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Pricing the Green Label: Greenium in the European Bond Market

Impact of the EU Green Bond Standard on the green premium

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Abstract

This study examines the impact of the European Green Bond Standard on the pricing of green bonds in the European bond market. The EU Green Bond Standard entered into force in December 2023 and its purpose is to enhance transparency and investor confidence by providing a clear framework for green bond issuance. Using a matched sample of 105 green and conventional bond pairs with weekly yield data, the study applies a two-stage empirical approach. A t-test confirms the presence of a statistically significant positive green premium, with green bonds trading at lower yields. A Random Effects model indicates that the premium widened after the regulation took effect. However, this effect becomes insignificant when bond-level characteristics are included in an OLS regression. Further analysis reveals that the regulation's impact varies across currencies, credit ratings, and maturities, suggesting that the green premium is shaped by both regulatory signals and bond-specific factors.

Keywords: Greenium, Green Bonds, European Green Bond Standard, Sustainable Finance, External Certifications

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1 Introduction

Sustainable finance is an emerging field driven by increasing awareness of climate change and involves using financial instruments to fund environmentally sustainable projects and support the transition to a low-carbon economy. Green bonds are a key financial instrument within this field, used to finance sustainable and environmentally friendly projects. The first green bond was introduced in 2007 when the European Investment Bank issued the “Climate Awareness Bond” and the first corporate green bond was issued by the Swedish property company Vasakronan in 2013 (European Investment Bank, 2020; CBI, 2013).

The issuance volume of green bonds increased significantly in the European Union between 2014 and 2023. This growth has been driven by a combination of factors, including a growing interest in financial products that support sustainability and heightened demand among investors to fund green activities. A major catalyst for this expansion has been the European Green Deal, which emphasizes the need to direct capital flows towards green investments and aims to fund the transition to a low-carbon, green economy (European Environment Agency, 2024).

A central concept in the green bond market is the green bond premium, or greenium, which refers to a borrowing cost advantage for green bond issuers, meaning green bonds can have lower yields compared to conventional bonds. This yield difference represents investors' willingness to accept lower yields or lower expected returns for a bond labelled as green. This positive attitude arises from the non-financial benefits investors associate with supporting sustainable activities, deriving positive value or utility from holding green assets beyond just the financial return. However, the extent to which investors accept lower yields is often influenced by the perceived credibility of a bond’s environmental claims.

Confidence in the authenticity of a bond’s green credentials can be strengthened through specific bond-level characteristics such as third-party certifications, external reviews, or alignment with established standards for green bonds. In the absence of such credibility signals, greenwashing concerns become prominent, which may undermine investor trust and the perceived integrity of green investments.

The rapid growth of the green bond market has highlighted the importance of frameworks and certifications to ensure credibility and environmental integrity of these instruments. Without clear guidelines, concerns regarding greenwashing increase and investors' confidence decreases. In response to the challenges, the European Union introduced the European Green Bond Standard (EU GBS) in 2021.

This framework is a voluntary standard based on the EU Taxonomy, which sets criteria for the use of the proceeds from green bonds (European Commission, n.d.). The EU Green Bond Standard was first discussed in 2019 when the Technical Expert Group on Sustainable Finance (TEG) published its interim report. A legislative proposal was introduced in July 2021 followed by a political agreement in 2023. The regulation was officially published in November 2023, and on 20 December 2023, the regulation entered into force. The EU Green Bond Standard, however, was not implemented until December 2024 (European Commission, n.d.; European Environment Agency, 2024). A detailed timeline of the regulation's development is provided in Appendix A.1.

This thesis contributes to the growing literature on green bond pricing by investigating whether the commencement of the EU Green Bond Standard in December 2023 was followed by a change in how investors price green bonds relative to comparable conventional bonds. The key metric used is the green bond premium, often referred to as the *greenium*, and is defined as the yield difference between matched green and conventional bonds, based on their mid-point yield to maturity in the secondary market. We begin by testing whether there is evidence of a green premium in our dataset. Then, we examine how the European Green Bond Standard influenced the green premium in the European green bond market, as well as which bond characteristics contribute to the premium.

The data consists of weekly yield observations and other explanatory variables for 105 pairs of bonds. We use the Bloomberg database to construct a sample of green bonds and conventional bonds issued in Europe between 01-01-2019 and 31-12-2024.

A two-layer regression model is employed to assess the hypotheses. The first layer is a random effects model, used to conduct an event study examining the change in the premium before and after the event. The event date is 20 December 2023, when the regulation entered into force. In the second layer we estimate an OLS regression to determine the extent to which various bond characteristics influence the yield difference.

The results of the study show a statistically significant green premium in the sample, averaging approximately 5.7 basis points, which is consistent with previous studies that report a positive yield differential for green bonds in secondary markets. Following the entry into force of the EU Green Bond Standard in December 2023, the yield difference increased by approximately 2.6 basis points on average. However, the OLS regression controlling for all bond characteristics shows that the overall event impact on the premium is not statistically significant. By introducing an interaction term between the *Post Event* dummy and *Currency*, the result shows that the impact of the event varies by currency denominations. Bond-specific factors, such as credit rating and maturity also significantly impact the premium.

Section 2 presents previous literature on the existence of a green premium and role of certifications. In Section 3 and 4, the data and empirical methodology are described, followed by Section 5, where the results from the study are presented. Lastly, in Section 6 conclusions from the study and findings will be discussed.

2 Literature Review and Hypothesis Formulation

Green bonds are fixed income instruments issued to finance sustainable and environmentally friendly projects (International Capital Market Association, 2022). Similar to conventional bonds, green bonds can be issued by corporations, governments or banks. However, there is a lack of universal definition or mandatory framework, giving issuers certain flexibility to define green bonds according to their own criteria (CBI, n.d.), leaving room for greenwashing, whereby companies issue green bonds to portray themselves as environmentally responsible but without taking tangible action (Flammer, 2021). Lam and Wurgler (2024) found that only 2% of corporate and municipal green bonds issued in the U.S. are used to fund sustainable projects. To prevent greenwashing risk, investors are often willing to accept lower returns on green bonds compared to conventional bonds (Kleffel & Muck, 2023).

