The Correlation Between Consumption Inequality and the EU ETS: Implications for Carbon Pricing Policy

Junyu Gan

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Abstract

This research explores the causal impact of the European Union Emissions Trading System (EU ETS) on consumption inequality across 38 OECD countries with consumption data from 1998 to 2015. My findings reveal crucial policy implications of the system and contribute to the ongoing dialogue on environmental sustainability and social equity from a consumption point of view. My investigation, framed through the lens of the Difference-in-Differences (DID) methodology, identifies a statistically significant reduction of consumption inequality in European OECD countries upon the EU ETS implementation by 0.9 %pt., countering the prevailing view of the regressivity of carbon trading schemes. The study also finds evidence for heterogeneity in these impacts, notably in the context of diverse inflationary environments, suggesting that the power of the EU ETS in mitigating consumption inequality is contingent upon specific macroeconomic conditions. While the findings recognize the EU ETS as an important tool to help achieve an environmental and social win-win scenario during the green transition, they also point out the need for a more adaptive and context-specific application of the EU ETS in terms of economic environments.

1 Introduction

The green transition is not only crucial for mitigating the destructive effects of climate change but also offers an opportunity to address social and economic inequalities. For example, Germany's Energiewende provides empirical evidence since it creates over 300,000 jobs in the renewable sector and widely distributes economic benefits through decentralizing energy ownership (Agora Energiewende 2022). Among the inequality metrics such as income and wealth, consumption inequality is of particular interest as it directly influences our day-to-day lives and stands to be significantly related to the green transition (Seyfang and Paavola 2008). The aim to reduce consumption inequality extends beyond the issue of social justice and holds implications for the efficiency and public acceptance of environmental policies. When the costs or benefits of environmental policies are distributed unevenly, it could risk eroding public support and even lead to counterproductive behaviour toward emission targets (Klenert et al. 2018; Andersson and Atkinson 2020). However, recently, increasing evidence suggests that well-designed green transition strategies can help achieve social equity goals (Boyce 2018; Ee et al. 2018; Rojas-Vallejos and Lastuka 2020; Zhao et al. 2022). This is a promising direction for further studies and policymakers, as it suggests that it is possible to design more effective and publicly supported green policies, which ensures both environmental sustainability as well as the social and political durability of the green transition.

Given this context, my study examines the short-run causal impact of the EU Emissions Trading System (EU ETS), an important cap-and-trade system facilitating the green transition in Europe, on consumption inequality based on country-level data over the 1998–2015 period from 38 OECD countries. The research also investigates the heterogeneity of this impact and the impact's evolvement as the EU ETS proceeds into Phase 2 (2008-2012).

The study focuses on the EU ETS for several key reasons that stem from both empirical and theoretical necessities: Firstly, the EU ETS is one of the world's largest and most established cap-and-trade systems for reducing greenhouse gas emissions (Ellerman et al. 2010). Its extensive data and operational history offer a mature empirical setting for analyzing its impact on consumption inequality. Also, as the EU ETS spans multiple member countries, its cross-border nature allows me to investigate this impact on a larger scale. Secondly, it will provide theoretical value for market-based approaches in incentivizing emission reductions, which are recognized as more economically efficient than command-and-control regulations (Stavins 1998). As global concerns regarding climate change arise and with the failure to introduce carbon taxation in Europe, the EU ETS is increasingly considered a central policy instrument (Convery 2009). However, its impact on consumption inequality is less well-understood (Bento et al. 2009). Therefore, studying this impact offers timely and critical insights for policymakers, especially within Europe.

The interaction between environmental regulation and inequality has long been a subject of intense debate. Consumption inequality can be affected by multiple variations, ranging from differences in prices and consumption components (Attanasio and Pistaferri 2016) to income shock durability (Blundell et al. 2008). An influencing factor of these variations warranting close attention is environmental regulation, more specifically, market-based mechanisms like ETS. On one hand, market-based mechanisms are criticized for being regressive (Bento et al. 2009; Owen and Barret 2020; Venmans 2012). Some argue that these policies can be designed to incorporate redistributive mechanisms that counteract this regressivity (Metcalf 1999; Boyce 2018; Zhang and Zhang 2020). Such debate has also raised concern about potential heterogeneity issues. Scholars argue that the actual impacts of market-based environmental policies are highly context-dependent and may vary significantly based on their practical implementation, and regional factors (Goulder and Schein 2013). These conflicting outcomes highlight the complex and region-specific distributional effects of carbon trading schemes, pointing to the heterogeneity issues that this study will try to address later.

As shown above, the EU ETS provides a practical real-world example that is not only policy-relevant but also theoretically significant for addressing the ongoing debates. Moreover, according to Attanasio and Pistaferri (2016), existing literature has focused on income inequality because of limited data access, rather than consumption inequality, which is also applicable to studies on ETS's impact. These reasons motivate me to conduct this research to investigate whether the EU ETS, an important source of variation in consumption patterns has actual causal impacts on consumption inequality.

The study extracts data from the Global Consumption Dataset for the period 1998-2015 given that the EU ETS was initiated in 2005. I choose a difference-in-differences (DID) design as my empirical strategy, which identifies the treatment effect of the EU ETS by comparing the average post-ETS change in consumption

Gini index between OECD countries that were under the ETS and those that are not. This is supported as a valid approach by doing a parallel-trend test with an event study design. The DID framework allows me to use a two-way fixed effect model to control for country/time fixed effects. I also take into consideration a series of country/time-varying characteristics such as GDP and include them as control variables in the model.

Contrary to the regressive distributional effects commonly found in carbon trading schemes, my findings introduce a different narrative. The baseline results reveal a statistically significant decrease in the consumption Gini index by 0.9 percentage points upon the implementation of the EU ETS for European OECD countries compared to the rest of OECD countries. This result remains valid to a series of robustness tests, including pre-emptive behavior testing, Propensity Score Matching (PSM)-DID approach, and alternative index testing.

To further understand this relationship, I conducted a heterogeneity analysis. The result reveals that the impact of the EU ETS varies significantly across countries due to inherent heterogeneities. More specifically, the EU ETS's mitigation effects on consumption inequality appear to be limited in countries with higher 2004 (one year before the implementation) inflation levels, which is likely due to the burden of pre-existing inflation on household expenditure. However, the results also suggest that the EU ETS's impact is not straightforwardly correlated with the levels of variables like GDP per capita, energy CPI, or CO2 emissions. For further discussion, I extend the analysis to explore the impact of the Phase 2 EU ETS on consumption inequality, focusing on the period from 1998 to 2012. The result also shows a statistically significant decrease in consumption inequality, indicating the consistency of the impact of EU ETS across phases.

