092	14092
N NUTS-3	1084	1084	1084
C Manufacturing			
treat	-0.009* 0.005	0.003 0.008	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

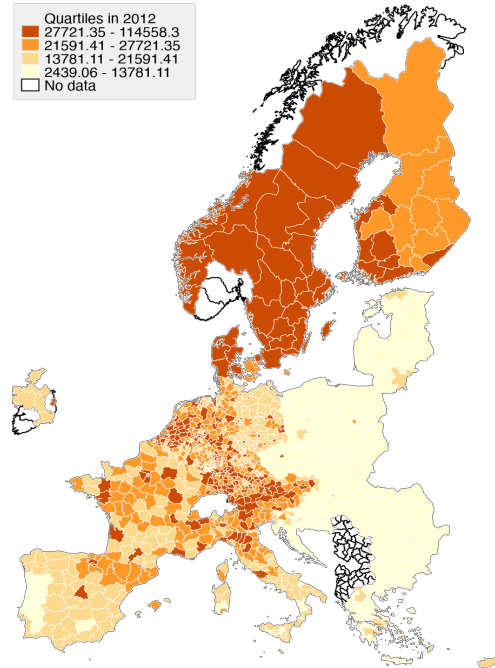
The results show similar patterns for industries B-E, with negative treatment effects on employment, GVA, and a smaller decline in PPE that is statistically significant at the 10%. Specifically, provinces in the top two quintiles saw a significant reduction in employment of around -0.9% during Phase 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 decrease of approximately 1% on PPE. When focusing on the industries in mining and utilities (B, D, E), we find larger and significant (at the 1% level) decreases in employment, GVA and PPE (approximately -4%, -7.7%, and -5.1%, respectively). When concentrating on changes in the manufacturing sector, the treatment impact is much more modest, with a decline of about -0.9%, only significant at the 10% level, and no significant effects on output or productivity. This pattern is in line with the literature on firm-level studies focused on the manufacturing sector, which typically finds limited or non-significant impacts on manufacturing employment (Colmer et al., 2024; Dechezleprêtre et al., 2023).

Table 12 and Figure 11 show the sub-industry results that normalize exposure by pre-treatment regional economic scale using GVA per capita in 2012. The results again indicate that adverse effects are concentrated in the most regulated industries excluding manufacturing. In particular, mining and utility sectors (B-E excluding manufacturing) experience statistically significant declines in employment and GVA, while the estimated effect on productivity per employee is negative but not statistically significant. For the broader B-E group, we find no significant effects across outcomes under this more granular treatment definition. In contrast, manufacturing exhibits a different adjustment pattern: employment declines modestly (−0.8% significant at the 10% level only), while output is unaffected and productivity per employee increases significantly. This combination suggests compositional or efficiency adjustments within manufacturing rather than a contraction in economic activity. Overall, these findings reinforce the conclusion that the economic impacts of the Phase 3 reform are sector-specific and remain robust when treatment is defined at the sub-industry level and scaled by pre-policy regional economic capacity.

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 heterogeneous treatment effects, using the sub-industry treatment definition. We split regions into quartiles according to their GVA per capita in 2012, representing different levels of economic development. Figure 6 shows a map of this categorization. In order to estimate interactions, we first estimate SDID models at the sub-industry level, where the treatment captures exposure to changes in free allocation of emission allowances between the pre-and post-Phase II periods (i.e., the interaction an indicator of being in the top two quintiles of allowance changes within a given industry with the post-2013 dummy). From each SDID specification, we extract the corresponding unit (ω_{ij}) and time weights (λ_t), that balance pre-treatment trends between treated and control regions.

Figure 6: Quartiles of GVA per Capita in 2012



We then use these SDID-derived weights to run two-way fixed-effects regressions on regional outcomes, weighing observations by the corresponding unit and time weights. This step allows us to recover heterogeneous treatment effects by interacting the treatment indicator with quartiles of GVA per capita in 2012, capturing how the employment and output effects of the EU ETS reform vary with level of regional economic development.

Table 4 and Figure 7 below show the heterogeneous treatment effects of the changes of Phase 3 of the EU ETS, using the SDID weights and interacting a post-2013 indicator, a treatment indicator and with an indicator of the GVA per capita quartile (Q1-Q4). The omitted quartile is Q4, the richest regions. In order to facilitate interpretation, we also report the treatment effect for the richest baseline group Q4 (shown by the Post X Treat indicator). The coefficient on Q1xPostxTreat shows how the treatment effect for the poorest quartile differs from Q4, similarly for other quartiles.

The first panel of Table 4 shows the heterogeneous treatment effects of changes in net paid allowances for the overall industry groups B-E. First we see that in the richest regions (Q4), there is a negative treatment effect on employment, around -1.5% and no significant impact on the other outcomes. Relative to Q4, the poorest regions (Q1) show a positive impact, with about a +3.5 percentage points larger treatment effect (relative to -1.5% for Q4). For GVA, the Q1 differential is positive and significant relative to Q4. For these industries overall, the employment

loss is concentrated in the richest regions, while middle-income regions show no significantly different impacts relative to Q4, and the poorest regions show a positive impact.

The second panel focuses on the treatment defined as sub-industry changes in industries B-E excluding manufacturing (Mining and quarrying, Electricity, gas, steam and air conditioning supply; Water supply), the sectors where changes in Phase 3 hit the hardest. In mining and utilities, employment losses are not statistically significant in high-income regions, but are significantly larger in middle-income regions (Q2) and, to a lesser extent, in low-income regions (Q1). This suggests that in these industries, employment adjustment costs are concentrated outside the richest regions, with the strongest effects observed in regions in the middle of the income distribution. These sectors also experience a large contraction in GVA of roughly 8-9 % following Phase 3 of the EU ETS, relative to the least treated regions. These output losses are statistically significant and similar across regions, with no evidence of systematic heterogeneity by regional income level. Productivity per employee in mining and utilities declines sharply following Phase 3 of the EU ETS, with losses of around 9 percent in high-income regions. These productivity losses are significantly attenuated in low-income regions, where the implied decline is close to zero and statistically smaller than in rich regions. We find no statistically significant differences for middle-income regions (Q2-Q3).