To address the concerns regarding greenwashing and to increase investor confidence, the European Union introduced the EU Green Bond Standard. The EU Green Bond Standard is a voluntary standard linked to the EU Taxonomy, which is a classification system to define what qualifies as an environmentally sustainable economic activity within the European Union (European Commission, n.d.). For issuers to be allowed to label their bond as a European Green Bond they will have to follow the criteria according to the EU Green Bond Standard. One of which is that at least 85% of the bond proceeds must be allocated to economic activities that are environmentally sustainable under Article 3 of EU Taxonomy Regulation (EU) 2020/852, as specified in the EU Green Bonds Regulation (Regulation (EU) 2023/2631).

The following sections review the literature on yield differences between green and conventional bonds, providing a foundation for evaluating how regulatory measures, such as the EU Green Bond Standard, may influence bond pricing.

2.1 Evidence of a Green Bond Premium

In recent years, there has been an increase in research about green bonds, particularly on analysing the green bonds' pricing structure compared to conventional bonds. This has given rise to a strand of literature that explores whether green bonds consistently trade at lower yields and what factors might explain these pricing differentials. Several studies provide evidence of a green premium in both the primary and secondary bond markets (Löffler et al., 2021; Petreski

& Stephan, 2021; Caramichael & Rapp, 2024; Zerbib, 2019). However, the magnitude and consistency of this pricing difference is still debated among researchers.

Studies show mixed results on whether a green premium exists in the bond market, with findings appearing to differ between the primary and secondary markets. Some literature reviews, see MacAskill et al. (2021) and Cortellini and Panetta (2021) for example, show stronger evidence of a premium in the secondary market compared to the primary market. MacAskill et al. (2021) conducted a systematic literature review examining the existence and determinants of the green premium in both primary and secondary bond markets. They found mixed results on whether there is evidence of a green bond premium in the primary market, with 56% of studies showing evidence of its presence, while 44% show no evidence. In the secondary market there is a stronger presence of a green bond premium with 70% of studies observing a positive premium.

Similarly, Cortellini and Panetta (2021), conducted a systematic literature review where they report that in the primary market, 40% of studies show evidence of a premium, 40% present inconclusive findings and 20% found no evidence. In the secondary market, around 63% of studies found evidence of a green bond premium while 37% found no evidence.

Literature suggests that the existence of the green bond premium depends on factors such as issuer, currency and bond credit ratings. Fatica et al. (2021) found that green bonds issued by supranational institutions and non-financial corporations were priced differently than comparable conventional bonds, however no such difference was observed for green bonds issued by financial institutions. Similarly, Kapraun et al. (2021) found that green bonds issued by governments, local governments, and supranational entities, as well as bonds denominated in Euro, trade at a lower yield than comparable conventional bonds in both the primary and secondary markets.

Some studies found no evidence of a green bond premium in the overall market (Flammer, 2021; Tang & Zhang, 2020; Kapraun et al., 2021). While Kapraun et al. (2021) found evidence of a premium for specific issuers, when investigating the whole bond market, no evidence of a positive premium was observed.

Few studies resulted in inconclusive findings regarding the existence of a green bond premium. Hackenberg and Schiereck (2018) observed a small premium for investment grade bonds, however, it was not statistically significant. Tang and Zhang (2020) did not observe a significant green premium when comparing bonds issued by the same firm.

2.2 The Role of External Verification on Green Bond Pricing

A growing body of research suggests that verified green bonds often benefit from a green premium, reflected in slightly lower yields relative to comparable conventional bonds. Pietsch and Salakhova (2022) find that green bonds with external reviews, such as second-party opinions or certifications, are more likely to trade at a premium compared to similar conventional bonds. They argue that this difference reflects greater investor confidence in the environmental credibility of the bond.

Similarly, MacAskill et al. (2021) observe that the presence of formal governance mechanisms, including third-party verification, is one of the most consistent characteristics linked to lower yields in the secondary market. These results indicate that external verification may act as a signal of quality, reducing uncertainty and increasing demand among investors who value environmental criteria. Tang and Zhang (2020) support this by noting that certification is often costly and signals a stronger commitment to environmental goals.

The European Environment Agency offers additional support for the role of verification, reporting that green bonds undergoing external certification or receiving second-party opinions tend to trade at lower yields than similar conventional bonds. This pricing advantage is attributed to stronger investor confidence in the environmental claims of verified bonds, which may reduce perceived risk and increase demand. Bonds that lack such verification, by contrast, often receive less investor interest, reinforcing investor trust and supporting potential pricing benefits (European Environment Agency, 2023).

Other studies, however, report more mixed results regarding the impact of external verification on green bond pricing. For example, Flammer (2021) concludes that external verification does not explain the green bond premium. Similarly, Tang and Zhang (2020) acknowledge that certification can serve as a signalling mechanism but suggest that this signal may not always translate into distinct pricing outcomes, depending on the broader context. Additionally, the effect of verification may vary depending on the type of investor, the issuer's environmental credibility, or the broader policy context (Kapraun et al., 2021; Fatica et al., 2021; Pietsch & Salakhova, 2022).

The varying effects of external verification have important implications for policy design, particularly in the context of efforts to standardize the green bond market. The EU Green Bond Standard requires all bonds carrying the 'European Green Bond' label to undergo external verification by an independent reviewer registered and supervised by ESMA (Regulation (EU) 2023/2631). This aims to improve comparability, limit greenwashing risks, and strengthen investor confidence by ensuring that proceeds are aligned with the EU Taxonomy and subject to a consistent level of assessment across the Union. The regulation responds to prior concerns about fragmented standards and unclear verification criteria (Deschryver & de Mariz, 2020; Cortellini & Panetta, 2021).

In summary, while academic studies provide mixed evidence on whether external verification consistently lowers yields, institutional perspectives such as that of the European Environment Agency offer more optimistic conclusions. The introduction of the EU Green Bond Standard represents a regulatory effort to standardize verification practices and potentially reduce variation in pricing outcomes.

2.3 Hypothesis Development

Based on the findings above, the following hypotheses have been formulated. While previous studies have explored the existence of a green bond premium, the findings are mixed. Some identify a significant positive premium, others find no statistically significant difference or report inconclusive results. Given the variation in findings, the first hypothesis aims to investigate whether a green bond premium is present in the data used in this study.

H1: Green bonds issued by European corporations are priced at a premium compared to comparable conventional bonds

The introduction of the EU Green Bond Standard represents an important change in how green bonds are regulated in Europe. The commencement of the EU Green Bond Standard in December 2023 may have acted as a market signal, shaping expectations about future verification practices and future rules and standards in the green bond market. Investors and issuers could interpret the regulation as a step toward greater consistency and credibility in the green bond market, potentially influencing pricing behaviour in anticipation of its future enforcement.

