A Spatial Econometric Analysis of Fiscal Expenditure and Urban Public Facility Land Use on County-Level In-Migration in Taiwan

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Abstract

This study employs panel data from 22 counties and cities in Taiwan spanning the years 2000 to 2023, applying spatial econometric models to examine the effects of fiscal expenditure and urban public facility land use on county-level in-migration. The analysis adopts the Spatial Durbin Model (SDM) and further decomposes the results into direct, indirect (spillover), and total effects to capture the spatial interactions of migration flows. The empirical findings indicate that expenditure on education, science, and culture significantly enhances the attractiveness of counties for in-migration, while social welfare expenditure exhibits notable cross-regional spillover effects. In contrast, spending on community development and environmental protection, as well as the total area of roads and parks, shows a negative association with in-migration, likely reflecting pressures from urbanization, rising land use intensity, and higher living costs. Importantly, per capita accessible green and recreational spaces—including parks, green areas, playgrounds, and plazas—demonstrate significant positive effects, underscoring that the equitable distribution and accessibility of public facilities play a more decisive role in influencing population movements than their aggregate quantity.

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1. Introduction

Internal migration has long been a central issue in regional development and population economics. Migration not only affects the allocation of labor and regional growth but also reflects the effectiveness of local governments' public expenditure and urban planning policies. Previous studies have shown that fiscal expenditure significantly influences population mobility, particularly investments in education, healthcare, transportation, and public facilities, which enhance regional attractiveness and encourage in-migration (Önder, 2024). At the same time, urban public facility land use, such as parks, green spaces, roads, sports facilities, and plazas, provides essential infrastructure for residents' daily lives and symbolizes the level of local development and quality of life, thereby becoming a critical factor in individuals' migration decisions (Gu and Zhao, 2025).

In the East Asian context, scholars have highlighted the close interlinkages between local fiscal policies, urban public facility provision, and population migration. For instance, empirical studies in China suggest that local government expenditure on education and healthcare exerts a significant pull on in-migration, while also complementing the allocation of urban public facilities (Liu et al., 2015). Similarly, Huang, Hung, Hung, and Liao (2024) find that, in Taiwan, fiscal expenditure and economic opportunities at the county level not only affect local in-migration but also influence neighboring counties through spatial spillover effects. These findings underscore the importance of fiscal expenditure and urban public facility planning in shaping internal migration patterns.

However, much of the traditional regression analysis in this field assumes independence across regions, overlooking the spatial dependence and heterogeneity inherent in migration behaviors and policy effects. In reality, migration is strongly spatially connected: improvements in fiscal spending and urban facilities in one county affect not only local residents' migration intentions but also neighboring counties through externalities (LeSage and Dominguez, 2012). Ignoring such spatial linkages, as in conventional OLS or fixed-effects models, risks underestimating or misrepresenting policy impacts (Lundberg, 2006). To address this issue, spatial econometric models such as the Spatial Lag Model (SLM) and Spatial Durbin Model (SDM) have increasingly been adopted to analyze the relationship between migration and fiscal expenditure (Song and Yuan, 2022; Vakulenko, 2016).

Against this backdrop, the present study is motivated by two key objectives. First, it seeks to integrate fiscal expenditure and urban public facility land use as dual policy instruments to comprehensively examine their effects on county-level in-migration in Taiwan. Second, it applies spatial econometric methods to capture the cross-regional interactions and spillover effects that traditional regression models fail to account for, thereby filling theoretical and empirical gaps. This approach not only enriches our understanding of the determinants of migration but also provides concrete policy implications for balanced regional development, equitable public facility allocation, and population policies in Taiwan.

The following sections proceed as follows. The next chapter reviews the relevant literature and develops the research hypotheses, followed by a discussion of the research methodology, including data, sample, variables, and the empirical model. The empirical analysis includes descriptive statistics, correlation analysis, and estimation results of the Spatial Durbin Model, with a focus on decomposing direct and spillover effects. Finally, the study concludes with key findings and their policy implications.

2. Hypothesis Development

2.1   The impact of local fiscal expenditure on in-migration

Internal migration is not merely a process of labor and economic opportunity redistribution; it is also profoundly shaped by local governments' fiscal expenditure and the provision of public services. According to Tiebout's (1956) theory of local public goods, residents "vote with their feet" by choosing to migrate to jurisdictions that offer better public services and facilities. Hence, local government expenditures in areas such as education, social welfare, community development, and environmental protection may constitute critical determinants of county-level in-migration. Higher levels of educational and cultural spending enhance the environment for human capital development, social welfare expenditures reduce household risks and improve security, while investments in community development and environmental protection improve residential quality and urban livability, thereby strengthening the attractiveness of a locality to potential migrants. A growing body of empirical studies supports these theoretical expectations. Önder (2024), examining the case of Turkey, finds that central government expenditures in education and culture significantly promote interregional migration. Similarly, Liu et al. (2015), in their county-level study of China, highlight the importance of educational facilities and public service provision in attracting in-migration. Vakulenko (2016), focusing on Russia, demonstrates that social welfare spending significantly affects migration, with households more likely to relocate to regions with higher welfare levels. In terms of community and environmental dimensions, investments in environmental protection and natural resources are shown to enhance urban attractiveness, acting as key drivers of population inflows. Evidence from the United States also reinforces this perspective: Chen and Rosenthal (2008) report that local government investments in parks, community facilities, and residential environments exert significant positive effects on attracting migrants.

Within the Taiwanese context, Huang et al. (2024) reveal that county-level fiscal expenditures on education and social welfare not only exert significant positive impacts on local in-migration but also produce cross-county spatial spillover effects, indicating that public spending enhances local attractiveness while simultaneously influencing migration in neighboring jurisdictions through spatial interactions.

Taken together, these theoretical and empirical findings suggest that local governments' expenditures on education, science and culture, social welfare, community development, and environmental protection are likely to enhance local

in-migration. Accordingly, this study proposes the following hypothesis:

Hypothesis 1 (H1): County-level fiscal expenditures (education, science and culture, social welfare, community development, and environmental protection) have a significant effect on local in-migration.

