Evaluating the Impact of ECO Policies on the Energy Efficiency Performance of Domestic Properties Across the UK

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# Abstract

*This study investigates the effectiveness of Energy Company Obligation policies in augmenting the energy efficiency of domestic properties across the United Kingdom. Despite significant investments and the vital importance of these policies in reducing greenhouse gas emissions and energy consumption, their impact remains under-evaluated, particularly concerning geographical differences. Using a panel data set comprising of quarterly issued Energy Performance Certificates from 2013 to 2023, this study employs 5 random effects models to analyse the influence of ECO policies on energy performance certificates in different UK regions. The findings suggest that while ECO policies have positively impacted energy efficiency in certain urban regions, their effectiveness in rural areas is less pronounced due to possible challenges such as information asymmetry and limited access to energy-efficiency technologies. The results also highlight the important role of regional location, suggesting a need for more regionally tailored approaches. This study contributes to policy refinement by providing an empirical analysis on the performance of ECO policies, offering insights for policymakers to refine and better the design of future energy efficiency initiatives in the future.*

# Introduction

Energy consumption in residential properties is a significant contributor to the overall energy usage and associated carbon emissions in the UK. As a response to the growing concerns about greenhouse gas emissions and the urgent need to reduce carbon footprints, the UK government has implemented various Energy Company Obligation (ECO) policies aimed at improving the energy efficiency of domestic properties. These policies not only seek to reduce the environmental impact but also aim to alleviate fuel poverty among households by alleviating the cost of the capital intensiveness of energy projects, as described by [1Bhattacharyya (2019)](#_Bhattacharyya,_S.C._and). Despite their potential benefits, the effectiveness of these initiatives in achieving their intended outcomes is under much debate and requires evaluation. This study intends to answer the questions of: how have these policies directly impacted the residential sector? Are the policies worth the large cost attached to them? And how important is geographical location towards energy efficiency, how important is this for ECO policies to include this aspect?

These policies are paramount in reducing the environmental impact and maximising the economic benefits in the housing sector, therefore it is crucial to review so they can be optimised and refined, and that is what this study intends to do.

# Background

### 2.1 Energy Company Obligation (ECO) Policies

[8Katris and Turner (2021)](#_Katris,_A._and) studied the concept of ECO policies using a CGE model, finding that “the underlying driver of sustained (economics gains) is actually realising energy efficiency gains”, with this they relate to information asymmetry where some households may be unaware of either the ECO policies, or how energy efficiency in their property could boost their disposable income, subject to any rebound effects. [10Miu et al (2018)](#_Miu,_L.M.,_Wisniewska,) also find a similar conclusion in their policy review of UK energy efficiency polices, suggesting that a mix of policies such as including tax benefits could work best, as it could potentially cost less than attempting to inform households. For this, a cost-benefit analysis is needed. [3Fawcett, Rosenow and Bertoldi (2018)](#_Fawcett,_T.,_Rosenow,) perform just that and conclude that ECO schemes can deliver great savings over a sustained period, but need to remain flexible as they can become very costly in the future. These studies, however, do not consider the fact that ECO policies must target some regions in the UK more than others, most rural areas in the UK have older and therefore less energy efficient houses – And may also suffer from a lack of technology resources such as limited companies to install solar panels or new boilers. They also may have to travel further to find stores that sell energy efficient appliances such as lightbulbs. This is supported by [14Ramos et al (2015)](#_Ramos,_A.,_Gago,) and [4Fillipini, Hunt and Zoric (2014)](#_Filippini,_M.,_Hunt,), who both find that policymaking in this sector is very complex, especially in addressing the information gap. They find that financial incentives have been the most effective in improving then energy efficiency of households.

