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How does Economic Policy Uncertainty affect Green Innovation?

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ABSTRACT

This study aims to examine the impact of economic policy uncertainty (EPU) on green innovation in the Chinese context. When economic policies are changed often, the Economic Policy Uncertainty (EPU) index rises. There is a dearth of studies examining how EPU affects corporate green innovation. This research shows that between 2007 and 2021, Economic Policy Uncertainty (EPU) would have a negative impact on green innovation inside Chinese corporations. Budgetary restraints cushion green innovation from the negative effects of Economic Policy Uncertainty (EPU). Subsidies for the environment provided by the government may help reduce EPU. Eco-friendly innovation is negatively connected with EPU, especially for privately owned businesses, those in less competitive sectors, and those in locations with weak intellectual property protections. This research suggests that in order to encourage environmentally responsible business innovation, authorities should increase the proportion of public monies spent on environmental protection and IP rights protection. Green innovation is more prevalent in times of high economic policy uncertainty. Different provinces, with varying degrees of marketization and FDI, display varying degrees of Economic Policy Uncertainty (EPU). The findings show that Environmental Policy Uncertainty (EPU) has a greater impact on green innovation in locations with higher degrees of marketization and trade openness compared to regions with lower levels of marketization and trade openness. The current study may be used to the investigation of government methods for fostering environmentally friendly innovation in the face of policy ambiguity.

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1. Introduction

Economic Policy Uncertainty (EPU) is described by Gulen and Ion (2016) and (Su, Khan, Tao, & Nicoleta-Claudia, 2019) as microeconomic entities' incapacity to predict a government's economic policy changes. After the global financial crisis of 2008, several nations adjusted their economic policies in an effort to dampen future fluctuations. We call this a state of economic policy uncertainty. As global temperatures rise and climate irregularities multiply, this is the reality we confront. To reach the goal of zero emissions by the turn of the century, governments are enacting carbon taxes, forest carbon sinks, and green power certificate trading schemes. Due to its low cost and market-oriented nature, carbon emission trading (CET) has replaced other policy measures in many nations. China is quickly becoming the world's biggest market for greenhouse gas emissions, particularly carbon dioxide. Carbon trading is a novel kind of Chinese finance. X. Li, Li, Su, Umar, and Shao (2022) express concern about institutional arrangements, market dynamics, regulatory frameworks, and price fluctuations. Analysis of the carbon market price requires knowledge of the factors that affect carbon prices. Carbon trading has environmental and economic benefits, and new information might make those benefits even greater.

In this manner do CET markets operate. The governing body for emission control agencies sets a maximum allowable level of carbon emissions. Obtaining more carbon emission permits may help businesses meet their emission reduction goals. By investing in clean technology, companies may improve energy efficiency and meet emission reduction criteria at a marginal cost that is less than the unit carbon price. This comment suggests that carbon market mechanisms and green technology innovation promote ecologically responsible and low-carbon emission corporate growth. New environmentally friendly technologies need funding to be developed. Green bonds are a great way to fund businesses. Green bonds, which are analogous to government and corporate debt, have been shown to mitigate price fluctuations on global financial markets. As opposed to conventional bonds, green bonds are issued only for the purpose of contributing to environmental improvement projects (ICMA, 2017). China's green finance system relies heavily on carbon trading and green bond market legislation. Investors concerned with the environment buy green bonds to hedge against the volatility of the carbon trading market. Green bonds and carbon pricing were also examined, such in the work of (Rannou, Boutabba, & Barneto, 2021). There is a dearth of research in this area. In view of the worldwide shift toward low-carbon development, research into carbon pricing through green bonds is crucial.

In the twenty-first century, the repercussions of the 2008 financial crisis and the COVID-19 outbreak were felt in economies throughout the world. These events have caused widespread economic instability and required several governmental shifts. Anti-globalization sentiment, trade protectionism, and economic policy uncertainty (EPU) have all increased as a result of the changing international environment. Stolbov and Shchepeleva (2020) highlight the expanding body of academic research on the consequences of unpredictability in economic policy. The carbon market is a subset of the financial market that is reportedly affected by government economic policy, as stated by Lee, Lin, and Zeng (2016). Chevallier (2011) argues that EPU creates significant uncertainty in the carbon market. Despite much scientific research, their link remains unclear. Adedoyin and Zakari (2020) found that carbon emissions rise when policymakers are unsure on where to take the economy. According to Adedoyin and Zakari (2020), carbon emissions are greatly influenced by economic policy uncertainty. Market actors may benefit from learning how the volatility of economic policy uncertainty affects the price of carbon.