2.2   The spatial spillover effects of fiscal expenditure in neighboring regions

Internal migration is characterized by strong spatial attributes, as population flows across regions are often influenced by the quality of public services and policy environments in neighboring areas. According to spatial interaction theory, socioeconomic activities exhibit substantial spatial dependence, such that public policies in one region not only affect local residents' migration decisions but also generate externalities for migration patterns in adjacent regions (LeSage and Dominguez, 2012). This implies that county-level fiscal expenditures in education, social welfare, community development, and environmental protection not only enhance local attractiveness but may also indirectly influence in-migration in neighboring jurisdictions through mechanisms of regional competition or cooperation.

Empirical evidence supports this perspective. Lundberg (2006), in his study of local development in Sweden, emphasized that neglecting spatial dependence in traditional regression models leads to underestimation of the external effects of public spending, as local expenditures frequently entail cross-regional spillover effects. Similarly, Song and Yuan (2022), using spatial econometric analysis of public service data in China, found that local government expenditures on education and social services affect not only local populations but also significantly shape development and migration in neighboring regions through strategic interactions and externalities. In the Taiwanese context, Huang et al. (2024) provided spatial econometric evidence demonstrating that county-level expenditures on education and social welfare exert not only positive effects on local in-migration but also significant spatial spillover effects on the in-migration of adjacent counties.

Moreover, externalities arising from community development and environmental protection expenditures have been documented in various studies. Environmental quality and green space, as shared public goods, extend benefits beyond administrative boundaries, thereby enhancing the overall attractiveness of surrounding areas. Vakulenko (2016), examining migration patterns in Russia, similarly found that regional disparities in social welfare and infrastructure spending significantly affect migration in neighboring regions, highlighting the critical role of external fiscal decisions in shaping in-migration flows.

Taken together, these theoretical and empirical insights suggest that county governments' expenditures on education, science and culture, social welfare, community development, and environmental protection not only directly increase local attractiveness to migrants but also exert significant influences on neighboring counties through spatial interactions and regional externalities. Accordingly, this

study proposes the following hypothesis:

Hypothesis 2 (H2): Fiscal expenditures in neighboring counties (education, science and culture, social welfare, community development, and environmental protection) have a significant effect on local in-migration.

2.3 The impact of local urban public facility land use on in-migration

Urban public facility land use constitutes a crucial indicator of urban livability and attractiveness. Through the planning and provision of various public facilities—such as roads, parks, green spaces, sports venues, and plazas—local governments not only meet residents' daily living and transportation needs but also enhance the overall environmental quality and social functions of cities. According to urban economics and location theory, migration decisions are often shaped by factors such as convenience of daily life, accessibility of recreational facilities, and the quality of public spaces (Chen and Rosenthal, 2008). Thus, the extent and effectiveness of urban public facility land use at the county level may be a critical determinant of local in-migration.

Extensive empirical evidence underscores the relationship between public facilities and population flows. First, road infrastructure improves transportation accessibility, significantly affecting urban in-migration. Studies have shown that well-developed planned roads and transportation facilities promote population agglomeration in regions with sound infrastructure (Liu et al., 2015). Second, the provision of parks and green spaces is a key factor in enhancing urban attractiveness. Environmental quality and natural resources serve as critical drivers of in-migration in Chinese cities, while studies of U.S. cities similarly demonstrate that residents are highly sensitive to the accessibility of parks, green areas, and community recreational spaces when choosing migration destinations (Chen and Rosenthal, 2008).

In addition, the social functions of public facilities play an equally important role. Children's playgrounds, sports facilities, and public plazas strengthen community cohesion and improve everyday convenience. Gu and Zhao (2025) show that well-developed recreational facilities in urban areas not only enhance residents' life satisfaction but also increase migrants' willingness to settle or transfer their household registration. Evidence from Taiwan further supports this view: Huang et al. (2024), using spatial econometric models, found that improvements in urban public facilities and living environments significantly attract population inflows and generate spatial spillover effects across counties.

Taken together, the effective use of urban public facility land—including planned road areas, developed park areas, and per capita accessible areas of parks, green spaces, playgrounds, sports facilities, and plazas—enhances urban livability and the supply of public resources, thereby strengthening cities' capacity to attract in-migration. Based on these theoretical and empirical findings, this study proposes the following hypothesis:

Hypothesis 3 (H3): Local urban public facility land use (planned road area, developed park area, and per 10,000 people area of parks, green spaces, playgrounds, sports facilities, and plazas) has a significant effect on county-level in-migration.

2.4 The spatial spillover effects of urban public facility land use in neighboring counties

Internal migration is inherently characterized by cross-regional and networked dynamics, as individuals often consider not only the facilities and living environments of their destination county but also those of neighboring regions when making migration decisions. According to spatial interaction and spillover theory, the supply of urban facilities in one jurisdiction can enhance its residential attractiveness while simultaneously exerting substitution or complementary effects on adjacent areas (LeSage and Dominguez, 2012). For instance, if neighboring counties possess more advanced road networks, improved commuting convenience enhances their own attractiveness but may also increase the residential value of surrounding counties. Similarly, when neighboring counties provide abundant parks, green spaces, or plazas, residents in adjacent areas can indirectly benefit, thereby influencing their migration choices.

Empirical studies provide strong support for this perspective. Lundberg (2006), analyzing local development in Sweden, found that neglecting the infrastructure and development levels of neighboring regions leads to underestimation of the external effects of public facilities. Song and Yuan (2022), in their empirical study of China, further demonstrated that the construction and use of public facilities entail significant regional interactions, with effects frequently transcending administrative boundaries. With respect to leisure and public spaces, Gu and Zhao (2025) emphasize that urban public facilities shape not only the life satisfaction and migration intentions of local residents but also those of populations in neighboring regions.

From an environmental perspective, natural resources and green space represent regionally shared goods whose impacts are not confined to a single city but extend across surrounding areas, thereby reshaping patterns of population mobility. In Taiwan, Huang et al. (2024) provided spatial econometric evidence showing that local living facilities and public investments not only attract in-migration within a county but also exert significant spillover effects on migration patterns in neighboring counties.

Taken together, these theoretical and empirical findings suggest that the use of urban public facility land in neighboring counties—including planned road areas, developed park areas, and per capita accessible areas of parks, green spaces, playgrounds, sports facilities, and plazas—not only influences local in-migration but also significantly shapes population inflows in adjacent counties through spatial spillover effects. Accordingly, this study proposes the following hypothesis:

Hypothesis 4 (H4): Urban public facility land use in neighboring counties (planned road area, developed park area, and per 10,000 people area of parks, green spaces, playgrounds, sports facilities, and plazas) has a significant effect on local in-migration.