### 3.1 Energy Performance Certificates (EPCs)

[11Olaussen, Oust and Solstad (2017)](#_Olaussen,_J.O.,_Oust,) explain one advantage of EPCs as an incentive to improve a property’s energy efficiency so the property can sell for more, and implement a fixed effects model using panel data on the Norwegian housing market between 2009-2014. They find small, positive relationships between EPC ratings and house prices, and a substantial positive relationship between prices and the unobserved fixed effects. With this finding, they suggest that there is little information asymmetry with EPCs. Much has been discussed about how effective ECO policies are at increasing EPC ratings in countries across Europe, [5Fuinhas et al (2022)](#_Fuinhas,_J.A.,_Koengkan,) conducted an empirical study on the effect of Portugal’s respective policies, using data from the 19 regions in Portugal between 2014-2021 in a linear random effects model. They found that Portugal’s policies had a positive effect on the higher EPC ratings, and a negative effect on the lower bands – Indicating that the policies achieved what they intended. Their study’s methodology will be useful for this current research and will provide a base, however they do not consider regional effects in their model which could indicate whether certain regions need more, or less targeting from energy efficiency policies.

# Methodology

## Data

The data used in this empirical analysis is a panel and will consist of quarterly data on new Energy Performance Certificate’s (EPC’s) issued in each of the 10 regions of the England and Wales, which are depicted in [Figure 1](#_Figure_1:_A), between 2013-2023. As well as UK wide data on other characteristics and the England and Wales ECO policies. The variables are described in [Tables 1](#_Table_1:_Description) and [2](#_Table_2:_Description). Scotland is excluded in this study due to a different EPC system and different ECO policies.

### Figure 1: A Map of Regions In Britain. Sourced from [9Kedia, N. (2017).](#_Kedia,_N._(2017).)

### 

### Table 1: Description of Dependent Variables

|  |  |  |  |
| --- | --- | --- | --- |
| Variable | Description | Time Period | Source |
| A | Number of Energy Performance Certificates issued with a rating of A | 2013/Q1-2023/Q4 | [7GOV.UK. (2024). *Energy Performance of Buildings Certificates: Data dashboard*](#_GOV.UK._(2024)._Energy) |
| B | Number of Energy Performance Certificates issued with a rating of B | 2013/Q1-2023/Q4 | [7GOV.UK. (2024). *Energy Performance of Buildings Certificates: Data dashboard*](#_GOV.UK._(2024)._Energy) |
| C | Number of Energy Performance Certificates issued with a rating of C | 2013/Q1-2023/Q4 | [7GOV.UK. (2024). *Energy Performance of Buildings Certificates: Data dashboard*](#_GOV.UK._(2024)._Energy) |
| D | Number of Energy Performance Certificates issued with a rating of D | 2013/Q1-2023/Q4 | [7GOV.UK. (2024). *Energy Performance of Buildings Certificates: Data dashboard*](#_GOV.UK._(2024)._Energy) |
| E | Number of Energy Performance Certificates issued with a rating of E | 2013/Q1-2023/Q4 | [7GOV.UK. (2024). *Energy Performance of Buildings Certificates: Data dashboard*](#_GOV.UK._(2024)._Energy) |
| F | Number of Energy Performance Certificates issued with a rating of F | 2013/Q1-2023/Q4 | [7GOV.UK. (2024). *Energy Performance of Buildings Certificates: Data dashboard*](#_GOV.UK._(2024)._Energy) |
| G | Number of Energy Performance Certificates issued with a rating of G | 2013/Q1-2023/Q4 | [7GOV.UK. (2024). *Energy Performance of Buildings Certificates: Data dashboard*](#_GOV.UK._(2024)._Energy) |

According [6Gov.uk](#_GOV.UK._(2024)._A) to when a domestic residence is listed for sale or to rent, the owner must obtain an EPC rating for prospective owners/tenants. The rating is then determined based on several factors such as whether the property has wall/loft insulation or solar panels, the efficiency of the boiler and other appliances, and many other criterions. The property is given a score from 1-100 and placed in one of the bands described above, where band F is below 38, band E is below 54 band D is below 68, and so on.

