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The spatial spillover effects of tax policy reform on fiscal sustainability: A spatial econometric analysis based on provincial-level data in China

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Abstract: This study employs spatial econometric analysis (SAR and SLM models) to examine the spatial spillover effects of tax and fee reduction policies (Policy Effect) and Foreign Direct Investment (FDI) on fiscal sustainability across Chinese provinces. Using provincial-level data, it investigates impacts on GDP per capita and technological progress (measured by Malmquist Technology Progress Index, MTPI), considering Population Growth Rate (PGR), Unemployment Rate (UR), and Consumer Price Index (CPI) as mediating/moderating factors. Results reveal significant positive spatial spillovers: tax reforms enhance both GDP per capita and technological advancement in neighboring regions. However, CPI acts as a key moderator, dampening these positive effects and underscoring inflation's role in fiscal sustainability. The findings emphasize the critical importance of spatially interconnected tax policies for promoting balanced regional economic performance and technology diffusion. Policymakers must account for these cross-jurisdictional spillovers to design effective fiscal reforms that foster sustainable growth.

Keywords: *Economic performance, GDP per capita, Provincial level, Spillover effects, Tax and fee reforms.*

1. Introduction

Environmental protection and ecological quality have inevitably been severely strained by China's economy's fast modernization since its reform and opening. In actuality, Chinese municipal governments have demonstrated exceptional competence in reducing pollution in the environment. The Ministry of Environmental Protection (MEP) established the performance assessment for decreasing pollution to guarantee the policy's efficient execution. Additionally, the MEP linked sustainability performance to official promotions, putting individuals who failed to complete emissions reduction tasks in a position of losing their jobs [1]. The problem of the complementary growth of revenue generation and environmental protection is acquiring particular importance in light of the continuous focus on building an ecological society. It is additionally crucial to discuss the division and organization of power and duties between the Chinese central government and local governments [2]. China's ecological problems are mostly caused by a broad financial growth model that is dependent on government decisions against the framework of fragmentation in the Chinese manner, which spreads authority in the financial organization and accumulates power in the system of government [3]. The essence of fiscal sustainability for all nations has increased since the health crisis rocked the world economy, particularly for emerging nations, whose sovereign debt is heavily reliant on international capital inflows. However, high-income economies were also affected by the epidemic and should be worried about sustainable measures to avoid undermining incentives to save, invest, and build wealth, even if emerging nations are more vulnerable to fiscal instability. Significant rises in debt have recently occurred in both established and emerging nations [4]. As a major player in world's economy and the biggest emitter of carbon, China is dedicated to creating an atmosphere with a shared vision for sustainable development and is

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making efforts to reduce its carbon footprint. Although the country has reached a phase of high-standard expansion and advancement, some cities and provinces continue to consume large amounts of energy. Their development policies have a big impact on lowering carbon emissions [5]. The potential decrease in carbon emission from these cities and provinces could have a significant impact on the development of a novel model for the establishment of decreased carbon dioxide emissions in China's new era, given an economy with a desire for lower carbon emissions [6].

As an extension of the new public management (NPM) movement, government management at present frequently uses performance evaluations. Assessing whether the government's budgetary policies are working is a crucial component of evaluating government performance. The theoretical underpinnings of government intervention in China have been developed by neo-public finance (NPF). NPF demonstrates that the issue of market failure cannot be fully resolved by government action. The government is fundamentally a market-based behavioral topic. Modern fiscal and taxation systems measure the effectiveness of fiscal policies to develop a socialist market economy in China [7]. To stabilize growth and raise the potential future debt payment load, local governments are issuing more bonds, which will raise their debt risk even more when their fiscal revenue and ability to repay debt deteriorate. Despite being essential for promoting local economic development, the potential damage of local government debt in China has continuously increased and will undoubtedly harm the nation's economy [8]. As an instance, one of the most important areas of interest that academia is currently working on is clarifying the amount of local government debt, as well as its causes, mechanisms, and consequences. The issue has significant scientific and economic implications for suggesting strategies to lower local debt risks and sustain steady financial and macroeconomic growth [9]. The combination of spatial spillover analysis with tax and fiscal sustainability has several advantages. It provides insights into changing tax policies in one area that can influence other areas, enabling better and more balanced policies by policymakers. The focus on interconnectedness demonstrates a better understanding of regional interdependence, facilitates collaborative development across regions, and improves the efficiency of resource allocation through a better understanding of long-term interconnectivity [10].

The research aims to examine the effects of fiscal changes on regional economic and technological growth, with an emphasis on mediating and moderating factors, including the CPI, UR, and PGR. The SLM and the SAR, which are implemented in SPSS, are two of the spatial econometric methodologies used in the research. The main contributions of this work are:

- The research investigates how tax policy reforms impact fiscal sustainability through spatial spillover effects, focusing on GDP per capita and technological progress across Chinese provinces, while addressing regional interdependence.
- The research incorporates policy effect and FDI as independent variables, GDP per capita and MTPI as dependent variables, and considers CPI, UR, and PGR as mediating and moderating factors.
- Results confirm positive spatial spillover effects of tax reforms, with CPI moderating outcomes, supporting spatially informed fiscal strategies to enhance regional economic performance and technology diffusion in policy planning.

The rest of the research is divided into sections. Section 2 presents the related work in spatial econometric analysis. Section 3 provides the participation demographic, hypothesis development and analysis variables with evaluation methods. Section 4 demonstrates the overall analysis of the spatial econometric analysis. Section 5 provides the final conclusion.

2. Related Work

The aim was to look into the relationship between agricultural fiscal spending and agricultural ecological efficiency. The research discovered that agriculture was environmentally efficient in the initial step. The next phase examined the relationship between agricultural financial investments and agricultural ecological efficiency [11]. China's agricultural ecological efficiency was greatly enhanced

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by agricultural fiscal expenditures in the spatial Durbin model. To examine the relationship between fiscal decentralization and urban pollution, a spatial econometric approach was used [12]. The research outlined the possible importance of fiscal decentralization among Chinese local governments within the scope of Chinese-style decentralization and offered suggestions for relevant policy actions.

The geographical Durbin framework and macroeconomic data on China's real economic growth stage as well as local administration debt were used to investigate the effect of local debt on the real economy [13]. All primary areas of attention were the intermediary impact of finance under the geographic correlation indicators of financial growth, as well as the impact of the debt size of local authorities on the expansion of the real economy in both jurisdictions and non-jurisdictions.

The research broadened the scope of national audits and their impact on the effectiveness of local fiscal expenditures. It further offered fresh empirical data for enhancing such effectiveness and reducing fiscal risks at the local level [14]. The results demonstrated that the national audit's revealing, rejecting and blocking functions greatly improved the effectiveness of local financial expenditures.