The third panel of Table 4 shows that for manufacturing, Phase 3 of the EU ETS is associated with only modest employment effects and no statistically significant declines in output or productivity. Employment falls slightly in high-income regions, while low-income regions experience a significantly different and less negative response. Manufacturing GVA does not decline, and in relative terms low-income regions perform better than high-income ones. Overall, the results confirm that manufacturing is largely resilient to the tightening of the EU ETS, with limited and heterogeneous adjustment across regions.

The distributional effects of Phase 3 of the EU ETS differ sharply across sectors. In mining and utilities, the policy generates large and statistically significant output and productivity losses with little evidence of heterogeneity across regions, with GVA declining by around 9 percent on average. Employment effects in these sectors are heterogeneous: job losses are not statistically significant in high-income regions, but are significantly larger in middle-income regions and, to a lesser extent, in low-income regions. Productivity losses are substantial in high-income regions but are significantly attenuated in low-income regions, indicating that adjustment occurs along different margins across space. By contrast, manufacturing exhibits considerable resilience. Employment declines are small and confined to high-income regions, while low-income regions experience a significantly different and less negative response. There is no evidence of output or productivity losses in manufacturing; if anything, low-income regions perform relatively better in terms of GVA. Taken together, these results suggest that the EU ETS does not generate broad

regional inequality but instead produces sector-specific adjustment costs, with mining and utilities bearing the brunt of the transition and manufacturing largely insulated from negative economic effects.

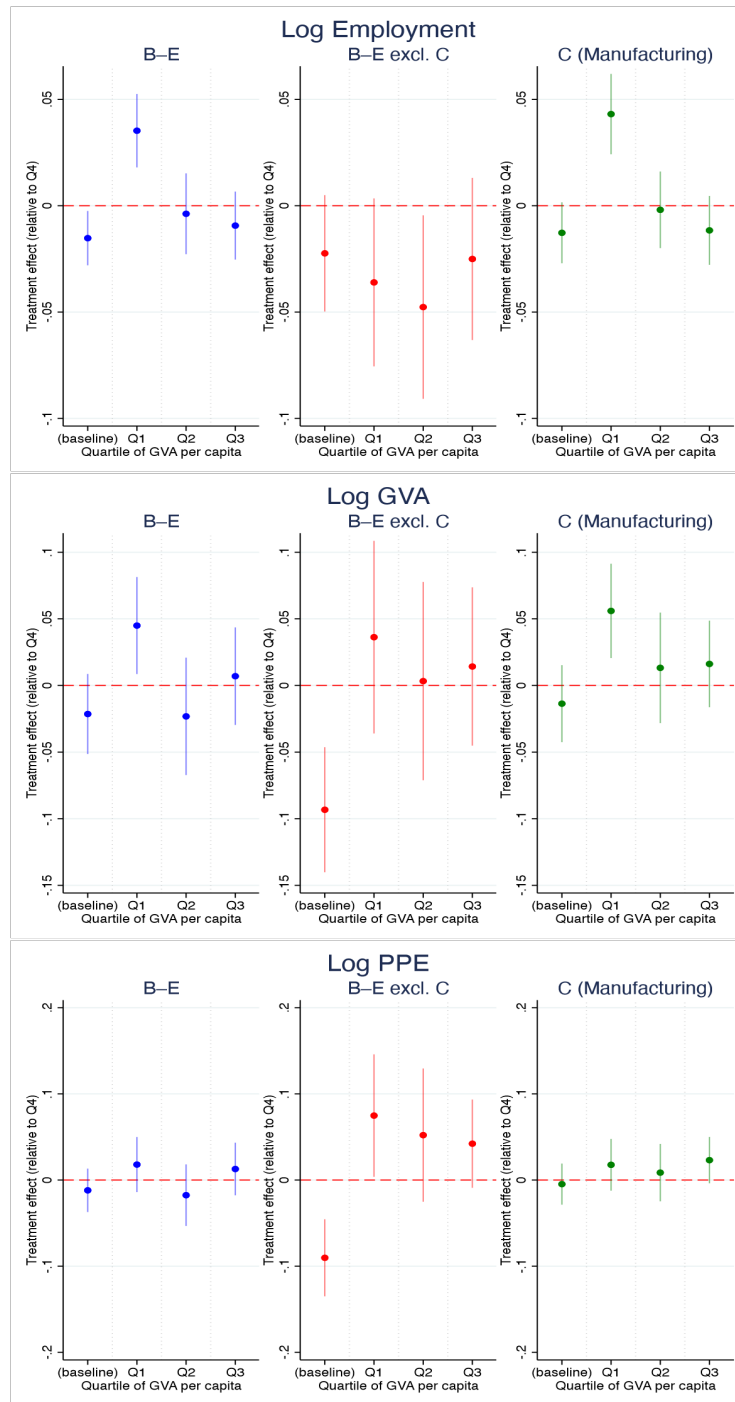
Table 4: Two-way FE DiD results with SDID weights and Treatment X GDP quartile interaction. Sub-industry Treatment

	log Emp.	log GVA	log PPE
B Mining and quarrying; C Manufacturing; D Electricity, gas, steam and air conditioning supply; E Water supply			
Post×Treat (effect on baseline Q4)	-0.015** 0.007	-0.021 0.015	-0.012 0.013
Q1 × Post – Q4 (Diff.)	0.035*** 0.009	0.045** 0.019	0.018 0.016
Q2 × Post – Q4 (Diff.)	-0.004 0.010	-0.023 0.022	-0.018 0.018
Q3 × Post – Q4 (Diff.)	-0.009 0.008	0.007 0.019	0.013 0.016
Observations	9639	9631	13833
N NUTS-3	1074	1074	1074
	log Emp.	log GVA	log PPE
B-E excluding Manuf.			
Post×Treat (effect on baseline Q4)	-0.022 0.014	-0.093*** 0.024	-0.090*** 0.023
Q1 × Post – Q4 (Diff.)	-0.036* 0.020	0.036 0.037	0.075** 0.036
Q2 × Post – Q4 (Diff.)	-0.048** 0.022	0.003 0.038	0.052 0.039
Q3 × Post – Q4 (Diff.)	-0.025 0.019	0.014 0.030	0.042 0.026
Observations	13591	9455	13577
N NUTS-3	1055	1055	1055
	log Emp.	log GVA	log PPE
C Manufacturing			
Post×Treat (effect on baseline Q4)	-0.013*	-0.014	-0.005

