

Green Fiscal Policy and Sustainable Transformation: Stimulating Environmental Innovation and Competitiveness in China

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Abstract

Green innovation is central to achieving sustainable environmental and economic transformation in China. This study examines the impact of green fiscal policy on green innovation in China over the period 1991–2020. Green fiscal policy is measured using two fiscal instruments: environment-related taxes and research and development (R&D) expenditure. Using the autoregressive distributed lag (ARDL) approach, the results show that environment-related taxes and R&D expenditure positively influence green innovation in China. As a robustness check, the quantile autoregressive distributed lag (QARDL) model indicates that environment-related taxes promote green innovation across quantiles, whereas R&D expenditure has a stronger long-run effect mainly at higher quantiles of green innovation. The findings provide policy-relevant evidence that well-designed fiscal instruments can stimulate environmental innovation and support China's sustainable transformation and long-run competitiveness.

Keywords: Green fiscal policy, Environmental innovation, Green innovation, ARDL, QARDL, Sustainable competitiveness, China

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1 INTRODUCTION

Fiscal policy has long been examined as a key instrument for influencing economic growth and macroeconomic performance (Turnovsky, 1996). More recently, attention has shifted toward the role of green fiscal policy in supporting the green economy, environmental sustainability, and innovation-led growth (Campiglio, 2016; Li & Du, 2021; Mughal et al., 2021). In this context, green innovation (GI) is increasingly viewed as an important channel through which economies can reduce environmental pressure while sustaining long-run development (Ahmed et al., 2022). However, the way fiscal instruments shape green innovation remains insufficiently understood, particularly in China, where policy intervention plays a central role in directing environmental and innovation outcomes.

Existing studies provide mixed evidence on the relationship between green fiscal policy and green innovation. Some research suggests that green fiscal tools can encourage firms to expand investment, improve R&D activity, and increase green innovation (Zhang, 2021; Li et al., 2022). Other studies argue that fiscal policy may weaken innovation incentives when it increases compliance burdens, alters financing decisions, or affects innovation quality and risk-taking (Wang et al., 2022; Huang et al., 2022). These mixed findings indicate that the fiscal

policy–green innovation relationship is context dependent and requires further empirical testing.

Government policy is particularly important in China because public intervention strongly influences innovation incentives, financial conditions, and environmental regulation. When policy uncertainty is high, firms may delay or reduce green innovation investment, whereas stable policy signals can encourage longer-term innovation planning (Noailly et al., 2022; Song et al., 2022). Fiscal policy can also interact with financial conditions by affecting liquidity creation, credit allocation, and investment incentives (Berger & Bouwman, 2017). In this respect, fiscal policy may support financial stability and green investment, but it may also restrain innovation if policy design is inefficient or uncertain (Jänicke, 2012; Zhao et al., 2023).

China provides an especially relevant setting for studying this issue. Evidence from China suggests that local government interventions, renewable energy policies, fiscal incentives, and environmental policy changes can influence R&D activity and green innovation outcomes (Zhao et al., 2021a; Zhao et al., 2023; Chang et al., 2022; Zhang et al., 2022). At the same time, policy uncertainty and delayed access to finance can reduce innovation activity, as shown in the context of initial public offering interventions in China (Cong & Howell, 2021). These findings suggest that green fiscal policy may play a decisive role in shaping the direction and intensity of green innovation in China (Cuerva et al., 2014).

Green innovation is generally understood as innovation that reduces pollution, resource use, and environmental harm (Ekins, 2010). Eco-innovation similarly refers to new products, processes, services, or organizational practices that reduce natural resource consumption and toxic waste (De Jesus et al., 2018). Prior studies identify several drivers of green innovation, including innovation strategies, stakeholder behavior, political capital, government subsidies, environmental regulation, and policy shocks (Latupeirissa & Adhariani, 2020; Shahzad et al., 2022). Fiscal instruments can therefore encourage green technological innovation by reducing private innovation costs and supporting environmentally oriented investment (Gramkow & Anger-Kraavi, 2018; Zhang, 2021).