This study reviews the short-run socio-economic impacts of the EU ETS by examining its causal relationship with consumption inequality within European countries. Focusing on the short-term effects aligns with data availability and provides timely insights into the immediate post-intervention adjustment, minimizing distortions from external shocks. While many previous studies have primarily predicted the potential consequences of ETS on income distribution, my research contributes to the existing literature by focusing on the consumption side of the effect and utilizing real-world consumption data. This empirical study provides an additional perspective on the social implications of carbon pricing mechanisms like the EU ETS. The findings aim to add to existing academic dialogue and may be of interest to those considering the intersection of environmental policies and social equity.

2 Background

2.1 Backgound of the EU ETS

According to "Development of EU ETS (2005-2020)", the EU ETS was first developed in response to the emissions reduction targets set by the 1997 Kyoto Protocol and was finally adopted among many of the proposed policies by the European Commission. It has been in operation since it was launched in 2005 and serves as the world's first and largest carbon market. Designed as a cap-and-trade system, it caps the total amount of greenhouse gas (GHG) emissions from heavy industry sectors and airlines, allowing companies to buy and sell emission allowances. As we can see from the statistics, the EU ETS has shown its outstanding power in reducing emissions. On average, the system covers 45% of Europe's GHG emissions from industries including manufacturing, power generation, and aviation in its member countries. By 2020, emissions from installations covered by the system have been reduced by 35% compared to that in 2005.

Over time, the EU ETS has undergone multiple reforms and is currently in its fourth phase (2021–2030), focusing on steeper emission reduction targets. The system was planned into phases, allowing the level of emission allowance and regulations to adjust from phase to phase based on its past performance. Therefore, this enables the EU ETS to adapt to exogenous shocks, Phase 1 (2005-2007) was a pilot period of "learning by doing" for Phase 2. It has several key characteristics including covering only CO2 emissions from power generators and energy-intensive industries, allowance given for free, and a 40 Euros per ton penalty fee for non-compliance. It was successful in setting up the market but due to limited emissions data, the estimated allowance exceeded emissions in Phase 1. As the EU ETS proceeded into Phase 2 (2008-2012), it introduced several key changes based on its Phase 1 performance, including the introduction of lower cap levels, higher penalty fees, new member countries, and new covered industry (aviation). My study will focus on the first two phases of the EU ETS, trying to see what changes the system has brought to the consumption inequality within this period and how such impacts change as the system evolves from Phase 1 to Phase 2.

2.2 Social Inequality in Europe

The increase of socio-economic inequality in Europe, with a specific lens on consumption disparities, presents a crucial challenge for society. In recent decades, Europe has witnessed a widening gap between various socioeconomic groups, not merely in the realm of income but also wealth and consumption. According to the report "Understanding the socio-economic divide in Europe" (2017), income and wealth inequality remains at an all-time high among OECD countries, including many European countries: today, the average income of the richest 10% is 9.5 times higher than that of the poorest 10%; unequal distribution of wealth is even worse since the 10% of wealthiest households hold 50% of total wealth while the 40% least wealthy own little over 3%. Moreover, although the level of consumption may not necessarily reflect levels of income and wealth, this increasing inequality in income and wealth still heavily affects consumption patterns (OECD, 2023). Consumption inequality refers to the disparities in the consumption of goods and services among different social strata. The upper deciles of society have seen a surge in their purchasing power, thereby amplifying their access to a large bundle of goods and services, conversely, the lower-income strata contend with constrained budgets, limiting their consumption capabilities. These disparities extend beyond consumption access, creating a socio-economic environment where opportunities, resources, and social capital are disproportionately leaning towards the rich. This increases social stratification and raises questions regarding social equity. Hence, an in-depth understanding of how can we reduce consumption inequality is important for designing equitable policies and strategies aiming for a just transition in Europe.

3 Theoretical Analysis

Before carrying out the empirical analysis, in order to comprehensively understand the impacts of the EU ETS on consumption inequality, a thorough examination of the underlying impact mechanisms is essential. I provide analysis for four theoretical pathways through which the EU ETS can potentially affect consumption inequality, elaborating on both their positive and negative implications.

1. Resource Allocation Mechanism: The price pass-through in goods with inelastic demand due to carbon pricing policies could exacerbate consumption inequality. Theoretically, the immediate response to the EU ETS from many firms might be to pass these new costs onto the consumer, particularly for goods with inelastic demand (Coase 1960; Tietenberg 1985; Cludius et al. 2020). As lower-income households typically spend a greater share of their income on necessities, they could be disproportionately affected in the short run, therefore widening consumption inequality (Fullerton 2011; Owen and Barret 2020).

2. Behavioral Response Mechanism: Transparency in emissions reporting could lead to sustainable consumption but risk widening consumption inequality. The EU ETS introduces a layer of transparency and accountability by requiring public emissions reporting. Consumers who previously might not have been aware of the carbon footprint of their purchases now have easy access to this information. Behavioral economics suggests that these informational "nudges" or "soft regulation" can significantly alter purchasing decisions (Thaler and Sunstein 2009; Sunstein 2014). This may induce consumer preference to shift towards more sustainable choices. However, this "green premium" on products could become a new form of luxury (Guyader et al. 2017), Only middle and upper-income households are more likely to transition to environmentally friendly products as they can comfortably afford them (Schmalensee and Stavins 2017). This increase in spending on green products for the rich may narrow their purchasing power gap with the poor, potentially reducing consumption inequality.

3. Income Redistribution Mechanism: The use of revenue obtained from the ETS can either mitigate or exacerbate consumption inequality through redistribution depending on the recycling method. If governments use the revenue for targeted social welfare programs, it could alleviate some of the negative impacts of increasing energy prices on lower-income households, therefore reducing consumption inequality (Bovenberg 1999; Goulder 2013; Boyce 2018; Rojas-Vallejos and Lastuka 2020). Alternatively, Acemoglu et al. (2012) suggested that optimal environmental regulation should always use a carbon

tax to control current emissions and alongside research subsidies to influence the direction of research. If the revenue from environmental policy is invested in public services that do not directly benefit low-income households, such as the research subsidies mentioned above, the inequality in consumption could even widen.

4. Innovation and Technological Change Mechanism: Firms incentivized by the EU ETS to invest in cleaner technologies and efficiency may initially incur high capital costs but are likely to gain from the reduced operational costs in the long run (Porter and van der Linde, 1995; Aghion et al. 2009). This will eventually benefit consumption inequality as the cap-and-trade system like the EU ETS functions on the principle of making firms internalize the external cost of pollution by cost-induced innovation instead of inflating energy prices(Baumol and Oates, 1988). When firms are required to pay for their emissions, it creates an economic incentive for them to reduce emissions—thus pushing them toward more efficient production technologies or cleaner inputs. As firms adopt more efficient technologies, they can reduce their marginal production costs over time. Lower marginal costs could then be passed on to consumers in the form of lower prices, potentially mitigating consumption inequality. However, this leaves the problem of a potential technology adoption divide. The speed of this technological transition could create a gap, as initially, the high fixed costs in production drive up the prices of green products. Thus, only wealthier households may be able to afford products that utilize these cleaner technologies. Over time, however, these technologies might become more affordable and accessible, reducing consumption inequality.