3. Methodology

3.1 Data and procedure

This study employs panel data from 22 counties and cities in Taiwan spanning the period 2000–2023 as the basis for empirical analysis. Taiwan's current administrative divisions comprise six special municipalities, thirteen counties, and three provincial cities, which together constitute the highest level of local government in the nation's administrative hierarchy. The statistical data used in this study are primarily drawn from the "Statistical Indicators by County and City" database, publicly released in 2024 by the Directorate General of Budget, Accounting and Statistics (DGBAS). This database provides comprehensive and comparable indicators on fiscal revenues and expenditures, socioeconomic conditions, and industrial structures for each county and city across years, making it well suited for longitudinal and cross-sectional empirical analysis.

Methodologically, the study follows the theoretical framework of spatial econometrics and conducts a series of statistical and model-building procedures. To capture the spatial interactions among Taiwan's counties and cities, a spatial weight matrix was constructed, with a contiguity matrix adopted as the basis for modeling spatial dependence. For model selection, the Spatial Durbin Model (SDM) was employed as the primary analytical framework. A series of diagnostic tests were conducted to determine whether the SDM could be simplified into a Spatial Autoregressive Model (SAR) or a Spatial Error Model (SEM). Furthermore, the Hausman test was applied to compare the appropriateness of fixed-effects versus random-effects specifications for the model's individual effects.

During the model evaluation stage, the study simultaneously considered the Log-Likelihood, Akaike Information Criterion (AIC), and Bayesian Information Criterion (BIC) as measures of model fit. The test results indicated that the SDM with spatial fixed effects was the most appropriate specification and was thus selected as the core framework for subsequent empirical analysis. Finally, effect decomposition was performed on the selected model, allowing for the estimation and interpretation of the direct effects, indirect effects (spatial spillover effects), and total effects of the independent variables on the dependent variable. This approach provides a more comprehensive understanding of the mechanisms through which fiscal expenditure and urban public facility land use influence county-level in-migration.

Through this empirical analysis, the study seeks to offer conclusions that are both theoretically grounded and practically relevant, providing local governments with evidence-based insights for fiscal allocation and policy design aimed at fostering balanced regional population development and enhancing urban competitiveness.

3.2   Sub paragraph One

The definitions and descriptions of the dependent and independent variables in the empirical model are as follows:

Dependent Variable

In-migration population (IM_{it}): Refers to the number of registered household in-migrants in county i of Taiwan in year t, excluding individuals who merely changed addresses within the same jurisdiction.

Independent Variables: Fiscal Expenditure

Education, Science, and Culture Expenditure ($ESCE_{it}$, million NT dollars): Refers to the fiscal expenditure of county i in year t on education, science, and cultural undertakings, including subsidies related to these functions.

Social Welfare Expenditure (SWE_{it}, million NT dollars): Refers to the fiscal expenditure of county i in year t on social welfare, including social insurance, social assistance, welfare services, employment programs, healthcare, and related subsidies.

Community Development and Environmental Protection Expenditure (CEE_{it}, million NT dollars): Refers to the fiscal expenditure of county i in year t on community development and environmental protection, including subsidies allocated to these functions.

Independent Variables: Urban Public Facility Land Use

Planned Road Area (PRA_{it}, hectares): Refers to the planned road land area in county i in year t, designated under urban planning regulations, including roads or alleyways established by legally designated building lines.

Developed Park Area (DPA_{it}, hectares): Refers to the developed park land in county i in year t, as designated under urban planning, provided as open space for public recreational activities and well-being.

Per 10,000 People Area of Parks, Green Spaces, Playgrounds, Sports Facilities, and Plazas ($PGPSP_{it}$, hectares): Refers to the average area of parks, green spaces, playgrounds, sports facilities, and plazas per 10,000 people within the urban planning area of county i in year t. The calculation formula is:

$PGCSSit$ = (Total developed area of parks, green spaces, playgrounds, sports facilities, and plazas within the urban planning area ÷ Population of the urban planning area at year-end) × 10,000

3.3   Empirical model

This study is grounded in Tobler's First Law of Geography, which states: "Everything is related to everything else, but near things are more related than distant things" (Tobler, 1970). This perspective emphasizes the importance of spatial proximity, suggesting that geographically closer regions tend to exhibit stronger interactions and linkages in economic and social activities. In other words, geographical contiguity results in interdependence of regional policies and resource allocation, thereby shaping patterns of population mobility and the spatial structure of regional development.

To capture such spatial dependence and the interactions among neighboring regions, this study adopts the Spatial Durbin Model (SDM) proposed by LeSage and Pace (2009) for empirical analysis. Compared with traditional spatial regression models, the SDM incorporates not only the spatial lag of the dependent variable but also the spatial lags of the independent variables. This allows the model to account simultaneously for local effects and indirect effects arising from neighboring regions, thereby fully revealing cross-regional spatial interactions. This feature makes the SDM particularly suitable for examining the spatial spillover effects among in-migration, fiscal expenditure, and urban public facility land use across counties.

Under this framework, the SDM in this study can be formally expressed as:

$$IM_{it} = \rho \sum_{j=1}^{N} W_{ij}IM_{jt} + \alpha + \beta_1 ESCE_{it} + \beta_2 SWE_{it} + \beta_3 CEE_{it} + \beta_4 PRA_{it}$$

$$+ \beta_5 DPA_{it} + \beta_6 PGPSP_{it} + \theta_1 \sum_{j=1}^{N} W_{ij}ESCE_{jt} + \theta_2 \sum_{j=1}^{N} W_{ij}SWE_{jt}$$

$$+ \theta_3 \sum_{j=1}^{N} W_{ij}CEE_{jt} + \theta_4 \sum_{j=1}^{N} W_{ij}PRA_{jt} + \theta_5 \sum_{j=1}^{N} W_{ij}DPA_{jt}$$

$$+ \theta_6 \sum_{j=1}^{N} W_{ij}PGPSP_{jt} + \mu_i + \varepsilon_{it}$$

$$i \neq j$$

Where IM_{it} is the dependent variable representing the number of in-migrants in county i in year t. Here, i and j denote the 22 counties and cities of Taiwan, and t represents the time dimension covering annual observations from 2000 to 2023.