This study contributes to the literature in several ways. First, while previous research has examined fiscal policy and innovation more generally, this study focuses specifically on the effect of green fiscal policy on green innovation. Second, the analysis adopts a macro-level perspective for China, thereby complementing firm-level studies and offering evidence on aggregate green innovation dynamics. Third, instead of relying only on conventional fiscal tools such as subsidies or tax credits, the study examines environment-related taxes and R&D expenditure as two key fiscal-policy instruments. Fourth, the study evaluates both short-run and long-run effects using ARDL and QARDL approaches, allowing a more complete assessment of how green fiscal policy affects green innovation across different innovation levels. Finally, the findings offer policy implications for strengthening environmental innovation and sustainable competitiveness in China.

The rest of the paper is organized as follows. Section 2 reviews the related literature and develops the hypotheses. Section 3 presents the model specification and methods. Section 4 describes the data and variables. Section 5 reports and discusses the empirical results. Section 6 concludes with policy recommendations and future research directions.

2 LITERATURE REVIEW

Fiscal policy broadly refers to the government's use of taxation and public spending to influence economic activity (Schuknecht, 2000). In this study, green fiscal policy refers to the use of fiscal instruments, including public spending and taxation, to encourage sustainable technologies and practices, climate-change mitigation, water preservation, and waste management. Kemp and Pearson (2007) define green innovation as the development and application of new products, processes, services, organizational practices, or managerial approaches that are new to the user or firm and that reduce pollution, environmental risks, and the adverse effects of energy and resource consumption. This definition emphasizes the reduction of environmental damage and the efficient use of resources (Hojnik & Ruzzier, 2016). Eco-innovation often requires substantial investment and can involve organizational, process, and product innovations supported by environmental regulation and sustainable technologies (Wei et al., 2023).

The distinctive characteristics of green innovation point to the need for policy tools that encourage related activities. Government initiatives, including administrative and fiscal incentives, significantly affect the creation and diffusion of green innovation (He et al., 2018). Regulatory measures may pressure firms to engage in green innovation to comply with social and legal expectations (Tang et al., 2020). By contrast, fiscal-policy measures provide constructive support by lowering costs, reducing uncertainty, and increasing expected returns from green innovation (Long & Liao, 2021). Recent evidence also highlights that environmental policies, financial development, and green innovation are important drivers of renewable-energy transition and sustainable development pathways (Umar et al., 2026). Researchers therefore examine the connection between fiscal-policy incentives and corporate innovation by assessing the effectiveness of tax incentives, direct subsidies, and public R&D support.

Tax incentives and direct subsidies are among the most widely used fiscal-policy instruments (Peng et al., 2019). Several studies have examined the effect of these fiscal measures on firms' R&D spending and innovation activity (Alam et al., 2019; Liu et al., 2020a). In theory, public support for enterprise R&D should generate additional effects by encouraging private R&D activity and accelerating projects that would otherwise be financially constrained (Becker, 2015). However, concerns remain about the possible crowding-out effects of subsidies on private R&D spending. For instance, Lach (2002) finds evidence that R&D subsidies stimulated company-financed R&D expenditure in Israeli firms, while other studies show that the effectiveness of public support may differ across firm types and policy designs (Mateut, 2018; Liu et al., 2020b). Targeted public support can reduce the cost and risk of R&D investment, making firms more willing to engage in green R&D programs (Cuerva et al., 2014).

Tax credits are often viewed as a more market-oriented policy tool because they give firms more discretion in organizing R&D activities. Unlike direct subsidies, tax credits reduce the need for governments to select specific projects or subsidy recipients (Czarnitzki et al., 2011). Although firms may respond slowly to tax credits at first, the response may become stronger over time (Long & Liao, 2021). Evidence from Japan and Taiwan suggests that R&D tax incentives can stimulate private R&D expenditure, particularly among firms with stronger innovation capacity (Koga, 2003; Yang et al., 2012). Recent evidence from China also indicates that tax-policy reform can promote corporate innovation (He et al., 2023).