### Table 2: Description of Explanatory Variables

|  |  |  |  |
| --- | --- | --- | --- |
| Price | The quarterly average prices for fuel and energy in the UK, indexed at the beginning of 2015. | 2013/Q1-2023/Q4 | [13Office for National Statistics (2024)](#_Office_for_National) |
| INS | The number of energy efficiency installations (ECO Measures) in the UK every quarter. This variable will also be lagged to explain potential scheduling issues. | 2013/Q1-2023/Q4 | [2Department for Energy Security and Net Zero](#_Department_For_Energy) |
| Y | The average weekly-income of the UK in real terms, indexed at 2005/Q2 | 2013/Q1-2023/Q4 | [12Office for National Statistics (2024)](#_Office_for_National_1) |
| COST | The total costs derived from the ECO policies in each quarter. | 2013/Q1-2023/Q4 | [2](#_Department_For_Energy)[Department for Energy Security and Net Zero](#_Department_For_Energy) |
| TEMP | The average temperature of the UK every quarter. | 2013/Q1-2023/Q4 | [15Statista](#_Statista._(2024)._UK:) |
| ECO1 | A dummy variable for if the ECO1 policy is active in each quarter. =1 if so, =0 if not. | 2013/Q1-2023/Q4 | [2Department for Energy Security and Net Zero](#_Department_For_Energy) |
| HTH | A dummy variable for if the HTH policy is active in each quarter. =1 if so, =0 if not. | 2013/Q1-2023/Q4 | [2Department for Energy Security and Net Zero](#_Department_For_Energy) |
| ECO3 | A dummy variable for if the ECO3 policy is active in each quarter. =1 if so, =0 if not. | 2013/Q1-2023/Q4 | [2Department for Energy Security and Net Zero](#_Department_For_Energy) |
| ECO4 | A dummy variable for if the ECO4 policy is active in each quarter. =1 if so, =0 if not. | 2013/Q1-2023/Q4 | [2Department for Energy Security and Net Zero](#_Department_For_Energy) |
| AWM | A dummy variable for if the AWM policy is active in each quarter. =1 if so, =0 if not. | 2013/Q1-2023/Q4 | [2Department for Energy Security and Net Zero](#_Department_For_Energy) |
|  |  |  |  |

According to [6Gov.uk](#_GOV.UK._(2024)._A), when a domestic residence is listed for sale or to rent, the owner must obtain an EPC rating for prospective owners/tenants. The rating is then determined based on several factors such as whether the property was wall/loft insulation or solar panels, the efficiency of the boiler and different appliances, and many of criterion. The property is then given a score from 1-100 and placed in one of the 6 bands described above, where band F is below 38, band E is below 54 band D is below 68, and so on.

The 5 dummy variables used are included to analyse the impact of each ECO policy to see whether they have achieved what was intended from them when they were active. Energy prices are included as it is expected that as they increase, households should be aiming to increase their energy efficiency which would in turn increase their EPC rating. The number of ECO measures installed are included because they should also be significant in increasing EPC ratings as it is one of the reasons why ECO policies exist, therefore we should see a positive correlation between the two variables. It is important that we include the COST variable so that we can analyse whether the ECO policies were worth the millions of pounds invested in them, if not then different strategies must be undertaken by the UK government. We expect this to have a positive relationship with the A, B and C dependent variables. Both Y and TEMP are included in the models because they are characteristics of the household and the country that we expect to influence EPC ratings, a higher income should correlated to investment in energy efficiency as the household has more available income to invest in efficiency measures, and if the country is colder then appliances such as the boiler will be used more frequently and for longer, this may encourage investment in a more efficient boiler to lower costs.

### A table of numbers and numbers Description automatically generatedTable 3: Summary Statistics of Variables

[Table 3](#_Table_3:_Summary) shows the descriptive statistics of the data described above. We can see that there are 43 observations per region included. One important observation to note is that is that the AWM dummy has a mean of 0.86, this is because the Affordable Warmth Policy was active from the beginning of the data set up until the introduction of ECO4, so it may be correlated with the other dummy variables, which could cause collinearity problems. We can also see that the average cost of the ECO policies per quarter is £170m for 88,639 installations. Another observation is more D ratings are given across the UK on average, compared to the other ratings.

In the models described later, these variables will be included in log form to linearise the relationships in the model, and to interpret the coefficients as a percentage change in the explanatory variables on a percentage change in the dependent variables.