Prior research suggests that external verification contributes to the green bond premium, especially when it improves transparency and reduces uncertainty. By establishing a formal framework for verification and taxonomy alignment, the EU Green Bond Standard may have reinforced these mechanisms even before taking effect. This leads to the second hypothesis:

H2: The EU Green Bond Standard had an impact on the green bond premium, increasing the yield differential between green and conventional bonds in the post-regulation period.

3 Data Selection

This chapter describes the data used in the analysis and outlines how the sample was constructed. It introduces the main selection criteria, explains the approach to matching green and conventional bonds, and provides an overview of the yield data used. Descriptive statistics for the sample are presented in the final section.

3.1 Sample Construction

The empirical data were obtained from Bloomberg Terminal, primarily because Bloomberg offers detailed information about bonds, which is essential for our analysis. Furthermore, Bloomberg's definition of green bonds aligns with standards set by both International Capital Market Association (ICMA) and Climate Bonds Initiative (CBI). The green bonds included in the sample have all been certified by either ICMA or CBI.

Prior to 2019, the green bond market was relatively underdeveloped, constrained by limited issuance volumes, a lack of standardized frameworks, and weak pricing signals (Deschryver & de Mariz, 2020). As highlighted by Caramichael and Rapp (2022), consistent evidence of a green bond premium only begins to emerge after 2019, coinciding with the growth of sustainable investing and the introduction of EU-level regulatory initiatives. Therefore, the sample period, from 01-01-2019 to 31-12-2024, was selected in order to capture a phase of significant development in the EU green bond market. The timeframe also includes important dates in the development of the EU Green Bond Standard, such as when the regulation was officially published on 30 November 2023 and when the regulation entered into force on 20 December 2023, which allows for an analysis of both pre- and post-regulatory impact.

The sample is limited to corporate bonds issued in Europe to ensure greater comparability and market-driven pricing behaviour. Financial institutions are excluded due to the indirect nature of their use of proceeds, which makes the assessments of environmental credibility difficult. As Fatica et al. (2021) show, green bonds issued by financial institutions exhibit no statistically significant positive premium, in contrast to non-financial corporates. Kapraun et al. (2021) similarly note that credibility signals are more difficult to interpret for financial entities. Governmental, supranational, and municipal issuers are also excluded, following Flammer (2021), as their issuance motivations and market dynamics differ from those of private-sector firms. This approach ensures a more homogeneous issuer group, where the green bond premium is more likely to reflect market perceptions of credibility. Recent findings by Löffler et al. (2021) and Pietsch and Salakhova (2022) support this decision, showing that credibility factors, especially certification, play a key role in variation of the premium across time and issuer type.

Bonds with missing data on either amount issued, time to maturity or currency were excluded from the sample. To ensure consistency in bond cash flow structure, only bonds with a bullet maturity type and a fixed coupon rate were included in the sample. Due to a large number of bonds with missing credit rating and to increase the sample size, we included bonds with missing credit rating in Bloomberg but treated them the same as bonds with "No Rating". This resulted in a sample consisting of 284 green bonds and 1851 conventional bonds.

3.2 Matching Structure

Each green bond is matched with a similar conventional bond issued by the same company, in the same currency and with the same credit rating. For the most accurate results of the yield differential, green bonds should be matched with identical conventional bonds. However, finding green and conventional bonds with perfectly comparable characteristics is practically impossible. Thus, the bonds were matched using the nearest neighbour method, an approach adapted from Kapraun et al. (2021).

To implement this method, a combination of exact matching for categorical variables and nearest neighbour matching for continuous variables was applied. Specifically, exact matching was used for variables such as currency, credit rating and issuer, ensuring that matched bonds had identical structural and issuer-related attributes. For numeric variables such as time to maturity and amount issued, strict matching often limited the number of pairs, therefore the nearest neighbour method was applied to those features. Following the approach used by Kapraun et al. (2021) and Flammer (2021), bond matching is based on remaining maturity rather than original maturity, to ensure comparability of duration risk and yield dynamics between green and conventional bonds.

Due to limited matched pairs, each green bond can be matched with more than one conventional bond. However, the reuse of conventional bonds across different pairs may also introduce some dependency in the sample, which is addressed through the use of robust standard errors clustered at the bond-pair level. After matching the bonds, we were left with 105 pairs of bonds. Green bonds that did not have a comparable conventional bond were dropped from the sample.

3.3 Descriptive Statistics

Table 1 presents summary statistics for the matched bond sample, separating green and conventional bonds.

Table 1: Descriptive Statistics for Matched Bonds

	Observations	Mean	Std. Dev.	25th	Median	75th
Green bonds						
Amount Issued (Million)	105	1145.73	2397.65	193.74	749.72	1082.76
Yield to Maturity (Mid)	105	4.06	1.14	3.27	4.08	4.81
Coupon(%)	105	3.00	1.85	1.38	3.00	4.55
Years to maturity	105	8.04	3.49	5.25	7.50	10.00
Rating	105	16.25	8.73	8.00	23.00	23.00
Conventional bonds						
Amount Issued (Million)	57	954.17	1483.39	208.99	573.56	1115.89
Yield to Maturity (Mid)	57	3.72	1.17	3.21	3.41	4.40
Coupon(%)	57	2.36	1.79	0.75	2.38	3.25
Years to maturity	57	7.56	3.27	5.00	7.26	10.00
Rating	57	14.88	9.55	6.00	23.00	23.00

Bond types are compared across the following metrics: Amount issued is the bonds' issue size, reported in millions of Euro. Yield to Maturity (Mid) is a bond's average of weekly mid-yields over the 56-week period, reported in basis points. Coupon(%) is bonds' coupon (for fixed coupon bonds only) and reported in %. Years to maturity is calculated as the difference between the Maturity Date and the Issue

Date, reported in years, and reflects the bond's original term at issuance. Rating represents a bond's credit quality based on the BBG Composite rating, converted to a numeric scale ranging from AAA=1 to NR=23 (not rated).