	0.007	0.015	0.012
Q1 × Post – Q4 (Diff.)	0.043***	0.056***	0.018
	0.010	0.018	0.015
Q2 × Post – Q4 (Diff.)	-0.002	0.013	0.009
	0.009	0.021	0.017
Q3 × Post – Q4 (Diff.)	-0.012	0.016	0.023*
	0.008	0.017	0.014
Observations	10686	10682	13839
N NUTS-3	1073	1073	1073

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

Figure 7: Two-way FE DiD results with SDID weights and Treatment X GDP quartile interaction. Sub-industry Treatment



We next examine heterogeneity using the normalized treatment definition, in which exposure is scaled by pre-treatment regional economic capacity, measured by GVA per capita prior to Phase 3. The results are shown in Appendix Section 3.1, Table 13. Comparing heterogeneity patterns

across treatment definitions highlights important differences. When treatment is measured in absolute terms, heterogeneous effects across regions are present but less systematic, likely reflecting variation in regional scale and industrial mass. Once treatment intensity is normalized, the patterns become sharper and more interpretable.

For the broader B–E industry group, we find that employment and output losses are concentrated in high-income regions. Employment declines significantly in the richest regions, while low-income regions exhibit a significantly less negative response, and middle-income regions do not differ statistically from the richest group. Similarly, GVA losses are largest in high-income regions, with low- and upper-middle-income regions performing significantly better relative to the richest regions. Productivity per employee also declines in high-income regions, but these losses are significantly attenuated in low-income regions.

Focusing on mining and utilities (B–E excluding manufacturing), we find large and statistically significant declines in employment, GVA, and productivity per employee in high-income regions. Differences across regional income groups are limited for employment and output, with interaction terms generally not statistically significant, suggesting heterogeneous adjustment in efficiency rather than employment.

Manufacturing exhibits a distinct pattern. In high-income regions, Phase 3 is associated with modest declines in output, while employment and productivity do not fall significantly. Low-income regions respond significantly better than high-income regions, particularly in employment and output, and upper-middle-income regions also perform relatively better in terms of output and productivity. Overall, these normalized results reinforce the conclusion that the distributional effects of the EU ETS are strongly sector-specific and vary systematically with regional income, with adjustment costs concentrated in carbon-intensive sectors and disproportionately borne by richer regions.

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*** (0.036)	-0.100*** (0.037)
Observations	12558	12441
N NUTS-3	966	957

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

Table 6: SDID Results on Total CO2 Emissions

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

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

To provide a sense of magnitude, applying the estimated percentage effects to the average baseline levels of emissions in highly exposed provinces suggests economically meaningful reductions in regulated emissions following Phase 3. At the same time, these environmental gains coincided with modest contractions in economic activity within the most carbon-intensive sectors, as documented in the previous sections. These results highlight the presence of sector-specific adjustment costs accompanying the environmental effectiveness of the reform, while avoiding evidence of widespread aggregate economic decline.

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 (-0.9% to -1.2%) 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.

Importantly, while sector-specific impacts are evident, we find no statistically significant decline in total economic activity when aggregating across all industries. This suggests that the economic consequences of the reform were concentrated in carbon-intensive sectors most directly affected by the tightening of free allowance allocation in Phase 3, rather than translating into broad regional downturns.

The distributional effects of Phase 3 are strongly sector-specific. Mining and utilities experience large and statistically significant declines in output and productivity. While output effects show limited heterogeneity across regions, employment and productivity responses vary by income level, with employment losses more pronounced outside the richest regions and productivity declines attenuated in lower-income regions. By contrast, manufacturing exhibits relatively modest employment adjustments and no systematic output or productivity losses, consistent with the firm-level literature documenting limited competitiveness effects of the EU ETS in this sector (Colmer et al., 2024; Dechezleprêtre et al., 2023). Across sectors, lower-income regions generally perform relatively better than high-income regions, particularly in manufacturing. Overall, the evidence indicates that the EU ETS generates sectoral adjustment costs without evidence of creating broad regional economic inequality.

While the EU ETS Phase 3 effectively reduced emissions, its economic costs highlight the need for complementary sector-specific 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. Future research should 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 relatively understudied phase. Following the growing literature focusing on the heterogeneous effects and the social externalities of the so-called green policies, our results highlight that while carbon pricing can achieve substantial emission reductions, its economic effects are uneven across sectors but do not necessarily translate into widening regional inequality.