1.1. Background of Study

Government intervention in the Chinese economy is obvious and varied (Bertaud, 2012). Since the financial crisis of 2008, the conventional model of economic development has met with much resistance. To prevent a catastrophic economic downturn and address the need for economic reform, the Chinese government has implemented a number of measures. There are two results from monetary policy. Economic Policy Uncertainty (EPU) might rise, but the domestic economy could benefit, say Hu, Shen, Yu, and Xu (2022). Therefore, both the theoretical and practical implications of Exchange Rate Pass-Through (ERPT) Uncertainty in China's economy need to be investigated.

Macroeconomic influences, such as economic oscillations and stock market fluctuations, have been the primary focus of EPU studies. Political uncertainty has been studied for its effect on microeconomic activity. How this influenced corporate investment and cash flow was studied by Bloom (2009). The effects of political unpredictability on a firm's carbon emissions have been studied by Anser, Apergis, and Syed (2021) and Adedoyin and Zakari (2020). Few empirical studies have looked at how EPU affects creative output. Since EPU is an exogenous variable, Atanassov et al. (2015) argue that state elections in the United States stimulate company R&D. Xu (2020) study found that EPU stifles creativity at 12,408 US firms. The high cost of financing and the fact that investments are usually irreversible provide obstacles to this. The EPU index was used in a nationwide study, although the innovation proxy variable was at the firm level. Green innovation is a powerful tool for environmental protection, but it has been under-researched until recently.

Concerns over the state of the planet's ecosystems have made "green innovation" a hot topic in the academy. According to the World Health Organization, 7 million people died from breathing polluted air in 2018. This is because 90% of the world's population is exposed to high pollutant levels. Global environmental consciousness has been heightened by the current environmental crises. Many developed countries have committed to maintaining and enhancing their competitive advantages via green innovation. Environmental management in the workplace is gaining importance. Companies who can swiftly implement environmentally friendly innovation and restructuring will have a competitive edge, as stated by (Chang, 2011; Qiu, Jie, Wang, & Zhao, 2020). The current model of economic growth is being tested by issues like pollution, lack of resources, and ecological deterioration. According to B. Li, Lin, and Guo (2020), green innovation is crucial for both economic growth and environmental preservation. There is a lack of clarity about EPU and eco-friendly innovation. Therefore, it is both theoretically and practically important to investigate EPU's impact on eco-friendly innovation. So, I have a few inquiries. Does the use of EPUs encourage and support the development of environmentally friendly technologies? Is there a variation in how EPU affects green innovation across regions with varying populations and degrees of market access?

Our research adds a lot to the field in four main ways. This is the first research to use panel data from Chinese provinces between 2000 and 2017 to examine the link between EPU and green innovation. EPU's capacity in political economy and innovation economics has been bolstered by this study. greater applications for green patents are submitted when there is greater uncertainty about economic policies. EPU may help green innovation in general. The most recent EPU index for China's 31 provinces (Yu, Shi, Guo, & Yang, 2021) is used in our second contribution. Using a provincial EPU score will allow for a more precise comparison to national research on the effects of EPU. To examine the connection between EPU and environmentally friendly innovation, we use a panel fixed effects model in this analysis. The results are supported by the literature on green innovation found in the Economic Policy Uncertainty (EPU) database. This research investigates whether or not EPU affects environmentally friendly innovations differently in countries with different levels of marketization and trade openness. Based on our research, we conclude that economic policy uncertainty (EPU) promotes environmentally friendly innovation in places with greater marketization and trade openness. In less urban locations, we lose statistical significance with this association.