In the matched sample, green bonds have an average issue size of approximately 1146 million Euro, an average mid-yield of 4.06% over the 56-week observation period, and a mean coupon rate of 3.00%. The average maturity is 8 years, and the average credit rating, based on the BBG Composite scale (converted to a numeric format), is 16.25, which corresponds with a rating of "B-". In comparison, conventional bonds have a slightly lower average issue size of 954 million Euro, a lower mid-yield of 3.72%, and a lower average coupon of 2.36%. Their average maturity is 7.56 years, and their credit quality is somewhat stronger, with an average rating of 14.88 (B+ rating).

3.4 Limitations

A significant challenge encountered during data collection was the monthly limitation on the volume of data that can be extracted from the Bloomberg database. This limited our ability to gather a larger and more detailed sample of bonds. As a result, some potentially relevant variables were not included in the analysis, increasing the risk of omitted variable bias and potential endogeneity in the regression models.

Following the matching process, a key limitation relates to Assumption 2, which concerns the independence and comparability of matched pairs. Because perfectly comparable conventional bonds for every green bond were not always available, many green bonds without suitable matches had to be dropped. This substantial reduction in the sample size raises concerns about the representativeness of the final matched sample, as it may no longer fully capture the broader European green bond market. Additionally, some conventional bonds were matched multiple times to different green bonds, potentially introducing dependencies that complicate statistical inference.

Furthermore, a large proportion of the bonds in the sample lack an official credit rating, with over half of the bonds either completely missing credit rating or labelled as "No Rating". This limitation constrained the model's ability to fully include credit ratings as an explanatory variable. This also made it impossible to incorporate credit ratings into the interaction terms, due to a number of missing values for ratings other than the "No Rating" category.

4 Methodology

This chapter outlines the empirical strategy used to test the two hypotheses of the study. It explains how the yield differential is calculated and presents the empirical methods used to assess each hypothesis, including the rationale for their selection. Each component is detailed in the following sections.

4.1 One-Sample T-Test

To test whether green bonds are associated with lower yields than comparable conventional bonds, the analysis begins by calculating the green bond premium for each matched bond pair over time. The yield differential is defined as:

$$\Delta y_{i,t} = y^{conv}{}_{i,t} - y^{green}{}_{i,t} \tag{1}$$

Where, $y^{conv}{}_{i,t}$ is the yield of the conventional bond in pair i at time t, and $y^{green}{}_{i,t}$ is the yield of the corresponding green bond at the same time. A positive value of $\Delta y_{i,t}$ indicates that the green bond in the pair trades at a lower yield than the comparable conventional bond, i.e. is traded at a premium. If the average value of $\Delta y_{i,t}$ across the sample is positive and statistically significant, it would provide evidence in support of a green bond premium.

To determine whether the average yield differential is statistically greater than zero across the sample, we apply a one-tailed one-sample t-test, where the independent variable is based on a winsorized version of the data, as explained below. The null and alternative hypotheses for the test are stated in Equation (2):

$$\begin{aligned} H_0 &: E[\Delta y_i] = 0 \\ H_\text{a} &: E[\Delta y_i] > 0 \end{aligned} \tag{2}$$

A significantly positive average yield differential would support the existence of a green bond premium.

Before applying the t-test, we assess whether the distribution of the premium is approximately normal using the Shapiro-Wilk test. The t-test assumes that the sample mean is normally distributed, and while this assumption can be relaxed in large samples, formal testing improves the reliability of inference. The Shapiro-Wilk test is applied to both the raw and winsorized data. The results suggest a deviation from normality in the sample, supporting the use of winsorization to reduce the impact of extreme values. To ensure robustness, the green bond premium is also analysed using a winsorized dataset, as described in the robustness checks section.

4.2 Two-Layer Regression Model

The second hypothesis evaluates whether, and to what extent, the yield differential changes in the periods before and after the commencement of the EU Green Bond Standard. To investigate this, we observe the behaviour of the green bond premium around the event period to identify any significant changes that can be linked to the EU Green Bond Standard.

The event is defined as the week of 18th to 22nd of December 2023. We define the event as a week rather than a single day for two main reasons. First, bond markets exhibit lower liquidity and slower price adjustments than other financial markets, meaning it takes longer to observe market reactions. Secondly, the data consists of weekly bond yields, therefore it ensures consistency in the analysis of the data.

The analysis is based on an event window spanning six months before and six months after the event, specifically from 01-06-2023 to 30-06-2024, a total of approximately 56 weeks [-28, +27]. Following Zerbib (2019), we employ a two-layer regression model to assess the second hypothesis. However, our specific regressions differ from those used by Zerbib (2019) due to differences in the dataset used in this study and Zerbib's study.

First, we will conduct an event study by employing a random effects model to estimate the changes in the yield spread before and after the event, which is followed by an OLS regression to estimate how the independent variables influence the green bond premium. The dataset has an unbalanced panel structure, where weekly bond yields are observed for the bond pairs. The dependent variable in both regressions is the yield differential, which is time-varying. We present the details of all dependent, independent and control variables in Appendix A.1.

4.2.1 Random Effects Model

To estimate the impact of the commencement of the EU Green Bond Standard, we begin with an event study by employing a random effects model, which is the first layer of the two-layer regression model. The choice of a random effects model over a fixed effects model is supported by the results of a Hausman test, as discussed in Section 4.2.3. The first layer aims to detect whether changes in the behaviour of the green bond premium occurred around the event by estimating the following model:

$$\Delta y_{i,t} = \alpha_i + \beta \cdot PostEvent_{it} + \varepsilon_{it} \tag{3}$$

The dependent variable, $\Delta y_{i,t}$, is the *winsorized yield differential*, representing the yield spread between the green and conventional bond in pair *i* at time *t*. The independent variable in the regression is a *Post Event* dummy variable, created to indicate the period before and after the event period. The dummy variable takes the value 1 for observations during and after the event week and takes the value 0 for observations before the event week. The coefficient, β, is associated with the event indicator variable, *Post Event*, and captures the average change in the yield differential in the pre-event window and post-event window, after controlling for the other independent variables. ε_{it} is the error term, accounting for unobserved shocks. The *Post Event* dummy was chosen as the only independent explanatory variable in the model to isolate the impact of the event on the green bond premium.

This model provides the first identification of whether, on average, the commencement of the EU Green Bond Standard is associated with a statistically significant change in the pricing of green bonds. The second layer of the model, presented in Section 4.2.2, incorporates additional explanatory variables and an interaction term to explore effect heterogeneity and assess robustness.