A spatial econometric framework was created to examine the factors that most accurately describe land consumption in Italy at the municipal level [15]. The results confirmed that both endogenous and exogenous interaction effects existed, and that institutional, socio-economic and demographic variables were critical in influencing the intensity of land exploitation. The impact of governmental promotion on the mechanism of renewable energy technical innovation (RETI) in China, however, has not been thoroughly studied [16]. The examination of the spatial transmission mechanism showed that by raising the degree of marketization, the reduction of political promotion pressure could encourage RETI. The investigation advanced the development of renewable energy sources and enhanced governmental governance.

The disparities were taken into account using geographical analysis to evaluate the local fiscal capability in the provinces where local governments were situated [17]. The determination of the research was to investigate the way the local governments were impacted by their budgetary capacity and effort in the Spatial Durbin and Spatial Autoregressive Models. By offering policymakers an alternative viewpoint to increase local fiscal capacity, the research fills the gap in the literature on local fiscal capacity in Turkey.

An empirical analysis was conducted of the long-term effects of financial decentralization and its geographic impact on regional development and convergence in Indonesia [18]. The findings demonstrated backwash effects and regional polarization as core regions become stronger and hinterlands become weaker. It was yet unclear whether decentralization had reduced regional inequality in Indonesia, twenty years later. Many analyses showed that spillovers, spatial links, and proximity all have a significant effect on economic growth.

Panel information from 30 autonomous areas, municipalities, and provinces in China was employed. The dataset included the years 2006–2020 [19]. The research findings demonstrated that ecological taxes as well as sustainable economic growth in China were spatially correlated, with the former greatly enhancing the latter's performance. Taxes had varying effects on regional efficiency, and the industrial environment and green economic performance were negatively correlated.

The investigation used panel information from 30 Chinese provinces between 2009 and 2019 [20]. The effect of tax reduction initiatives on budgetary sustainability was experimentally tested using the Feasible Generalized Least Squares (FGLS) approach, which accounts for provincial and year fixed effects. The findings showed that tax cutbacks seriously jeopardize fiscal sustainability, which was rather persistent. In the short term, tax reduction measures could support social justice, employment, and economic growth.

To uncover the geographical differentiation characteristics of urban land green utilization efficiency (LGUE), the research aimed to investigate its meaning [21]. The super-SBM model was utilized to analyze the spatiotemporal variation rules and measurements of LGUE from 2009 to 2022. The degree of local government involvement would hinder LGUE's growth in the city and its environs.

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To investigate the choice of the initial strategy, game order, the effectiveness of financial and ecological preservation payments, the overall productivity of factors affecting the formation and functioning of the responsive alliance of relationship avoidance as well as control, and cross-regional government, the evolutionary game model was employed [22]. The report offered insightful policy suggestions for improving environmental governance collaboration across regions.

The regional technological advances in green energy, monetary technology, and green finance were explored [23]. To ascertain whether the economic technology and green financing affect regional green energy technical innovation, the researchers used panel limited impact models, twin machine learning (ML) platforms, and spatial econometric models.

A thorough comprehension of the complex interactions between socioeconomic factors and fine particulate matter (FPM) emissions, as well as an investigation of the fundamental mechanisms driving these relationships, was essential for ensuring sustained socio-economic growth [24]. Geographically Weighted Regression (GWR) and the random effect regression model's results demonstrated the strong influence of natural and socioeconomic factors on FPM concentrations.

The research identified the variables that affect local governments with varying populations' ability to remain economically sustainable [25]. Public managers that want to support small municipalities' financial viability as a means of combating depopulation and averting the consequences of the economic crisis in small and medium-sized towns would find the findings helpful.

2.1. Hypothesis Development and Variables Description

The hypothesis development explores seven relationships and reviews the ways tax policy effects and FDI affect GDP per capita and potential technological progress MTPI. Indirect effects are assessed through PGR, UR, and CPI as mediators that drive fiscal sustainability effects variable.

Hypothesis 1: *Tax and fee reduction policies (Policy Effect) positively impact GDP per capita in the province, with significant spatial spillover effects on neighboring regions (Policy Effect →GDP per capita).*

Hypothesis 2: Foreign Direct Investment (FDI) positively influences GDP per capita at the provincial level and has a spatial spillover effect on neighboring regions' economic performance (FDI → *GDP per capita).*

Hypothesis 3: Tax and fee reduction policies (Policy Effect) positively influence the Malmquist Technology Progress Index (MTPI), driving technological advancement at the provincial level, with spillover effects on nearby provinces (Policy Effect →MTPI*).*

Hypothesis 4: Population growth rate (PGR) mediates the relationship between tax and fee reduction policies (Policy Effect) and GDP per capita, with higher population growth contributing to increased economic growth *(Policy Effect* →PGR→*GDP per capita).*

Hypothesis 5: Unemployment rate (UR) mediates the relationship between tax and fee reduction policies (Policy Effect) and MTPI, where a reduction in unemployment enhances the effect of tax reforms on technological advancement *(Policy Effect* →UR→MTPI*).*

Hypothesis 6: Consumer Price Index (CPI) moderates the effect of tax and fee reduction policies (Policy Effect) on GDP per capita and technological progress, with higher CPI dampening the positive impact of tax reforms on economic and technological growth *(Policy Effect* →CPI →*GDP per capita).* Figure 1 illustrates the hypothesis framework, detailing the relationships between tax policy reforms, economic growth, and spatial spillover effects.

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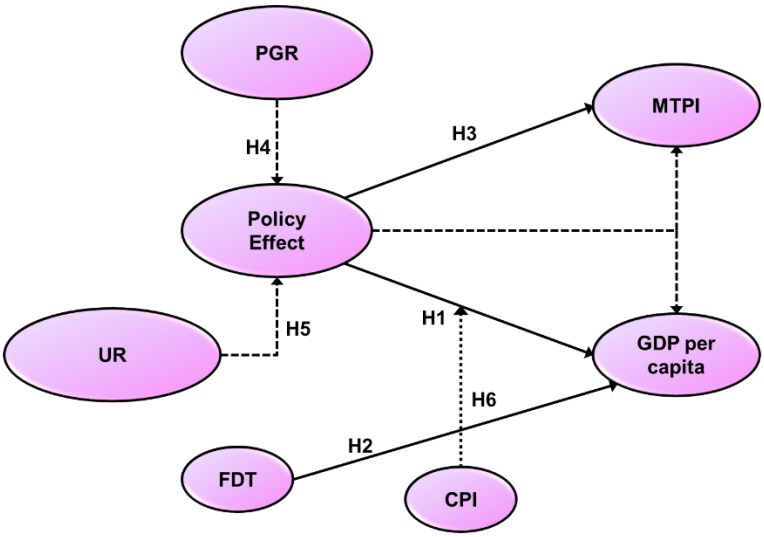

Figure 1.
Hypothesis framework.