2. Literature Review

The term "Economic Policy Uncertainty" (EPU) is frequently characterized as the variation between the public's anticipated expectations of government economic policies, as per the definition provided by (Baker, Bloom, & Davis, 2016). Economic Policy Uncertainty (EPU) has been studied on macroeconomic entities and microeconomic activity. Previous studies have shown that EPU slows down macroeconomic development. As Bloom (2009) points out, rising levels of uncertainty are bad for output and the job market because businesses cease investing and hiring. Economic policy uncertainty (EPU) is a known market-moving factor, according to (Liu, Luo, & Wang, 2019). Conventional innovation theory is the source of green innovation, which prioritizes ecological and economic growth. What we now call "sustainable innovation," "eco-innovation," or "environmental innovation" increases the effectiveness of both green and innovative practices.

Scholars have investigated what motivates green innovation. Investment in environmental management costs, according to Brunnermeier and Cohen (2003), would increase green patents. According to C. Li et al. (2022), companies are motivated to develop more eco-friendly goods by the potential for financial gain from doing so. Liu et al. (2019) investigated FDI and eco-friendly innovation using a panel threshold regression model. Multiple weak spots in the framework were identified. Environmental regulations, as demonstrated by (Berrone, Fosfuri, Gelabert, & Gomez-Mejia, 2013), encourage the development of new government green technologies. R&D investment might go up as a result of institutional pressure, too. The effect of political capital on corporate green innovation was studied by Lin, Chen, and Huang (2014). According to the findings, political capital is a barrier to green innovation in the corporate sector. Green innovation has been connected to government effectiveness and statutes, according to research by (Wen, Deng, Zhang, & Chang, 2021). The impact of environmental regulations on green innovation was studied by Luo, Salman, and Lu (2021). Data was collected from 30 provinces in China. Green innovation is harmed by market-based regulation, but FDI is beneficial.

3. Data and Methodology

The study used a quantitative research design, which entailed a numerical analysis of the interdependencies among the variables. In order to gain useful insights, quantitative studies are conducted when statistical results are required. Based upon the above statistics, the variables used to look into the relationship between Employment and minimum wage rate, along with education and industry are control variables. The study utilized the Chinese A-share market's complete list of companies between 2007 to 2021 as the initial sample. The methodology of Liu et al. (2019) was followed, which involved the exclusion of financial institutions, firms receiving special treatment, and incomplete firm-year observations. The data on corporate green innovation was obtained from the Chinese Research Data Services Platform (CNRDS), while the data on the China EPU index was sourced from (Baker et al., 2016). The data on firm characteristics was procured from the China Stock Market and Accounting Research (CSMAR) database. The model is given below,

$$GI = \beta_o + \beta_1 EPU + \beta_2 R\&D + \beta_3 GDP + \beta_4 FDI + \beta_5 POP + \varepsilon_t \quad (1)$$

4. Results and Discussion

Testing the model required validating the data with descriptive statistics, correlation analysis of all variables. Descriptive statistics, which summarize and classify the attributes of a dataset, were employed first. The level of linear relationship between variables is then calculated using the Pearson Correlation Coefficient. Finally, the Breusch-Godfrey Lagrange and Pearson Correlation Before running the Ordinary Least Squares (OLS) regression to test the relationships between dependent and independent variables, we used the Least-Squares (LM) tests to characterize the relationship between the observations of the same variable over time in statistics and guarantee that our results are free from autocorrelation.

4.1 Descriptive Statistics

"Descriptive statistics" refers to any data analysis that helps describe, present, or summarize data. Descriptive statistics can summarize study data. They provide brief scenarios and safety tips. Quantitative data analysis starts with them and graph analysis. Descriptive statistics includes the mean, median, mode, standard deviation, variables, and skewness and kurtosis. The descriptive statistics of this study is given below,

Table 1: Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
G1	15	194.558	116.089	3.67	306.14
RD	15	1.194	.374	.639	1.78
GDP	15	9.896	1.786	7.662	14.231
FDI	15	.619	.259	.369	1.235
POP	15	.664	.173	.483	1.023
EPU	15	3.893	.507	2.9	4.8

