Analysing the impact of migration flows on regional per capita GDP in Türkiye: a spatial panel data approach

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Abstract

This paper investigates the effects of net international and internal migration on per capita GDP in Türkiye's 81 provinces. Unlike prior research, it analyses both migration types within the same spatial panel model and accounts for spatial dependence. The first model (2016-22) examines overall migration effects, the second (2009-22) focuses on the effects of migrants' educational levels. We find that net international immigration significantly boosts per capita, GDP, with highly educated migrants contributing more to growth. The robustness checks further highlight the complementary role of financial deepening in boosting regional economic performance.

Keywords: internal migration, international migration, financial inclusion, per capita GDP, spatial panel data analysis

1 INTRODUCTION

Migration is a complex phenomenon influenced by – and at the same time influencing – many economic, social, cultural and political developments. Over recent years, international migration has gained considerable traction in public and political debates around the world. However, it is important to remember that migration not only takes place internationally, i.e., across national borders, but also internally, i.e., between different regions of a given country. The literature typically focuses on one or the other form of migration: most often, human capital growth models are used to study international migration, and convergence models are used for internal migration. This paper looks at the effects of both international and internal migration on regional economic growth in Türkiye.

Due to its location at the nexus between Asia and Europe, Türkiye has long been a significant transit and destination state for migrants. In recent years, the country has experienced a rise in international migration: the number of international migrants increased from around 381,000 in 2016 to 494,000 in 2022 (TurkStat), amounting to approximately 0.6% of the Turkish population. This increase was mostly a result of the war in Ukraine – the number of migrants from Russia and Ukraine increased from around 13,000 in 2016 to 132,000 in 2022 (TurkStat) – and emigration from the Middle Eastern countries. This is a relatively modest number compared to some other countries: Poland, for example, had migration equal to 2.7% of its population in 2022. According to Eurostat, there were 2 million Ukrainians in Poland before the war in Ukraine, whereas 5.4 million came after the start of the war in 2022, to a population of 36 million. In 2023, the number of new migrant arrivals in Spain was approximately 2.5% of the total population, while in Greece it was just over 1%. While the change in immigration to Türkiye has been less pronounced than elsewhere, this is precisely what makes it a good case study: immigration numbers have actually remained relatively stable, and there are unlikely to be outsize effects from irregular migrant flows.

Given the scale of international and internal migration, it is natural to ask what its macroeconomic effects have been. Most of the literature considers the effects of international and internal migration separately, at aggregate country level, and does not distinguish between different types of migrants. We consider the effects of both types of migration simultaneously, and study them at the regional level, using a unique dataset covering all of Türkiye's 81 provinces. This setup provides an opportunity to analyse the relationship between migration and economic growth in greater depth. Moreover, we look at how migrants with different education levels affect regional growth.

Empirical studies directly testing this effect are rare (Chen, 2006; Orefice, 2010; Di Maria and Lazarova, 2012; Boubtane, Dumont and Rault, 2016; Șerban et al., 2020). We believe that this study is among the first to analyse the effect of settled migrants' educational levels on per capita GDP using the spatial panel data approach.

Our main finding is that migration contributes positively to Türkiye's regional economic performance, although the magnitude of the effect differs by migrant type. Specifically, international migration has a small but positive impact on per capita GDP, while internal migration driven by educated individuals significantly enhances regional income levels. In contrast, less educated internal migrants have an insignificant effect, implying that their movement neither hampers nor improves regional per capita income. These results highlight the importance of human capital in shaping the economic impact of migration.

To check the robustness of our baseline result, we added a lagged dependent variable (to account for trend population growth) and indicators of financial inclusion such as population per bank branch and per capita bank deposits, which have been shown in the literature to affect per capita GDP growth (e.g. Kim, Yu and Hassan, 2018; Sonkar and Sarkar, 2020; Kanga et al., 2022; Afonso and Blanco-Arana, 2024). The robustness checks confirm the stability of our main empirical results. The inclusion of a lagged dependent variable, time trend, and financial inclusion indicators does not alter the direction or significance of estimated relationships. Moreover, when spatial dependencies are accounted for through spatial autoregressive models with additional autoregressive error structure (SARAR), the positive link between migration and per capita GDP remains intact. This consistency across model specifications suggests that our baseline findings are robust to variations in model design.

The remainder of this paper is structured as follows. Section 2 reviews the literature on migration and growth. Section 3 describes the data and lays out the estimating framework. Section 4 presents the estimation results. Section 5 discusses the robustness of our baseline model specification. Section 6 concludes.

2 LITERATURE REVIEW

The relationship between economic development and migration has long been regarded as a foundational yet intricate area of inquiry. This complexity stems from different ways in which migration impacts economies, including labour market dynamics, human capital accumulation, and spatial interactions. To provide an overview of the existing empirical research, studies examining the relationship between migration and economic growth are summarised in appendix table A1. This summary table serves as a framework for positioning the present study within the broader literature. As seen in the table, most existing studies analyse either international or internal migration separately and generally focus on country-level data. To our knowledge, there are no studies that have addressed both dimensions simultaneously or examined how migrants' characteristics influence regional economic outcomes – an area to which this study contributes. Moreover, studies employing the spatial panel data analysis method, which accounts for spatial dependence, are quite limited (e.g. Vakulenko, 2014; Manavgat and Saygılı, 2016; Yürük and Batmaz, 2023).

In the broader study of immigration, research dating back to Ravenstein (1885) both explores and explains the complexity of international and internal migration. More recently, Greenwood (1975; 1997) examined internal migration in advanced economies, Lucas (1997) addressed internal migration from the perspective of developing economies, Borjas (1999) analysed the phenomenon of migration on an international scale, and Etzo (2008) surveyed the literature on internal migration.

In studies of migration and economic growth specifically, three dominant frameworks have emerged: early Solow-Swan growth models, human capital models, and convergence models. The early models treated migration as an extended version of the traditional Solow-Swan growth model with a production technology that features declining marginal productivity of labour. In such models, population growth is traditionally associated with negative effects on per capita productivity and per capita income growth (see e.g. Dolado, Goria and Ichino, 1994).

Human capital and convergence models both evolved from the Solow-Swan growth model, but they have been typically used in different contexts: the former is favoured in studies of international migration, and the latter in those of internal migration. This is because international migration often implies a skill or human capital differential between migrants and locals, whereas internal migration processes are often understood as a rebalancing or convergence between regional labour markets and wages. For clarity, this literature review will first look at research on international and internal migration separately, with the latter focussing on Türkiye, and then identify some of the gaps in the literature.