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7 Appendix

Figure 8: SDID Trends

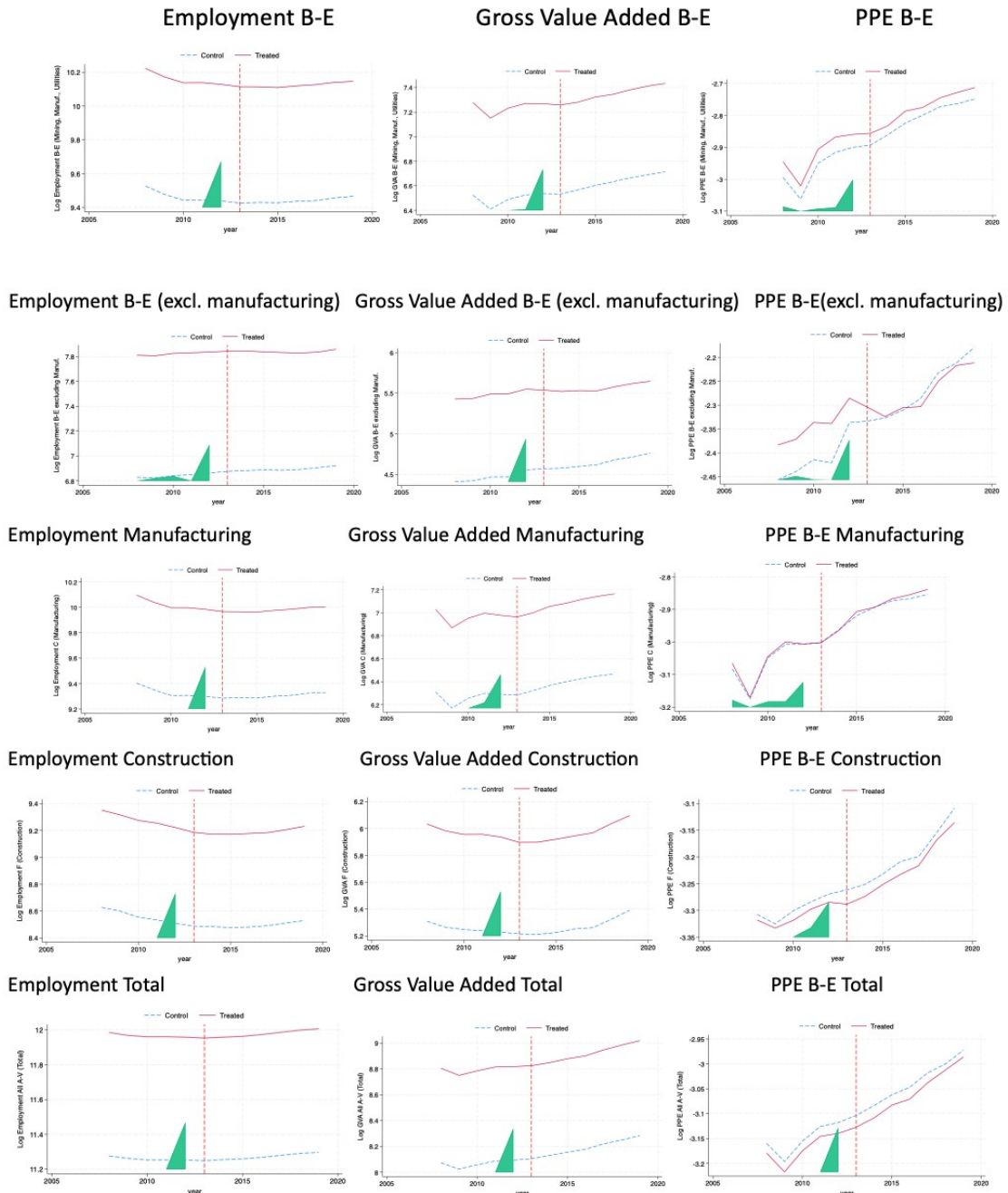


Figure 9: SDID Trends: Sub-industry Treatment

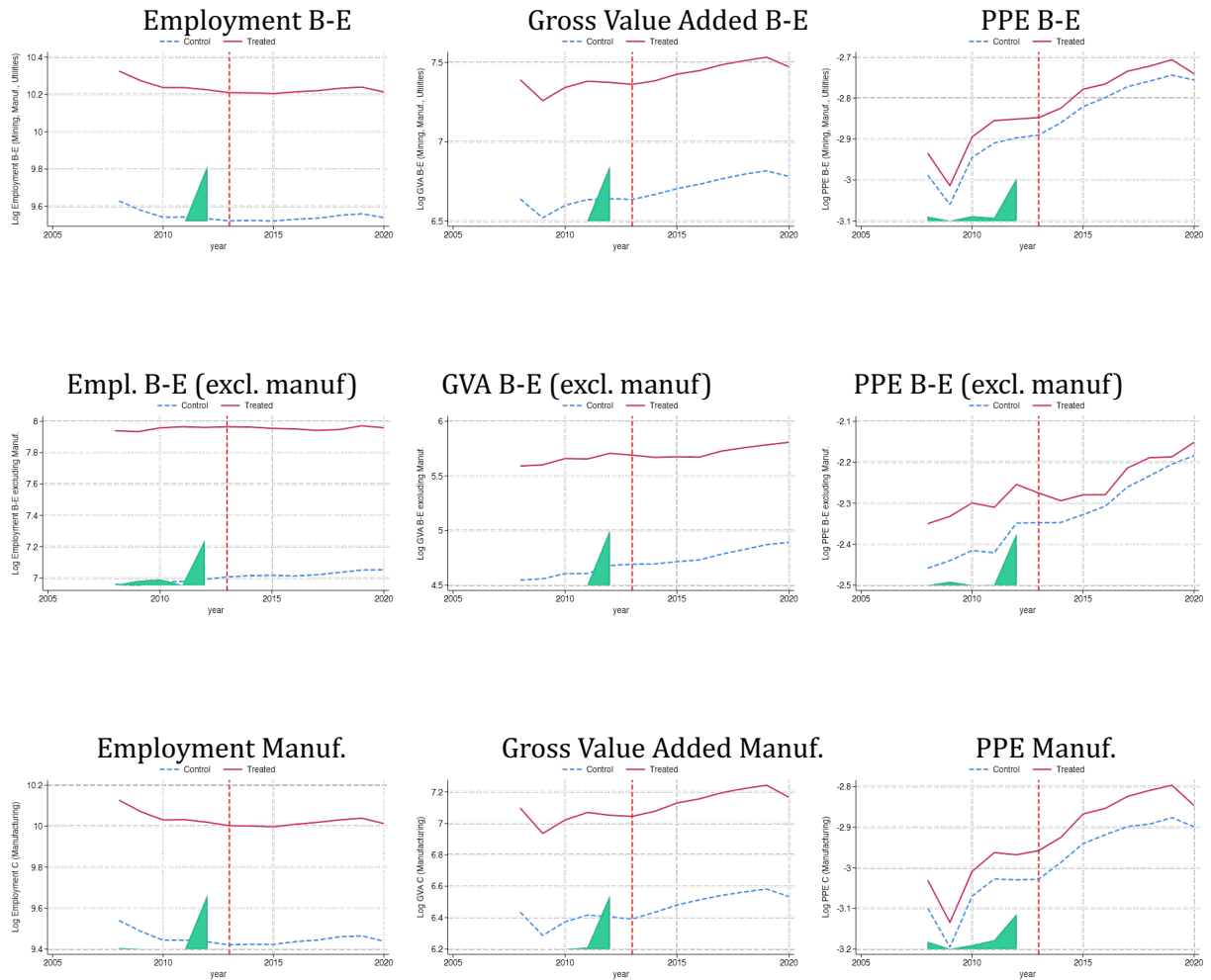


Table 7: SDID Results by Sub-industry and Total. Treatment defined as Q5

	logEmployment	logGVA	logPPE
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 quintiles are 1-4.

Table 8: 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 0.005	-0.028*** 0.010	-0.025*** 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 0.005	-0.028*** 0.010	-0.025*** 0.008
Observations	14391	14391	14391
N NUTS-3	1107	1107	1107
B-E Excluding Manufacturing			
treat	-0.047*** 0.013	-0.111*** 0.018	-0.078*** 0.020
Observations	14092	14092	14092
N NUTS-3	1084	1084	1084
C Manufacturing			
treat	-0.004 0.006	0.001 0.010	-0.004 0.008
Observations	14391	14391	14391
N NUTS-3	1107	1107	1107
F Construction			
treat	-0.014 0.009	-0.003 0.017	-0.007 0.013
Observations	14404	14404	14404
N NUTS-3	1108	1108	1108
Total: All Industries			
treat	0.003 0.003	-0.003 0.006	-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 quintiles are 1-4. Full sample.

Table 9: List of countries in the analysis for balanced sample

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)	96
Croatia (HR)	7
Hungary (HU)	18
Italy (IT)	106
Luxembourg (LU)	1