## 3.2. Method

Similarly to [5Fuinhas et al (2022)](#_Fuinhas,_J.A.,_Koengkan,), The estimation method initially chosen for this analysis was that of a fixed effects models for each EPC band, to control for any unobserved heterogeneity and time-invariant characteristics, such as factors that could influence a household’s decision in a specific region to use any policies or install their own efficiency measures. The estimation is shown as:

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Where k (k = A, B, C, D, E, F, G) for every region i in each quarter t. Xt = (lnPrice, lnINS, LnINSt-1, lnY, lnTEMP, lnCOST) and Pt represents the 5 policy dummy variables, and Ri represents each region in England to capture the regional effects on each EPC rating and represents the individual fixed effects for the region, i.

## 3.3. Robustness Tests

Before the model can be estimated, the data must undergo several robustness tests to assess the statistical properties of this dataset and whether the correct model is being used.

### 3.3.1. Normality

The first test will be to check whether the data is normally distributed, if this is violated then the estimates given from the model will be biased and inconsistent. The Shapiro-Wilk Test was used for this assumption, the test has a null hypothesis that the variable data is normally distributed.

#### Table 4: Shapiro-Wilk Test for Normality Results

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[Table 4](#_Table_4:_) shows the results of this test on each variable, from this we can see that every variable except for lnC, ECO1 and ECO3 has failed the test as the null hypothesis is rejected at a 1% significance level. However, the assumption may be relaxed if the sample size is sufficiently large.

### 3.3.2. Multicollinearity

Following the normality results, multicollinearity must be tested for. Multicollinearity cause problems with the model providing uncertain estimates and inflated standard errors. Each model was examined for using the Variance Inflation Factor (VIF). As expected, the AWM dummy variable had to be removed as it caused a high mean VIF, the HTH variable also had to be removed.

#### Table 5: The VIF Test Results

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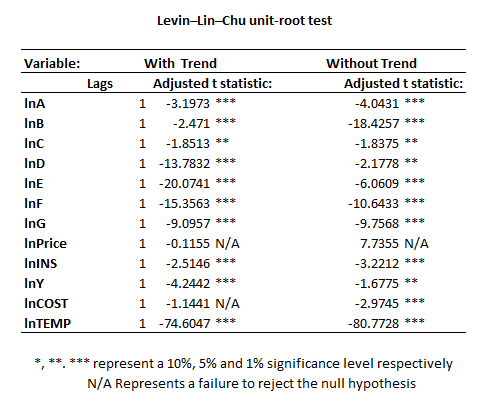
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[Table 5](#_Table_5:_The) shows the mean VIF for each model after the removal of AWM and HTH. A VIF factor of 1 shows no correlation between the explanatory variables, a factor below 4 indicates moderate correlation.

### 3.3.3. Unit Roots

Before running the model, each variable must be tested for a unit root. If the variable is stationary, then it’s variance and mean does not change over time. A non-stationary variable could lead to a spurious regression where the estimates could be incorrect. A Levin, Lu and Chu (LLC) test was Implemented for this data which carries a null hypothesis that the series contains a unit root. We aim to reject the null hypothesis. The results are shown in [Table 6](#_Table_6:_LLC).

#### Table 6: LLC Unit Root Test Results



From [Table 6](#_Table_6:_LLC), we can see that the null hypothesis is rejected decisively for every variable except lnPrice which will need to be differenced, this means that interpretation on the model coefficient for lnPrice will need to be carefully interpreted as it will show the change in percentage points of the variable and not the percentage change.

Following these 3 tests, the model and be estimated and post-estimation tests can be implemented.

### 3.3.2. Heteroskedasticity

Heteroskedasticity must be tested for to find out if the variance is constant across all levels of the explanatory variables and the estimates are efficient. A modified Wald test for groupwise heteroskedasticity was used for the estimation, which has a null hypothesis of σ2i = σ2 , indicating homoskedasticity. Using this test, every model rejected the null hypothesis at a 1% significance level except for where B was the dependent variable. The results are shown in [Table 7](#_Table_7:_Post-Estimation).

### 3.3.3. Autocorrelation

The model was then tested for autocorrelation, if the model’s errors are correlated with the previous observations, then the model will be biased and inconsistent. The Wooldridge test for autocorrelation in panel data was implemented here, the test carries a null hypothesis that there is no first order autocorrelation in the model. The null hypothesis was also rejected in every model at a 1% significance level. The results are also shown in [Table 7](#_Table_7:_Post-Estimation).