4 Data & Methodology

4.1 Data and sample selection

My study employs a panel dataset covering all OECD countries from 1998 to 2015. The data of the core variables of interest, representing consumption patterns, such as the consumption Gini index and Palma ratio are extracted from the Global Consumption dataset (GCD) under the UN-WIDER Global Consumption and Income Project. The GCD includes annual data from 149 countries and spans multiple decades starting from 1960. For all the OECD countries, the dataset is updated until 2015. As Bettarelli et al (2023) stated, the GCD sources its data from several national account databases and surveys that are standardized for cross-country comparability. Notably, it utilizes the World Income Inequality Database (Version 3.3) and the World Development Indicators. The GCD offers various consumption inequality metrics, making it unique in terms of consumption data scope (Lahoti et al. 2016). According to Lahoti et al. (2016), the Lorenz curve estimated via the generalized quadratic parametric estimation suggested by Villaseñor and Arnold (1989) is preferred in constructing the consumption profile for the GCD. Once they have the Lorenz curve, they combine it with the mean estimate to create a consumption profile consisting of an estimated mean income or consumption level for every decile of the country-year. The reason for using the consumption data is crucial for this study. Leveraging consumption data over income offers a more immediate reflection of individuals' well-being, capturing the real-time variations and disparities in living standards (Deaton 2005; Attanasio and Pistaferri 2016). Additionally, consumption is a more stable measure due to consumption smoothing. Thus, they're often less affected by fluctuations that can distort income, making it a potent tool for studying economic inequality (Attanasio and Pistaferri 2016).

In the wake of the EU ETS policy's official implementation in 2005, my dataset distinctly identifies OECD countries enveloped by Phase 1 of the EU ETS as the treatment group, where the rest of the countries are in the control group. This is captured through the policy interaction term $Post * Treatment$ in the DID empirical model, where only observations in the treatment group that are treated are assigned a value of 1, 0 otherwise.

To ensure a robust analysis, my study also incorporates an array of control variables that vary by country based on the literature (see Furceri and Ostry, 2019, for a review), which are introduced below. Complementing the primary source, I have integrated these key economic indicators from the World Bank and OECD official databases. These databases employ rigorous data collection methodologies and are widely recognized for providing comprehensive economic data across countries.

1. GDP per capita (Natural log): GDP per capita serves as a reliable measure of a country's economic development. Hossain (2012) underscores the intricate link between GDP per capita and consumption disparities. As countries grow wealthier, consumption patterns, especially in green products often experience transformations, which can potentially amplify or mitigate the ETS's impact on consumption inequality.

2. Total Consumer Price Index (CPI): The total CPI reflects the prevailing price levels or inflation in an economy. Disparities in consumption can often be traced back to inflation changes or price shocks. As stated by Coibion et al. (2017), unexpected decreases in inflation that benefit savers and hurt borrowers will increase consumption inequality (as savers are normally wealthier than borrowers), which shows that inflation could be a potential factor influencing the results.

3. Unemployment rate: A nation's unemployment rate reveals its labor market's current situation. Elevated unemployment can result in shifts in consumption patterns as joblessness typically translates to diminished purchasing power for affected households. Coibion et al. (2017) have found a strong but negative correlation, highlighting the importance of taking it into account.

4. Government expenditure (% of GDP): Governments play a pivotal role in shaping economies, mainly through expenditures. Their spending, especially in welfare and social programs, has high redistributive capacity and can significantly modulate consumption disparities within a nation. Specifically speaking, following an increase in government spending, consumption inequality may decrease as consumption rises at the bottom of the distribution and declines, potentially due to increasing access to the capital market (Giorgi and Gambetti 2012).

5. Urban population ratio (% of total population): The urban-rural divide is an important determinant of economic disparities. Urban areas, with their concentration of services and industries, often showcase different consumption patterns compared to their rural counterparts. Ravallion et al. (2007) delve into the dynamics of urbanization and its impact on poverty, which enlightened me to incorporate urban population ratio into the model as a control for the impact of countries' urbanization levels.

6. Dependency ratio (% of working-age population): Measures the ratio of dependents to working-age individuals and reflects a country's demographic structure. It also varies across countries and can significantly affect my regression results. This is mainly because productivity and needs change as the population ages, which leads to varying consumption patterns in countries with different demographic characteristics (Bloom et al. 2010).

4.2 Methodology

To investigate the causal impacts of the implementation of the EU ETS on consumption inequality, I use the DID framework, an instrumental method in utilizing temporal and spatial variations induced by policy to establish causal associations. Although the dataset covers annual data until 2015, I only choose observations from 1998 to 2007 for examining the initial treatment effect of the implementation in the baseline analysis as the system undertook reforms in 2008 when moving into Phase 2.

The primary equation for baseline analysis is constructed as:

$$Gini\ Index_{it} = \beta_0 + \beta_1 Post * Treatment_{it} + \beta_2 X_{it} + \ \upsilon_i + \delta_t + \epsilon_{it} \tag{1}$$

$Gini\ Index_{it}$ represents the consumption Gini coefficient for country i in year t. The core of the regression is the interaction term $Post * Treatment$ defined above. It takes on the value of 1 for observations from the post-policy period in the treatment group, and 0 otherwise. With common trends assumption holds, the DID model can utilize the control group as the counterfactual to identify treatment effects by comparing the average post-policy changes in the Gini Index between the treatment group and the control group. Thus, a negative and statistically significant β_1 implies that the EU ETS may play a role in reducing consumption inequality. X_{it} encompasses the array of control variables that have been specified. I include country (υ_i) and year (δ_t) fixed effects to account for latent heterogeneity. By clustering standard errors at the country level, I mitigate the issue of correlated shocks by accounting for the fact that data points within the cluster are not independent of each other.

Central to the credibility of the DID model is the common trends assumption. For this to be validated, in the absence of the treatment, both treated and control groups should follow similar trends over time. Since this assumption is not testable for the period after the treatment, the event-study design offers a lens, investigating the pre-treatment period year-by-year to see if any significant deviations exist between the treated and control groups. This facilitates a more reliable validation of the parallel trend assumption.

$$\begin{aligned} Gini\ Index_{it} = \alpha_0 + \sum_{\tau=6}^{1} \alpha_\tau Before_{\tau,it} + \alpha_C Current_{it} \\ + \sum_{\tau=2}^{1} \alpha_{A\tau} After_{\tau,it} + \beta X_{it} + \lambda_i + \theta_t + \omega_{it} \end{aligned} \tag{2}$$

The $Before$ variables capture the years leading up to the policy's introduction. For instance, $Before_1$ is an indicator that takes the value of 1 for the year before the policy and 0 otherwise. The coefficients α_1 to α_6 catch the differentials between the treated and control groups for each respective year before the policy. If they are statistically insignificant, it means that there were no significant differences in pre-treatment trends between the treatment and control groups Thus, the common trend assumption could be validated, supporting my DID design and allowing me to attribute post-policy changes to the EU ETS (Angrist and Pischke 2008).