The above table 1 represents the descriptive statistics of the variables GI, RD, GDP, FDI, POP, and EPU. The arithmetic average of the GI is 194.5, with a corresponding standard deviation of 116.08. The statistical measure of central tendency for RD is the mean value of 1.194, with a corresponding standard deviation of 0.374. The average GDP value is 9.89, with a standard deviation of 1.78. The statistical measure of central tendency for Foreign Direct Investment (FDI) is represented by the mean value of 0.61, while the measure of variability or dispersion is indicated by the standard deviation of 0.25. The population mean of a certain variable, denoted as POP, is 0.66, with a corresponding standard deviation of 0.17. The statistical analysis reveals that the average value of EPU is 3.89, accompanied by a standard deviation of 0.507.

4.2 Correlation Matrix

A correlation analysis is a statistical method for determining whether or not a linear relationship exists between two variables, or between one variable and two or more other variables, and, if such a relationship does exist, for determining the strength of that relationship. Find out how Y will change as a result of a change in X. Y is dependent on X. To conduct a correlation analysis, it is necessary for both variables to be continuous and normally distributed. The correlation matrix results indicate that all the variables are not strongly correlated that’s why there is no chance of Multicollinearity in the model. The correlation matrix is given below in table 2.

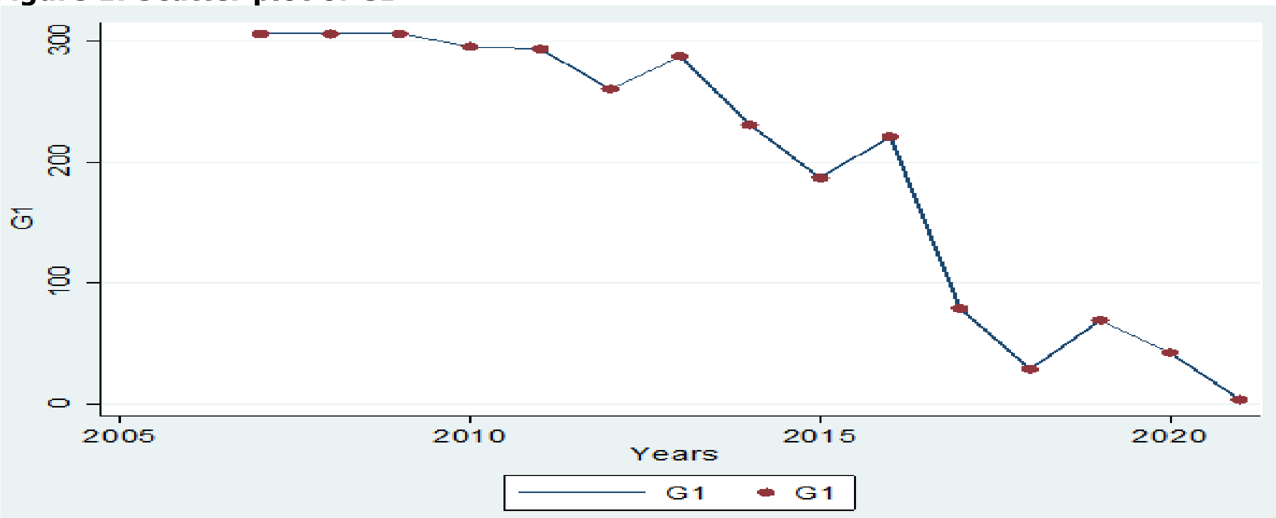
Table 2: Pairwise correlations

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(1) Years	1.000						
(2) G1	-0.932	1.000					
(3) RD	-0.994	0.926	1.000				
(4) GDP	-0.523	0.633	0.505	1.000			
(5) FDI	-0.675	0.588	0.651	0.215	1.000		
(6) POP	0.926	-0.941	-0.924	-0.600	-0.627	1.000	
(7) EPU	-0.156	0.134	0.180	0.167	0.319	-0.313	1.000

4.3 Scatter Plot of Dependent Variable

The figure 1 indicates the Scatter plot of dependent variable GI with time. The graph shows that from 2007 to 2021 the Green innovation decreases.