Several gaps emerge from this discussion. Although many studies examine the role of fiscal policies in promoting green innovation, their conclusions remain inconsistent. One strand of

literature finds that green fiscal policies enhance green innovative activity, whereas another suggests that such policies may discourage innovation under some conditions. Prior studies also emphasize private investment and firm-level drivers of innovation while giving less attention to the macro-level role of public spending and environment-related taxation. This gap is also relevant because recent studies show that policy stringency and green innovation can shape low-carbon transition pathways, but the role of fiscal instruments remains less directly examined (Chang et al., 2026). In addition, much of the literature focuses on subsidies and tax credits, whereas less attention has been paid to the effects of R&D expenditure and environment-related taxes on national green innovation. This study addresses these gaps by examining whether green fiscal policy promotes green innovation in China.

H1a: Environment-related taxes positively affect green innovation in China.

H1b: R&D expenditure positively affects green innovation in China.

3 MODEL SPECIFICATION AND METHODS

Following the innovation literature, we use key variables that drive green innovation in our model setup (Gramkow & Anger-Kraavi, 2018). More specifically, green innovation is assumed to share a long-run relationship with green fiscal policy, economic development, and financial sector development. Thus, we specify the following model:

$$GI_t = \alpha_0 + \alpha_1 ET_t + \alpha_2 RD_t + \alpha_3 GDP_t + \alpha_4 FD_t + \varepsilon_t \quad (1)$$

In Equation (1), green innovation (GI) depends on environment-related taxes (ET), R&D expenditure (RD), economic development (GDP), financial sector development (FD), and the error term. Theoretical intuition suggests that stronger green fiscal policy should increase GI in the long run. Accordingly, the coefficients on ET and RD are expected to be positive. Similarly, economic growth and financial development are expected to support green innovation, implying positive expected coefficients for GDP and FD.

$$\begin{aligned} \Delta GI_t = & \beta_0 + \sum_{i=1}^p \lambda_i \Delta GI_{t-i} + \sum_{i=0}^{p-1} \beta_i \Delta ET_{t-i} + \sum_{i=0}^{p-1} \gamma_i \Delta RD_{t-i} + \sum_{i=0}^{p-1} \delta_i \Delta GDP_{t-i} + \sum_{i=0}^{p-1} \varphi_i \Delta FD_{t-i} + \theta_1 GI_{t-1} \\ & + \theta_2 ET_{t-1} + \theta_3 RD_{t-1} + \theta_4 GDP_{t-1} + \theta_5 FD_{t-1} + \varepsilon_t \end{aligned} \quad (2)$$

Equation (2) specifies the ARDL error-correction form. The parameters attached to the first-differenced variables capture short-run effects, whereas the lagged-level terms are used to obtain long-run parameters. The null hypothesis of no long-run relationship is $H_0: \theta_1 = \theta_2 = \theta_3 = \theta_4 = \theta_5 = 0$; rejection of this hypothesis using the bounds F-test supports cointegration. The t-test on the lagged dependent variable provides additional evidence on error-correction behavior. Because the F-statistic and t-statistic follow non-standard distributions, the decision is made using the critical bounds proposed by Pesaran et al. (2001). The ARDL approach is appropriate for small samples and for variables integrated as $I(0)$ and $I(1)$, provided that none is $I(2)$. The Akaike information criterion (AIC) is used to determine the optimal lag length. Serial correlation, heteroscedasticity, residual normality, model specification, and stability are assessed using the Lagrange Multiplier, Breusch-Pagan, Jarque-Bera, Ramsey RESET, CUSUM, and CUSUMSQ tests.

$$\Delta GI_t(\tau) = \beta_0(\tau) + \rho(\tau) ECM_{t-1} + \sum \psi_i(\tau) \Delta X_{t-i} + u_t(\tau), \quad \tau \in (0,1) \quad (3)$$

To validate the baseline findings, the study employs the QARDL model, which allows the coefficients to vary across quantiles of green innovation. In Equation (3), X includes ET, RD, GDP, and FD. This specification tests whether the effects of green fiscal policy differ at low, middle, and high levels of green innovation.