For heterogeneity analysis, I explore whether the EU ETS's impact varies across countries with different economic and environmental characteristics. First, I construct four distinct interaction terms—$m1$, $m2$,$m3$, and $m4$. These interaction terms are products of the policy interaction term $Post * Treatment$ and binary indicators GDP per capita (ln) 2004, energy CPI 2004, CO2 emissions (ln) 2004, and total CPI 2004 that respectively group countries based on certain 2004 thresholds.

For instance, the interaction term $m1$ is derived by multiplying the policy interaction term $Post * Treatment$ with a binary indicator that assumes a value of 1 if the country's 2004 GDP per capita surpasses the 2004 mean GDP per capita, and 0 otherwise. Regression models incorporating these interactions are:

$$Gini\ Index_{it} = \beta_0 + \beta_1 m1_{it} + \beta_2 Post * Treatment_{it} + \beta_3 X_{it} + \upsilon_i + \delta_t + \epsilon_{it} \tag{3}$$
$$Gini\ Index_{it} = \beta_0 + \beta_1 m2_{it} + \beta_2 Post * Treatment_{it} + \beta_3 X_{it} + \upsilon_i + \delta_t + \epsilon_{it} \tag{4}$$
$$Gini\ Index_{it} = \beta_0 + \beta_1 m3_{it} + \beta_2 Post * Treatment_{it} + \beta_3 X_{it} + \upsilon_i + \delta_t + \epsilon_{it} \tag{5}$$
$$Gini\ Index_{it} = \beta_0 + \beta_1 m4_{it} + \beta_2 Post * Treatment_{it} + \beta_3 X_{it} + \upsilon_i + \delta_t + \epsilon_{it} \tag{6}$$

Note that GDP per capita (ln) in Equation (3) and total CPI in Equation (6) are not included as control variables in X_{it} because they are absorbed by the country fixed effects. Such regressions help discern whether the EU ETS's effects are amplified or attenuated for countries with specific economic or environmental characteristics.

Following the baseline and parallel trend analyses, the study also examines the effects of the EU ETS across its different phases for further discussion as I want to account for the multi-phase characteristic of the EU ETS and better understand its impact over time. The primary variable of interest for this extended examination is $dd2$. This binary interaction term assumes a value of 1 under two conditions:

1. The country is an active participant in the EU ETS.
2. The year of observation falls in the post-treatment era of that country. For example, since Iceland joined the EU ETS in 2008, for all observations afterwards (including 2008), the variable $dd2$ equals 1, 0 otherwise.

To investigate the treatment effects under this multi-phase structure, I employ the regression model:

$$Gini\ Index_{it} = \beta_0 + \beta_1 dd2_{it} + \beta_2 X_{it} + \upsilon_i + \delta_t + \epsilon_{it} \tag{7}$$

which is similar to the baseline model except for using $dd2$ as the policy interaction term. This regression is restricted to the years spanning from 1998 to 2012. The timeframe is extended from 2007 to 2012 because the study no longer focuses on Phase 1 only and includes observations from Phase 2. X_{it} is the list of control variables that have already been defined in the baseline regression. Country (υ_i) and year (δ_t) fixed effects are also incorporated and standard errors are clustered at the country level, enhancing the robustness of estimates.

5 Empirical Analysis

5.1 Baseline Results

Table 2, column (1) represents the results from the baseline regression without control variables, and only fixed effects are considered. The coefficient for the interaction term $Post * Treatment$ is -0.009 and is statistically significant at the 5% level (with a standard error of 0.003). This means that on average, compared to the control group, the treatment group sample saw a reduction in the Gini index by 0.009 units after the policy was implemented. i.e., for countries under the ETS, it is 0.009 units lower than it would have been without the ETS (counterfactual). Given that in 2004 (one year before the implementation) the average value of the Gini index was 0.33 among the treatment group, we can observe that although compared to the 0.33 mean, a 0.9 percentage point decrease can be seen as a relatively moderate shift, in the field of economic inequality, changes often occur slowly and are hard to achieve, making a significant 0.9 percentage point reduction caused by the EU ETS noteworthy. In essence, the negative coefficient indicates that the introduction of the EU ETS has a dampening effect on consumption inequality, showing the potential of the system to achieve a win-win scenario of inequality and environmental sustainability. This outcome may be attributed to the EU ETS leading to a shift in consumption patterns, with carbon-intensive goods becoming more expensive and potentially affecting higher-consuming households more significantly.

In column (2) Table 2, the set of control variables defined previously is incorporated. Despite the inclusion of these controls, the coefficient for the policy interaction term $Post*Treatment$ remains stable at -0.009 and maintains its significance at the 5% level. This stability is crucial as it suggests that the observed relationship between the EU ETS and consumption inequality is robust, even when accounting for potential confounding factors. It's worth noting that, typically, the inclusion of control variables might either attenuate or amplify the coefficient of the variable of interest if those controls were previously omitted and correlated with both the dependent and independent variables. In this case, the consistency suggests that the control variables might not be strong con-founders or are capturing different aspects of the data. But still, the consistent negative effect, even after accounting for these controls, further underscores the significant impact of the EU ETS on consumption inequality.

5.2 Parallel trend test

The validity of the DID approach is contingent upon satisfying the parallel trends assumption. This foundational principle means that in the absence of the treatment i.e., the implementation of the EU ETS, the treatment and control groups would have progressed along parallel trajectories in the consumption Gini coefficient. To test for this assumption, my analytical strategy unfolds in two stages:

1. Graphical Exploration: I conduct a preliminary figure (Figure 1) by charting the evolution of the consumption Gini coefficient over time for both treatment and control groups to visually assess the trends. As we can see from Figure 1, while the graph generally indicates parallel trends leading up to the introduction of the EU ETS, one could argue that there's a divergence starting around 2001 that can be observed from the plot. Nevertheless, subsequent event-study analysis, which statistically tests for parallel trends, does not find this divergence to be statistically significant, emphasizing the broader coherence observed in Figure 1.

2. Event-Study Analysis: Building on the graphical insights, I employ an event-study design to quantitatively test for the assumption, and the specification employed is shown in Equation (2). The main focus of this test should be on the pre-policy indicators ($Before_6$ to $Before_1$). These binary indicators capture the differential effects between the treatment and control groups in the years leading up to the EU ETS. Crucially, for the parallel trends assumption to hold, the coefficients on these indicators should not be statistically significant otherwise, we will see deviating trends. The regression results in Figure 2 affirm this—none of the coefficients for these indicators are statistically significant, thereby reinforcing the validity of the DID setup.