4.2.2 Ordinary Least Squares Regression Model

For the second layer of the two-layered regression model, we employ an Ordinary Least Squares (OLS) regression model to examine which bond characteristics influence the green bond premium and the extent of their impact. Following the approach of Zerbib (2019) and Fatica et al. (2021), we estimate the following regression model:

$$\Delta y_{i,t} = \alpha_{0+}\beta_1 \cdot \log(AvgAmountIssued_i) + \beta_2 \cdot AvgMaturity_i + \beta_3 \cdot PostEvent_{it} + \sum_j \beta_{4j} \cdot Rating_{ij} + \sum_k \beta_{5k} \cdot Currency_{ik} + \sum_k \beta_{6k} \cdot \left(PostEvent_{it} \times Currency_{ik}\right) + \varepsilon_{it} \tag{4}$$

The dependent variable, $\Delta y_{i,t}$, is the *winsorized yield differential*, where extreme values have been adjusted at the 5% and 95% level to reduce the influence of outliers. The independent variables used in the regression are: *Average Issued Amount, Average Time to Maturity, Rating, Currency* and a *Post Event* dummy variable. Following Zerbib (2019) we use average values for amount issued and time until maturity of each bond pair.

Currency is included in the regression to control for potential differences in the yield differential due to varying macroeconomic conditions, interest rates, inflation expectations, and liquidity across currency zones. Maturity is used as an explanatory variable to determine if investors value green features more (or less) for long-term vs. short-term bonds. To keep consistency in the analysis, the amount issued for all bonds has been converted to euros.

Dummy variables for bond rating and currency are included to account for the potential influence of credit rating differences and currency denomination. The dummy variable for *Post Event* is the same as in the first layer, where it takes the value of 1 during and after the event week and takes the value 0 before the event week. A vector of coefficients, β_i, is associated with the independent variables and controls for the potential influence of the variables on the yield differential.

According to the Gauss Markov theorem, for OLS to be the Best Linear Unbiased Estimator (BLUE), the following five assumptions have to be satisfied: the parameters are linear; the sample is randomly drawn; the error term has a zero conditional mean; there is no perfect multicollinearity; and the error term is homoscedastic (Wooldridge, 2020, p. 57). To account for violations of the assumptions we have applied robust methods as needed. We perform statistical tests, discussed further in Section 4.2.3, to see which adjustments needed to be made. For each violation robust methods were applied to adjust for it.

We assume that the relationship between the independent variables and the dependent variable is linear in parameters. Given the structure of the model, assumption one is considered satisfied. Due to the matching method, a large number of bonds were dropped from the sample. For that reason, we cannot claim with certainty that our final bond sample is representative for the entire bond population. However, for the purpose of this study, we assume that the final sample is broadly representative of the European green bond market. To mitigate the risk of omitted variable bias, which violates the third assumption, we explored the following interaction terms:

Currency x Rating, *Industry x Rating*, *Currency x Industry* and *Post Event x Currency*. The first three interactions introduced high multicollinearity to the model and were therefore excluded. This left us with the *Post Event x Currency* interaction, which provides insight into whether the impact of the event on the yield differential varies depending on the currency of issuance.

Based on VIF calculations, discussed in chapter 4.3, there is no evidence of multicollinearity in the data, confirming that assumption four is satisfied. We conducted a Breusch-Pagan test to test for heteroskedasticity. The result showed strong evidence of heteroskedasticity. To account for heteroskedasticity and potential correlation of errors within bond pairs, we clustered standard errors at the bond-pair level. This adjustment ensures valid inference even if residuals are not independent within clusters, addressing a key assumption of the OLS framework (Wooldridge, 2020, p.57).

A Durbin-Watson statistic of 1.748, confirms no significant first-order autocorrelation in the residuals. To reduce skewness and for earlier inference, we take the natural logarithm of Average Issued Amount (Euro). The final OLS model includes the adjustments and interaction terms stated above.

4.3 Robustness Checks

The green bond premium is generally described as small, often averaging just a few basis points, particularly in the secondary market, and highly sensitive to market conditions and bond characteristics, leading to significant variation and potentially larger values in specific cases (Zerbib, 2019; Caramichael & Rapp, 2024). To improve the robustness of the analysis and ensure that the results reflect underlying pricing patterns rather than noise, we base all results on a winsorized version of the data. Researchers commonly use winsorization in empirical research to limit the influence of extreme observations, particularly in financial studies where yield differentials, like the green bond premium are small and highly sensitive to outliers (Zerbib, 2019; Fatica et al., 2021, Caramichael & Rapp, 2024).

In this study, the top and bottom 5% of the yield differential values were adjusted to reduce the influence of outliers. This helps limit the impact of data noise, reporting errors, or unusually volatile market conditions that can affect average effects. The direction and significance of the results remain consistent with the non-winsorized data, but the winsorized estimates are more representative of the central trend in the sample.

To test if the approaches described in Section 4 are appropriate for the characteristics of the panel data, a series of robustness checks were implemented. To determine whether a fixed effects model or a random effects model is more appropriate we employ a Hausman test. The null hypothesis is presented in Equation (5):

$$H_0: Cov(x_{it}, \alpha_{it}) = 0 \tag{5}$$

If the null hypothesis is rejected, a fixed effects model is more appropriate. A failure to reject the null hypothesis, suggests that a random effects model is more appropriate. The p-value from the Hausman test is 0.959 (>0.05), indicating that a random effects model is a better fit.

To ensure that the OLS regression satisfies the assumptions required for it to be the best linear unbiased estimator, a series of statistical tests were conducted. The Variance Inflation Factor (VIF) was calculated for each of the independent variables to check for multicollinearity. The result showed no signs of multicollinearity in the data.

To test for heteroscedasticity, which violates assumption five, a Breusch-Pagan test was conducted. The test had a p-value of 0.0, providing strong evidence of heteroskedasticity. We adjust the model by clustering standard errors at the bond-pair level, which accounts for both heteroscedasticity and potential autocorrelation within bond pairs.

5 Empirical Results

This chapter presents the empirical results of the study and interprets them in relation to the two hypotheses. First, we examine whether a green bond premium is present in the sample, followed by an assessment of how its behaviour evolved around the week when the EU Green Bond Standard entered into force. The findings are discussed in light of previous literature and the theoretical context introduced in earlier chapters.

5.1 Evidence for the Existence of a Green Bond Premium

The first step in the analysis is to test for the presence of a green bond premium by examining whether the average yield differential is significantly different from zero, and to evaluate its direction and magnitude. This is done through a series of descriptive and distributional statistics and a one-tailed t-test using winsorized data to account for outliers.