Latvia (LV)	6
Malta (MT)	2
Netherlands (NL)	40
Norway (NO)	2
Poland (PL)	64
Portugal (PT)	25
Romania (RO)	42
Sweden (SE)	21
Slovenia (SI)	12
Slovakia (SK)	8
Total	1,107

Table 10: 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.

Treatment 2 (normalized) based on log quintiles of net changes in free allowances divided by pre-treatment GVA

Table 11: 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 0.006	-0.024*** 0.008	-0.013** 0.006
Observations	14391	14391	14391
N NUTS-3	1107	1107	1107
B-E Excluding Manufacturing			
treat	-0.050*** 0.011	-0.073*** 0.016	-0.033* 0.018
Observations	14092	14092	14092
N NUTS-3	1084	1084	1084
C Manufacturing			
treat	-0.006 0.006	-0.013 0.010	-0.009 0.008
Observations	14417	14417	14417
N NUTS-3	1109	1109	1109
F Construction			
treat	-0.020*** 0.007	-0.021* 0.012	-0.019* 0.011
Observations	14430	14430	14430
N NUTS-3	1110	1110	1110
Total: All Industries			
treat	-0.009*** 0.003	0.005 0.005	0.011** 0.006
Observations	14430	14430	14430
N NUTS-3	1110	1110	1110

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

Figure 10: SDID Results: Normalized Treatment (GVA Per Capita) Effect of Policy Change.

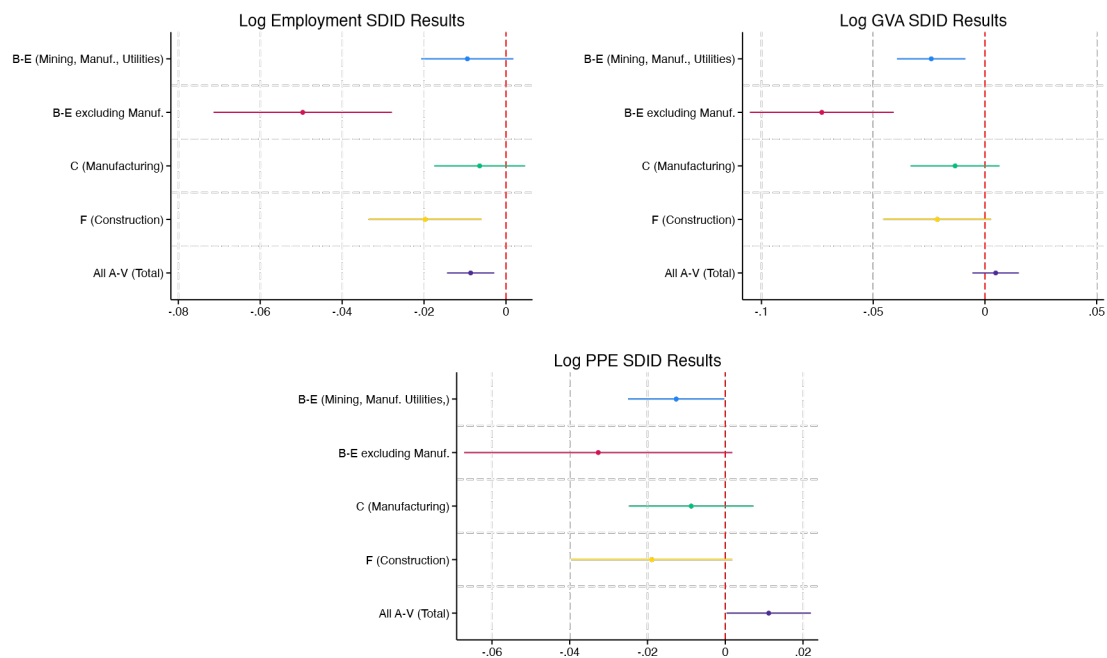


Figure 11: SDID Results: Treatment Effect of Policy Change. Normalized Treatment (GVA Per Capita) Defined at the Industry Level.