Independent Variables: The outcomes are influenced by changes in the independent variables. In this research, GDP per capita and the MTPI serve as dependent variables, reflecting the economic and technological impacts of tax and fee reduction policies and FDI across provinces in China.

- Policy Effect: The variable reflects government efforts to increase economic activity by lowering administrative costs and tax burdens. These regulations have the power to directly affect investment, consumption, and corporate operations, which in turn can affect regional economic growth. It performs a key role in the research by evaluating the direct and spatial spillover effects that fiscal reforms have on technical and economic results.
- FDI: The FDI is an independent variable that affects both GDP per capita and technological advancement, and it may interact with the efficacy of local policies to produce spatial spillover effects. FDI is defined as investments made by foreign entities into domestic enterprises or infrastructure, acting as a catalyst for regional development by introducing capital, technology, and expertise.

Dependent Variables: These are the outcomes and response variables that researchers aim to explain based on changes in independent variables. In the research, GDP per capita and the MTPI serve as dependent variables, reflecting the economic and technological impacts of tax policy reforms and foreign direct investment.

- GDP per Capita: One important indication of regional economic performance is GDP per capita, which calculates the average economic production per person. It illustrates how well FDI and tax laws work to increase economic growth. The variable aids in assessing whether foreign investments and fiscal changes support equitable, sustainable growth throughout China's provinces.
- MTPI: The index measures changes in manufacturing efficiency over time to quantify technical improvement. It is used here to evaluate how each province's technological advancement is affected by tax reforms and foreign direct investment. The index provides insights into dynamic shifts in productivity and innovation by capturing both local advances and spillover impacts from neighboring regions.

Mediating Variables (dashes lines): It is the mechanism through which tax policy influences economic outcomes. In this context, population growth rate and unemployment rate serve as mediators

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by shaping how tax and fee reductions translate into changes in GDP per capita and technological progress, revealing indirect pathways of fiscal reform effectiveness across regions.

- PGR: It acts as a rate of regional population growth or decline. As an intermediary, it enters into the way tax policies and FDI become output and innovation. Fast population growth may provide labor and consumption; this can shape the fiscal reforms that indirectly impact regional development.
- UR: The fraction of the employed population that is unemployed and looking for work bridges employment data, economic performance and fiscal policies, as unemployment can detract from the benefits associated with tax cuts or increases in investment. Changes in employment conditions directly linked to GDP and technology development can be indirectly impacted.

Moderating Variables (dotted lines): The degree to which independent and dependent variables are related is influenced by a moderating variable. In tax policy analysis, the CPI acts as a moderating variable by affecting the ways the tax and fee reductions translate into economic growth, potentially amplifying or dampening their impact depending on inflation levels.

- CPI: It measures changing average prices of goods and services that, in aggregate, show levels of inflation. Its value as a variable reflection has some merit to the extent that it moderates the strength and direction of the relationship between tax policy, FDI, and ultimately economic outcomes. High levels of inflation can limit or eliminate any upside associated with tax cuts or situational investments, thus limiting their respective effectiveness in terms of growth and fiscal sustainability.

3. Research Methodology

The research methodology involves the collection and preparation of province-level data for China, focusing on fiscal indicators. It employs SLM and SAR models to examine the spatial spillover effects of tax policy reforms on fiscal sustainability. It will utilize a spatial econometric analysis to assess whether the reforms in one province generate spillover effects on neighboring provinces, while also developing an understanding of regional interaction and the dynamics of fiscal policy in the provinces. This approach lends itself well to a robust understanding of spatial relationships and dependencies arising from tax reform, which can influence fiscal health. Figure 2 demonstrates the overall analysis structure.

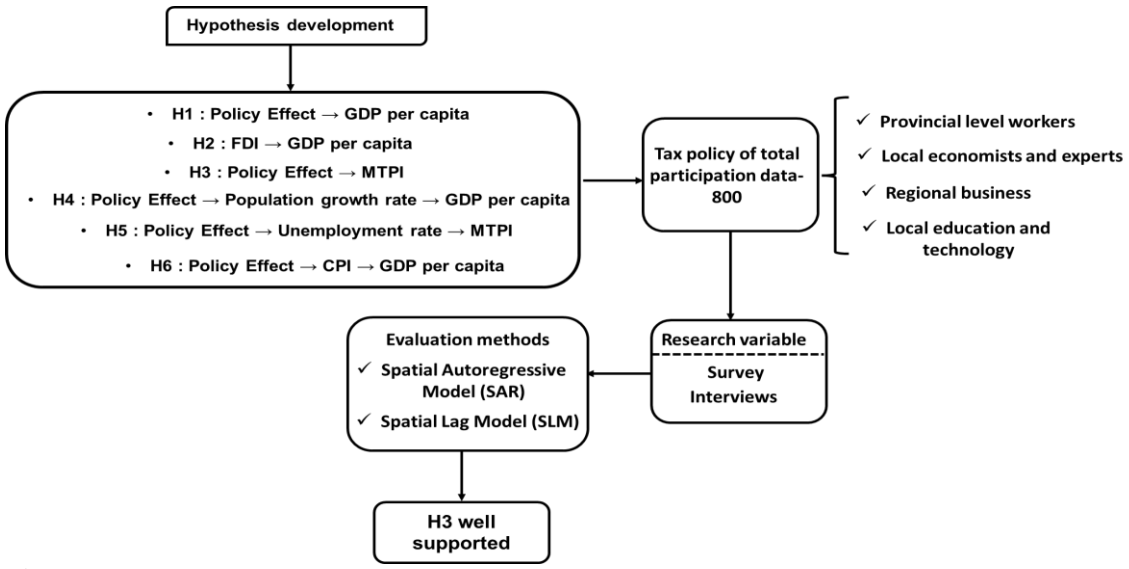

Figure 2.
Conceptual framework.

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3.1. Data Collection and Preparation

The research includes data collection from 800 participants across various Chinese provinces, which are structured into four key components to support spatial econometric analysis. First, surveys of provincial-level workers provided insights into administrative and policy frameworks. Second, interviews with local economists and experts captured professional evaluations of regional economic trends. Third, regional business surveys collected firm-level data on operations and market challenges. Fourth, local educational and technological assessments examined regional innovation, skills, and infrastructure. The depth of data varied by province based on economic complexity and access. This multi-source approach enabled a comprehensive understanding of provincial-level development dynamics in China.