Table 2 presents descriptive statistics for the yield differential between conventional and green bonds used for this analysis. The average green bond premium is 0.0572, or 5.72 basis points, based on the 5% winsorized dataset. This value is higher than the mean calculated using the original, non-winsorized data (0.0031), which was more influenced by extreme values. The 95% confidence interval for the winsorized mean ranges from 0.0502 to 0.0642, suggesting that the true mean is likely above zero.

Table 2: Descriptive Statistics of the Green Bond Premium

Variable	Observations	Mean	Std. Err.	Std. Dev.	95% CI Lower
Original Yield Differential	4622	0.0031	0.0075	0.5127	-0.0117
5% Winsorized Yield Differential	4622	0.0572	0.0036	0.2441	0.0502

This table presents summary statistics for the original and 5% winsorized green bond premium, including the number of observations, mean, standard error, standard deviation, and 95% confidence intervals.

To check whether the yield differential follows a normal distribution, we applied the Shapiro-Wilk test. The results are presented in Table 3. The original green bond premium was highly skewed and exhibited excess kurtosis. After winsorization, both skewness and kurtosis were reduced considerably, improving the distribution but not fully achieving normality. Since normality is not required for large samples when using robust methods, this is not a major concern.

Table 3: Distributional Statistics

Variable	Skewness	Kurtosis (excess)	Shapiro-Wilk W	P-value
Original Yield Differential	-3.8671	19.8949	0.6044	0.0000
5% Winsorized Yield Differential	-0.1961	0.6210	0.9422	0.0000

This table displays skewness, excess kurtosis, and results of the Shapiro-Wilk test for normality for both the original and 5% winsorized green bond premium. The winsorized version shows significantly reduced skewness and kurtosis, indicating a distribution closer to normality.

To test for the existence of a green bond premium, we performed a one-tailed one-sample t-test using the winsorized version of the data, as described in Section 4.1. The purpose of the test was to determine whether the average yield differential is significantly greater than zero, which would support the presence of a positive premium in the sample. The test returned a t-statistic of 15.931 and a p-value of 0.0000, strongly rejecting the null hypothesis of no premium at conventional significance levels.

These results indicate that, on average, green bonds trade at significantly lower yields than their conventional counterparts. This finding holds even after controlling for the influence of outliers through winsorization. In other words, the green bond premium is significantly positive, providing strong statistical evidence of its existence in the secondary market.

5.2 Estimating the Impact of the EU Green Bond Standard

5.2.1 Impact of the EU Green Bond Standard on Green Bond Pricing

The results from the Random Effects model provide initial support for the second hypothesis. As shown in Table 4, the model identifies a statistically significant increase in the yield differential of 2.58 basis points on average following the commencement of the EU Green

Bond Standard. This suggests that, on average, green bonds were priced at slightly lower yields relative to their matched conventional counterparts after the regulation came into effect.

Table 4: Random Effects Model Results

Variable	Coefficient	Std. Error	T-statistic	P-value
Intercept	0.0272	0.0212	1.2854	0.1987
Post Event	0.0258	0.0035	7.438	0.0000
Observations	4622			
R^2 (within)	0.0123			
R^2 (overall)	-0.0041			

This table presents the estimation results from the Random Effects panel model assessing the effect of the EU Green Bond Standard on the green bond premium. The dependent variable is the yield differential between matched conventional and green bonds. The main explanatory variable, Post Event, is a binary indicator equal to one for weeks following the commencement of the EU Green Bond Standard on 20 December 2023. Standard errors are unadjusted. R-squared values represent model fit within entities and overall, as detailed in Appendix B.1.

The observed increase in the green bond premium is consistent with the idea that the EU Green Bond Standard acted as a signal to the market, improving expectations around future verification and standardisation. The result aligns with the literature discussed in Section 2.2, which suggests that verification can strengthen the credibility of green bonds and reduce uncertainty for investors. By setting clear expectations for what qualifies as a green bond and how it should be verified, the regulation may have led to a shift in demand, which in turn affected prices.

While the statistical result is strong, the model explains only a small portion of the overall variation in the yield differential. This is not unexpected, as this first model only includes a binary variable for the regulatory event and does not control for other bond-specific or market factors. The purpose of this layer is to test whether any measurable pricing shift occurred at the time of the policy change, without accounting for differences across bond types.

Overall, the findings suggest that the EU Green Bond Standard may have had a market effect even before its full implementation in December 2024, which is consistent with prior research showing that regulation and verification can influence investor behaviour. The following model layer builds on this result by including additional variables and interaction terms to test whether the effect differs across bond characteristics.

5.2.2 Influence of Bond Characteristics on the Green Bond Premium

In the second layer of the two-layered regression model, an OLS regression is estimated to examine the influence of various bond characteristics, as well as the influence of the event on the magnitude of the green bond premium. This model aims to explain the cross-sectional variation in the yield differential observed in the sample. Table 5 presents the OLS regression results for bond characteristics and general event impact, while Table 6 focuses specifically on the interaction effects of the EU Green Bond Standard and currency denominations.

Table 5: OLS Regression Result on Bond Characteristics and Event Impact

Variable	Coefficient	Std. Error	T-statistic	P-value
Intercept	-0.1131	0.287	-0.394	0.694
Rating: A-	0.0118	0.060	0.199	0.843
Rating: AAA	0.0049	0.041	0.188	0.906
Rating: BBB	0.1004	0.084	1.202	0.229
Rating: BBB+	0.3299	0.074	4.450	0.000
Rating: NR	0.0897	0.111	0.806	0.420
Currency: EUR	0.0141	0.081	0.176	0.861
Currency: GBP	-0.1217	0.105	-1.159	0.246
Currency: JPY	0.2191	0.224	0.980	0.327
Currency: NOK	-0.0526	0.081	-0.649	0.516
Currency: SEK	-0.1470	0.089	-1.657	0.098
LogIssuedAmount	0.0291	0.037	0.788	0.431
AverageMaturity	-0.0211	0.011	-1.955	0.051
Post Event	-0.0211	0.024	-0.872	0.383
Observations	4622			
R^2	0.173			
Adjusted R^2	0.170			

This table presents the results from the OLS regression, showing the effect of bond-specific characteristics and the general Post Event dummy on the green bond premium. Coefficients, standard errors, T-statistics, and p-values are reported for each variable. The standard errors are clustered. Further details on the model fit are presented in Appendix B.2.