In the examination of the parallel trends assumption, we can observe from Figure 2 a sequential decline in the coefficients for our pre-policy indicators. Specifically, it may suggest that there exist other underlying and unobserved factors affecting the groups differently, which slightly narrowed the gap between the trends of the treatment and control groups at first and then started widening it in the years preceding the EU ETS's implementation. Such factors, if persistent post-treatment, could potentially confound the treatment effect we aim to measure.

However, it's important to note that while this pattern draws attention, the declines are statistically insignificant. This means that while the decline might be observable, the differences could well be attributed to chance or natural fluctuations and might not be substantive enough to disrupt our parallel trend assumptions. Consequently, we maintain that the DID approach remains a suitable and robust method to estimate the causal effects of the EU ETS on consumption inequality.

5.3 Robustness test

To assess the validity of my primary findings, I subjected the results to a series of robustness checks.

In Table 3, I examine the potential pre-emptive behaviors—actions taken in anticipation of the policy implementation. Specifically, I employ a model similar to the one used in the baseline analysis but introduce an interaction term between the treatment group and a dummy variable for the year 2004 ($i.treatment\#i.d2004$). The rationale is to test if there were obvious differentials or changes in the consumption Gini coefficient for the treated entities one year prior to the policy introduction. The coefficient of this interaction term is not significant at -0.007. It is in the same direction as the coefficient of the core explanatory variable $Post * Treatment$ and is also as large as it, indicating that there might be some pre-treatment activities. However, this effect of pre-emptive behavior still is not significant enough for us to conclude that it does make a difference. More importantly, the core treatment effect, as measured by the coefficient of $Post * Treatment$, retains its magnitude, significance, and sign, reinforcing the credibility of the primary estimation.

In Table 4, I harness the Propensity Score Matching-Difference-in-Differences (PSM-DID) method developed by Rosenbaum and Rubin (1983). This approach matches treated and untreated observations based on their propensity scores, thereby mitigating potential selection bias. The matched sample is then subjected to a DID analysis. As shown in Table 4, the sign, magnitudes, and significance of the $Post * Treatment$ coefficient are consistent at -0.008 with the baseline result, even after this rigorous matching process, supporting the robustness of my baseline results. The consistency of the PSM-DID outcome with the primary findings underlines that the results do not suffer from the problems of omitted variable bias or endogenous treatment assignment.

Lastly, in Table 5, I examine the robustness of my findings with an alternative measurement of consumption inequality. Instead of the consumption Gini index, I use the *Palma ratio* from consumption data—a measure of inequality that focuses on the disparity between the top 10% and the bottom 40% of the distribution. From the table, we can observe that the coefficient of the policy interaction term $Post * Treatment$ remains significantly negative at -0.058. Given that the average value of the *Palma ratio* is 1.36 among the treatment in 2004, -0.058 shows a significant decrease in the treatment group compared to the control. This 0.058/1.36 ratio is indeed higher, but the direction and significance are in line with the baseline result. Thus, the test suggests that the core findings persist even when we shift our lens to the extremes of the distribution, highlighting the overarching nature of the policy's impact on consumption inequality.

These robustness checks, through various aspects and methods, consistently support the negative causal impact of the implementation of the EU ETS on consumption inequality, increasing the credibility and reliability of the core findings.

5.4 Heterogeneity test

The heterogeneity, arising from variations in economic structures, developmental stages, and past policy decisions, can shape the effectiveness of the EU ETS, thereby adding layers of complexity to the primary research.

To account for this heterogeneity, I employ an approach in which I multiply the treatment variable, $Post*Treatment$, with various country-specific indicators and generate new interaction terms ($m1$, $m2$, etc. as defined previously) that may capture the differential treatment effects. Specifically, I categorize countries based on thresholds set using levels of several key indicators in the year 2004 that are discussed below. If a country's indicator value surpasses the mean value for that year, it is flagged with a value of 1; otherwise, it is 0. This binary categorization allows me to separate countries and understand if the EU ETS's impact varies between these two groups defined by a certain indicator. By doing so, I aim to shed light on whether countries with certain characteristics are more heavily (or the opposite) affected by the policy.

In column (1) of Table 6, I classified samples according to their levels of GDP per capita. The level of GDP per capita serves as a bellwether for a country's economic prosperity and development trajectory. According to the Kuznets Curve hypothesis (Kuznets 1955), as an economy develops, there's an initial increase in inequality, which eventually decreases after its income or GDP reaches a certain turning point. Countries with a higher GDP per capita might have already past the peak of their curves, implying potentially different impacts of environmental regulations on their consumption inequality. From the table, however, we can observe that the coefficient for the interaction term $m1$ is insignificant at -0.005, which suggests that the difference in impacts for countries with different GDP per capita levels is not significant. This could be because the inflection points of the Kuznets Curves of the countries with different GDP per capita levels are different, which means that they may still be at similar positions on the curves. Thus, a simple stratification by GDP per capita does not seem to be enough to account for the complex heterogeneity. On the other hand, the magnitude of the coefficient is relatively large, with a similar value as the main effect. This to some extent reveals that regions with better economic development levels are more likely to alleviate consumption inequality following the implementation of the policy, even though it is not significant at the current confidence level of the model.

The Energy Consumer Price Index also provides a window into a country's energy cost dynamics. High energy price levels often result in cost-induced innovations and efficiency improvements in the industrial sector (Porter and van der Linde 1995; Ambec et al., 2013; Kong et al. 2020). Such countries with already high energy prices or used to have high energy prices might be in a better position to respond to environmental regulations without pronounced changes in consumption inequality because of innovations and high efficiency. In column (2) of Table 6, I show the results after categorizing the sample using their energy CPI level. The insignificance of the coefficient of the interaction term, $m2$, could indicate that the relationship between energy costs and ETS's impact on consumption inequality is still unclear, requiring more in-depth studies.

In column (3), the samples are classified according to their level of CO2 emission. The logarithm of CO2 emissions represents a country's environmental situation. High-emission countries might face dual pressures - from global environmental agreements and domestic calls for environmental actions. This could help overcome the ideological barrier when introducing new policies like the EU ETS and make carrying out the ETS a lot easier. However, the coefficient for the interaction term $m3$ is insignificant at -0.004, showing that the level of CO2 emission cannot explain the heterogeneity as well. But it's worth noticing that the relatively large magnitude may still indicate that economically, regions with more prominent environmental issues see more effective alleviation of consumption inequality after the policy is implemented, echoing my statement above.