2.1 INTERNATIONAL MIGRATION

There is little consensus on whether international migrants contribute to the economic growth of the host country. Some evidence is positive: Mariya and Tritah (2009) found that migration generally led to an increase in income of the host country, and Docquier, Peri and Ruyssen (2014) established a positive correlation between GDP growth and migration rates. Others showed more modest effects: Bashier and Siam (2014) found that migrants had a positive but insignificant effect on real GDP, and Öztop, Köse and Ünlü (2024) identified a statistically significant yet quantitatively small effect of foreign nationals arriving in Türkiye on province-level GDP. Another set of studies suggests the existence of a negative relationship between net migration and economic growth (Güner and Yalınız, 2013; Sevinç et al., 2016).

When account is taken of factors such as skill level, time, and age distribution, the picture becomes even more varied. Some models found that skilled migration flows had a less negative impact on per capita income growth than overall population growth (Barro and Sala-i-Martin, 2004; Dolado, Goria and Ichino, 1994). Boubtane, Dumont and Rault (2016), Orefice (2010) and Șerban et al. (2020) measured migrants' human capital based on their educational attainment and found it to be positively correlated with per capita GDP growth in host countries. Kang and Kim (2018) highlighted the role of migration from developed economies in enhancing growth of developing countries through the transfer of advanced knowledge and skills. But Chen (2006) and Di Maria and Lazarova (2012) found that skilled labour migration, regardless of origin, negatively affected economic growth of the host country.

With regard to the time dimension, Brunow, Nijkamp and Poot (2015) concluded that net migration helped raise growth in the long run in both developed and developing economies, but they could not detect a statistically significant relationship between migration and growth in the short run. By contrast, Ortega and Peri (2009) showed that migration increased the overall GDP level of the host country in the short run and was neutral in the long run.

In a study that considered the age of migrants, Aleksynska and Tritah (2015) found that a high proportion of young immigrants had a negative impact on host country per capita income, whereas a high proportion of older immigrants had a positive effect.

Another strand of the literature, often using the cointegrating framework, focused on the direction of causality between migration and growth, as the decision to emigrate was shown to be largely driven by differences in GDP levels (Draženović, Kunovac and Pripužić, 2018). Felbermayr, Hiller and Sala (2010) and Göv and Dürrü (2017) thus claimed that the causality ran from migration to growth; Boubtane, Coulibaly and Rault (2013a) and Morley (2006) that it ran from growth to migration; while Boubtane, Coulibaly and Rault (2013b) and Altunç, Uçan and Akyıldız (2017) emphasised a positive bidirectional relationship.

Our study addresses both internal and international migration, and distinguishes between domestic and foreign citizens among international migrants, as well as between skilled and unskilled internal migrants. Using a spatial panel data rather than a cointegrating framework we assess how these different types of migrants affect regional per capita GDP. This perspective complements the predominantly country-level analysis and contributes to a better understanding of the spatial dimension of migration and economic growth.

2.2 INTERNAL MIGRATION

Studies examining the relationship between internal migration and economic growth have also been inconclusive. Theoretical models generally predict that a migrant will move from low- to higher-wage regions, or to regions where the expected wage is higher (Bauer and Zimmermann, 1999).

The empirical work has mostly relied on convergence models to explain the effects of migration on growth. In early contributions, Barro and Sala-i-Martin (1992; 2004) found that net migration had a positive but insignificant effect on growth. This finding was echoed in several other studies (Bayraktar and Özyılmaz, 2019; Foldvari, van Leeuwen and van Zanden, 2013; Huber and Tondl, 2012; Özgen, Nijkamp and Poot, 2010; Peri, 2010). Studies of spatial interactions in migration, triggered for example by income differentials and labour market conditions in neighbouring regions, have been less common (see e.g. LeSage and Fischer, 2009).

When looking at Türkiye specifically, Özyılmaz and Bayraktar (2021) established that net internal migration increased growth in all of its NUTS-2 regions. Manavgat and Saygılı (2016) found that, as surplus labour moved from lower-productivity provinces, per capita income increased both in the provinces the migrants left and in those to which they relocated. Ulucan (2022) also noted that increases in per capita income in a given province contained emigration from that province and attracted a significant immigration from other provinces. This finding supports the view that income differences are the primary driver of internal migration, while demographic structure and education level of workers explain in addition which provinces receive or release domestic migrants. Yürük and Batmaz (2023) found that there was no statistically significant relationship between the extent of internal immigration and economic growth, but provinces that lost part of their workforce experienced a significant slowdown in growth. As in the case of international migration, it is important consider the direction of causality: there are studies suggesting that economic growth leads to internal migration (Bunea, 2012; Ghatak, Mulhern and Watson, 2008; Zhang and Song, 2003) rather than the opposite.

In contrast to these studies, Kırdar and Saraçoğlu (2012) found that internal migration had a negative effect on regional growth in Türkiye. Huber and Tondl (2012) found a similar negative long-term effect on per capita GDP of migrant-sending regions in the EU. Vakulenko (2014) looked at regional migration and per capita income differences in Russia and found a negative relationship between these two variables. Ortega (2008) reported that that regional migration in Spain slowed per capita income growth. Borozan (2017) found that the effect of net migration on long-term economic growth in Croatia was insignificant.

The level of human capital was found to be quite important in explaining the relationship between migration and growth. Several studies found a statistically significant and positive relationship between the share of highly educated settled migrants and per capita GDP (Akbari and Haider, 2018; Özyılmaz and Bayraktar, 2021). Pouliakas et al. (2009) found that migration of highly skilled workers led to productivity losses in certain regions in Greece, while migration of unskilled workers had a positive effect on regional GDP.

Building on these insights, our research explores how internal migration interacts with regional economic performance once spatial dependence and spillover effects – i.e. the influence of migration and economic conditions in one region on growth outcomes of geographically neighbouring regions – are explicitly modelled. While previous studies have generally relied on non-spatial models or national-level data, our study incorporates spatial interactions, regional data, as well as the education level of migrants.