Several bond-specific characteristics significantly influence the green bond premium. Among them, credit rating emerges as one of the most influential factors. In particular, bonds with a BBB+ rating have a statistically significant positive coefficient (0.3299), indicating that green bonds holding a BBB+ rating are associated with a substantial increase in the yield differential. This implies that investors are willing to accept a notably lower yield for these bonds. Other credit rating categories included in the model do not show a statistically significant impact.

Currency denomination appears to have limited influence on the pricing difference when considered independently. However, SEK-denominated bonds have a statistically significant negative coefficient (-0.1470), indicating a lower yield differential for these bonds, although this is only significant at the 10% level. This implies that green bonds issued in SEK have lower pricing advantage, and potentially trade at a "brown discount", where investors demand a higher yield compared to conventional bonds in these currencies. Bonds issued in EUR, GBP, JPY and NOK do not exhibit statistically significant effects on the yield differential.

The size of the bonds issuance has a small positive coefficient (0.0291) but is not statistically significant. This implies that, in the sample, the size of the bond issuance does not significantly affect the yield differential. Average maturity has a negative coefficient (-0.0211) that is statistically significant at the 10% level, indicating that longer maturities are associated with slightly lower premium compared to shorter maturities. This suggests that investors demand higher premium for more risk.

The *Post Event* dummy has a negative coefficient (-0.0211) and is not statistically significant. This implies that, when controlling for all variables and considering the sample as a whole, the event did not significantly alter the green bond premium.

To further explore whether the impact of the EU Green Bond Standard varies based on currency denomination, we also include an interaction term between *Post Event x Currency.* The results of the interaction term are presented in Table 6.

Table 6: Interaction Effects of Post Event and Currency on the Green Bond Premium

Variable	Coefficient	Std. Error	T-statistic	P-value
Intercept	-0.1131	0.287	-0.394	0.694
Post Event x EUR	0.0716	0.032	2.238	0.025
Post Event x GBP	0.0220	0.052	0.426	0.670
Post Event x JPY	-0.3190	0.248	-1.287	0.198
Post Event x NOK	0.0292	0.028	1.036	0.300
Post Event x SEK	0.0577	0.027	2.152	0.031
Observations	4622			
R^2	0.173			
Adjusted R^2	0.170			

This table displays the result of the interaction term between Post Event and Currency in the OLS regression. The interaction term explores how the impact of the EU Green Bond Standard on the green bond premium varies across different currencies. The full regression output is provided in Appendix B.2.

The analysis of the interaction terms included in the model show significant and heterogeneous effects following the post event period. The interaction term between *Post Event* and *EUR-denominated* bonds, shows a statistically significant positive coefficient (0.0716). This reveals that, following the commencement of the EU Green Bond Standard, the yield differential for bonds denominated in EUR increased more than for bonds denominated in other currencies included in the model. Similarly, green bonds issued in SEK, also experienced an increased pricing advantage after the EU Green Bond Standard came into effect, as shown by the statistically significant positive coefficient (0.0577).

The interaction terms for GBP, JPY and NOK are not statistically significant, indicating that the EU Green Bond Standard did not have a significant effect on the green bond premium in those currency markets. This pattern suggests that the EU Green Bond Standard had a stronger effect on currency markets that are part of the European Union. The statistically significant increase in yield differential for bonds denominated in EUR and SEK indicate that investors may have responded more positively to the EU Green Bond Standard in these markets. In contrast, the currencies which are not part of the European Union (GBP, JPY and NOK), do not show a significant increased pricing advantage, suggesting that the impact is more significant within the European Union.

6 Conclusion and Discussion

This study addresses two main questions: whether a green bond premium exists in the European corporate bond market, and how the EU Green Bond Standard influenced it. Using a panel of matched green and conventional bonds over a 56-week period around the commencement of the EU Green Bond Standard in December 2023, the empirical results address both the presence of a green bond premium and its response to the regulation.

Hypothesis 1 tested for the existence of a green bond premium in the sample. The results indicate a positive and statistically significant premium, with green bonds trading at lower yields than their conventional counterparts. The result is consistent with earlier empirical studies, particularly those focused on the secondary market. Estimates fall within the range reported by Zerbib (2019) and Löffler et al. (2021). They also match the proportions cited in reviews by MacAskill et al. (2021) and Cortellini and Panetta (2021), which find that a majority of studies report a yield advantage for green bonds in the secondary market.

The role of outliers is also worth considering. In this study, the raw premium showed considerable skewness and kurtosis, with a much smaller average value and wide variation. Once the most extreme 5% of values on each end were winsorized, the distribution improved substantially, and the average green bond premium became both larger and statistically significant. This suggests that extreme observations can mask or distort underlying patterns in the data. Similar concerns are noted in prior studies such as Zerbib (2019), who emphasized the small and sensitive nature of the yield differential, and Caramichael and Rapp (2024), who used robust filtering methods to address noise and data irregularities.

Hypothesis 2 assessed whether the EU Green Bond Standard affected the size of the green bond premium. The Random Effects model shows a statistically significant increase in the yield differential following the regulation's entry into force. This indicates that the EU Green Bond Standard may have strengthened yield differentials between green and conventional bonds. These findings align with previous research that links third-party verification and regulatory clarity with stronger investor demand for labelled bonds (MacAskill et al., 2021; Tang & Zhang, 2020).

In the second-layer OLS regression, the average post-regulation effect becomes statistically insignificant after controlling for bond-level variables. This indicates that the overall increase observed in the Random Effects model may not be uniform across all bonds. The results show a stronger effect for SEK-denominated bonds, suggesting variation across sub-markets. Bonds with lower credit ratings and longer maturities show limited or no change in the yield differential after the regulation. This pattern is consistent with research that links yield differential magnitude to issuer credibility and bond structure (Flammer, 2021; Zerbib, 2019).

Overall, the findings in this study are in line with the majority of secondary market evidence and support the view that environmental labelling can influence bond pricing, at least for the matched sample analysed here.

It could be interesting for future researchers to evaluate how the yield differential changed before and after the implementation date, 21.12.2024, as well as a to examine if bonds labelled as EU Green Bonds have higher premium than bonds that hold a different certification. Due to data limitations when using the Bloomberg database, the dataset in this study was small. It could be interesting to repeat this study on a bigger dataset.