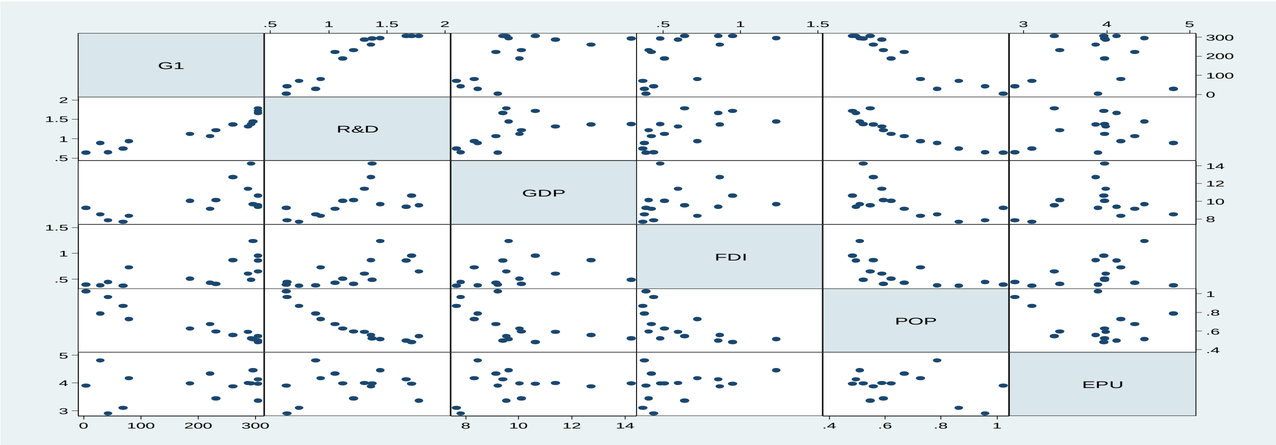
Figure 1: Scatter plot of GI



4.4 Scatter Plot of All Variables

In general, scatterplots are a potent instrument for the visualization and examination of the correlation between two continuous variables.

Figure 2: Scatter Plot of all variables



Apart from detecting patterns and correlations, scatter plots can serve the purpose of detecting outliers, which are data points that are situated at a considerable distance from the bulk of the data points on the scatter plot. The identification and comprehension of outliers are crucial when dealing with data analysis due to their potential to substantially influence statistical outcomes. The scatter plot of all variables is depicted in Figure 2. The presence of a linear pattern in the scatter plot implies a potential strong linear correlation between the two variables. When the data points on a scatter plot exhibit a greater degree of dispersion and lack a discernible pattern, it may indicate a weak or nonexistent correlation between the two variables.

4.5 Regression Analysis

The main objective of this study to find the impact of Economic Policy Uncertainty on Green Innovation. The dependent variable is green innovation. The independent variables are economic policy uncertainty, population, research and development and foreign direct investment. The regression analysis is given below in table 3.

Table 3: Linear Regression

G1	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
RD	.047	76.584	3.29	.028	-74.199	272.293	**
GDP	.044	7.203	5.20	.001	-7.649	24.938	***
FDI	.071	53.544	2.20	.048	-110.555	131.696	***
POP	-.022	177.896	-2.25	.001	-802.35	2.506	***
EPU	-.074	22.305	-4.43	.007	-82.331	18.583	***
Constant	73.728	272.999	1.37	.204	-243.837	991.294	*
Mean Dependent var		194.558		**SD Dependent var**		116.089	
R-squared		0.935		**Number of obs**		15	
F-test		25.766		**Prob > F**		0.000	
Akaike crit. (AIC)		155.232		**Bayesian crit. (BIC)**		159.480	