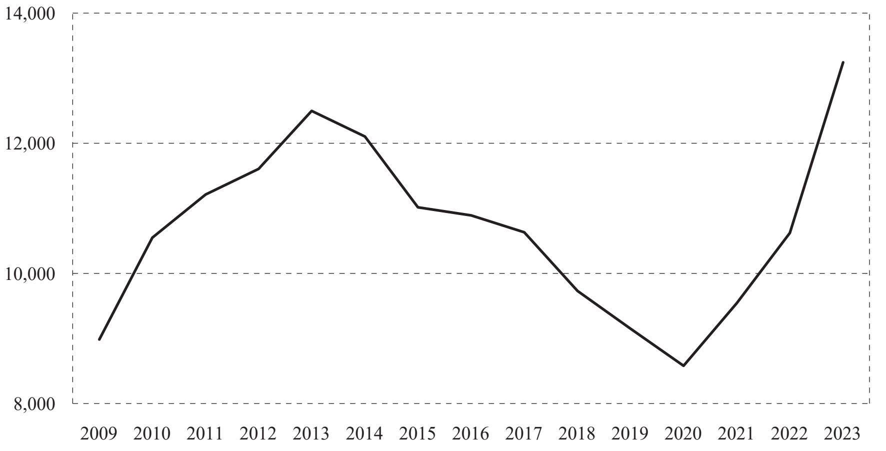
3 DATA AND EMPIRICAL FRAMEWORK

The dataset covers two periods, 2009-22 and 2016-22, for which the most comprehensive migration data are available and when intensive migration flows into and within Türkiye took place. The migration data comprise net international and net internal migration; the latter is also broken down by education status for all of Türkiye's 81 NUTS-3 (Nomenclature of Territorial Units for Statistics) provinces. The migration data were obtained from the Turkish Statistical Institute (TÜİK). Net internal migration is defined as the difference between the in-migration and out-migration in a province, while net international migration is defined analogously for the country as a whole. Since the data are regularly compiled from the address-based population registration system, foreigners with short-term visas or residence permits, as well as Syrians present in the country with temporary protection status, are not considered.[1]

We use the level of per capita GDP in US dollar terms as the dependent variable. Figure 1 shows the evolution of per capita GDP at the country level.

[1] According to the Presidency of Migration Management of Türkiye (2024), around 2.5 million Syrians were living in the country in 2023 with temporary protection status. In addition, over 75,000 Syrians had residence permits, while about 239,000 people of Syrian origin had acquired Turkish citizenship. In addition, around 1.1 million foreigners had short-term residence permits. These groups add up to some 3% of the total population of Türkiye but are not included in the statistics of the address-based population registration system.

Figure 1
Republic of Türkiye per capita GDP in US dollars, 2009-23



Source: Turkish Statistical Institute; authors' estimates.

We checked the stationarity of per capita GDP levels with unit root tests at both provincial and country levels. The augmented Dickey-Fuller (ADF) test, incorporating a deterministic trend and employing the Akaike Information Criterion (AIC) for lag selection, showed that within the 2009-22 panel, a trend was present in 8 of the 81 provinces at the 5% significance level; in the remaining 73 provinces there was no statistically significant trend. For the shorter 2016-22 subsample, only 5 provinces had a significant trend, with the other 76 exhibiting none. The cross-sectionally augmented Im, Pesaran, and Shin test (CIPS) test developed by Pesaran (2007) indicated that the panel dataset was stationary in first differences for both subsamples (with $p < 0.01$). Nevertheless, we checked for robustness of the baseline specification in levels by adding a lagged per capita GDP level and time trend to the regressions (see table 3).

Our first model covers both international (*INM*) and internal net migration (*IM*), with net migration measured as a percentage of the population in the country or a province period t. Among people migrating internationally, we consider separately both domestic (INM^D) and foreign (INM^F) citizens. For the data set containing observations on Turkish provinces, denoted $i = (1, ..., N)$, assumed to be observable over the entire period, $t = (1, ..., T)$ (with no attrition or missing data), our first model can be represented as:

$$ln(GDPpc)_{it} = \beta_0 + \beta_1 IM_{it} + \beta_2 INM_{it}^D + \beta_3 INM_{it}^F + v_{it} \qquad (1a)$$

where the composite error term $v_{it} = \mu_i + \lambda_t + \varepsilon_{it}$ includes time-invariant province-specific effects (μ_i), time-specific effects capturing common macroeconomic shocks affecting all provinces simultaneously (λ_t), and an error term ε_{it} assumed to be independently and identically distributed with zero mean and constant variance σ_i^2.

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We test the following three hypotheses:

H1: $\beta_1 > 0 \rightarrow$ Internal net migration positively affects the per capita GDP of a province.

H2: $\beta_2 > 0 \rightarrow$ International net migration of the domestic population has a positive effect on the per capita GDP of a province.

H3: $\beta_3 > 0 \rightarrow$ International net migration of foreign nationals has a positive effect on the per capita GDP of a province.

Equation (1a) describes the overall effect of net migration on per capita GDP. Other things equal, net migration inflows increase labour supply and raise potential output and hence per capita GDP (Mariya and Tritah, 2009; Docquier, Peri and Ruyssen, 2014; Özyılmaz and Bayraktar, 2021). However, as internal migration in Türkiye comprises mainly low-skilled rural-urban movements, it might also affect per capita GDP of a province negatively (Kırdar and Saraçoğlu, 2012). The sign of the β_1 coefficient is thus a priori indeterminate.

Similarly, the signs of β_2 and β_3 coefficients are *a priori* indeterminate as they depend, among other factors, on the skills composition of domestic workers leaving and foreign workers entering Türkiye. For different samples, Kang and Kim (2018), for example, estimated these coefficients to be positive, while Chen (2006) and Di Maria and Lazarova (2012) estimated them to be negative.

In the second model we analyse internal migration. We consider separately internal migrants with at least a bachelor's degree (IM^B) and those without a bachelor's degree (IM^{NB}):

$$ln\left(GDPpc\right)_{it} = \alpha_0 + \varnothing_1 IM_{it}^{NB} + \varnothing_2 IM_{it}^{B} + u_{it} \tag{1b}$$

where u_{it} is the composite error term $u_{it} = \mu_i + \lambda_t + \varepsilon_{it}$ defined analogously to equation (1a).

For this model, we test two additional hypotheses:

H4: $\varnothing_1 < 0 \rightarrow$ Low-skilled net internal migration negatively affects the per capita GDP of a host province.

H4: $\varnothing_2 > 0 \rightarrow$ High-skilled net internal migration positively affects the per capita GDP of a host province.

In the empirical literature there is a somewhat greater consensus on the expected signs of coefficients $\varnothing_1$ and $\varnothing_2$: net inflow of low-skilled workers is generally estimated to dampen per capita GDP of the host province (e.g. Özyılmaz and Bayraktar, 2021), while net inflow of high-skilled workers is generally estimated to raise the per capita GDP of the host province through the positive effect on its potential output (e.g. Akbari and Haider, 2018).

3.1 SPATIAL PANEL MODEL

Spatial panel models help exploit both observable and unobservable heterogeneity among provinces. The former comprises differences in per capita GDP levels, the latter, e.g. differences in spatial structure such as the nature of provincial borders, location and distance of settlements, transportation and agglomeration infrastructures, industrial structures, etc. These characteristics influence migration decisions in origin regions and result in variability in regression coefficients, which could result in biased estimates if not accounted for, as e.g. in non-panel or non-spatial settings used in cross-sectional regressions (Anselin, Gallo and Jayet, 2008).