W_{ij} is the spatial weight matrix, which is a square, symmetric matrix with both rows and columns equal to the number of counties (22 in this study). The Queen contiguity principle is applied in constructing this matrix: if two counties share a common boundary or corner, they are defined as neighbors, and the corresponding element W_{ij} = 1; otherwise, it is set to 0. For the same county ($i = j$), no contiguity is assumed, and thus the diagonal elements are all zero. For Taiwan's three outlying island counties (Penghu, Kinmen, and Lienchiang), which do not share borders with other counties, their adjacency values with all other regions are also set to 0. The spatial weight matrix is defined as follows:

$$W_{ij} = \begin{cases} 1, & \textit{regions i and j are neighboring regions} \\ 0, & \textit{regions i and j are not neighboring regions} \end{cases}$$

$W_{ij}IM_{jt}$ represents the spatially lagged dependent variable, which is an endogenous variable. This term captures the influence of the number of in-migrants in neighboring county j (IM_{jt}) on the number of in-migrants in county i (IM_{it}).

The parameter ρ is the spatial autoregressive coefficient of the dependent variable, reflecting the direction and magnitude of the effect of in-migration in neighboring regions (IM_{jt}) on local in-migration (IM_{it}). A significant ρ indicates the presence of spatial dependence among dependent variables. If $\rho \neq 0$, spatial relationships exist among neighboring regions. A positive ρ ($\rho > 0$) implies positive spatial spillover effects, indicating favorable spillovers. The magnitude of ρ reflects the degree of spatial diffusion or spatial spillovers across regions.

α denotes the constant term. The coefficients β_k are the parameters to be estimated, representing the direct effects of the independent variables on local in-migration. The independent variables include $ESCE_{it}$ (education, science, and culture expenditure), SWE_{it} (social welfare expenditure), CEE_{it} (community development and environmental protection expenditure), PRA_{it} (planned road area), DPA_{it} (developed park area), and $PGPSP_{it}$ (per 10,000 people area of parks, green spaces, playgrounds, sports facilities, and plazas).

The coefficients θ_k correspond to the spatial lag terms of the independent variables, measuring the indirect effects (spatial spillover effects) of fiscal and urban public facility land use variables in neighboring regions on local in-migration. A positive θ indicates positive spillover effects from neighboring areas on IM_{it}, while a negative θ suggests competitive effects among neighboring regions.

μ_i denotes spatial individual effects, reflecting unobserved heterogeneity specific to county i. ε_{it} is the random error term, assumed to be independently and identically distributed, with the possibility of spatial autocorrelation.

4. Results

4.1   Descriptive statistics

Table 1 presents the descriptive statistics of the main variables used in this study, covering 528 observations across 22 counties and cities in Taiwan during the period 2000–2023. The average number of in-migrants (IM) was 52,534, with a standard deviation of 60,285, indicating substantial variation across counties; the minimum number of in-migrants was only 684, while the maximum reached 266,683. The average education, science, and culture expenditure (ESCE) was NT$15,525 million, with a wide range (from 400.57 to 73,385), reflecting significant disparities in educational and cultural investments across counties. Social welfare expenditure (SWE) averaged NT$6,368 million, with a standard deviation of 8,321, likewise highlighting considerable differences in resource allocation for social protection policies. Community development and environmental protection expenditure (CEE) averaged NT$2,422 million, ranging from as low as 63.44 to more than 20,000, suggesting highly uneven concentration of such expenditures among counties.

In terms of urban public facility land use, the average planned road area (PRA) was 1,554 hectares, while the developed park area (DPA) averaged 255 hectares, again indicating large disparities in facility development among counties. Moreover, the average per 10,000 people area of parks, green spaces, playgrounds, sports facilities, and plazas (PGPSP) was 6.07 hectares, though the variation across counties was

substantial, ranging from a minimum of 0.63 to nearly 24 hectares.

Table 2 reports the Pearson correlation coefficients among the main variables. In-migration (IM) is highly positively correlated with ESCE, SWE, CEE, PRA, and DPA, with all coefficients statistically significant at the 1% level. For example, the correlation between IM and ESCE reached 0.850, indicating that counties with higher investments in education and culture tended to experience greater in-migration. By contrast, PGPSP exhibited significant negative correlations with other variables, implying that in some counties, a larger per capita area of parks and recreational spaces did not necessarily correspond to higher levels of in-migration. This outcome may reflect the interplay between urbanization and population density. Overall, the correlation analysis suggests that fiscal expenditure and urban public facility land use are strongly associated with in-migration, though the pathways of influence vary across different variables.

Table 1: Summary of descriptive statistics

Variables	Obs.	Mean	Std. Dev.	Min.	Max.
IM	528	52534.50	60284.64	684.00	266683.00
ESCE	528	15524.99	17128.55	400.57	73384.66
SWE	528	6368.21	8320.84	180.82	44720.84
CEE	528	2421.68	3805.22	63.44	20164.01
PRA	528	1554.05	1568.29	43.00	5919.00
DPA	528	254.75	411.16	7.00	2313.62
PGPSP	528	6.07	5.19	0.63	23.89

Note: Obs.: Observations.
TWD: New Taiwan dollar (equal to USD 0.031).
In-migration population (IM), Education, Science, and Culture Expenditure (ESCE, million NT dollars), Social Welfare Expenditure (SWE, million NT dollars), Community Development and Environmental Protection Expenditure (CEE, million NT dollars), Planned Road Area (PRA, hectares), Developed Park Area (DPA, hectares), Per 10,000 People Area of Parks, Green Spaces, Playgrounds, Sports Facilities, and Plazas (PGPSP, hectares).

Table 2: Pearson correlation analysis

	NRS	GGE	EDE	ESCE	CEE	TR	OATR
IM	1						
ESCE	.850**	1					
SWE	.723**	.942**	1				
CEE	.814**	.932**	.917**	1			
PRA	.815**	.784**	.676**	.691**	1		
DPA	.570**	.729**	.727**	.687**	.783**	1	
PGPSP	-.346**	-.254**	-.171**	-.204**	-.213**	.069	1

Note: ** p<0.01.
TWD: New Taiwan dollar (equal to USD 0.031).
In-migration population (IM), Education, Science, and Culture Expenditure (ESCE, million NT dollars), Social Welfare Expenditure (SWE, million NT dollars), Community Development and Environmental Protection Expenditure (CEE, million NT dollars), Planned Road Area (PRA, hectares), Developed Park Area (DPA, hectares), Per 10,000 People Area of Parks, Green Spaces, Playgrounds, Sports Facilities, and Plazas (PGPSP, hectares).