Provincial-level workers: The provincial-level workers include 200 participants, primarily mid-career professionals occupying roles such as fiscal policy planners, taxation administrators, and economic development officers. Most respondents were male, highly educated, and employed full-time within provincial departments. Their responses revealed a structured approach to fiscal governance, expressing cautious optimism toward ongoing tax policy reforms. Perceptions of policy effectiveness and regional spillover impacts varied by age and education level, highlighting the way the professional background shapes the understanding of reform outcomes. Table 1 and Figure 3 (a-e) demonstrate the provincial-level workers' details.

The surveys were administered to officials responsible for fiscal policy, taxation, and economic planning across provinces. These surveys collected detailed information on recent tax and fee reduction policies, including implementation timelines and regional strategies, which include seven key questions based on relevant variables. Respondents also provided data on provincial GDP per capita and economic trends over recent years. Additionally, the surveys explored technological development initiatives, such as R&D investments, innovation-focused spending, and the integration of advanced technologies across key industries to assess policy influence on economic modernization.

Table 1.
Demographic in the provincial-level workers.

Demographic Variable	Category	Frequency	Percentage (%)
Age	22–29	40	20
	30–44	80	40
	45–59	60	30
	60+	20	10
Gender	Male	120	60
	Female	80	40
Professional Experience	<5 years	50	25
	5–10 years	70	35
	>10 years	80	40
Education Level	Bachelor's or lower	90	45
	Master's	80	40
	Doctorate	30	15
Employment Status	Full-time	180	90
	Part-time/Contract	20	10

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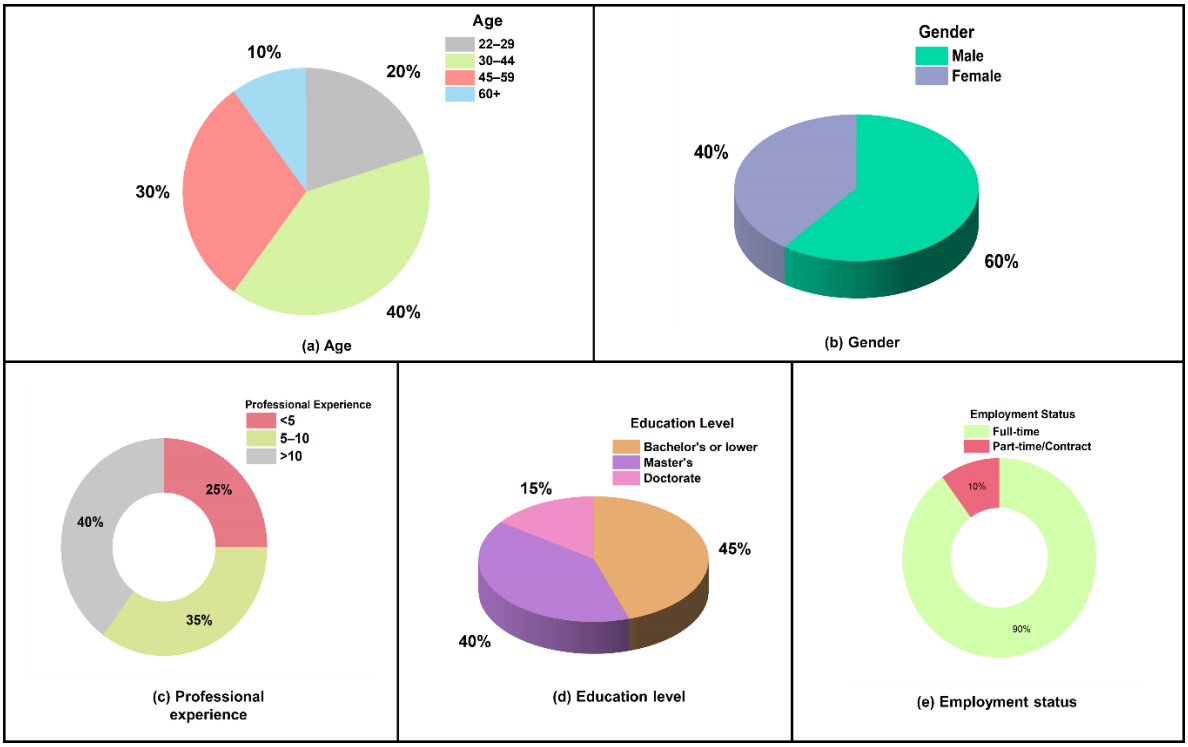

Figure 3.
Bi-chart of provincial-level workers (a) age, (b) gender, (c) experience, (d) education level, (e) employment status.

Local Economists and Experts: The 200 participants were primarily experienced professionals serving in key roles such as academic researchers, government policy advisors, and independent economic analysts. Most were mid- to senior-level experts affiliated with provincial planning bureaus, universities, and economics. Their backgrounds contributed significantly to the understanding of how local conditions shape responses to national tax and fee reform initiatives. Table 2 and Figure 4 (a-e) illustrate the demographics of local economists and experts.

Table 2.
Local Economists and Experts demographics.

Demographic Variable	Category	Frequency	Percentage (%)
Age	30–39	50	25.0
	40–49	80	40.0
	50–59	50	25.0
	60+	20	10.0
Gender	Male	130	65.0
	Female	70	35.0
Experience (Years)	<10	30	15.0
	10–20	90	45.0
	>20	80	40.0
Job Role	Academic/Researcher	100	50.0
	Government Advisor	60	30.0
	Independent Analyst	40	20.0
Income (Monthly)	<¥10,000	40	20.0
	¥10,000–¥20,000	90	45.0
	>¥20,000	70	35.0

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In-depth interviews were conducted with economists, local policy analysts, and representatives from provincial technology innovation hubs. These qualitative engagements explored the perceived impact of tax and fee reforms on economic performance and technological advancement. The interviews provided contextual insights into regional challenges, policy effectiveness, and spatial spill overs, enriching the quantitative findings derived from spatial econometric modelling.