4 DATA AND VARIABLES

This study explores the effect of green fiscal policy on green innovation in China over the period 1991–2020. The analysis relies on data obtained from the OECD and the World Bank. Green innovation is captured through the share of environment-related technology developments as a percentage of global inventions. Green fiscal policy is measured using two proxies: environment-related taxes as a percentage of GDP (ET) and R&D expenditure as a percentage of GDP (RD). Following previous studies (Gramkow & Anger-Kraavi, 2018; Luo et al., 2021), GDP at current US dollars and financial development (FD) are included as control variables. Natural logarithmic transformation is applied to the FD and GDP series. Table 1 reports descriptive statistics for GI, ET, GDP, FD, and RD, while Appendix Table A summarizes the definitions and data sources of all variables. The mean values of GI, ET, GDP, FD, and RD are positive, with values of 3.998, 0.734, 28.65, 4.766, and 1.307, respectively. The skewness statistics show that GDP and RD are negatively skewed, whereas the remaining variables are positively skewed. The standard deviation and kurtosis statistics are within acceptable ranges.

Tab. 1 – Descriptive statistics. Source: own research

	GI	ET	GDP	FD	RD
Mean	3.998	0.734	28.65	4.766	1.307
Median	2.410	0.820	28.55	4.742	1.338
Maximum	15.51	1.680	30.31	5.209	2.401
Minimum	0.190	0.010	26.67	4.433	0.194
Std. Dev.	4.429	0.527	1.210	0.211	0.678
Skewness	1.192	0.150	-0.068	0.234	-0.067
Kurtosis	3.298	2.058	1.613	2.228	1.679

5 EMPIRICAL ANALYSIS AND DISCUSSION

Table 2 presents the outcomes of the DF-GLS and PP unit root tests and includes the final order of integration. The results indicate that RD is stationary at level, whereas GI, ET, GDP, and FD become stationary after first differencing. Because the variables are a mixture of I(0) and I(1) and none is I(2), the ARDL approach is appropriate. The next step involves determining the appropriate lag length. Table 3 reports the lag selection results, and both the AIC and SC criteria suggest choosing one lag for the regression analysis. Based on this, the ARDL model is employed to estimate the long-run and dynamic coefficients of the model.

Tab. 2 – Unit root tests. Source: own research

	DF-GLS		PP		Order
	Level	First difference	Level	First difference	Final order
GI	-0.598	-1.698*	-0.725	-3.689***	I(1)
ET	-0.965	-4.658***	-1.358	-4.985***	I(1)
GDP	-0.345	-2.635**	-1.321	-2.652*	I(1)
FD	0.425	-5.368***	-0.498	-5.489***	I(1)
RD	-1.789*	—	-2.789*	—	I(0)

Note: *, **, *** indicate significance levels of 10%, 5%, and 1%, respectively. I(0) and I(1) denote stationarity at level and first difference.

Tab. 3 – Lag order selection criteria. Source: own research

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-25.20	NA	0.000	2.158	2.396	2.230
1	138.6	256.9*	3.10e-1*	-7.737*	-6.310*	-7.301*
2	155.0	20.22	0.000	-7.144	-4.528	-6.345

Table 4 reports the estimated ARDL dynamic coefficients. Because the table includes lagged level terms such as GI(-1) and ET(-1), these estimates should be interpreted as dynamic ARDL results rather than as a standalone ECM short-run table. The results show that ET has a significant positive association with GI, indicating that environment-related taxes enhance green innovation in China. A one-unit increase in ET is associated with a 2.573-unit increase in GI, holding other factors constant. FD has an insignificant effect on GI, while GDP shows a significant positive relationship with GI; a one-unit increase in log GDP is associated with a 1.792-unit increase in GI.