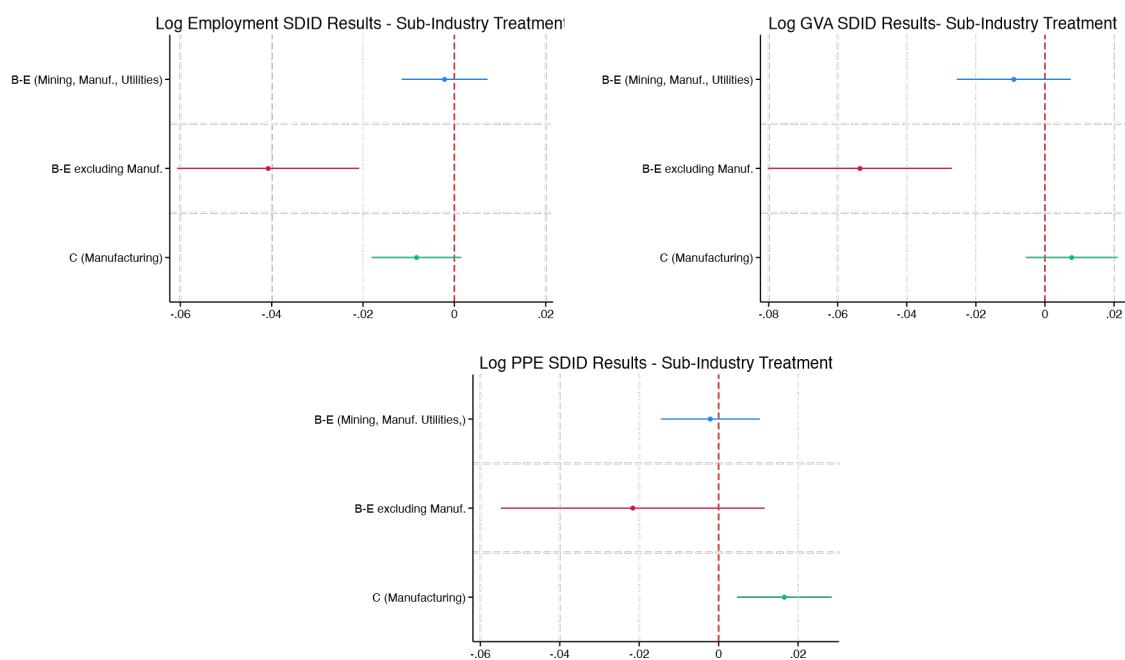


Table 12: SDID Results by Sub-industry and Total. Normalized (Per Capita GVA) Treatment Defined at the Industry Level.

	log Employment	log GVA	log PPE
B Mining and quarrying; C Manufacturing; D Electricity, gas, steam and air conditioning supply; E Water supply			
treat	-0.002 0.005	-0.009 0.008	-0.002 0.006
Observations	14391	14391	14391
N NUTS-3	1107	1107	1107
B-E Excluding Manufacturing			
treat	-0.041*** 0.010	-0.054*** 0.014	-0.022 0.017
Observations	14092	14092	14092
N NUTS-3	1084	1084	1084
C Manufacturing			
treat	-0.008* 0.005	0.008 0.007	0.017*** 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

Table 13: Two-way FE DiD results with SDID weights and Treatment X GDP quartile interaction. Sub-industry Treatment Normalized (GVA Per Capita)

	log Emp.	log GVA	log PPE
B Mining and quarrying; C Manufacturing; D Electricity, gas, steam and air conditioning supply; E Water supply			
Post×Treat (effect on baseline Q4)	-0.025** 0.011	-0.052** 0.022	-0.031* 0.017
Q1 × Post – Q4 (Diff.)	0.044*** 0.013	0.077*** 0.024	0.046** 0.019
Q2 × Post – Q4 (Diff.)	0.011 0.015	-0.013 0.027	-0.020 0.022
Q3 × Post – Q4 (Diff.)	0.005	0.044*	0.036*

	0.013	0.025	0.020
Observations	9607	9599	13801
N NUTS-3	1070	1070	1070
	log Emp.	log GVA	log PPE
B-E excluding Manuf.			
Post×Treat (effect on baseline Q4)	-0.038**	-0.116***	-0.086***
	0.015	0.032	0.030
Q1 × Post – Q4 (Diff.)	-0.017	0.078	0.090**
	0.022	0.047	0.045
Q2 × Post – Q4 (Diff.)	-0.039	0.003	0.032
	0.028	0.053	0.055
Q3 × Post – Q4 (Diff.)	-0.005	0.055	0.051
	0.025	0.041	0.035
Observations	13489	9365	13478
N NUTS-3	1044	1044	1044
	log Emp.	log GVA	log PPE
C Manufacturing			
Post×Treat (effect on baseline Q4)	-0.009	-0.032*	-0.024
	0.009	0.016	0.015
Q1 × Post – Q4 (Diff.)	0.042***	0.072***	0.039*
	0.011	0.026	0.021
Q2 × Post – Q4 (Diff.)	-0.001	0.030	0.021
	0.011	0.026	0.021
Q3 × Post – Q4 (Diff.)	-0.011	0.041*	0.043**
	0.011	0.022	0.019
Observations	10639	10637	13793
N NUTS-3	1068	1068	1068