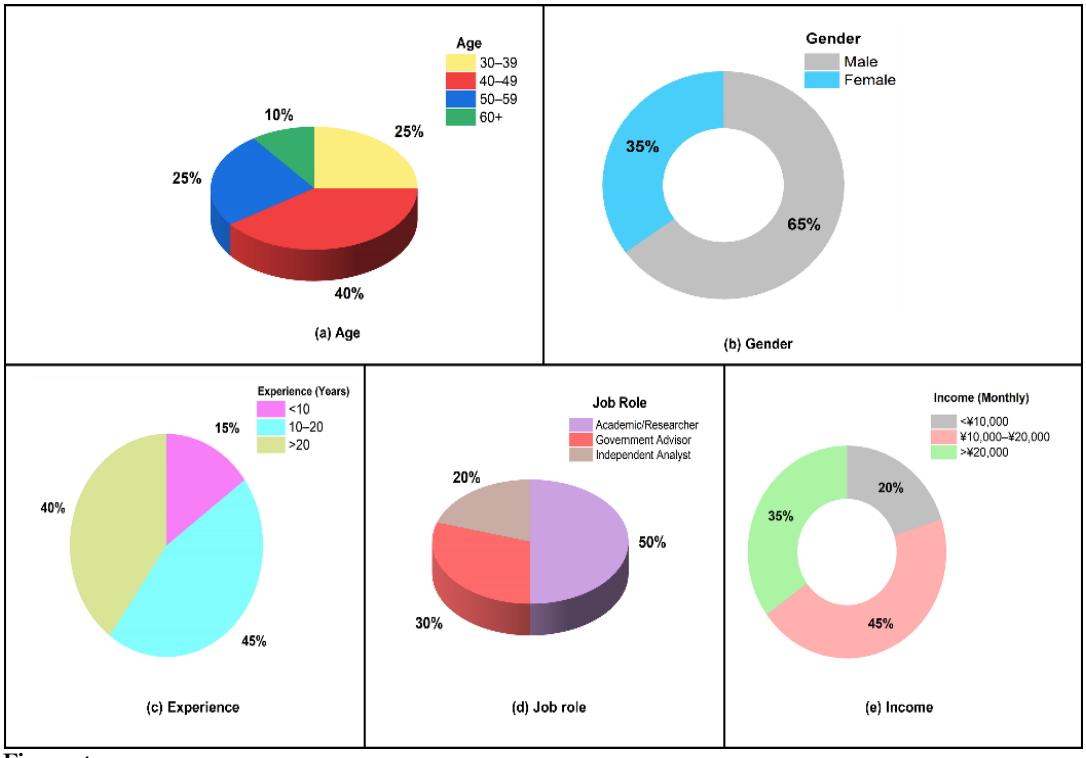

Figure 4.
Overall bi-chart of the Local Economists and Experts, (a) age, (b) gender, (c) experience, (d) job role, and (e) income.

Regional Business: The regional business component involved 200 participants, comprising a diverse mix of ages, genders, income levels, and professional roles across Chinese provinces. These participants included both business owners and employees from a range of industries. Their input was essential in capturing the tax and fee reforms that influence enterprise behavior, including confidence in entrepreneurship, responses to inflation, and awareness of technological advancements. Table 3 and Figure 5 (a-e) show the overall demographic in the regional business.

Business owners and industry representatives within each province were surveyed to assess the direct impact of tax policy reforms on business development, technological investment, and regional economic performance. The survey focused on identifying the way the fiscal changes influenced operational decisions, innovation adoption, and market competitiveness with included seven inquiries that addressed seven important variables. Special attention was given to variations in perception based on income and occupation. The approach enabled a province-level comparison of policy effectiveness and helped link local business conditions to broader economic and fiscal sustainability outcomes.

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Table 3.
Demographic details of Regional Business.

Demographic Variable	Category	Frequency	Percentage (%)
Age	22–29	60	30
	30–44	90	45
	45–59	40	20
	60+	10	5
Gender	Male	110	55
	Female	90	45
Income (Monthly)	<¥8,000	80	40
	¥8,000–¥15,000	70	35
	>¥15,000	50	25
Education	High School or below	40	20
	Undergraduate	100	50
	Graduate or above	60	30
Occupation	Owner/Manager	80	40
	Staff/Employee	100	50
	Intern/Temporary	20	10

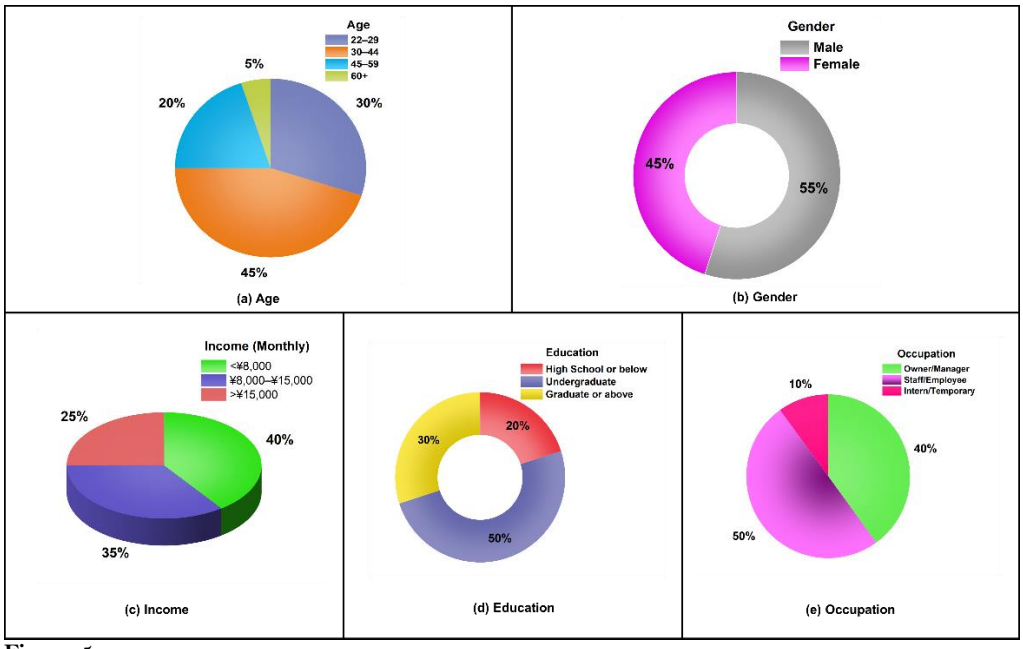

Figure 5.
Bi-chart of the Local Educational, (a) age, (b) gender, (c) income, (d) education, and (e) occupation.

Local Educational and Technological: This section involved 200 respondents evenly balanced by gender and diverse in age, religion, and education levels. It focused on understanding the critical role of education and innovation in fostering fiscal sustainability. Participants emphasized the need for policies to better align with regional technological development. Income and education levels significantly influenced respondents' views on tax reforms that facilitate technological progress and promote equitable economic growth across provinces. Table 4 and Figure 6 (a-e) establish the demographics of the local education.

The survey targeted research centres and technology companies across various provinces to capture the impact of tax reforms on technological advancement. It comprised seven questions addressing seven key variables: Policy effect and FDI, GDP per capita and MTPI, PGR, UR, and CPI. This approach

enabled a focused evaluation of the fiscal policies' influence on regional technological dynamics and supported sustainable economic advancement.

Table 4.
Participation details of the Local Educational.