Tab. 4 – ARDL dynamic estimates. Source: own research

Variable	Coefficient	S.E	t-Stat	Prob.*
GI(-1)	0.743***	0.116	6.396	0.000
ET	2.573***	0.778	3.307	0.004
ET(-1)	2.639**	1.107	2.385	0.027
RD	0.049	3.243	0.015	0.988

Variable	Coefficient	S.E	t-Stat	Prob.*
FD	0.621	2.703	0.230	0.821
GDP	1.792*	1.067	1.671	0.097
C	20.34*	10.95	1.857	0.093

Note: *, **, *** indicate significance levels of 10%, 5%, and 1%, respectively.

Table 5 reports the long-run estimates. The results show that ET has a significant positive effect on GI in China. This indicates that environment-related taxes can improve green innovation and may serve as an effective policy instrument for encouraging environmentally oriented innovation. The coefficient indicates that a one-unit increase in ET is associated with a 7.851-unit increase in GI, holding other factors constant. This result is consistent with the Porter hypothesis, which suggests that well-designed environmental regulation can stimulate innovation and improve environmental performance in the long run (Hassan et al., 2025; Zhao et al., 2022). Different levels of environmental taxation may also have dynamic and nonlinear effects on GI (Zhao et al., 2022; Chen et al., 2023). RD is the second proxy for green fiscal policy. The results show that RD also has a significant positive effect on GI in China, indicating that public and economy-wide R&D spending can support the development of green technologies. The coefficient indicates that a one-unit increase in RD is associated with a 2.082-unit increase in GI, holding other factors constant. This finding is consistent with Gramkow and Anger-Kraavi (2018), who argue that fiscal instruments can encourage green technological innovation. It is also supported by Bai et al. (2019), who show that government R&D subsidies promote green innovation in Chinese energy-intensive firms. Environmental innovations are essential instruments for achieving sustainable green growth through environment-related technologies (Ji & Wang, 2026; Chen et al., 2023). Environment-related taxes can encourage behavioral change at the individual and firm levels by raising the cost of environmentally harmful activities, thereby motivating firms to adopt greener technologies and improve energy efficiency. Luo et al. (2021) also provide support for this view by showing that firms may adopt green innovation by shifting toward renewable inputs and changing production methods through advanced technologies. Zhang (2021) further suggests that public finance tools can influence firm structure, with taxes playing an important role.

The effects of FD and GDP on GI are insignificant in the LR, indicating that increases in financial development and economic output do not automatically translate into higher green innovation in China. These results suggest that green fiscal policy, through ET and RD, is more directly relevant for overcoming green innovation-related constraints.

Tab. 5 – Long-run results. Source: own research

Variable	Coefficient	S.E	t-Stat	Prob.
ET	7.851**	3.005	2.612	0.017
RD	2.082**	1.050	1.983	0.041
FD	2.420	10.57	0.229	0.821
GDP	6.978	5.936	1.176	0.254

Note: ** indicates significance levels of 5%.