### 3.3.4. Cross-Sectional Dependence

If the assumption of Cross-Sectional independence is violated, then the residuals could be correlated across units. Pesaran’s test is employed to test for this which carries a null hypothesis of no cross-sectional dependence. As we can see in [Table 7](#_Table_7:_Post-Estimation), the null hypothesis is rejected at a 1% significance level in every model.

#### Table 7: Post-Estimation Test Results

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Following the detection of heteroskedasticity, autocorrelation and cross-sectional dependence, clustered standard errors around the regions are implemented.

### 3.3.5. Hausman Test

The final test to be carried out is the Hausman Test, which tests the assumptions behind choosing between a fixed effects and a random effects model. The test involves running both models and calculating the difference between the coefficients. Because our model has clustered standard errors, a Cluster-Robust Hausman test must be undertaken. The results from this test are shown in [Table 8](#_Table_8:_Cluster-Robust).

#### Table 8: Cluster-Robust Hausman Test Results

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We can see that every model failed to reject the null hypothesis, suggesting that a Random Effects Model should be used for this data. This model assumes that the random effects are orthogonal to the set of explanatory variables included in this model.

# Results and Discussion

The results from the Random Effects model with clustered standard errors are shown in [Tables 9](#_Table_9:_Results) and [10](#_Table_10:_Results).

#### Table 9: Results From Models A-C

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#### A table of numbers with black text Description automatically generated Table 10: Results From Models D-G

From these results we can see that all policy dummies were significant at a 1% level in explaining each EPC rating. However, ECO 1 and 3 have negative coefficients on lnA-C. One reason could be because ECO policies were focused on fuel-poor households with low EPC ratings, higher rated and income-richer households would not be able to take advantage of them, however this would mean that the policy should not be significant, and this should only be with band A. Bands B and C are expected to have the highest coefficients on Installations and the ECO policies, but we find statistically significant, negative coefficients on all of these variables except ECO4. For example, when ECO1 was active, the average number of new Band C ratings falls by (e-0.16 -1) x 100 = 15%, on average, ceteris paribus. However, the negative coefficients on ECO1-3 in the lower bands do show that the policies did reduce the number of these poor ratings given when they were active.

the most recent ECO policy, ECO4 does have a positive relationship with bands A-C, suggesting that is working better than previous versions, as it is similar but has been reworked.

Using these results, we can also identify the regional effect, using the same calculation we can find that the average number of new Band B ratings in the London area are 139.4% than the baseline region (East Midlands), on average, ceteris paribus. This is a significant impact and could be because London is a typically higher income area, compared to the rest of England and Wales, therefore there is more scope to invest in the energy efficiency of properties. Energy efficiency may be highly encouraged in London as the demand for energy is much higher,

We can also see the opposite effect in Wales, where the number of new G ratings is 37.7% higher than in the East Midlands, this could be because Wales is a typically rural area where properties are older and less energy efficient.

Another result to note is that the number of installations, and the quarterly cost have a negative coefficient in every model, this suggests that the funding of the policies has not been sufficient over the last 10 years.

## 4.1 Caveats

One major caveat with this analysis is the very strong assumption of the random effects estimator that the random effects are independent of the explanatory variables, theoretically, a fixed effects estimator suits this data setting more to control for household and landlord characteristics, and any information asymmetry. The intra-class coefficient, rho, is also very high in these models, meaning that a large proportion of variances in the date is due to differences between the clusters. Cross-cluster correlation should also be tested for because this could violate the assumption of the randoms effect estimator, which could lead to biased and inconsistent results.

Another Caveat to be mentioned is the assumption of normality, it is possible that the sample size of 430 may not be high enough to relax this assumption, which could be skewing our results. This analysis would have benefitted from more available data.

The regional coefficients are also inconsistent, they are all statistically significant but contradict each other, for example the Southwest dummy variable has a positive relationship with every EPC band, this could be due to the previous caveats described.