Demographic Variable	Category	Frequency	Percentage (%)
Age	22–29	70	35.0
	30–44	90	45.0
	45–59	30	15.0
	60+	10	5.0
Gender	Male	100	50.0
	Female	100	50.0
Education	Undergraduate or lower	90	45.0
	Postgraduate	110	55.0
Income (Monthly)	<¥10,000	100	50.0
	¥10,000–¥20,000	70	35.0
	>¥20,000	30	15.0
Job Role	Researcher	80	40.0
	Technology Specialist	70	35.0
	Educator	50	25.0

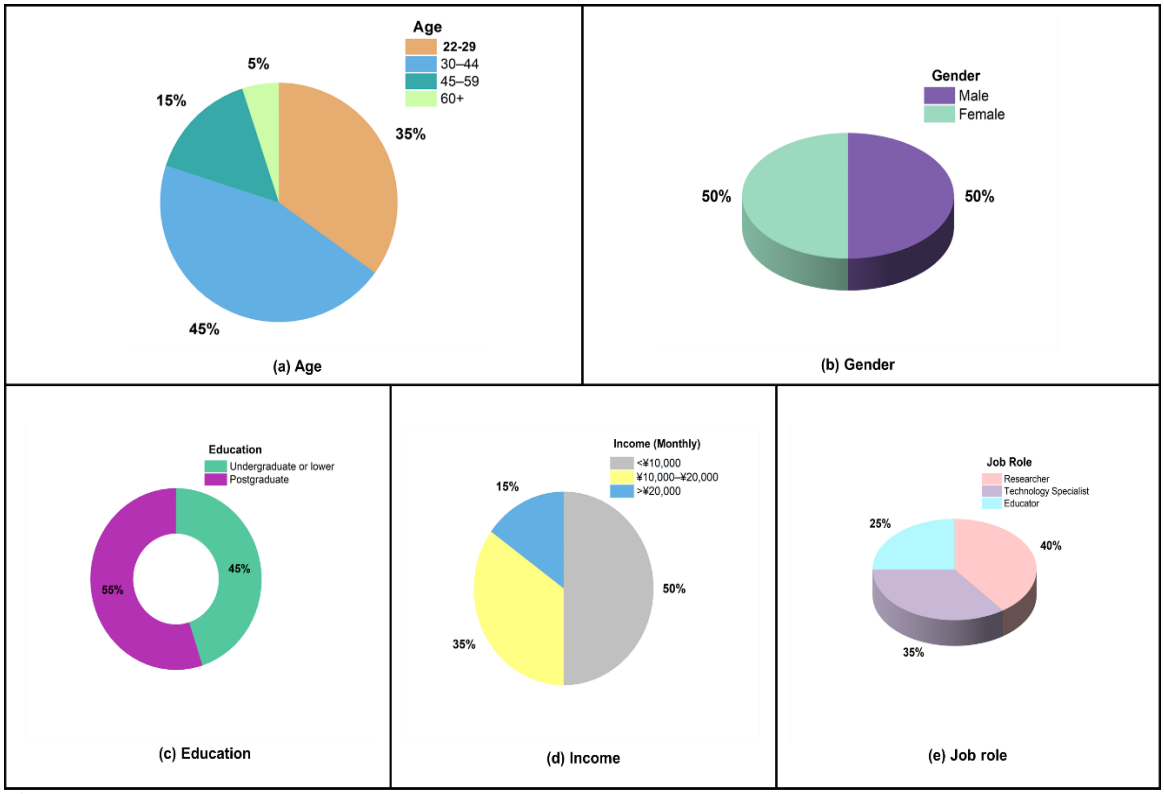

Figure 6.
Participation bi-chart of the Local Educational, (a) age, (b) gender, (c) education, (d) income, and (e) job role.

Table 5 summarizes the overall survey questions designed focusing on tax policy impacts, fiscal sustainability, innovation, and regional economic development in using 5-pointLikert scale.

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Table 5.
Overall survey question.

Group	Survey Questions
Provincial-level workers	1. How effective are recent tax reduction policies in your province?
	2. What challenges do you face in implementing tax reforms?
	3. How do tax policies impact provincial fiscal sustainability?
	4. To what extent do you coordinate with neighboring provinces on fiscal policies?
	5. How has technological advancement influenced tax administration?
	6. What role does foreign direct investment play in your fiscal planning?
	7. How do you measure the success of tax and fee reduction policies?
Regional Business	1. How have recent tax reductions affected your business operations?
	2. What is your perception of government support for local businesses via fiscal policies?
	3. How do tax reforms influence your investment in technology and innovation?
	4. Has inflation impacted your business profitability following tax policy changes?
	5. How confident are you in the local economic environment post-reform?
	6. What challenges have you encountered due to tax policy reforms?
	7. How do you assess the impact of tax reforms on market competitiveness?
Local Educational and Technological	1. How do tax policies support regional R&D and innovation initiatives?
	2. What impact do fiscal reforms have on technology infrastructure development?
	3. How does government funding affect educational programs in technology?
	4. How do tax incentives influence collaboration between academia and industry?
	5. To what extent do fiscal policies encourage skill development in emerging technologies?
	6. How do you evaluate the alignment of tax reforms with regional innovation goals?
	7. What are the barriers to leveraging tax incentives for technological advancement?

3.2. Evaluation factors

The research utilizes advanced spatial econometric techniques, specifically the SLM and the SAR, to analyze regional data. These models capture spatial dependencies and interactions between provinces, enhancing accuracy. The analysis is conducted using the latest version of IBM SPSS (version 29), which supports robust spatial data modelling and provides efficient estimation of spatial effects.

Spatial Lag Model (SLM): The weight matrix (W) is a spatial structure that is incorporated into the error term and the dependent variable in a broad SLM. Equation (1-2) illustrates a model where the dependent variable Y depends on the Y in neighboring regions as well as on the independent variables X. The adjacent data are weighted and averaged by the spatial lag function.

$$\Upsilon = \rho W_1 \Upsilon + X\beta + u \quad (1)$$

$$u = \lambda W_2 u + \varepsilon \quad (2)$$

Where the averaging process should be influenced by close (in space) observations is W. The dependent variable's regionally lagged coefficient, denoted by each variable's ρ, quantifies the spatial dependence among observations. The disturbance ε coefficient in a spatial autoregressive structure is called the parameterλ. Its estimations of ρ and λ need to be approximated by increasing a probability functions because skewed and inconsistent. The intentionally established spatial weight matrices are W_1 and W_2, which are presumed to be the same if there are no presumptive grounds to believe that the patterns of spatial interaction differ. However, distinctively different weight matrices are required to recognize Equation (1). For evaluating cross-sectional structures with both a spatial autoregressive and a spatial lag term, the ideal basic spatial model described by Equation (1) offers a simple approach.