4.2   Results of the Wald test and Likelihood-ratio test

Following the theoretical frameworks of LeSage and Pace (2009) and Elhorst (2010), the Spatial Durbin Model (SDM), by incorporating both spatially lagged dependent and independent variables, provides greater flexibility and explanatory power than the Spatial Lag Model (SLM) and the Spatial Error Model (SEM). Nevertheless, before conducting empirical analysis, it is necessary to test whether the SDM can be simplified into either the SLM or SEM by evaluating whether the coefficient vector of the spatially lagged independent variables (θ) is significantly different from zero. If the null hypothesis $H_0: \theta = 0$ is rejected, this indicates that spatially lagged independent variables exert significant effects on the dependent variable, thereby supporting the SDM as the more appropriate model specification. In this study, both the Wald test and the Likelihood-Ratio (LR) test were employed to compare the fit of the SLM and SDM across different model structures, including spatial fixed effects, time fixed effects, two-way fixed effects (spatial and time), and random effects. The results are summarized in Table 3. Under the spatial fixed-effects specification, the Wald test yielded $\chi^2=18.15$, p<0.01, while the LR test yielded $\chi^2=17.96$, p<0.01, both indicating that the SDM is superior to the SLM. Under the time fixed-effects model, the Wald and LR tests produced highly significant results ($\chi^2 =77.41$, p<0.001; $\chi^2=34.04$, p<0.001), again rejecting the

simplification hypothesis in favor of the SDM. When both spatial and time fixed effects were included, the Wald test (χ^2 =24.66, p<0.001) and LR test (χ^2=29.06, p<0.001) continued to support the SDM as the most suitable model. Under the random-effects specification, the Wald test (χ^2 =17.68, p<0.01) and LR test (χ^2 =17.48, p<0.01) also confirmed the superior fit of the SDM.

A further comparison between the SDM and SEM was also conducted using both the Wald test and LR test under the four model structures, with results reported in Table 4. Under the spatial fixed-effects model, the Wald statistic was χ^2 =64.16, p<0.001, and the LR statistic was χ^2 =61.82, p<0.001, both strongly favoring the SDM over the SEM. For the time fixed-effects specification, the Wald and LR tests were again significant (χ^2 =38.70, p<0.001; χ^2 =18.17, p<0.01), confirming the robustness of the SDM. With two-way fixed effects, both tests remained highly significant (χ^2 =53.31, p<0.001; χ^2 =42.17, p<0.001), indicating that the SDM continues to outperform the SEM. Finally, under the random-effects model, the Wald test (χ^2 =60.94, p<0.01) and LR test (χ^2 =60.56, p<0.001) once again demonstrated that even without controlling for spatial or temporal fixed effects, the SDM maintains significant explanatory advantages.

Taken together, these results confirm that, regardless of whether fixed-effects or random-effects structures are applied, the SDM consistently outperforms both the SLM and SEM in terms of explanatory power and model fit. Therefore, the SDM is selected as the primary model for subsequent empirical analysis.

Table 3: Spatial lag model (SLM)

Variables	Model 1 SLM with spatial fixed-effects		Model 2 SLM with time fixed-effects		Model 3 SLM with spatial and time fixed-effects		Model 4 SLM with random-effects	
	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
ESCE	0.366**	0.126	2.412***	0.248	0.295*	0.144	0.361**	0.128
SWE	0.033	0.156	-2.933***	0.396	-0.051	0.171	0.014	0.159
CEE	-2.080***	0.420	6.712***	0.701	-1.880***	0.449	-2.162***	0.429
PRA	-8.084**	2.979	17.491***	1.277	-8.045*	3.190	-4.939	3.101
DPA	-32.107*	2.371	-35.262***	4.588	-30.548***	2.528	-32.782***	2.426
PGPSP	470.584**	147.869	-79.235	200.237	404.088*	158.917	467.098**	151.048
Constant							41741.040**	15858.130
n		528		528		528		528
Spatial ρ	0.448***	0.031	-0.003	0.031	0.364***	0.042	0.452***	0.031
within R^2	0.569		0.025		0.562		0.566	
between R^2	0.725		0.971		0.759		0.626	
overall R^2	0.539		0.859		0.572		0.399	
Log-likelihood	-5489.120		-5977.487		-5487.973		-5584.243	
Wald test	$H_0: \theta = 0$ $x^2 = 18.15^{**}$ $p\text{-value} = 0.0059$		$H_0: \theta = 0$ $x^2 = 77.41^{***}$ $p\text{-value} = 0.000$		$H_0: \theta = 0$ $x^2 = 24.66^{***}$ $p\text{-value} = 0.000$		$H_0: \theta = 0$ $x^2 = 17.68^{**}$ $p\text{-value} = 0.0071$	
Likelihood-ratio test	H_0: SLM nested within SDM LR $x^2 = 17.96^{**}$ $p\text{-value} = 0.0013$		H_0: SLM nested within SDM LR $x^2 = 34.04^{***}$ $p\text{-value} = 0.000$		H_0: SLM nested within SDM LR $x^2 = 29.06^{***}$ $p\text{-value} = 0.000$		H_0: SLM nested within SDM LR $x^2 = 17.48^{**}$ $p\text{-value} = 0.0037$	

Note: * p<0.05; ** p<0.01; *** p<0.001
TWD: New Taiwan dollar (equal to USD 0.031).
SLM: Spatial lag model.
SDM: Spatial Durbin model.
Coef.:Coefficient.
Std. Err.: Standard error.
Education, Science, and Culture Expenditure (ESCE, million NT dollars), Social Welfare Expenditure (SWE, million NT dollars), Community Development and Environmental Protection Expenditure (CEE, million NT dollars), Planned Road Area (PRA, hectares), Developed Park Area (DPA, hectares), Per 10,000 People Area of Parks, Green Spaces, Playgrounds, Sports Facilities, and Plazas (PGPSP, hectares).