One important point to note when looking at these results is that is possible for a household to take advantage of these policies and not receive an EPC rating, therefore the true impact of these explanatory variables may not be entirely captured in this model.

# Conclusion and Recommendations

This study reviewed the impacts of ECO policies and geographic locations on domestic EPC ratings, finding that whilst ECO policies did show a fall in ratings below C, we found that they were ineffective in increasing higher ratings across England and Wales. These results support the analysis performed by [14Ramos et al (2015)](#_Ramos,_A.,_Gago,) and , [5Fuinha et al (2022)](#_Fuinhas,_J.A.,_Koengkan,), which highlight the complexity of policymaking in this sector.

The significance of the regional effects indicates the need for regional targeting within ECO policies, [1Bhattacharrya (2019)](#_Bhattacharyya,_S.C._and) explains that analysing aggregated energy demand and efficiency at a national level is not sufficient, given the diverse needs of households across a country. This study would recommend that more care should be taken in the construction of future ECO policies in this respect.

We also find that the funding of the ECO policies followed a similar trend in reducing the lower bands, but also reducing the higher bands – Indicating inappropriate pricing within the ECO policies that may need to be reworked. This could also highlight different market failures such as the information asymmetry that still exists or the financing barriers that lower-income households still face. However, the social benefits from these policies must also be considered, such as a reduction in greenhouse gas emissions as efficiency and the number of renewable energy sources increase as an outcome of these policies.

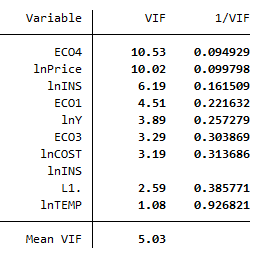
# Appendix

##### Table 1: Summary Statistics in Log Form

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##### Table 2: VIF Test Results



##### Figure 1: lnCOST No Trend Plot

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### 6.1 LnA Model Tests and Outputs

##### Table 3: Shapiro-Wilk Test Results

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##### Figure 2: Pesaran’s Test Results

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##### Figure 3: Modified Wald Test Results

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##### Figure 4: Wooldridge Test Results

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##### Figure 5: Cluster Robust Hausman Test Results

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##### Figure 6: Random Effects Model Output

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### 6.2 LnB Model Tests and Outputs

##### Figure 7: Pesaran’s Test Results

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##### Figure 8: Modified Wald Test Results

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##### Figure 9: Wooldridge Test Results

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##### Figure 10: Cluster Robust Hausman Test Results

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##### Figure 11: Random Effects Model Output

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### 6.3 LnC Model Tests and Outputs

##### Figure 12: Pesaran’s Test Results

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##### Figure 13: Modified Wald Test Results

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##### Figure 14: Wooldridge Test Results

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##### Figure 15: Cluster Robust Hausman Test Results

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##### Figure 16: Random Effects Model Output

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### 6.4 LnD Model Tests and Outputs

##### Figure 17: Pesaran’s Test Results

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##### Figure 18: Modified Wald Test Results

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##### Figure 19: Wooldridge Test Results

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##### Figure 20: Cluster Robust Hausman Test Results

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##### Figure 21: Random Effects Model Output

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### 6.5 LnE Model Tests and Outputs

##### Figure 22: Pesaran’s Test Results

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##### Figure 23: Modified Wald Test Results

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##### Figure 24: Wooldridge Test Results

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##### Figure 25: Cluster Robust Hausman Test Results

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##### Figure 26: Random Effects Model Output

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### 6.6 LnF Model Tests and Outputs

##### A black text on a white background Description automatically generatedFigure 27: Pesaran’s Test Results

##### Figure 28: Modified Wald Test Results

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##### Figure 29: Wooldridge Test Results

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##### Figure 30: Cluster Robust Hausman Test Results

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##### Figure 31: Random Effects Model Output

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### 6.7 LnG Model Tests and Outputs

##### Figure 32: Pesaran’s Test Results

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##### Figure 33: Modified Wald Test Results

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##### Figure 34: Wooldridge Test Results

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##### A computer code with black text Description automatically generatedFigure 35: Cluster Robust Hausman Test Results

### Figure 31: Random Effects Model Output

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