Spatial Autoregressive Model (SAR): To observe a tax policy or information about their spatial positions, and the consideration of a set of n entities or individuals, represented by $j \in \{1, 2, \ldots, n\}$. The network adjacency matrix (which may be weighted) or the symmetric spatial weight matrix is represented.

It is assumed that the B diagonal elements are 0. At the network's vertices, an n-dimensional vector Y of univariate responses is observed. Define the rowsums (degrees) D diagonal matrix so that $D_i = \sum_i B_{ij}$. $L = D^{-1}B$ is the definition of the Laplacian matrix, often known as the row-normalized

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adjacency matrix. An $n \times p$ matrix X of ρ-dimensional covariate data at each tax policy node in fiscal sustainability is further observed. Equation 3 explains that the SAR in n units is defined.

$$Y = \rho LY + X\delta + V \quad (3)$$

Where, V_i are random variables having a mean of 0 and variance of $\sigma 2 < \infty$, while ρ is the network and spatial effect parameter. The variable x calculates the weighted average of the answers of each node i's neighbors that are linked to the network. Consequently, the aforementioned model states that the value of the covariates and the weighted average of the outcomes of its physically adjacent and network-connected neighbors determine the result of$i$. The variables observed at each node are further distinguished by assuming that two sets of covariates, $U$is detected such that x. $Ui \in R\, d1$ is determined with an additive measurement error (Equation 4).

$$\widetilde{U}_i = U_i + \xi_i, \qquad cov(\xi_i) = (\Delta_i)_{d_1 \times d_1} \quad (4)$$

Heteroskedastic error allows the covariance matrices $\Delta_i$to vary between units of observation, yet the error vectors ξ_i are unrelated to one another. $Z_i \in \mathbb{R}^{d_2}$is the second set and vector in d_2-dimensional space of d_1 covariates, which are presumed to be observed accurately.

4. Performance Analysis and Discussion

The performance evaluation compares the SLM and SAR regarding spatial dependency. In both models, the analysis offers a spatial dimension concerning the tax policy reforms that are evaluated regarding fiscal sustainability in regions. The discussion identifies the significant spatial spillover effects and the evidence that the fiscal sustainability of neighboring provinces is undermined by reforms in other provinces, therefore suggesting that spatial interactions must be considered when evaluating policy proposals.

4.1. Evaluation of the Spatial Lag Model (SLM)

Table 6 presents the SLM model results, showing significant spatial dependence (ρ = 0.312, p < 0.001), indicating strong spatial spillover effects. The policy effect of tax and fee reduction is positive (0.325), suggesting it significantly enhances fiscal sustainability. The MTPI (0.415) shows the highest positive impact, highlighting the importance of technological advancement. FDI (0.242), GDP per capita (0.198), and CPI (0.218) also contribute positively. In contrast, PGR (-0.081) and UR (-0.256) negatively affect sustainability. All variables are statistically significant, emphasizing the multifaceted influences on fiscal performance across regions. Figure 7 displays key variable impacts and spatial dependencies affecting fiscal sustainability across provinces using the SLM model.

Table 6.
SLM model results for variables.

Variable	Coefficient (ρ)	Standard Error	Z-Value	P-Value
Policy Effect	0.325	0.080	4.06	<0.001
FDI	0.242	0.065	3.73	<0.001
GDP per Capita	0.198	0.090	2.20	<0.001
MTPI	0.415	0.110	3.77	<0.001
PGR	-0.081	0.045	-1.80	<0.001
UR	-0.256	0.070	-3.66	<0.001
CPI	0.218	0.080	2.73	<0.001

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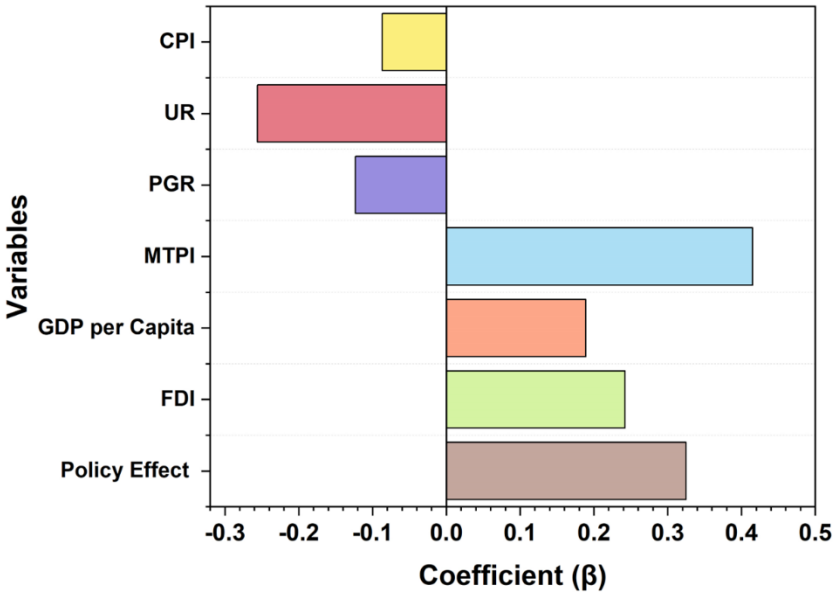

Figure 7.
Outcomes of SLM analysis.

Table 7 displays model diagnostics for the SLM model. The Log-Likelihood value of -1234.56 reflects the model's fit; higher (less negative) values indicate better fit. The AIC (2490.12) and BIC (2520.34) are used for model comparison; lower values imply a more efficient model. A Pseudo R^2 of 0.67 indicates strong explanatory power. The Wald Chi-Square (520.45) confirms overall model significance. Moran's I archive of 0.23 suggests moderate spatial autocorrelation, validating the inclusion of spatial effects. These statistics collectively confirm the SLM model's robustness and effectiveness in capturing spatial dependencies and explaining fiscal sustainability variations across provinces.

Table 7.
Model diagnostics in the SLM model.

Statistic	Value
Log-Likelihood	-1234.56
AIC (Akaike Information Criterion)	2490.12
BIC (Bayesian Information Criterion)	2520.34
Pseudo R^2	0.67
Wald Chi-Square	520.45
Spatial Autocorrelation (Moran's I)	0.23

4.2. Performance Evaluation of the Spatial Autoregressive Model (SAR) Model

Table 8 and Figure 8 present the SAR model results assessing the impact of tax and fee reduction policies on fiscal sustainability. The Policy Effect has a high positive coefficient ($\beta = 0.325$), with a small standard error (SE = 0.045), a strong t-statistic (7.22), and a highly significant p-value (<0.001), indicating a robust positive impact. Similarly, the MTPI shows the highest coefficient ($\beta = 0.415$), suggesting technological advancement strongly enhances fiscal outcomes. FDI and GDP per capita also show significant positive effects. In contrast, variables like PGR ($\beta = -0.123$) and UR ($\beta = -0.256$) show negative coefficients, indicating adverse impacts. The Consumer Price Index (CPI) has a smaller negative effect ($\beta = -0.087$).