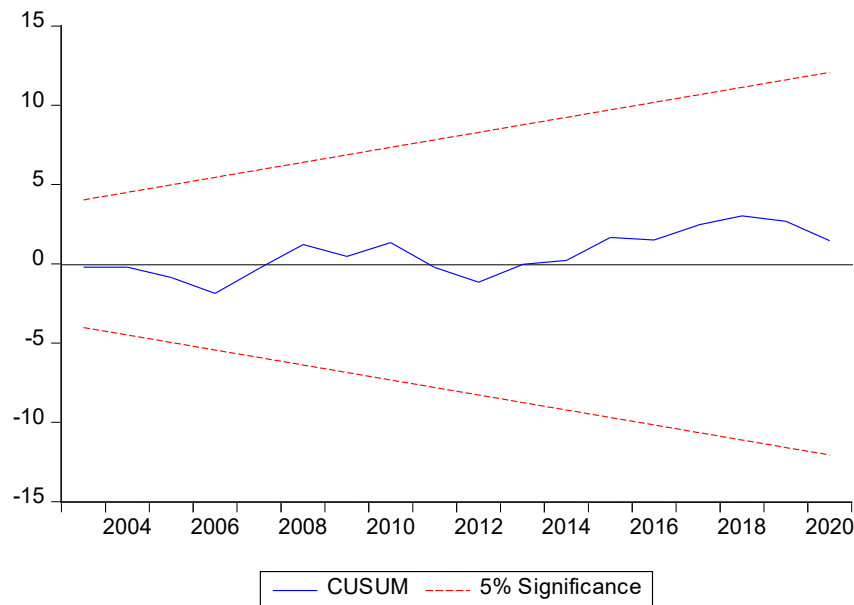
Table 6 reports the diagnostic tests. The R-squared value confirms the explanatory power of the model. The bounds F-statistic of 4.968 exceeds the 5% upper-bound critical value of 4.01

for $k = 4$ under the Pesaran et al. (2001) bounds-testing framework, supporting the presence of a long-run cointegration relationship among the variables. The error-correction coefficient is negative and statistically significant, confirming convergence toward the long-run equilibrium. The serial correlation, Breusch-Pagan, Jarque-Bera, and Ramsey RESET statistics do not indicate serious autocorrelation, heteroscedasticity, non-normality, or misspecification concerns. The CUSUM and CUSUMSQ plots also confirm model stability (Figure 1). Overall, the diagnostic results support the validity of the ARDL estimates.

Tab. 6 – Diagnostic tests. Source: own research

Diagnostic item	Reported value / decision	Interpretation
R-squared	0.854	High explanatory power
Bounds F-statistic	4.968**;	Long-run cointegration supported
ECM(-1)	-0.452***	Convergence toward long-run equilibrium
Serial correlation LM	1.456	No serious autocorrelation indicated
Breusch-Pagan (BP)	1.369	No serious heteroscedasticity indicated
Jarque-Bera	0.369	Residual normality not rejected
Ramsey RESET	0.369	Functional form acceptable

Note: ** and *** indicate significance levels of 5% and 1%, respectively. Bounds decision is based on Pesaran et al. (2001) critical values for $k = 4$.