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

Figure 12: Two-way FE DiD
X GDP quartile interaction.
Per Capita)

results with
Sub-industry

SDID weights and Treatment
Treatment Normalized (GVA

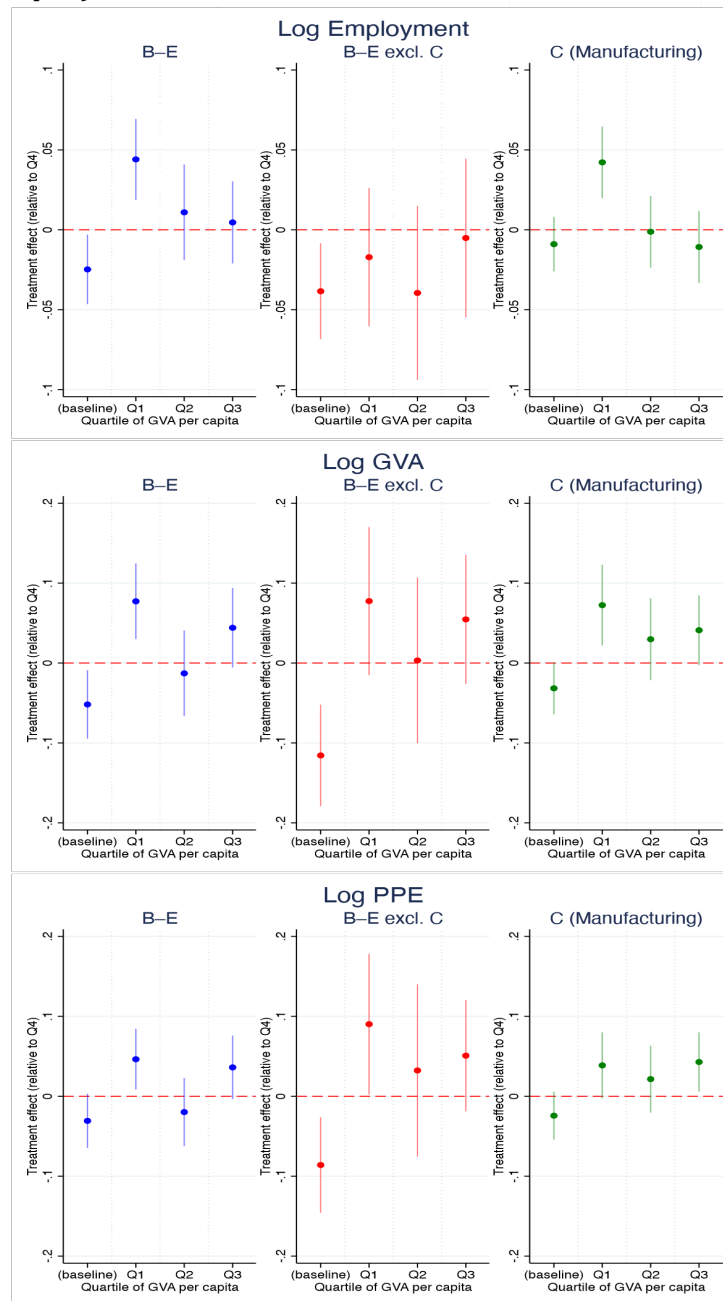


Figure 13: SDID Trends.