The use of the spatial panel model also improves the accuracy of estimates for larger sample sizes. As spatial dependence increases in large sample sizes, test power decreases and rejection rates in right-tailed tests approach zero. The spatial panel model prevents this loss of power by accounting for effects of neighbouring units (Kang, 2018). Spatial panel models also allow a better modelling of dynamic relationships across multiple time periods. For example, Pu et al. (2019) demonstrate that interprovincial migration flows in China exhibit strong temporal dependence and spatial spillovers. They use a spatial dynamic panel model to decompose migration effects over contemporaneous, short-run, and long-run periods, showing how spatial panel models can be efficient in capturing dynamic relationships over time.

4 ESTIMATION RESULTS

To assess the impact of migration dynamics on per capita GDP in Türkiye, two spatial panel data models are estimated. Panel A analyses the effects of internal migration (IM), international domestic and foreign migration (INM^D, INM^F) on the per capita GDP of Türkiye's 81 provinces. Panel B disaggregates internal migration by education level, examining the effects of migrants with higher (IM^B) and lower education (IM^{NB}) on per capita GDP at the provincial level. All variables associated with internal and international migration are expressed in terms of net migration. Descriptive statistics and definitions of variables are shown in appendix table A2.

Table 1 presents estimates for pooled data, fixed effects (within), and random effects models without considering spatial autocorrelation. These estimates serve as a diagnostic step in analysis, enabling us to assess whether ignoring spatial dependence introduces a significant bias in estimates.

Intuitively, the pooled data model treats the entire sample as a single cross-section repeated over time and estimates the *average* effect of migration on per capita GDP (equations (1a) and (1b)). The fixed effects model eliminates any fixed differences between provinces via province-specific intercepts α_i, which are potentially correlated with regressors, and examines only changes over time, assuming that $\varepsilon_{it} \sim N\left(0,\sigma^2\right) i.i.d.$:

$$\ln\left(GDPpc\right)_{it} = \beta_{10} + \beta_{20} IM_{it} + \beta_{31} INM_{it}^{D} + \beta_{32} INM_{it}^{F} + \alpha_i + \varepsilon_{it} \quad (2a)$$

$$\ln\left(GDPpc\right)_{it} = \alpha_0 + \alpha_1 IM_{it}^{NB} + \alpha_2 IM_{it}^{B} + \alpha_i + \varepsilon_{it} \quad (2b)$$

The random effects model treats the unobserved heterogeneity as random effects ($\varepsilon_{it} \sim N\left(0,\sigma^2\right) i.i.d.$) drawn from a larger sample, enabling efficient estimates that leverage both cross-sectional and time-series variation in data:

$$\ln\left(GDPpc\right)_{it} = \beta_{10} + \beta_{20} IM_{it} + \beta_{31} INM_{it}^{D} + \beta_{32} INM_{it}^{F} + \alpha + u_{it} \tag{3a}$$

$$u_{it} = \alpha_i + \varepsilon_{it} \tag{3b}$$

$$\ln\left(GDPpc\right)_{it} = \alpha_0 + \alpha_1 IM_{it}^{NB} + \alpha_2 IM_{it}^{B} + \alpha + u_{it} \tag{3c}$$

$$u_{it} = \alpha_i + \varepsilon_{it} \tag{3d}$$

Panel A estimates suggest that internal migration (*IM*) has a statistically significant and quantitatively large positive effect on per capita GDP in both pooled and random effects models. This result aligns with findings of Barro and Sala-i-Martin (1992, 2004) and the Türkiye-specific findings of Özyılmaz and Bayraktar (2021). However, when country-specific unobservable heterogeneity is controlled for in the fixed effects model, the significance of internal migration disappears, suggesting that unobserved, time-invariant characteristics of provinces such as infrastructure or industrial structure rather than migration may account for the effect on per capita GDP.

Table 1
Estimates without consideration for spatial autocorrelation

Variables	Pooled data	Fixed effects (within)	Random effects (GLS)
Dependent variable: ln(GDPpc)			
Panel A: 2016-22[1]			
Intercept	8.8324*** (0.0150)		8.8548*** (0.0310)
IM	0.0491*** (0.0050)	0.0040 (0.0020)	0.0056** (0.0020)
INM^D	-0.0002 (-0.0120)	0.0008 (0.0050)	0.0008 (0.0060)
INM^F	0.2565*** (0.0400)	0.0504 (0.0150)	0.0576*** (0.0160)
R^2 adjusted	0.1907	-0.1407	0.0261
Panel B: 2009-22[2]			
Intercept	8.9508*** (0.0100)		8.9429*** (0.0270)
IM^{NE}	0.1006*** (0.0080)	-0.0094** (0.0040)	-0.0054 (0.0040)
IM^B	0.1281*** (0.0280)	0.1030*** (0.0160)	0.0999*** (0.0160)
R^2 adjusted	0.1397	-0.0382	0.0297

[1] For the 2016-22 period, 567 observations. [2] For the 2009-22 period, 1,134 observations.
*Note: *, ** and *** denote 10, 5 and 1% statistical significance levels, respectively. The values in parentheses are standard errors.*

International migration of domestic population (INM^D) does not seem to have any statistically significant effect on per capita GDP of provinces. By contrast, international migration of foreign residents (INM^F) is estimated to have a strong and statistically highly significant positive effect in both pooled data and random effects models. But as with internal migration, this effect disappears in the fixed effects specification, indicating that unobserved time-invariant characteristics of provinces are probably more important determinants of per capita GDP than foreign resident immigration.

Panel B introduces information on the educational level of internal migrants, enabling an assessment of the impact of migrants' human capital attainment on regional per capita GDP. The estimates substantiate the role of education: the coefficient on internal migrants with at least a bachelor's degree (IM^B) is positive and statistically highly significant across all three specifications, corroborating the view that better educated internal migrants boost the per capita GDP of host provinces, as documented by Akbari and Haider (2018) and Özyılmaz and Bayraktar (2021).

Internal migrants with only secondary or primary level education (IM^{NB}) seem to contribute to the per capita GDP of host provinces in the pooled data model, lower it in the fixed effects model and are statistically insignificant in the random effects model. This sign instability suggests that the contribution of migrants with lower educational attainments is highly sensitive to, and often outweighed by, fixed province-specific factors. Negative values of adjusted R^2 in the fixed effects model arise from inclusion of many province-specific intercepts (α_i).