Table 4: Spatial error model (SEM)

Variables	Model 5 SEM with spatial fixed-effects		Model 6 SEM with time fixed-effects		Model 7 SEM with spatial and time fixed-effects		Model 8 SEM with random-effects	
	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
ESCE	0.348*	0.135	2.098***	0.227	0.321*	0.140	0.364**	0.138
SWE	-0.291	0.183	-3.119***	0.396	-0.201	0.183	-0.311	0.187
CEE	-1.347**	0.414	7.238***	0.636	-1.478**	0.434	-1.410**	0.423
PRA	-7.697**	2.965	20.426***	1.259	-7.007*	3.063	-4.802	3.071
DPA	-26.821***	2.352	-34.455***	4.043	-27.609***	2.443	-27.722***	2.408
PGPSP	245.053	147.438	108.650	188.005	296.045	154.306	249.355	150.543
Constant							65278.20***	16537.14
n		528		528		528		528
Spatial λ	0.572***	0.041	0.364***	0.053	0.368***	0.052	0.576***	0.041
within R^2	0.478		0.018		0.479		0.474	
between R^2	0.757		0.964		0.764		0.750	
overall R^2	0.583		0.858		0.584		0.541	
Log-likelihood	-5511.050		-5956.380		-5494.530		-5605.785	
Wald test	H_0: $\theta+\rho\beta=0$ $x^2 = 64.16***$ p-value = 0.000		H_0: $\theta+\rho\beta=0$ $x^2 = 38.70***$ p-value = 0.000		H_0: $\theta+\rho\beta=0$ $x^2 = 53.31***$ p-value = 0.000		H_0: $\theta+\rho\beta=0$ $x^2 = 60.94***$ p-value = 0.000	
Likelihood-ratio test	H_0: SEM nested within SDM LR $x^2 =61.82***$ p-value = 0.000		H_0: SEM nested within SDM LR $x^2 = 18.17**$ p-value = 0.0032		H_0: SEM nested within SDM LR $x^2 = 42.17***$ p-value = 0.000		H_0: SEM nested within SDM LR $x^2 = 60.56***$ p-value = 0.000	

Note: * p<0.05; ** p<0.01; *** p<0.001
TWD: New Taiwan dollar (equal to USD 0.031).
SEM: Spatial error model.
SDM: Spatial Durbin model.
Coef.:Coefficient.
Std. Err.: Standard error.
Education, Science, and Culture Expenditure (ESCE, million NT dollars), Social Welfare Expenditure (SWE, million NT dollars), Community Development and Environmental Protection Expenditure (CEE, million NT dollars), Planned Road Area (PRA, hectares), Developed Park Area (DPA, hectares), Per 10,000 People Area of Parks, Green Spaces, Playgrounds, Sports Facilities, and Plazas (PGPSP, hectares).

4.3   Results of the Hausman test

To further determine whether the Spatial Durbin Model (SDM) should be specified with fixed effects or random effects, this study employed the Hausman test proposed by Hausman (1978). The Hausman test assesses whether individual (county) or time effects are correlated with the explanatory variables. If such correlation exists, a fixed-effects model is preferred to avoid endogeneity bias. Table 5 reports the Hausman test results under three model specifications, which are explained as follows.

First, when comparing the SDM with spatial fixed effects against its corresponding random-effects specification, the test result was $\chi^2 = 13.59$, $p < 0.05$. This significant rejection of the null hypothesis indicates that the random-effects model suffers from systematic bias, and thus the spatial fixed-effects model is more appropriate. Second, for the SDM with only time fixed effects, the result was $\chi^2 = 417.25$, $p < 0.001$, again strongly rejecting the null hypothesis. This suggests that the random-effects specification is unsuitable in this context, and a time fixed-effects model should be adopted to control for unobserved temporal heterogeneity that is correlated with the explanatory variables. Finally, in the specification incorporating both spatial and time fixed effects, the Hausman test yielded $\chi^2 = 2.98$, $p > 0.05$, failing to reject the null hypothesis. This finding implies that, under such conditions, the random-effects model provides a more appropriate estimation strategy.

In summary, the test results indicate that fixed-effects models are preferable when only spatial or temporal effects are considered. However, when both spatial and temporal effects are simultaneously included, the random-effects model demonstrates superior suitability for estimation.

Table 5: Results of the Hausman Test

	Hausman test		Result
	χ^2	p-value	
SDM with spatial fixed-effects v.s. SDM with random-effects	13.59	0.0346	$H_0: \mathrm{E}(x_{it}, \mu_i) = 0$ Null hypothesis (random-effects model) rejected; adopt SDM with spatial fixed-effects
SDM with time fixed-effects v.s. SDM with random-effects	417.25	0.0000	$H_0: \mathrm{E}(x_{it}, \mu_i) = 0$ Null hypothesis (random-effects model) rejected; adopt SDM with time fixed-effects
SDM with spatial and time fixed-effects v.s. SDM with random-effects	2.98	0.8108	$H_0: \mathrm{E}(x_{it}, \mu_i) = 0$ Null hypothesis (random-effects model) not rejected; adopt SDM with random-effects

4.4 Spatial Durbin model analysis results

Table 6 summarizes the empirical results of the four estimated Spatial Durbin Models (SDM) under different fixed- and random-effects specifications. Based on the results of the Hausman test discussed earlier, Model 11 (SDM with spatial and time fixed-effects) and Model 12 (SDM with random-effects) did not provide relatively robust estimates and were therefore excluded from the subsequent analysis. The focus of this study is thus on the comparison between Model 9 (SDM with spatial fixed-effects) and Model 10 (SDM with time fixed-effects).

The models were estimated using the Maximum Likelihood Estimation (MLE) method, and their performance was evaluated using three model fit criteria: Log Likelihood (LL), Akaike Information Criterion (AIC), and Schwarz Bayesian Information Criterion (SBC or BIC). Theoretically, the optimal model should exhibit the highest log-likelihood value while simultaneously minimizing the AIC and BIC values, thereby achieving a balance between data fit and model parsimony. The comparison results indicate that Model 10 (SDM with time fixed-effects) outperforms Model 9 across all three evaluation criteria. Specifically, Model 10 achieves a higher log-likelihood value as well as lower AIC and BIC scores, demonstrating superior explanatory and predictive power. However, when considering both theoretical appropriateness and the specific research context, this study ultimately selects Model 9 (SDM with spatial fixed-effects) as the primary analytical framework for subsequent effect decomposition and policy inferences.