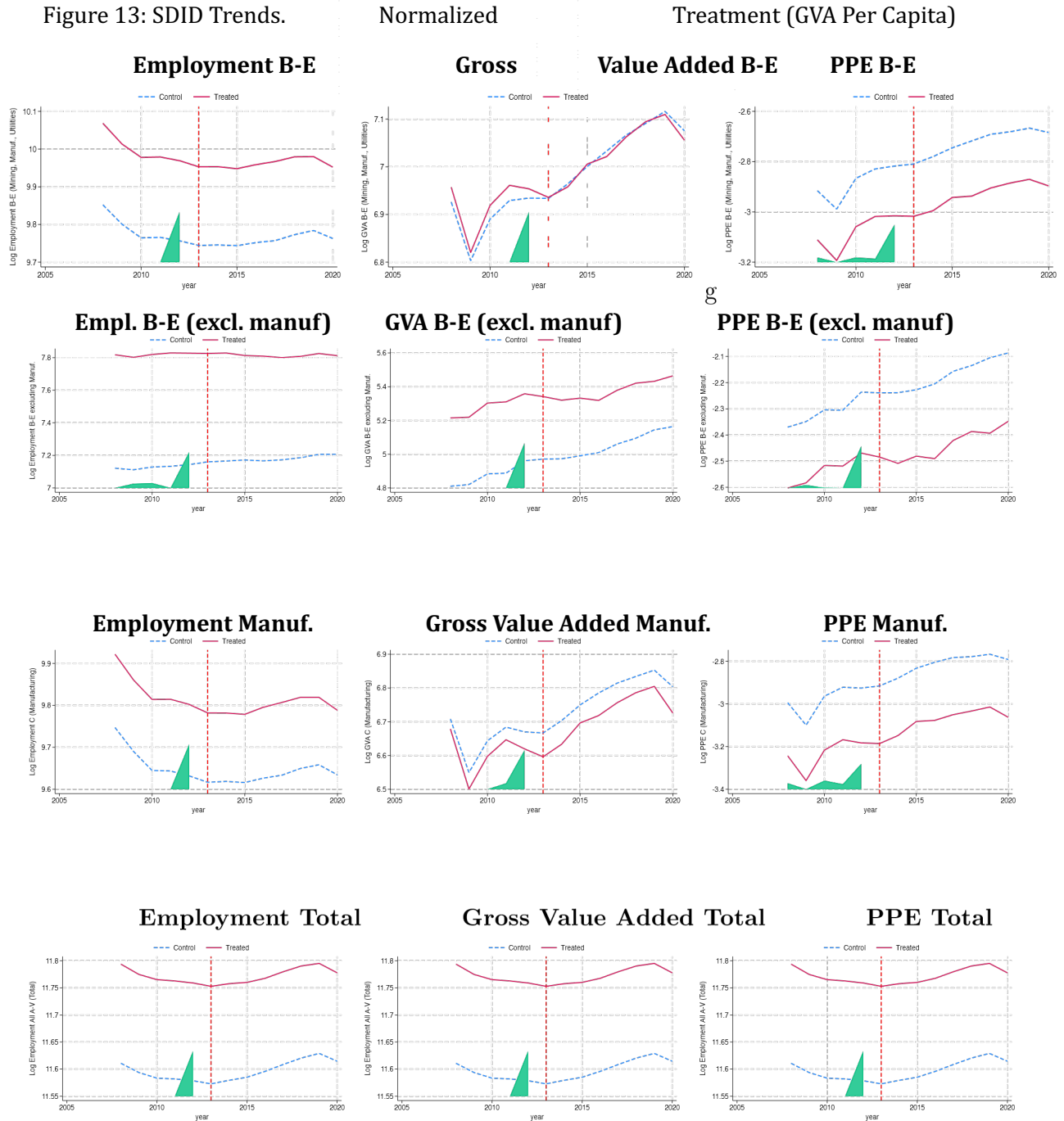
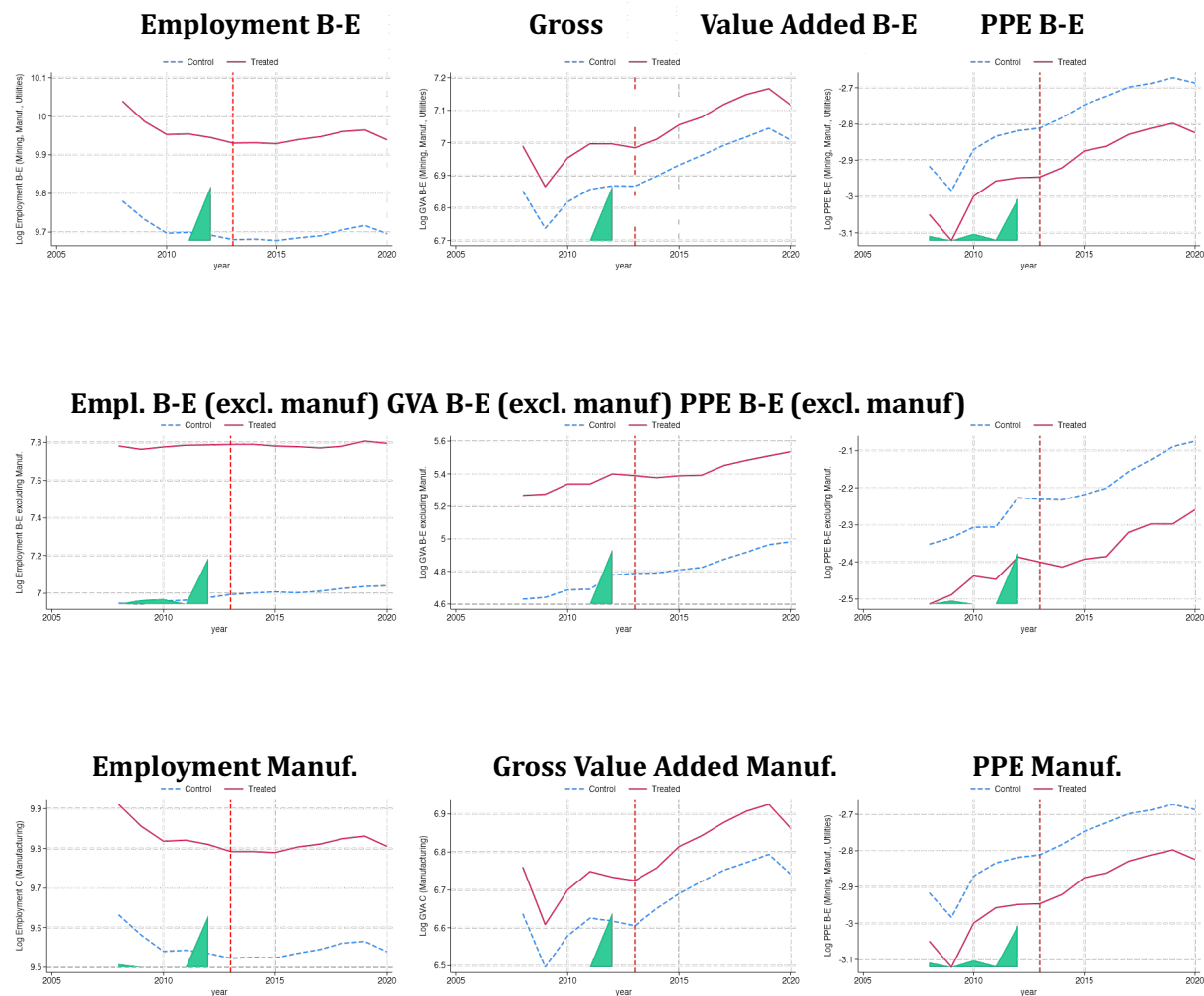


Figure 14: SDID Trends: Sub-

industry

Treatment (Normalized GVA Per Capita)



Using treatment based on share of GVA in industries B-E (excluding manufacturing) in 2000-2004 out of total output, split into quintiles

Table 14: 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	-0.010**	-0.030***	-0.026***
	0.004	0.007	0.006
Observations	14391	14391	14391
N NUTS-3	1107	1107	1107
B-E Excluding Manufacturing			
treat	-0.060***	-0.115***	-0.077***
	0.010	0.017	0.018
Observations	14092	14092	14092
N NUTS-3	1084	1084	1084
C Manufacturing			
treat	-0.009**	0.004	0.006
	0.004	0.008	0.007
Observations	14417	14417	14417
N NUTS-3	1109	1109	1109
Total: All Industries			
treat	-0.013***	-0.005	0.006
	0.003	0.005	0.006
Observations	14430	14430	14430
N NUTS-3	1110	1110	1110

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

Figure 15: SDID Results: Treatment Effect of Policy Change