To ascertain whether the fixed or random effects specification offers a superior fit for the data, we performed a Hausman specification test (appendix table A3). The test results consistently reject the random effects specification at a 1% significance level for both panels (Panel A: $\chi^2 = 14.89, p < 0.01$; Panel B: $\chi^2 = 17.82, p < 0.01$). In what follows, our spatial panel models therefore use the fixed effects specification.

The Lagrange multiplier (LM) test statistics for spatial autoregressive (SAR) and spatial error (SEM) models have significant values for all specifications (appendix table A3). The more precise robust LM statistics for spatial lag and spatial error further confirm the presence of spatial dependence in the data across specifications, indicating that the omission of spatial effects would lead to biased and inefficient estimates.

We also conducted Moran's I spatial autocorrelation analysis for per capita GDP to assess directly the degree of spatial dependence (appendix table A4). The test shows significant positive spatial autocorrelation with extremely low p-values, indicating a strong tendency for similar per capita GDP values to cluster spatially.

The SEM approach is often preferred over the SAR approach in method selection (Salima, Julie and Lionel, 2018). However, given that the null hypothesis of no spatial dependence is rejected by robust LM spatial lag and spatial error tests (table A3), as well as Moran's I spatial autocorrelation test (table A4), we proceeded to estimate the spatial autoregressive lag and error (SARAR) model that incorporates both types of spatial interaction.

We estimate the pooled data and fixed effects models with spatial autocorrelation of errors and spatial autoregressive coefficients using several spatial panel econometrics techniques: SEM models that account for spatial correlation in the error term; generalised method of moments (GMM) models that control for fixed effects; and the SARAR models, which provide the most comprehensive framework for interpretation of estimates, as they simultaneously address interactions among provinces and unobserved spatial linkages. Specifically, the model based on Lee and Yu (2010a) incorporates both spatial lag and ensures consistent estimators and centred distributions.[2]

Table 2 presents estimates of the pooled data and fixed effects models with spatial parameters. A key result across both panels is the highly significant and large values of the spatial error ρ and the spatial autoregressive coefficient λ. In SARAR models, estimated coefficients on these variables are statistically significant at the 1% level, suggesting that per capita GDP and unobserved shocks in neighbouring regions strongly and significantly affect the per capita GDP of a given province.

In Panel A, the estimated coefficient on internal migration (*IM*) is statistically significant in the pooled data model, but not in the fixed effects models. The coefficient on international migration of domestic population (INM^D) is statistically insignificant in all models, suggesting there is no substantial effect on provinces' per capita GDP from residents leaving the country – those who migrate abroad from Türkiye are mostly looking for better economic opportunities and their departure does not affect the per capita income of those who remain. But immigration of foreign residents is positively and statistically significantly correlated with per capita GDP in all specifications. For example, a 1% increase in net foreign immigration is associated with about 1.7% increase in per capita GDP in the fixed effects, and 1.6% in SARAR models. The reason for this positive link is most likely the increase in personal consumption of additional immigrant population (Gür, 2017). The receiving province also experiences this increase through spillovers from neighbouring provinces.

[2] Lee and Yu (2010a) show that the transformation using the orthonormal eigenvector matrix of $J_T = \left(I_T - \frac{1}{T} \iota\iota' \right)$ increases the accuracy of variance estimation by compensating for the degrees of freedom. This correction is particularly important when T is small. The variance parameter representing the correction is simply $\frac{T}{T-1}\hat{\sigma}^2_{nT}$ where $\hat{\sigma}^2_{nT}$ is the residuals variance (Piras, 2014).

Table 2

Estimates of the pooled data and fixed effects models with spatial autocorrelation of errors and spatial autoregressive coefficients

	Pooled data	Fixed effects (MV) Baltagi error	Fixed effects (MV) KKP error	Fixed effects (GMM)	Fixed effects (SARAR)	Fixed effects (SARAR) Lee-Yu
Dependent variable: ln(GDPpc)						
Panel A: 2016-22[1]						
IM	0.0191***	0.0019	0.0019	0.0019	0.0018	0.0018
	(0.0040)	(0.0010)	(0.0010)	(0.0010)	(0.0010)	(0.0010)
INM^D	-0.0086	-0.0018	0.0018	-0.0018	-0.0015	-0.0015
	(0.0130)	(0.0020)	(0.0020)	(0.0020)	(0.0020)	(0.0020)
INM^F	0.0669**	0.0170**	0.0170**	0.0174**	0.0156*	0.0156*
	(0.0310)	(0.0080)	(0.0080)	(0.0080)	(0.0080)	(0.0080)
Constant	8.8414***					
	(0.0450)					
ρ		0.8838***	0.8838***	0.8475***	0.9417***	0.9417***
		(0.0200)	(0.0200)	(0.0020)	(0.0150)	(0.0160)
λ					-0.5811***	-0.5811***
					(0.1550)	(0.1670)
Panel B: 2009-22[2]						
IM^{NB}	0.0340***	0.0038	0.0038	0.0035	-0.0011	-0.0011
	(0.0060)	(0.0020)	(0.0020)	(0.0020)	(0.0010)	(0.0010)
IM^B	0.1120***	0.0227***	0.0227***	0.0243***	0.0264***	0.0264***
	(0.0210)	(0.0070)	(0.0070)	(0.0080)	(0.0050)	(0.0050)
Constant	8.9260***					
	(0.0360)					
ρ		0.9023***	0.9023***	0.8510***	-0.7883***	-0.7883***
		(0.0120)	(0.0120)	(0.0400)	(0.1050)	(0.1090)
λ					0.9533***	0.9533***
					(0.0070)	(0.0080)

[1] For the 2016-22 period, 567 observations. [2] For the 2009-22 period, 1,134 observations.

Note: ρ = spatial error parameter; λ = spatial autoregressive coefficient. MV and GMM denote Maximum Likelihood and Generalised Method of Moments (Kelejian and Prucha, 1999) estimators. Baltagi error targets spatial dependence in the remainder term (Baltagi, Song and Koh, 2003), while KKP error captures dependence in all error components (Kapoor, Kelejian and Prucha, 2007). SARAR simultaneously models spatial dependence in both dependent variable and error term (Kelejian and Prucha, 2010). SARAR (Lee-Yu) refers to the bias-corrected estimator specifically designed for fixed effects models (Lee and Yu, 2010b).

, ** and * denote 10, 5 and 1% statistical significance levels, respectively. The values in parentheses are standard errors.*

Estimates in Panel B suggest a positive effect of skilled internal migration on per capita GDP: coefficient values of 0.0227 on IM^B in fixed effects, and 0.0264 in SARAR models suggest, e.g. that a 1% (net) increase in skilled domestic migrant population in a province increases its per capita GDP by 2.3-2.6%. This supports the view that better allocation of highly skilled labour improves per capita GDP of all provinces, even though for some it represents a "brain drain" (Pouliakas et al., 2009). Better-educated migrants bring valuable skills that contribute to overall growth, not least because the sectors that employ them tend to generate higher value added.