In column (4), I classify samples based on their 2004 total CPI level, a measurement of a country's overall inflation in 2004. Countries with higher CPI levels in 2004 were likely suffering from greater inflationary pressures. This can, in turn, affect how they experience the impacts of policies like the EU ETS. While the primary regression indicates that the EU ETS generally acts as a mitigating force against consumption inequality, this heterogeneity analysis with CPI being the threshold paints a more complex picture. The positive and significant coefficient of the interaction term m4 suggests that in countries that had high inflation levels before the policy, the beneficial effects of the EU ETS on consumption inequality are diminished. One potential reason is that in these countries, which are already dealing with the burden of high inflation, we might see more firms passing on allowance-induced costs to consumers. The compounded effect of existing inflation and the additional costs caused by the EU ETS could lead to elevated consumption prices. Consequently, this exacerbates the real income decline, especially in energy consumption. This disproportionately affects lower-income households who had energy spending taking a large share of their expenditure and therefore widening consumption inequality. Thus, while the EU ETS has an overall positive role in curtailing consumption inequality, its impact is notably attenuated in countries with significant inflationary pressure.

In sum, the study has shown empirically that heterogeneity exists in the impacts of EU ETS on consumption inequality across countries. Specifically speaking, I find that higher inflation could be an important factor that significantly affects the power of the EU ETS. While among the other indicators, some to an extent show the potential to account for the heterogeneity, the empirical results are not significant enough for me to come to that conclusion, pointing toward further studies.

5.5 Further Discussion

The inclusion of Phase 2 countries in the EU ETS provides us with insights into the policy's broader implications. The results from this extended analysis show consistency with the baseline results to some extent that the EU ETS may slightly reduce consumption inequality. From Table 7, we can observe that the coefficient of the interaction term $dd2$ in the new specification is -0.006 and is also statistically significant at the 10% significance level. This represents a 33.33% decrease in magnitude compared to the baseline model, where the coefficient was -0.009 and significant at the 5% level. Despite this reduction, the coefficient remains negative, indicating that the EU ETS continues to have a dampening effect on consumption inequality in Phase 2, but even more moderate and less pronounced.

This relatively large reduction in the coefficient's magnitude requires careful consideration. Here, I propose several factors that might explain this change:

Heterogeneity Across Countries: The inclusion of Phase 2 countries in the analysis introduces a greater level of heterogeneity in economic, social, and environmental contexts, which could be, more specifically, in the form of varied policy implementation strategies, compliance mechanisms, or consumption patterns. As a result, the impact of the EU ETS on consumption inequality could be less uniform across this broader sample, leading to a weaker overall effect.

Policy Adaptation: It is plausible that countries that were initially under the EU ETS have adapted over time. The Phase 1 EU ETS might have a strong initial impact, reshaping the consumption pattern and stimulating green investment, which led to the alleviation of consumption inequality. However, as the EU ETS proceeded into Phase 2, these behavioral shifts might have already become a new normal and squeezed the room for further improvement. Therefore, ETS's marginal impact on consumption inequality was reduced. What's more, as Phase 2 EU ETS is developed based on its Phase 1 performance, the markets and consumers could make expectations and adapt, pointing out the potential of having pre-emptive behavior that can make the real impact of the policy not being fully identified.

Also, the reduced significance level (from 5% in the baseline to 10% in the further discussion) highlights the need for caution in generalizing these findings. It points to the possibility that the policy's effectiveness could be subject to various country-specific factors and as I expand the size of the study to include more countries, the EU ETS's overall impact now may not be as robust as the initial impact found for Phase 1.

6 Conclusion and Policy Implications

The EU ETS has emerged as a crucial policy mechanism in the EU's green transition towards environmental sustainability. As a widely implemented cap-and-trade system aiming for a just transition, its broader socio-economic influence, especially on consumption inequality, is worth further exploration. Drawing from a dataset with annual consumption data spanning all 38 OECD countries from 1998 to 2015, I find robust results linking the EU ETS and consumption inequality:

1. The EU ETS has significantly reduced consumption inequality in European OECD countries. Specifically, my baseline results show that the policy interaction term of interest in the model exhibited a coefficient of -0.009, significant at the 5% level. This can be interpreted as there is an additional 0.9 %pt. decrease in the Gini index caused by the implementation of the EU ETS. Further expanding the analysis to integrate Phase 2 countries, the results indicate a moderation in the policy's impact, but still in the same direction. The coefficient for the new interaction term stood at -0.006, with a significance level of 10%, marking a 33.33 % decrease in magnitude compared to the baseline findings. This moderated effect reveals the varied dynamics in the impact introduced by the inclusion of Phase 2 countries, pointing towards potential heterogeneity in economic, social, political, and environmental contexts that require further studies.

2. The relationship between the EU ETS and consumption inequality is heterogeneous in countries with different inflationary pressures prior to the implementation. In countries with higher total CPI, the

EU ETS's impact on consumption inequality is diminished or even offset compared to those with lower total CPI or inflation levels.

From these findings, several policy implications can be made. Firstly, the EU can aim to expand the reach of the system. This may involve both integrating more industries under its purview and considering its extension beyond the current geographical boundaries. The EU ETS has demonstrated tangible benefits in both environmental sustainability and the reduction of consumption inequality. An expanded reach could potentially replicate the observed benefits across a broader size, fostering environmental and socio-economic improvements. Among all sectors, residential and commercial building requires special attention. Covering the sector, the ETS can enhance and facilitate the investment in energy-efficient buildings, expanding the use of insulation material. Such shifts may lead to job creation and may potentially reduce energy poverty. However, the external applicability of my findings in this sector requires further studies. What's more, the heterogeneity in the EU ETS's impact due to different inflationary pressures, as highlighted in our results, necessitates a more targeted approach. The differential impacts experienced by countries with different inflation levels are rooted in their unique economic and developmental profiles. Policymakers should consider custom or targeted implementations of the EU ETS. By targeting the policy to align with the specific inflation levels of individual countries, the system's efficiency can be maximized.

In conclusion, the EU ETS, while environmentally driven, offers a promising avenue to address consumption inequality. However, its intricate dynamics, influenced by varied country contexts, call for adaptive strategies and sustained evaluations. As we move forward, it's important to exploit its full potential to balance environmental objectives with socio-economic equity. Future research should delve deeper into its long-term implications and potential refinements to optimize its dual objectives.