In the estimation results of Model 9, the spatial lag coefficient is positive and statistically significant, suggesting that in-migration exhibits significant positive spatial autocorrelation. In other words, an increase in in-migration in neighboring counties stimulates in-migration growth in the local county, reflecting the presence of regional complementarities and spatial interdependencies in population movements. This finding aligns with Tobler's First Law of Geography, which states that "near things are more related than distant things."

In sum, although Model 10 demonstrates superior statistical performance, Model 9 is theoretically more consistent with the study's objectives and offers stronger explanatory power. As such, Model 9 not only reveals the spatial interaction mechanisms of in-migration among Taiwan's counties and cities but also provides the empirical foundation for subsequent effect decomposition and policy recommendations.

Table 6: Spatial Durbin model analysis results

Variables	Model 9 SDM with spatial fixed-effects		Model 10 SDM with time fixed-effects		Model 11 SDM with spatial and time fixed-effects		Model 12 SDM with random-effects	
	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
ESCE	0.512***	0.132	1.955***	0.258	0.433**	0.146	0.511***	0.135
SWE	-0.216	0.178	-2.649***	0.407	-0.226	0.183	-0.234	0.181
CEE	-1.768***	0.428	4.830***	0.715	-1.540**	0.457	-1.835***	0.436
PRA	-7.669*	2.992	21.859***	1.381	-7.563*	3.221	-4.514	3.114
DPA	-33.502***	2.498	-27.756***	4.717	-33.482***	2.624	-34.186***	2.551
PGPSP	488.949**	149.621	-669.913**	224.081	468.539**	158.675	484.051**	152.571
W×ESCE	-0.462**	0.174	0.694	0.433	-0.667**	0.211	-0.478**	0.178
W×SWE	0.801**	0.257	1.566*	0.651	0.796**	0.290	0.790**	0.263
W×CEE	-0.877	0.569	-4.232***	1.118	-0.854	0.631	-0.883	0.580
W×PRA	-4.517	5.844	-16.229***	3.108	-4.063	6.897	-3.950	5.616
W×DPA	-2.058	4.466	-3.915	7.020	-5.549	4.825	-1.381	4.547
W×PGPSP	520.245	306.101	73.763	417.817	671.423	344.528	486.111	312.203
Constant							49463.260**	17774.50
n		528		528		528		528
Spatial ρ	0.423***	0.047	0.368***	0.055	0.317***	0.055	0.431***	0.046
within R^2	0.590		0.030		0.584		0.589	
between R^2	0.670		0.970		0.703		0.650	
overall R^2	0.513		0.853		0.535		0.430	
Log-likelihood	-5480.143		-5960.467		-5473.445		-5575.503	
AIC	10980.29		11934.93		10966.89		11173.01	
BIC	11022.98		11964.82		11009.58		11219.97	

Note: * $p<0.05$; ** $p<0.01$; *** $p<0.001$
TWD: New Taiwan dollar (equal to USD 0.031).
SDM: Spatial Durbin model.
Coef.:Coefficient
Std. Err.: Standard error.
Education, Science, and Culture Expenditure (ESCE, million NT dollars), Social Welfare Expenditure (SWE, million NT dollars), Community Development and Environmental Protection Expenditure (CEE, million NT dollars), Planned Road Area (PRA, hectares), Developed Park Area (DPA, hectares), Per 10,000 People Area of Parks, Green Spaces, Playgrounds, Sports Facilities, and Plazas (PGPSP, hectares).

4.5   Decomposition results of the SDM with spatial fixed-effects

LeSage and Pace (2009) argue that since the Spatial Durbin Model (SDM) simultaneously incorporates spatial lags of both the dependent and independent variables, interpreting results solely based on coefficient estimates often fails to capture the true marginal effects of explanatory variables. This discrepancy arises from the feedback effects inherent in spatial models, wherein the influence of an independent variable on both local and neighboring dependent variables can circulate back to the original unit, thereby causing a divergence between estimated coefficients and actual impacts (LeSage and Pace, 2009). To address this, the SDM effects must be decomposed into three components: direct effects, indirect effects (i.e., spatial spillover effects), and total effects. Following the methodology of Elhorst (2010), this study conducted such a decomposition for the final chosen SDM

with spatial fixed-effects. The results are presented in Table 7.

The findings in Table 7 reveal several important patterns. Education, science, and culture expenditure (ESCE) exerts a significant positive direct effect on in-migration (0.489, $p < 0.001$). However, its indirect effect is negative and statistically insignificant, resulting in a total effect that is only weakly positive and insignificant. This suggests that the impact of ESCE is primarily localized, without substantial spillover benefits to neighboring regions. In contrast, social welfare expenditure (SWE) shows insignificant direct effects but significant positive indirect (0.982, $p < 0.01$) and total effects (0.838, $p < 0.05$), highlighting the cross-regional spillover effects of welfare policies in shaping migration flows.

Community development and environmental protection expenditure (CEE) exhibits consistently negative effects across all dimensions, with a significant direct effect (-1.905, $p < 0.001$), indirect effect (-2.170, $p < 0.01$), and total effect (-4.076, $p < 0.001$). This indicates that such expenditures not only fail to attract in-migrants but may also reinforce outward migration through spatial interdependencies. Similarly, the planned road area (PRA) shows significant negative impacts, with a direct effect of -8.722 ($p < 0.01$) and a total effect of -19.640 ($p < 0.05$), suggesting that large-scale road development may be associated with land-use pressures and urban congestion effects.

A noteworthy finding is that developed park area (DPA) consistently exerts highly significant negative effects across all decompositions: direct (-35.337, $p < 0.001$), indirect (-22.657, $p < 0.001$), and total (-57.994, $p < 0.001$). This suggests that large-scale park facilities may not necessarily attract in-migration, possibly reflecting the scarcity of land and high housing costs in core urban areas where such facilities are concentrated. By contrast, the per 10,000 people area of parks, green spaces, playgrounds, sports facilities, and plazas (PGPSP) demonstrates significant positive effects. Both the direct effect (581.021, $p < 0.001$) and indirect effect (1,040.369, $p < 0.05$) are strongly positive, leading to a significant total effect (1,621.390, $p < 0.01$). This underscores that accessibility-based per capita indicators are more effective than aggregate facility measures in capturing the attractiveness of public facilities for in-migration.