By contrast, the effect of unskilled internal migration is estimated to be positive and statistically significant only in the pooled data model that does not consider spatial effects. When these effects are taken into account, coefficients on IM^{NB} are not statistically significant, i.e. integration of unskilled domestic migrants into local labour market neither increases nor decreases per capita GDP of the province.

Parameter estimates on spatial autoregressive coefficients r and λ confirm spillovers from per capita GDP of neighbouring provinces and unmodelled spatial shocks on per capita GDP in a given province. For instance, the spatial autoregressive coefficient λ = -0.58 in Panel A indicates that a 1% increase in per capita GDP in neighbouring provinces leads, other things being equal, to a 0.58% decrease in the per capita GDP of a given province. By contrast, the spatial autoregressive coefficient λ = 0.94 in Panel B suggests that a 1% increase in the per capita GDP of neighbouring provinces leads to an almost equivalent increase in the host province's per capita GDP, holding other factors constant. This striking difference suggests that spatial interaction effects depend significantly on the time period and type of migration.

Positive estimates of the spatial error parameter ρ indicate that unobserved shocks such as regional economic distress or regional policy changes tend to propagate across provinces. In the SARAR specification for internal migration, for example, the negative value of the spatial error parameter (ρ = -0.78) alongside a positive spatial autoregressive coefficient (λ = 0.95) suggests that unobserved shocks can partly offset spatial spillovers. Technically, this negative coefficient serves as a correction mechanism, balancing the dominant positive effect of spatial dependence.

5 ROBUSTNESS CHECKS

To verify the reliability of spatial panel data models estimated in table 2, we performed three robustness checks. First, we used a lagged dependent variable $ln(GDPpc)_{t-1}$; second, we added financial control variables, i.e. the number of bank branches per capita and the amount of bank deposits per capita; and third, we added a time trend (table 3).

A comparison of table 3 with the baseline results in table 2 indicates that the size of migration coefficients in table 3 is larger, and previously insignificant estimates become statistically significant. This pattern implies that the baseline model provided a conservative estimate, with the omission of financial variables masking the full impact of internal migration. By accounting for this heterogeneity, the expanded model reduces residual variance, thereby enhancing estimator precision and revealing a more pronounced migration-regional income nexus.

Table 3

Robustness test results: spatial panel data estimations with lagged dependent variable and financial control variables

	Pooled data	Fixed effects (MV) Baltagi error	Fixed effects (MV) KKP error	Fixed effects (GMM)	Fixed effects (SARAR)	Fixed effects (SARAR) Lee-Yu
Dependent variable: ln(GDPpc)						
Panel A[1]						
$\ln(GDPpc)_{t-1}$	1.0095*** (0.0101)	0.8582*** (0.0532)	0.3952** (0.0440)	-0.1353** (0.0543)	0.3357*** (0.0453)	-0.1514*** (0.0584)
IM	-0.0022 (0.0014)	-0.0033 (0.0020)	-0.0001 (0.0010)	-0.0005 (0.0014)	-0.0004 (0.0013)	-0.0004 (0.0015)
INM^D	-0.0072* (0.0044)	-0.0079* (0.0047)	-0.0060** (0.0027)	-0.0041 (0.0025)	-0.0037 (0.0023)	-0.0037 (0.0026)
INM^F	0.0245** (0.0096)	0.0304** (0.0122)	0.0165** (0.0079)	0.0218** (0.0088)	0.0202** (0.0082)	0.0202** (0.0092)
Population per bank branch	-0.0237 (0.1901)	-0.1471 (0.2203)	-0.0305 (0.1364)	-0.1176 (0.1459)	-0.1072 (0.1354)	-0.1072 (0.1514)
Per capita bank deposit	0.5621*** (0.0881)	0.5548*** (0.0972)	0.1674*** (0.0614)	0.2205** (0.0958)	0.2130** (0.0894)	0.2130** (0.1000)
Constant	33.3542*** (6.4863)					
Trend	0.0167*** (0.0032)	0.0111*** (0.0038)	0.0034 (0.0082)	0.0048 (0.0049)	0.0051** (0.0024)	0.0051** (0.0024)
ρ		0.7508*** (0.0407)	0.8581*** (0.0262)	0.7215*** (0.0028)	-0.2171*** (0.1620)	-0.2171*** (0.1620)
λ					0.7863*** (0.0356)	0.7863*** (0.0356)
Panel B[2]						
$\ln(GDPpc)_{t-1}$	-0.9789*** (0.0007)	0.6566*** (0.0203)	0.6315*** (0.0243)	-0.6195*** (0.0235)	-0.6251*** (0.0256)	-0.6251*** (0.0256)
IM^{NB}	-0.0006 (0.0019)	-0.0036 (0.0022)	-0.0021 (0.0017)	-0.0023 (0.0017)	-0.0022 (0.0017)	-0.0022 (0.0017)
IM^B	0.0045 (0.0062)	0.0120 (0.0089)	0.0111* (0.0062)	-0.0115* (0.0065)	-0.0114* (0.0063)	-0.0114* (0.0063)
Population per bank branch	-0.5210 (0.1113)	-0.2951*** (0.1055)	-0.1648** (0.0777)	-0.1738** (0.0807)	-0.1535* (0.0785)	-0.1535* (0.0785)
Per capita bank deposit	1.1888** (0.0931)	0.7543** (0.0531)	0.1646** (0.0432)	0.2240** (0.0445)	0.1466** (0.0438)	0.1466** (0.0438)
Constant	-37.7120*** (1.7747)					
Trend	-0.0189*** (0.0009)	-0.0180*** (0.0008)	-0.0131*** (0.0022)	-0.0138*** (0.0014)	-0.0213*** (0.0041)	-0.0213*** (0.0041)
ρ		0.8539*** (0.0017)	0.8283*** (0.0207)	0.7053*** (0.0250)	0.8926*** (0.0198)	0.8926*** (0.0198)
λ					-0.5455*** (0.1781)	-0.5455*** (0.1991)

[1] For the 2016-22 period, 486 observations. [2] For the 2009-22 period, 1,053 observations.

Note: ρ = spatial error parameter; λ = spatial autoregressive coefficient. MV and GMM denote Maximum Likelihood and Generalised Method of Moments (Kelejian and Prucha, 1999) estimators. Baltagi error targets spatial dependence in the remainder term (Baltagi et al., 2003), while KKP error captures dependence in all error components (Kapoor et al., 2007). SARAR simultaneously models spatial dependence in both dependent variable and error term (Kelejian and Prucha, 2010). SARAR (Lee-Yu) refers to the bias-corrected estimator specifically designed for fixed effects models (Lee and Yu, 2010b).