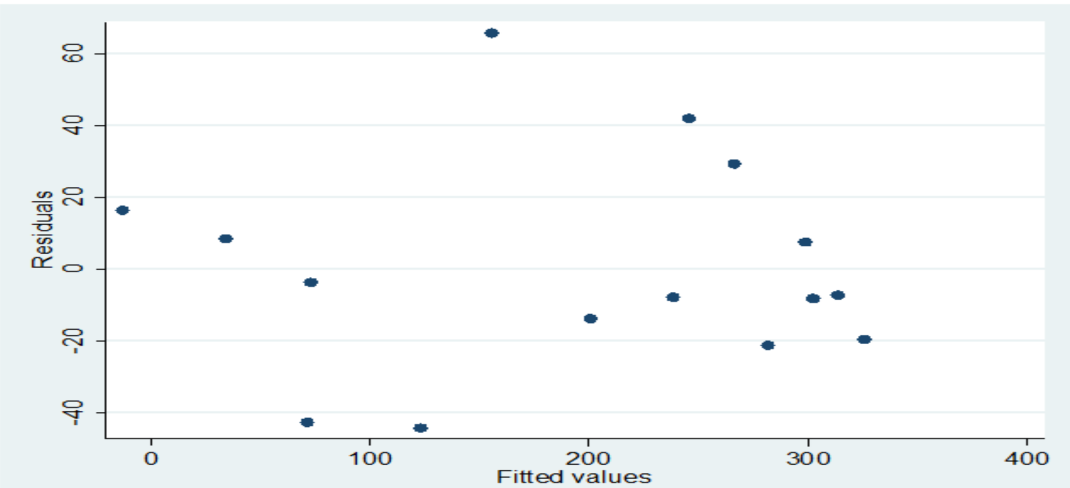
**** p<.01, ** p<.05, * p<.1*

The regression result indicates that there is negative and highly significant relationship between Economic Policy Uncertainty and Green Innovation. The coefficient indicates that if 1% increase in economic policy uncertainty increase then 7% decreases in green innovation. It implements that economic policy stability is important for green innovation. There is positive and highly significant relationship between research & development and Green Innovation. If 1% increase in research & development, then 4% increases in green innovation. There is positive and highly significant relationship between GDP and Green Innovation. If 1% increase in GDP, then 4% increases in green innovation. There is positive and highly significant relationship between FDI and Green Innovation. If 1% increase in FDI then 7% increases in green innovation. The result indicates that there is negative and highly significant relationship between population and Green Innovation. The coefficient indicates that if 1% increase in population increase then 2% decreases in green innovation. The value of R square is 0.93 that indicates that 93% variation in green innovation by the all the independent variables.

4.6 Residuals verse Fitted Plot

The residuals versus fitted plot is a visual aid utilized in the examination of linear regression within the realm of statistical analysis. The graph presented depicts the residuals, which denote the differences between the actual and predicted values of the dependent variable, plotted against the fitted values, which represent the expected values of the dependent variable. The residual plot versus fitted values is a useful tool for evaluating the appropriateness of a linear regression model and identifying potential anomalies in the model. The comprehensive evaluation of the underlying assumptions of linear regression often involves the use of supplementary diagnostic plots, such as the normal probability plot and the plot of residuals against the independent variable. The fitted graph is given below in figure 3.

Figure 3: Residuals verse Fitted Plot



4.7 Diagnostics Tests

4.7.1 Multicollinearity Test

Multicollinearity test is checked by the VIF. The results are given below in table 6. The results show that there is evidence of multicollinearity in the model.

Table 4: VIF table for Multicollinearity

Variables	VIF	1/VIF
POP	9.650	0.104
RD	8.390	0.119
FDI	1.970	0.509
GDP	1.690	0.591
EPU	1.310	0.765
Mean VIF	4.600	

4.7.2 Heteroscedasticity Test

Using the sequential connection and the Breusch-Godfrey Lagrange Multiplier (LM) test, we ensured that our results would be free of autocorrelation. The Breusch-Godfrey test determines whether or not the errors in a regression model exhibit autocorrelation. Both the analysis and the test statistic used in regression analysis are derived from the model under consideration. Up until order p, null is never substituted. It is sometimes referred to as the LM test for serial correlation, after its inspiration, the Lagrange multiplier test.

Table 5: Breusch-Pagan / Cook-Weisberg test for heteroskedasticity

Ho: Constant variance
Variables: fitted values of G1
chi2(1) = 0.47
Prob > chi2 = 0.4925

4.7.3 Autocorrelation

The results of Durbin Watson d statistic show that there is no autocorrelation in the model because the value is 2.93.