Overall, the decomposition results highlight the differentiated impacts of fiscal expenditure and urban public facility planning on migration inflows. While education and social welfare expenditures exhibit positive influences—particularly with welfare spending generating strong cross-regional spillovers—community development spending, road area, and park area demonstrate negative effects, likely reflecting the unintended side effects of urbanization. In contrast, per capita recreational space availability emerges as a critical factor in enhancing quality of life and accessibility, thereby serving as an important strategy for attracting migrants.

Table 7: Direct, indirect, and total effects of SDM with spatial fixed-effects

Variables	Direct Effect		Indirect Effect		Total Effect	
	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
ESCE	0.489***	0.139	-0.347	0.241	0.142	0.302
SWE	-0.145	0.171	0.982**	0.310	0.838*	0.337
CEE	-1.905***	0.430	-2.170**	0.811	-4.076***	1.038
PRA	-8.722**	3.037	-10.918	8.169	-19.640*	9.742
DPA	-35.337***	2.448	-22.657***	6.319	-57.994***	7.602
PGPSP	581.021***	163.242	1040.369*	469.946	1621.390**	570.010

Note: * p<0.05; ** p<0.01; *** p<0.001
TWD: New Taiwan dollar (equal to USD 0.031).
Coef.:Coefficient.
Std. Err.: Standard error.
Education, Science, and Culture Expenditure (ESCE, million NT dollars), Social Welfare Expenditure (SWE, million NT dollars), Community Development and Environmental Protection Expenditure (CEE, million NT dollars), Planned Road Area (PRA, hectares), Developed Park Area (DPA, hectares), Per 10,000 People Area of Parks, Green Spaces, Playgrounds, Sports Facilities, and Plazas (PGPSP, hectares).

5. Conclusion and Suggestions

5.1 Conclusion

This study, based on panel data from 22 counties and cities in Taiwan covering the years 2000–2023, employs spatial econometric methods to investigate the effects of fiscal expenditure and the use of urban public facility land on county-level in-migration, while further examining the spatial spillover effects of neighboring regions. Using the Spatial Durbin Model (SDM) as the analytical framework, the study conducted a series of specification tests to determine the appropriateness of fixed-effects settings, followed by effect decomposition to distinguish between direct, indirect, and total effects.

The empirical results indicate that education, science, and culture expenditure exerts a significant positive impact on in-migration, primarily through local effects, underscoring the importance of investments in education and culture for enhancing urban attractiveness. While social welfare expenditure did not demonstrate significance in its direct effects, its indirect and total effects were both positive and significant, suggesting that welfare policies often extend beyond administrative boundaries, generating attractiveness for neighboring counties and highlighting their spillover characteristics. By contrast, community development and environmental protection expenditures, as well as the total area of roads and parks within public facility land, displayed negative effects. This may reflect the fact that such investments, in highly urbanized areas, are often accompanied by land-use pressures and rising living costs, thereby reducing incentives for in-migration. However, per capita-based indicators of public facility provision, particularly the area of parks, green spaces, playgrounds, sports facilities, and plazas per 10,000 people, demonstrated strong positive effects. This suggests that accessibility and equitable distribution of public space play a more decisive role in shaping migration

decisions than aggregate facility size.

Overall, the findings confirm the importance of fiscal expenditure and urban public facility land use in shaping internal migration processes while further revealing the presence of spatial spillover effects. The results not only support Tobler's First Law of Geography, which emphasizes spatial dependence, but also supplement traditional regression analyses by capturing interregional interactions that are otherwise overlooked. From a policy perspective, the study suggests that local governments, when promoting public expenditure and urban planning, should account not only for local demand but also for interactions with neighboring counties to avoid zero-sum competition in resource allocation and instead leverage spillover effects to foster regional cooperation and balanced population development. Particularly in the context of simultaneous population concentration and declining fertility, strengthening social welfare policies and improving the accessibility of public facilities will be crucial strategies to enhance urban attractiveness and promote more rational cross-regional migration flows.

5.2   Policy suggestions

The empirical results of this study reveal that local fiscal expenditures and the use of urban public facility land exert significant yet complex effects on in-migration, with notable spatial spillover effects across regions. These findings provide important insights for Taiwan's efforts to promote balanced regional development and formulate population policies.

First, the significant positive impact of education, science, and culture expenditure on local in-migration underscores the central role of educational resources and cultural facilities in enhancing local attractiveness. Local governments should continue to strengthen investments in education and cultural infrastructure, both to cultivate human capital and to foster cultural advantages that attract young and professional populations to settle. In addition, the spillover effects of social welfare expenditure indicate that welfare policies not only improve the well-being of local residents but also enhance the attractiveness of neighboring regions. Accordingly, welfare planning should incorporate cross-regional cooperation and resource sharing to avoid interregional welfare competition, while policy design should emphasize equitable improvements in overall population welfare.

On the other hand, the empirical evidence also shows that community development and environmental protection expenditures, along with total areas of roads and parks, do not promote in-migration as expected but instead have negative effects. This outcome may reflect the unintended side effects of urbanization, such as increased land-use pressures, rising living costs, and escalating housing prices. Policymakers should therefore integrate cost-of-living controls and livability enhancement measures into large-scale development projects to prevent public investment from inadvertently deterring in-migration. At the same time, this study finds that per capita accessibility to recreational facilities—such as the area of parks, green spaces, playgrounds, and plazas per 10,000 residents—exerts significant positive effects on

population flows. This suggests that "equitable distribution" and "accessibility" are more critical than merely expanding the total supply of facilities. In other words, policies should shift from emphasizing the "quantity" of facilities toward enhancing their "quality," by optimizing per capita provision and spatial accessibility to maximize the attractiveness of public infrastructure.

In sum, this study recommends that governments consider not only the internal development needs of individual counties but also the interactive effects and potential spillovers across regions when designing fiscal expenditure and urban planning policies. Only through cross-county policy coordination, strengthened investment in education and welfare resources, and equitable allocation of public facilities can Taiwan effectively enhance local competitiveness, promote a more balanced population distribution, and establish a more sustainable foundation for regional development in the face of declining fertility and accelerating population aging.

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