, ** and * denote 10, 5 and 1% statistical significance levels, respectively. The values in parentheses are standard errors.*

It is instructive to view the dynamics of the lagged dependent variable through the lens of econometric theory. While the positive coefficients in pooled OLS models likely stem from upward bias due to unobserved heterogeneity, the negative estimates in standard fixed effects models reflect the so-called Nickell (1981) bias. Consequently, the persistence of negative coefficients in our bias-corrected Lee-Yu and GMM specifications should be interpreted not as an artifact, but as robust evidence of conditional convergence.

Regarding spatial dynamics, Panel A estimates for the SARAR and Lee-Yu models show a positive spatial autoregressive coefficient: $\lambda = 0.78$ indicates strong economic integration among provinces. The model balances the excessively positive income interaction with a negative spatial error parameter ($\rho = -0.21$). On the other hand, in Panel B, a negative spatial autoregressive coefficient ($\lambda = -0.54$) suggests the presence of inter-regional competition and backwash effects, while the diffusion of shocks is confirmed by a positive spatial error parameter ($\rho = 0.89$). Furthermore, positive values of the spatial error parameter ρ across the Baltagi, KKP, and GMM specifications confirm the spatial diffusion of unobserved regional shocks across different model specifications.

Regarding additional controls, the size of bank deposits per capita is positively and significantly associated with provincial per capita GDP. This result aligns with expectations: for instance, in SARAR models, 1% higher bank deposits are associated with a 0.15 – 0.20% higher per capita income. This supports findings by Kim et al. (2018) and Afonso and Blanco-Arana (2024) that retail deposit growth stimulated economic activity. Surprisingly, population per bank branch is negatively correlated with regional per capita GDP. The time trend coefficient varies by period: it is positive in 2016-22 (Panel A), reflecting a steady upward trend, but negative in the longer 2009-22 period (Panel B), likely capturing the lingering effects of the Global Financial Crisis.

6 CONCLUSION

This study used spatial panel models to analyse the impact of international and internal migration on per capita GDP of provinces in Türkiye. Our findings suggest that migration from other countries into Türkiye is associated with a small positive effect on the per capita GDP of provinces. Regarding internal migration, the level of migrants' human capital is important: educated internal migrants have a statistically significant positive effect on per capita GDP of host provinces, whereas less educated migrants have no significant effect, i.e. their migration neither decreases nor increases the per capita GDP of the province they move into.

Our estimates control for spatial dependencies, i.e. spillovers from nearby provinces on the link between net migration and per capita GDP in a given province. They are also robust to alternative specifications that include a lagged per capita GDP, a time trend, and financial development variables.

The weak but positive effect of net international migration on per capita GDP of Türkiye's provinces is consistent with the view that foreign workers contribute positively to the domestic economy. However, the small magnitude of this effect suggests that additional factors, such as the type of employment and integration policies for incoming migrants, might not fully exploit the potential contribution of this pool of workforce to the Turkish economy.

The significant positive effect of educated native migrants on per capita GDP is in line with the literature suggesting that reallocation of a highly educated workforce benefits domestic economic growth (Akbari and Haider, 2018; Özyılmaz and Bayraktar, 2021). The finding that less-educated domestic migrants do not depress per capita GDP in the provinces they move into is also interesting. We believe that this interpretation is more important than the view that low-skilled labour merely has a "limited impact" on per capita GDP, as argued e.g. by Marto, Lourenço Marques and Madaleno (2022).

One contribution of our paper to the existing literature is that we consider spatial dependency of per capita GDP in a province on per capita GDP in neighbouring provinces. Another is that we account for errors caused by unobservable common factors (e.g. regional policies) that affect neighbouring provinces. The inclusion of these spatial interaction parameters did not change the sign of relationships between migration variables and per capita GDP of provinces. The varying statistical significance of spatial parameters suggests that income inequalities across regions may affect per capita GDP. This opens a new avenue for future research. The main limitations of this study are that indirect effects of migration on per capita GDP of provinces are not analysed, and the time period under study is limited.

The main policy implication of our findings is that one needs to create favourable conditions for the integration of international and as well as of internal migrants into provincial labour markets. Policies that guide migrants to sectors aligned with their skills and human capital could increase the positive impact of migration on the per capita GDP of Türkiye's provinces. Without such guidance, migrants may end up in the informal sector, lowering their potential contribution to economic growth and public finances. The significant role of human capital suggests that attracting and retaining skilled migrants could be a key regional policy priority. Having said that, public policy coordination to address spatial dependencies and ensure balanced economic development across provinces is essential.

Disclosure statement
The authors have no conflicts of interest to declare.

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APPENDIX

Table A1

Overview of the empirical literature on migration and economic growth

Author	Country or region	Time span	Method	Result
International migration and economic growth				
Dolado et al. (1994)	23 OECD countries	1960-1985	Panel NLS, NLS2SLS	M*→G (+)
Chen (2006)	USA, Philippines	1985-1994	Stochastic dynamic model method	M→G (+) M*→G (-)
Morley (2006)	Australia, Canada, USA	1930-2002	ARDL, Granger non-causality tests	G=> M
Mariya and Tritah (2009)	20 OECD countries	1960-2005	Panel regressions analysis	M→ G (✓)
Ortega and Peri (2009)	74 countries	1980-2005	Panel OLS, 2SLS	M→ G (+)
Orefice (2010)	24 OECD countries	1998-2007	Panel OLS, 2SLS	M*→G (+)
Boubtane, Coulibaly and Rault (2013a)	22 OECD countries	1980-2005	Bootstrap panel Granger causality analysis	G=> M
Boubtane, Coulibaly and Rault (2013b)	22 OECD countries	1987-2009	Panel VAR	M↔G (+)
Güner and Yalınız (2013)	EU 14 countries	1984-2008	Panel data fixed effect model	M→ G (-)
Bashier and Siam (2014)	Jordan	1980-2012	Fully modified ordinary least squares method (FMOLS)	M→ G (+)
Docquier et al. (2014)	138 sending countries and 30 major destination countries	2000-2010	OLS regression analysis	G→M (+)
Aleksynska and Tritah (2015)	20 OECD countries	1960-2005	Panel 2SLS	M→ G (+/-)
Brunow et al. (2015)	149 countries	1950-2010	Panel OLS	M→ G (+)
Boubtane, Dumont and Rault (2016)	22 OECD countries	1986-2006	SYS-GMM	M*→G (+)
Sevinç et al. (2016)	18 developing countries	1962-2012	Panel data methods	M→ G (-)