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Appendix A: Descriptions

Appendix A.1

Table A.1- Timeline of the EU Green Bond Standard (EU GBS)

Date	**Event**
14 January 2020	Commission publishes Sustainable Europe Investment Plan
11 December 2020	European Council invites legislative proposal for Green Bond Standard
08 July 2021	ECB adopts climate roadmap, supporting green bond regulation
28 February 2023	Political agreement reached on the European Green Bond Standard
05 October 2023	European Parliament adopts position on EU GBS Regulation
23 October 2023	Council adopts position on EU GBS Regulation
30 November 2023	Publication of Regulation (EU) 2023/2631 in the Official Journal
20 December 2023	**Regulation EU GBS enters into force**
21 December 2024	Implementation of the EU GBS

This table outlines significant events in the development and implementation of Regulation (EU) 2023/2631, including legislative milestones, adoption dates, and enforcement timelines. Source: European Commission website

Appendix A.2

Table A.2- Variable definitions

Variable	***Description***	***Source***
Greenium	*Yield difference between a green bond and its matched conventional bond, measured weekly*	*Calculated from Bloomberg bond yield data*
Post Event	*Dummy variable equal to 1 for dates on or after 20 December 2023, equals 0 otherwise, indicating post-regulation period*	*Constructed based on EU GBS entry into force date*
AvgIssuedAmountEUR	*Average amount issued for each bond pair, in millions of euros*	*Bloomberg bond issuance data*
AvgMaturity	*Average time to maturity (in years) for the green and conventional bond in a pair*	*Bloomberg bond characteristics*
Rating	*Credit rating category assigned to the bond (e.g., AAA, BBB)*	*Bloomberg composite rating*
Currency	*Currency in which the bond is denominated (e.g., EUR, SEK, CHF)*	*Bloomberg bond metadata*
Industry	*Sector classification of the bond issuer*	*Bloomberg issuer profile*
PairID	*Unique identifier for each matched green and conventional bond pair*	*Constructed during matching process*
Date	*Week date of yield observation (panel time index)*	*Constructed from Bloomberg yield series*

Appendix B: Regression Results

Appendix B.1

Table B.1-Random Effects Regression Result (First Layer)

```
                        RandomEffects Estimation Summary
================================================================================
Dep. Variable:                 Greenium   R-squared:                        0.0116
Estimator:                RandomEffects   R-squared (Between):             -0.0077
No. Observations:                  4622   R-squared (Within):               0.0123
Date:                  Wed, May 14 2025   R-squared (Overall):             -0.0041
Time:                          10:29:50   Log-likelihood                    3566.0
Cov. Estimator:              Unadjusted
                                          F-statistic:                      54.065
Entities:                           105   P-value                           0.0000
Avg Obs:                         44.019   Distribution:                  F(1,4620)
Min Obs:                         1.0000
Max Obs:                         57.000   F-statistic (robust):             55.323
                                          P-value                           0.0000
Time periods:                        57   Distribution:                  F(1,4620)
Avg Obs:                         81.088
Min Obs:                         63.000
Max Obs:                         105.00

                             Parameter Estimates
==============================================================================
            Parameter  Std. Err.     T-stat    P-value    Lower CI    Upper CI
------------------------------------------------------------------------------
const          0.0272     0.0212     1.2854     0.1987     -0.0143      0.0688
PostEvent      0.0258     0.0035     7.4380     0.0000      0.0190      0.0326
==============================================================================
```

Appendix B.2

Table B.2- OLS Regression Result (Second Layer)

OLS Regression Results

Dep. Variable:	Greenium_winsor	R-squared:	0.173
Model:	OLS	Adj. R-squared:	0.170
Method:	Least Squares	F-statistic:	4.280
Date:	Sun, 18 May 2025	Prob (F-statistic):	1.59e-06
Time:	20:21:38	Log-Likelihood:	398.75
No. Observations:	4622	AIC:	-759.5
Df Residuals:	4603	BIC:	-637.2
Df Model:	18		
Covariance Type:	cluster		

	coef	std err	z	P>|z|	[0.025	0.975]
Intercept	-0.1131	0.287	-0.394	0.694	-0.676	0.450
C(Rating)[T.A-]	0.0118	0.060	0.199	0.843	-0.105	0.129
C(Rating)[T.AAA]	0.0049	0.041	0.118	0.906	-0.076	0.085
C(Rating)[T.BBB]	0.1004	0.084	1.202	0.229	-0.063	0.264
C(Rating)[T.BBB+]	0.3299	0.074	4.450	0.000	0.185	0.475
C(Rating)[T.NR]	0.0897	0.111	0.806	0.420	-0.128	0.308
C(Currency)[T.EUR]	0.0141	0.081	0.176	0.861	-0.144	0.172
C(Currency)[T.GBP]	-0.1217	0.105	-1.159	0.246	-0.328	0.084
C(Currency)[T.JPY]	0.2191	0.224	0.980	0.327	-0.219	0.657
C(Currency)[T.NOK]	-0.0526	0.081	-0.649	0.516	-0.211	0.106
C(Currency)[T.SEK]	-0.1470	0.089	-1.657	0.098	-0.321	0.027
LogIssuedAmount	0.0291	0.037	0.788	0.431	-0.043	0.102
AvgMaturity	-0.0211	0.011	-1.955	0.051	-0.042	5.89e-05
PostEvent	-0.0211	0.024	-0.872	0.383	-0.068	0.026
PostEvent:C(Currency)[T.EUR]	0.0716	0.032	2.238	0.025	0.009	0.134
PostEvent:C(Currency)[T.GBP]	0.0220	0.052	0.426	0.670	-0.079	0.123
PostEvent:C(Currency)[T.JPY]	-0.3190	0.248	-1.287	0.198	-0.805	0.167
PostEvent:C(Currency)[T.NOK]	0.0292	0.028	1.036	0.300	-0.026	0.085
PostEvent:C(Currency)[T.SEK]	0.0577	0.027	2.152	0.031	0.005	0.110

Omnibus:	326.714	Durbin-Watson:	1.748
Prob(Omnibus):	0.000	Jarque-Bera (JB):	511.958
Skew:	-0.561	Prob(JB):	6.76e-112
Kurtosis:	4.183	Cond. No.	214.

Notes:
[1] Standard Errors are robust to cluster correlation (cluster)