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A Tables

Table 1

Variable	Obs	Mean	Std. Dev.	Min	Max	Source
Gini Index	342	0.342	0.037	0.281	0.450	GCD
Post ∗ Treatment	342	0.167	0.373	0	1	N/A
GDP per capita (ln)	342	10.056	0.453	8.863	10.724	OECD Data
Unemployment rate	342	7.468	3.290	2.067	15.483	OECD Data
Total Consumer Price Index	342	3.223	2.702	0.293	16.586	OECD Data
Government expenditure	342	18.686	3.541	9.841	24.629	World Bank Open Data
Urban population ratio	342	74.367	10.876	50.701	90.866	World Bank Open Data
Dependency ratio	342	49.424	4.410	43.964	66.346	World Bank Open Data

Note: Summary Statistics

Table 2

	(1) Gini Index	(2) Gini Index
Post ∗ Treatment	-0.009**	-0.009**
	(0.003)	(0.003)
GDP per capita (ln)		0.023
		(0.022)
Unemployment rate		-0.001
		(0.001)
Total Consumer Price Index		-0.001*
		(0.000)
Government expenditure		-0.000
		(0.001)
Urban population ratio		0.002*
		(0.001)
Dependency ratio		0.000
		(0.001)
cons	0.349***	-0.027
	(0.001)	(0.238)
N	380	342
r2 (Within)	0.054	0.125

Standard errors clustered in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$
Note: Table 2 presents the benchmark DID regression results of Equation (1). The dependent variable Gini Index is the consumption Gini index measuring consumption inequality. The key explanatory variable measuring the treatment effects is the interaction term Post ∗ Treatment. For specification (2), GDP per capita, unemployment rate, total Consumer Price Index, government expenditure, urban population ratio, and dependency ratio are included as control variables.

Table 3

	(1) Gini Index
Post $*$ Treatment	-0.010**
	(0.004)
i.treatment# i.d2004	-0.007
	(0.004)
GDP per capita (ln)	0.024
	(0.022)
Unemployment rate	-0.000
	(0.001)
Total Consumer Price Index	-0.001*
	(0.000)
Government expenditure	-0.000
	(0.001)
Urban population ratio	0.002
	(0.001)
Dependency ratio	0.001
	(0.001)
cons	-0.037
	(0.237)
N	342
r2 (Within)	0.136

Standard errors clustered in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Note: Table 3 presents the DID regression results of the pre-emptive behaviour test of the robustness check. The dependent variable Gini Index measures consumption inequality. The policy explanatory variable is the interaction term Post $*$ Treatment. The key variable measuring pre-emptive behaviours is the interaction term i.treatment# i.d2004. The control variables include GDP per capita, unemployment rate, total Consumer Price Index, government expenditure, urban population ratio, and dependency ratio.

Table 4

	(1) Gini Index
Post $*$ Treatment	-0.008**
	(0.004)
GDP per capita (ln)	0.035
	(0.022)
Unemployment rate	-0.001
	(0.001)
Total Consumer Price Index	-0.001**
	(0.000)
Government expenditure	-0.001
	(0.001)
Urban population ratio	0.004***
	(0.001)
Dependency ratio	-0.001
	(0.001)
cons	-0.219
	(0.238)
N	281
r2 (Within)	0.202

Standard errors clustered in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Note: Table 4 presents the PSM-DID regression results of robustness check. The dependent variable Gini Index is the consumption Gini index measuring consumption inequality. The key explanatory variable measuring the treatment effects in the PSM-DID model is the interaction term Post $*$ Treatment. The control variables include GDP per capita, unemployment rate, total Consumer Price Index, government expenditure, urban population ratio, and dependency ratio.

Table 5

	(1) Palma Ratio
Post ∗ Treatment	-0.058*
	(0.030)
GDP per capita (ln)	0.144
	(0.176)
Unemployment rate	-0.005
	(0.007)
Total Consumer Price Index	-0.004
	(0.003)
Government expenditure	-0.005
	(0.011)
Urban population ratio	0.006
	(0.008)
Dependency ratio	0.008
	(0.007)
cons	-0.668
	(1.763)
N	342
r2 (Within)	0.097

Standard errors clustered in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$
Note: Table 5 presents the DID regression results of the alternative index test of the robustness check. The dependent variable Palma ratio measures consumption inequality but is calculated differently from the Gini index. The key explanatory variable measuring the treatment effects is the interaction term Post ∗ Treatment. The control variables include GDP per capita, unemployment rate, total Consumer Price Index, government expenditure, urban population ratio, and dependency ratio.

Table 6

	(1) Gini Index	(2) Gini Index	(3) Gini Index	(4) Gini Index
Post $*$ Treatment	-0.004	-0.009**	-0.006*	-0.012***
	(0.005)	(0.004)	(0.003)	(0.004)
m1	-0.005			
	(0.005)			
m2		0.002		
		(0.006)		
m3			-0.004	
			(0.006)	
m4				0.011*
				(0.006)
cons	0.219***	-0.027	-0.025	0.015
	(0.073)	(0.235)	(0.232)	(0.224)
N	342	342	342	342
r2 (Within)	0.117	0.125	0.131	0.136

Standard errors clustered in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.
Note: "m1", "m2", "m3" and "m4" stand for the interaction terms of the policy interaction term Post $*$ Treatment and binary variables GDP per capita (ln) 2004, energy CPI 2004, CO2 emissions (ln) 2004, and total CPI 2004 that demarcate countries based on certain 2004 thresholds of the indicator separately. For any indicator, if the 2004 value of a country surpasses the 2004 mean, the binary variable will take a value of 1, 0 otherwise. Control variables in the baseline model are included and hidden. Note that GDP per capita (ln) in (1) and total CPI in (4) are not included as control variables as they are absorbed by the country fixed effects.

Table 7

	(1) Gini Index	(2) Gini Index
dd2	-0.003	-0.006*
	(0.004)	(0.003)
GDP per capita (ln)		0.026*
		(0.015)
Unemployment rate		0.000
		(0.001)
Total Consumer Price Index		-0.000
		(0.000)
Government expenditure		-0.001
		(0.001)
Urban population ratio		0.001
		(0.001)
Dependency ratio		0.001
		(0.001)
cons	0.348***	-0.008
	(0.001)	(0.181)
N	570	529
r2 (Within)	0.006	0.085

Standard errors clustered in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.
Note: Table 7 presents the DID regression results of Equation (7). The dependent variable Gini Index is the consumption Gini index measuring consumption inequality. The key explanatory variable measuring the treatment effects covering Phase 2 countries and years is $dd2$. It takes a value of 1 under two conditions: 1. The country is an active participant in the EU ETS. 2. The year of observation falls in the post-treatment era of that country. The control variables include GDP per capita, unemployment rate, total Consumer Price Index, government expenditure, urban population ratio, and dependency ratio.