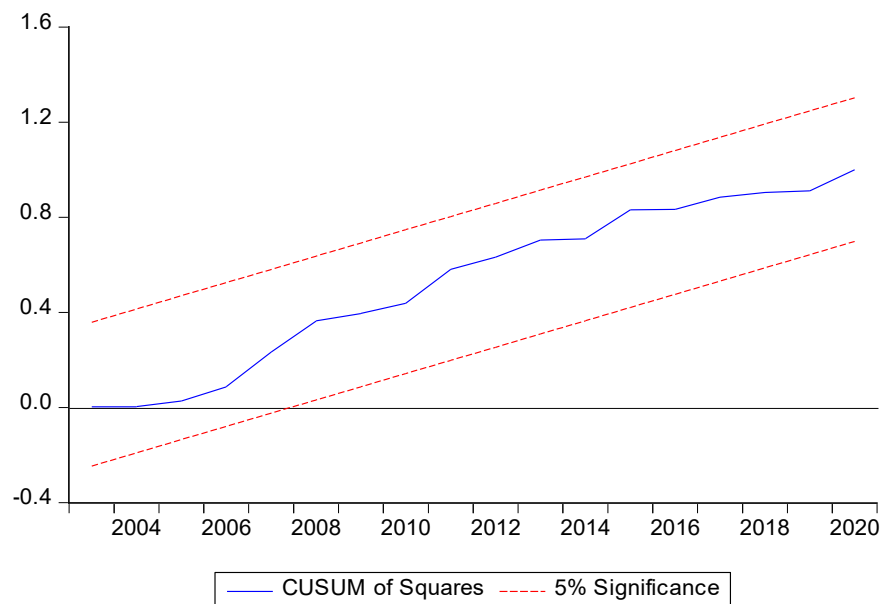


Fig. 1 – CUSUM and CUSUMSQ stability plots. Source: own research

Table 7 presents the QARDL results. In the long run, ET has a positive and statistically significant relationship with GI across all quantiles, indicating that stronger environment-related taxation promotes green innovation at different points of the green innovation distribution. For RD, a significant long-run relationship with GI emerges mainly at the upper quantiles, particularly 0.80, 0.90, and 0.95. This suggests that R&D expenditure stimulates green innovation most strongly when the level of green innovation is already relatively high. The findings also show that FD has a positive and significant long-run effect on GI across quantiles, indicating that financial development can support green innovation under the QARDL framework. Similarly, GDP has a positive and statistically significant long-run effect on GI across quantiles, suggesting that economic growth supports improvements in green innovation. In the short run, RD has a positive and significant effect on GI across quantiles, demonstrating its immediate contribution to innovation. ET also shows a positive and significant short-run association with GI across quantiles, confirming that environment-related taxes promote green innovation in both the short run and the long run.

Tab. 7 – QARDL results. Source: own research

			Long-run				Short-run				
	C	ECM	ET	RD	FD	GDP	ET	RD	FD	GDP	GDP(-1)
0.05	7.983	-0.481***	0.354***	0.092	2.242***	2.777***	0.416***	1.431***	1.066***	2.611	1.606
	(1.602)	(-6.340)	(4.901)	(0.091)	(2.811)	(8.784)	(5.651)	(5.592)	(4.995)	(1.303)	(0.022)
0.10	9.022	-0.283***	0.354***	0.035	2.264*	2.945***	0.246***	1.363***	0.405***	2.354	1.564
	(1.232)	(-4.154)	(3.382)	(0.020)	(1.940)	(7.974)	(3.461)	(3.490)	(2.713)	(1.072)	(0.940)
0.20	11.30	-0.231***	0.364***	0.151	2.159*	3.059***	0.188***	1.038***	0.187***	2.104	1.423
	(1.041)	(-4.510)	(2.732)	(0.085)	(1.702)	(6.524)	(3.322)	(3.422)	(2.891)	(1.620)	(1.082)
0.30	13.91	-0.179***	0.434***	0.024	2.184*	3.285***	0.125***	0.705***	0.086***	1.925	1.012
	(1.261)	(-5.060)	(2.645)	(0.012)	(1.740)	(7.036)	(3.672)	(3.783)	(2.750)	(0.822)	(0.602)
0.40	14.70*	-0.157***	0.626**	0.163	1.805**	3.856***	0.106***	0.604***	0.075**	2.062	0.824
	(1.770)	(-5.335)	(2.410)	(0.144)	(1.963)	(7.384)	(4.103)	(4.425)	(2.382)	(1.015)	(0.782)
0.50	13.50***	-0.137***	0.888***	0.612	0.384**	4.206***	0.084***	0.489***	0.063*	1.863	0.493
	(3.201)	(-4.380)	(4.184)	(0.314)	(1.972)	(6.750)	(3.445)	(3.642)	(1.883)	(0.702)	(0.540)
0.60	11.23***	-0.115***	1.025***	0.293	0.143*	5.417***	0.080***	0.488***	0.069*	0.044	0.372
	(2.792)	(-3.032)	(12.16)	(0.122)	(1.804)	(5.618)	(2.670)	(2.994)	(1.735)	(0.012)	(0.130)
0.70	10.93***	-0.127***	1.034***	0.485	0.886**	5.110***	0.095***	0.559***	0.185*	0.634	0.124
	(2.684)	(-3.260)	(18.72)	(0.234)	(2.292)	(6.148)	(3.436)	(3.672)	(1.814)	(0.202)	(0.035)
0.80	9.052**	-0.185*	1.123***	1.185***	1.162***	3.439***	0.157*	0.724**	0.930**	0.852	0.346
	(2.253)	(-1.894)	(18.92)	(2.792)	(3.432)	(9.296)	(1.832)	(2.167)	(2.071)	(0.173)	(0.070)
0.90	8.044**	-0.291***	1.323***	1.825**	1.413***	3.978***	0.265***	1.113***	1.035**	1.856	0.732
	(2.364)	(-2.673)	(8.421)	(2.180)	(2.945)	(3.840)	(2.822)	(4.140)	(2.122)	(0.950)	(0.654)
0.95	7.540**	-0.321***	1.422***	2.045*	1.836***	3.465***	0.295***	1.241***	1.249***	2.034	1.085
	(2.272)	(-3.841)	(8.590)	(1.765)	(2.801)	(3.095)	(3.865)	(5.180)	(3.126)	(0.975)	(0.411)