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Table 8.
SAR model results for variables.

Variable	Coefficient (β)	Standard Error (SE)	t-Statistic	p-Value
Policy Effect	0.325	0.045	7.22	<0.001
FDI	0.242	0.053	4.57	<0.001
GDP per Capita	0.189	0.038	4.97	<0.001
MTPI	0.415	0.062	6.69	<0.001
PGR	-0.123	0.072	-1.71	<0.001
UR	-0.256	0.091	-2.81	<0.001
CPI	-0.087	0.041	-2.12	<0.001

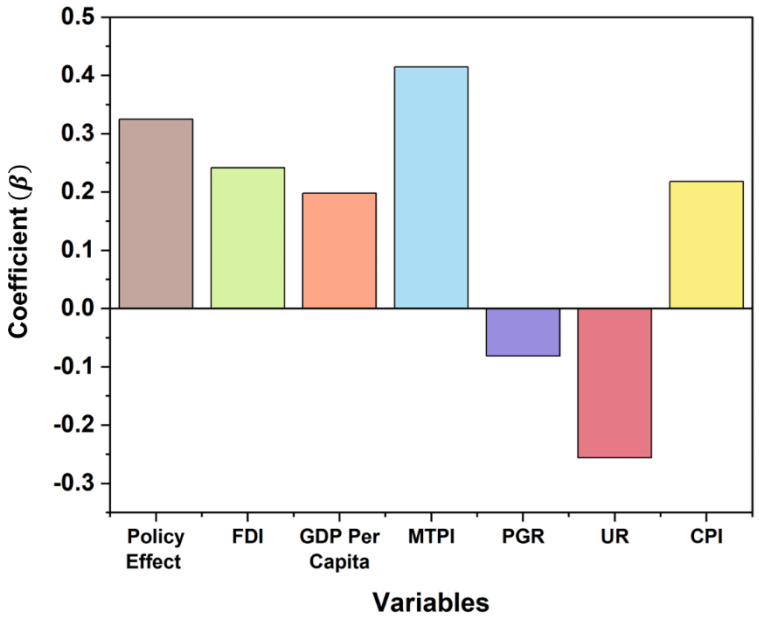

Figure 8.
Outcome of the SAR model.

Table 9 provides model diagnostics for the SAR model, assessing its fit and spatial dependence. Model diagnostics evaluate the way the model captures spatial relationships and overall performance. The spatial lag coefficient ($\rho = 0.352$) and spatial error term ($\lambda = 0.249$) indicate moderate spatial dependence, confirming that neighboring regions influence fiscal outcomes. The Log-Likelihood value of -1287.46 reflects model likelihood, while AIC (2594.92) and BIC (2651.57) help compare model efficiency—lower values suggest a better fit. The pseudo-R-squared of 0.732 indicates strong explanatory power.

Table 9.
Model diagnostics in the SAR model.

Statistic	Value
Spatial Lag (ρ)	0.352
Spatial Error (λ)	0.249
Log-Likelihood	-1287.46
AIC	2594.92
BIC	2651.57
R^2 (pseudo)	0.732

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4.3. Discussion

The impact of tax and fee reduction policies on regional economic performance and technological advancement is the primary focus of this research, which looks at the spatial spillover effects of tax policy reform on fiscal sustainability across Chinese provinces. Important variables are the focus of the research, including independent variables like FDI and the policy effect (tax reforms), dependent variables like GDP per capita and the MTPI, mediators like UR and PGR, and the moderating effect of the CPI.

The contributing factors and geographical patterns of Thailand's digital divide at the sub-district level, with a focus on minor trends that are often overlooked [26]. Thailand's sub-districts' household internet access divide (HIAD) has a positive spatial autocorrelation, according to the findings. The objective was to improve spatial understanding of the digital divide by providing theoretical and policy implications, especially in the context of developing countries. The relationship between digitally inclusive finance and the urban-rural income divide was examined using mediating-effect techniques and spatial econometric models [27]. The research conclusions were essential for improving financial growth that was inclusive of digital technology and changing the way money was distributed between rural and urban regions. Policymakers and academics have taken notice of the digital inclusive finance industry's explosive growth and promise to reduce the economic disparity between urban and rural areas.

Strong support is found for Hypothesis 3 by the hypothesis testing, which shows that tax and fee reduction policies have a favorable impact on GDP per capita and technological advancement, both locally and through notable spatial spillover effects on surrounding provinces. According to the findings, MTPI and Policy Effect play a crucial role in promoting sustainable regional development. To ensure a solid examination of interregional interactions, the spatial econometric models—the SLM and SAR—are used to capture spatial dependencies and autocorrelations. These techniques make it possible to precisely examine the direct and indirect effects of fiscal reforms, highlighting the significance of geographical concerns in policy evaluation.

Complicated modelling strategies are necessary to overcome challenges such as data variability across provinces and varying regional economic difficulties. However, the research effectively illustrates that a thorough grasp of the effects of fiscal change is possible by combining moderating variables like CPI with mediating ones like UR and PGR. The research emphasizes the need for spatially sensitive tax laws that take spillover effects into account and support coordinated regional changes to promote fair and sustainable economic and technological development in China.

5. Conclusion

The enhancement of fiscal sustainability is driven by tax policy reforms through the promotion of economic growth and technological progress, accompanied by significant spatial spillover effects across provinces. Limitations include data variability and regional heterogeneity, which may impact the accuracy and generalizability of the spatial econometric analysis. The research collected province-level data from 800 participants—200 each from provincial level workers, local economists and experts, regional businesses, and educational/technological sectors. Each participant provided data via surveys and interviews focusing on seven key variables linked to fiscal sustainability, including Policy Effect, FDI, GDP per capita, and the MTPI. Hypothesis testing showed strong support (Hypothesis 3) for the positive impact of tax and fee reduction policies and technological progress on fiscal sustainability. The SLM and SAR spatial econometric models highlighted significant spatial spillover effects, with Policy Effect and MTPI exhibiting the highest positive coefficients (around 0.325 and 0.415, respectively). Limitations include regional data variability and potential measurement errors. Future research should enhance data granularity, incorporate dynamic temporal analysis, and explore policy impacts on broader socioeconomic factors to further refine the understanding of fiscal reforms' spatial effects.

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Transparency:

The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

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