B Figures

Figure 1

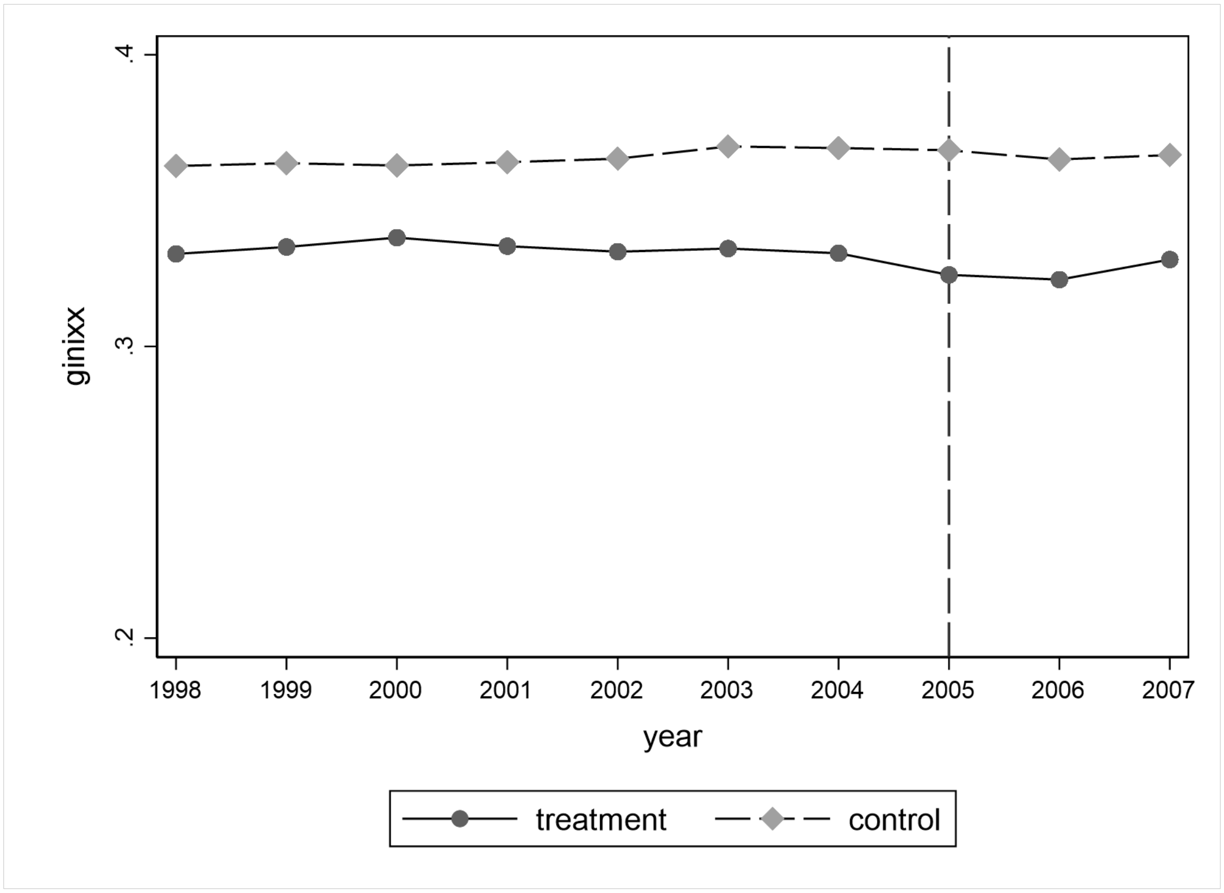

Figure 1 plots the trends of consumption Gini index for both treatment and control group over time. The vertical axis measures the Gini index and the horizontal axis measures time. We can see a parallel trend visually in the plot.

Figure 2

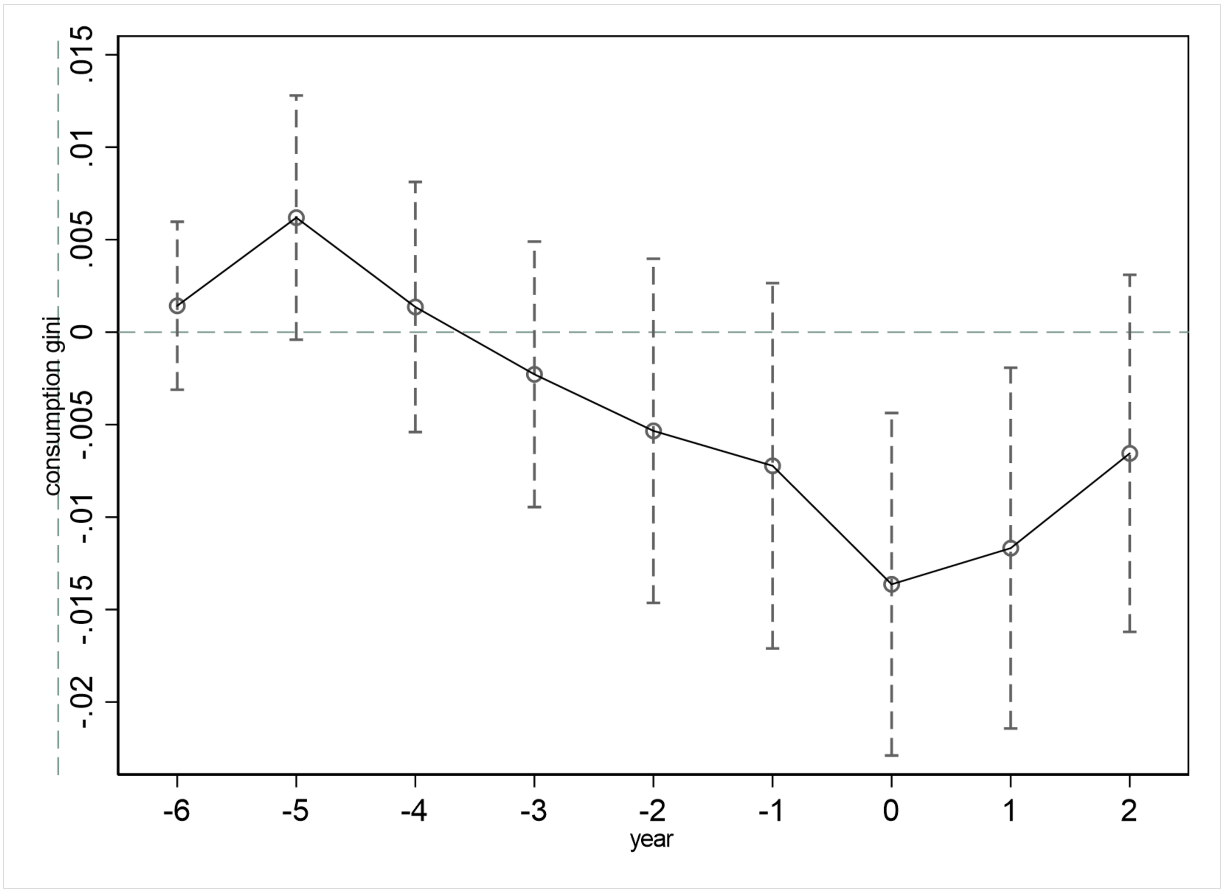

Figure 2 plots the results of the parallel trend test. We can see that before year 0, all of the coefficients are insignificant.

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