Note: *, **, *** indicate significance levels of 10%, 5%, 1%.

6 CONCLUSION AND POLICY RECOMMENDATIONS

This study examines the effect of green fiscal policy on green innovation in China over the period 1991–2020. Green fiscal policy is measured using two instruments: environment-related taxes and R&D expenditure as percentages of GDP. Using the ARDL approach, the study estimates both dynamic and long-run relationships. The results show that environment-related taxes positively influence GI in the ARDL dynamic estimates and in the long-run estimates, while R&D expenditure supports GI in the long run. The diagnostic tests validate the reliability of the ARDL model. The QARDL robustness results further show that environment-related taxes increase GI across quantiles, while R&D expenditure supports GI mainly at higher quantiles. Overall, the findings demonstrate that green fiscal policy can play an important role in stimulating environmental innovation in China.

The findings provide several policy implications for green fiscal policy and sustainable transformation in China. First, strengthening green fiscal incentives for GI is important for the sustainable development of China's industrial sector. Public finance should be increased in R&D activities that support the development of green technologies. Second, providing incentives for GI should remain a central fiscal-policy objective because green financing and fiscal support can accelerate the transition toward a greener economic structure. The government should provide tax exemptions, targeted tax credits, and subsidies to industries involved in R&D projects for eco-friendly innovation. Such incentives should support projects that improve environmental quality and enhance energy efficiency. Third, the Chinese government should strengthen public-private partnerships among government agencies, private firms, and research institutions to accelerate the development and diffusion of green technologies. Finally, supportive regulatory frameworks and regular policy evaluation are necessary to ensure that green fiscal policies remain effective over time. By encouraging green innovation and cleaner production, these policies can also strengthen China's sustainable competitiveness.

This study has several limitations that can be addressed in future research. First, the analysis considers China at the aggregate national level; future studies may examine provincial or firm-level data to capture regional and organizational heterogeneity. Second, the sample period may be extended as more recent data become available. Third, future research may include additional policy and institutional variables to better explain the channels through which green fiscal policy affects green innovation. Finally, future studies may examine nonlinear relationships among the relevant variables using alternative quantile-based or structural approaches.

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APPENDIX

Tab. A – Variables and data sources. Source: own research based on OECD and WDI

Variables	Definitions	Sources
GI	Development of environment-related technologies, % inventions worldwide	OECD
ET	Environment-related taxes, % of GDP	OECD
RD	Research and development expenditure (% of GDP)	WDI
GDP	GDP (current US\$), natural logarithm	WDI
FD	Domestic credit to private sector (% of GDP), natural logarithm	WDI