Table 6: Autocorrelation Test

Durbin Watson d statistic (6, 15) = 2.399222

5. Conclusion and Policy Recommendations

The adoption of environmentally sustainable innovation has been recognized as a feasible approach to tackle the issue of reconciling economic expansion and ecological deterioration within China's current economic milieu. This research employs an empirical approach to examine how regional green innovation is affected by the unpredictability of economic policy. The study makes use of a data collection covering China from 2007 through 2021. The provincial EPU index and the number of green patent applications are the major instruments used in this analysis. We found that when there is more Environmental Policy Uncertainty (EPU), there are more green patent applications. Our research shows that there is an increase in green patent filings when there is more Environmental Policy Uncertainty (EPU). This data reveals a strong link between EPU and the dissemination of eco-friendly technological advances. There is clear regional heterogeneity in the effect of Economic Policy Uncertainty (EPU) on the creation of eco-friendly technologies, as is shown by the current research. Provinces with more marketization are more adaptable to Economic Policy Uncertainty (EPU), which is good news for the development of eco-friendly innovation in such places. Furthermore, in places defined by higher levels of trade liberalization, the impact of EPU on environmentally friendly innovation is noticeably stronger. However, the aforementioned connection does not reach statistical significance in areas with less marketization and trade openness. This research deviates from the existing literature by exploring the link between EPU and green innovation at the provincial level. The scope of innovation economics is extended into political economy as we also investigate the varied effects of this association. This is fundamental to grasping both economic volatility and long-term growth. Therefore, we suggest the subsequent policy ramifications.

Our research shows that the positive effect of Environmental Policy Uncertainty (EPU) on green innovation may be amplified by creating a more business-friendly environment, one with more marketization or trade openness. Given the volatile nature of global economic policies, it is imperative for the government to implement measures aimed at fostering a more favorable external economic climate. The process of marketization has the potential to optimize the allocation of resources and elements, resulting in improved social efficiency and increased promotion of environmentally sustainable innovation. The enhancement of marketization can be achieved by the government through the implementation of structural tax cuts and universal fee reductions. This will serve to alleviate the financial strain on enterprises and encourage the development of eco-friendly innovation capabilities. Furthermore, in order to enhance trade liberalization and promote the development of eco-friendly technologies within the region, the government may consider implementing measures to acquire and assimilate cutting-edge technologies from foreign sources, enhance the technological market landscape, and convert green innovation into commercial viability. Provinces characterized by a low level of trade openness ought to enhance their technological exchanges and interactions with other regions as a means of facilitating the unfettered movement and optimal allocation of resource factors across provinces. Whilst a greater level of Environmental Policy Uncertainty (EPU) can have a positive impact on the development of environmentally-friendly innovations, it is important to note that an increase in uncertainty can also result in adverse consequences, including a reduction in enterprise investments and an escalation in economic instability. Hence, it is imperative for governments to consider the various impacts of Economic Policy Uncertainty (EPU) while implementing or modifying economic policies with the aim of alleviating a recession and promoting environmentally sustainable innovation.

5.1 Policy Implications

In order to address the adverse economic effects of Environmental Policy Uncertainty (EPU), one potential solution for the government is to augment enterprise subsidies. This approach would alleviate financial limitations faced by corporations and stimulate their development of environmentally-friendly innovations.

This study exhibits certain limitations that warrant further investigation in subsequent research. The present study did not extensively explore the various subcategories within the domains of economic uncertainty or innovation. Does an increase in EPU result in a corresponding rise in energy innovation? What will be the impact of actual economic uncertainty on the development of green innovation? Secondly, it is noteworthy to investigate the diverse impacts of Environmental Protection Units (EPU) on the pricing and market expansion of eco-friendly commodities across distinct provinces, apart from the realm of green innovation. It is important to note that the provincial EPU index has limited availability. This is primarily due to constraints in data availability. It is anticipated that additional regions and temporal intervals will be subject to analysis in forthcoming research. The empirical investigation of transmission mechanisms between Economic Policy Uncertainty (EPU) and green innovation can be conducted through various means, including but not limited to corporate cash holding, market competition, and government subsidy.

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