Author	Country or region	Time span	Method	Result
International migration and economic growth				
Altunç et al. (2017)	Türkiye	1985-2015	Johansen cointegration test, Granger causality tests	M→ G (X) M<=> G
Göv and Dürrü (2017)	7 OECD countries	2000-2016	Panel causality test	M=> G
Kang and Kim (2018)	90 countries	1960-2000	Panel GMM	M*→G (+)
Öztop et al. (2024)	Türkiye	2022	Spatial regression analysis	M→ G (✓)

*Note: (→) and (↔) signify one-way and bi-directional relationships; (=>) and (<=>) signify one-way and a bi-directional causal nexus; (✓) and (X) indicate that a relationship exists or does not exist; (+) and (-) indicate positive and negative relationship; * refers to human capital.*

Overview of the empirical literature on migration and economic growth (continued)

Author	Country or region	Time span	Method	Result
Internal migration and economic growth				
Barro and Sala-i-Martin (1992)	Japan and United States	1900-1987	Regression analysis	M→ G (+)
Zhang and Song (2003)	China	1978-1999	Time series and cross-section analyses	G→ M (+)
Ghatak et al. (2008)	Poland	1995-2001	SURE, FGLS SURE, ML	G→ M (+)
Ortega (2008)	Spanish regions	1998-2008	Panel OLS	M→ G (+)
Pouliakas et al. (2009)	Scotland, Greece, Latvia	2004/2005	CGE analysis	M*→G (+/-)
Peri (2010)	USA	1960-2006	Panel 2SLS	M→ G (+)
Bunea (2012)	Romania	2004-2008	Fixed effects and generalized method of moments	G→ M (+)
Huber and Tondl (2012)	EU27 NUTS2 regions	2000-2007	Panel system GMM	M→ G (+/-)
Kırdar and Saraçoğlu (2012)	Türkiye	1975-2000	OLS	M→ G (-)
Foldvari et al. (2013)	Holland	1570-1800	VAR analysis	M→ G (+)
Vakulenko (2014)	Russian	1995-2010	Spatial dynamic panel data analysis	M→ G (-)
Manavgat and Saygılı (2016)	Türkiye	2008-2011	Spatial danel data analysis	G→ M (+/-)
Borozan (2017)	Croatia	2000-2011	Panel data analysis	M→ G (-)
Akbari and Haider (2018)	Canada	2006-2013	Feasible generalized least squares (FGLS)	M*→G (+)
Bayraktar and Özyılmaz (2019)	Türkiye's NUTS-2 Regions	2008-2017	POLS, fixed effects and random effects models	M→ G (+)
Özyılmaz and Bayraktar (2021)	Türkiye	2008-2019	Bootstrap quantile regression method	M→ G (+) M*→G (+)
Ulucan (2022)	Türkiye	2008-2019	Fixed effect panel method	G→ M (-)
Yürük and Batmaz (2023)	Türkiye	2008-2020	Spatial panel data analysis	M→ G (-)

*Note: (à) and (↔) signify one-way and bi-directional relationships; (+) and (-) indicate positive and negative relationship; * refers to human capital.*

Table A2
Descriptive statistics

Variables	Mean	St. dev.	Min.	Max.
Panel A				
Per capita GDP (USD)	7,5100	2,7270	2,9070	18,2690
IM (% of population)	-0.2600	2.3400	-21.0600	14.9700
INM^D (% of population)	0.0300	0.6900	-10.0800	6.6300
INM^F (% of population)	0.1700	0.3300	-0.9000	2.9400
Population per bank branch	0.0100	0.0200	-0.0600	0.0800
Per capita bank deposit	0.1200	0.0500	-0.0200	0.2600
Panel B				
Per capita GDP (USD)	8,0460	2,9950	2,7670	20,8830
IM^{NB} (% of population)	-0.0400	1.2400	-9.2900	11.8900
IM^B (% of population)	-0.1500	0.3500	-3.3800	2.4800
Population per bank branch	0.0000	0.0200	-0.1200	0.0800
Per capita bank deposit	0.0900	0.0500	-0.0800	0.2600

Note: N for Panel A = 567; N for Panel B = 1,134. Panel A examines the effects of net internal migration (IM) and net international migration separated into domestic (INM^D) and foreign (INM^F) components, on per capita GDP in USD. Panel B disaggregates internal migration by high (IM^B) and low education (IM^{NB}).

These statistics underscore the pronounced regional disparities that underpin our spatial approach. The mean per capita GDP in fixed US dollars during the core period was $7,500, but the standard deviation of the data exceeded $2,700, indicating a high degree of dispersion. In the economic laggard eastern provinces, the median per capita income was below $3,000, whereas in the more prosperous urban west it approached $18,000.

These differences are further exacerbated by net internal migration losses (negative averages across panels) and extreme outliers (e.g. 21% outflows in rural areas versus 15% inflows in urban areas). Such fluctuations are indicative of the risk of brain drain in peripheral regions and may have a negative impact on the growth of neighbouring regions unless balanced by foreign capital inflows or skilled migration.

Population per bank branch indicators highlight persistent inclusivity gaps: near-zero log ratios for branches imply sparse coverage (typically 1 branch per 10,000+ people), while per capita bank deposit shares are below 10 – 12% of per capita GDP and show negative values in underserved areas. This situation has the effect of limiting productivity growth in remittance revenues and increasing spatial inequalities.

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Table A3
Spatial dependence test

	Panel A	Panel B
	Chi-squared statistic	Chi-squared statistic
Hausman test	14.8900***	17.8190***
Hausman test for spatial error models	0.2062	0.2991
Hausman test for spatial lag models	0.4085	0.3393
	LM statistic	LM statistic
LM spatial lag	1622.4000***	3814.8000***
LM spatial error	1620.7000***	3768.0000***
Robust LM spatial lag	15.5500***	68.9320***
Robust LM spatial error	13.8380***	22.1580***

*Note: *, ** and *** denote 10%, 5% and 1% statistical significance levels, respectively.*

Table A4
Moran's I spatial autocorrelation test for per capita GDP

Year	Observed Moran's I value	Z-score
2009	0.4997	11.6213***
2010	0.4942	11.4987***
2011	0.4966	11.5725***
2012	0.4975	11.5890***
2013	0.4803	11.2300***
2014	0.5305	12.3582***
2015	0.5343	12.4742***
2016	0.5348	12.4831***
2017	0.5251	12.2924***
2018	0.5274	12.3391***
2019	0.4972	11.6083***
2020	0.4885	11.4015***
2021	0.5092	11.9086***
2022	0.5429	12.6434***

*Note: *, ** and *** denote 10%, 5% and 1% statistical significance levels, respectively.*