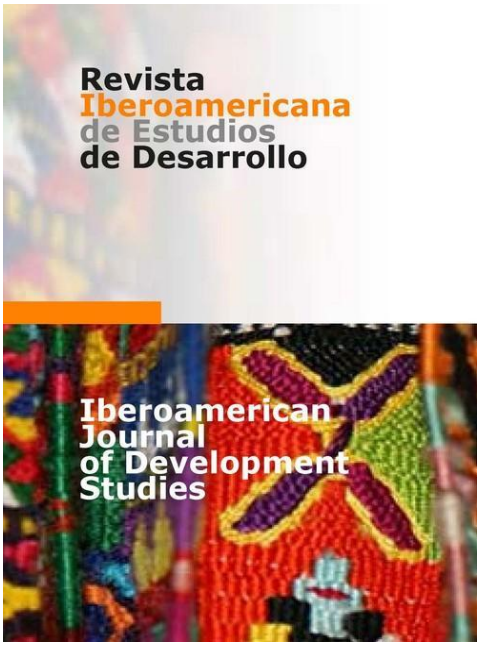
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Rural-urban connectivity and development: village roads, market access, and agglomeration in emerging Turkish provinces, 2011-2021



Conectividad rural-urbana y desarrollo sostenible: caminos rurales, acceso a los mercados y aglomeración en las provincias emergentes de Turquía, 2011-2021

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Rural-urban connectivity and sustainable development: village roads, market access, and agglomeration in emerging Turkish provinces, 2011-2021

Conectividad rural-urbana y desarrollo sostenible: caminos rurales, acceso a los mercados y aglomeración en las provincias emergentes de Turquía, 2011-2021

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Abstract

Transport infrastructure fosters agglomeration, by reducing trade costs and enhancing market access. Village road networks drive intra-regional cohesion, by establishing rural-urban connectivity. In Turkey, the 2012 administrative reform effectively restricted village road provision to non-metropolitan provinces. This paper estimates the reduced-form income and growth effects of village roads under this policy through a market access channel. To account for temporal adjustments and endogeneity, this study employs a dynamic panel data model estimated via a system generalized method of moments framework. The results indicate a positive relationship between village roads and both the level and growth rate of gross domestic product per capita. However, the marginal income gains become statistically insignificant at an urbanisation threshold of approximately 42 %. These findings suggest that rural road investment decisions should consider regional urbanisation rates. Additionally, they provide economic justification for the policy shift through the 2012 administrative reform. Post-estimation diagnostics validate the model specifications and instrument validity.

Keywords: agglomeration, market access, rural-urban connectivity, sustainable development, system GMM, village roads.

JEL Classification Codes: C33, H54, O11, O18, R11, R42.

Resumen

La infraestructura de transporte fomenta la aglomeración, al reducir los costes comerciales y mejorar el acceso al mercado. Las redes de caminos rurales impulsan la cohesión intrarregional, al establecer la conectividad rural-urbana. En Turquía, la reforma administrativa de 2012 restringió efectivamente la provisión de caminos rurales a las provincias no metropolitanas. En este artículo, se estiman los efectos, de forma reducida, sobre el ingreso y el crecimiento de los caminos rurales bajo dicha política a través del canal de acceso al mercado. Para considerar los ajustes temporales y la endogeneidad, este estudio emplea un modelo de datos de panel dinámico estimado mediante un marco de método generalizado de momentos. Los resultados indican una relación positiva entre los caminos rurales, además del nivel y la tasa de crecimiento del ingreso bruto per cápita. Sin embargo, las ganancias marginales de ingreso se vuelven estadísticamente insignificantes en un umbral de urbanización de, aproximadamente, el 42 %. Estos hallazgos sugieren que, en las decisiones de inversión en caminos rurales, deben considerarse las tasas de urbanización regional. Además, proporcionan una justificación económica para el cambio de política a través de la reforma administrativa de 2012. Los diagnósticos posteriores a la estimación validan las especificaciones del modelo y la validez del instrumento.

Palabras clave: aglomeración, acceso al mercado, conectividad rural-urbana, desarrollo sostenible, sistema GMM, caminos rurales.

Códigos de clasificación JEL: C33, H54, O11, O18, R11, R42.

1

Introduction

Rural roads are essential transport infrastructure in less developed remote areas, and critical policy tools for achieving inclusive industrialisation (SDG 9.1) and sustainable transport (SDG 11.2). The economic benefit of rural roads stems from enhancing urban-rural linkages, a key objective promoted in SDG 11.a. Strengthening rural-urban connectivity is also the explicit purpose of Turkey's village roads policy, which aligns the country's transport strategy with these broader sustainable development goals. This paper investigates the impact of this policy on provincial economic activity through the market access channel.

The economic benefit of transport infrastructure stems from its public good characteristics (Aschauer 1989), but it is also associated with regional agglomeration through reduced transport costs (Krugman 1991). The latter is linked to increased nominal wages via improved market access within the agglomeration process (Mion 2004, Redding & Venables 2004, Hanson 2005, Brakman *et al.* 2006, Knaap 2006). This dynamic further explains regional growth in terms of population (Redding & Sturm 2008, Baum-Snow *et al.* 2020), and agricultural land values (Donaldson & Hornbeck 2016).

Regarding Turkey, there is evidence that the market access mechanism results in higher human capital (Karahasan & Bilgel 2020) and manufacturing wages (Karahasan *et al.* 2016). Studies on the productivity effects of railroads and roads provide additional evidence in favour of this link (Akgüngör 2006, Beyzatlar & Kuştepeli 2011, Elburz & Cubukcu 2021). Overall, these findings highlight the importance of transport infrastructure in Turkish regional development.

In the household literature, findings on low- and middle-income countries indicate income, consumption, and welfare benefits arising from rural roads in lagging regions (Warr 2010, Lancelot *et al.* 2015, Nakamura *et al.* 2020, Anega & Alemu 2023). This infrastructure is also associated with access to labour activities (Gachassin *et al.* 2010) and urban markets (Asher & Novosad 2020), which imply intra-regional market access effects. The latter is further supported by the recent findings in Takada *et al.* (2021).

Despite the evidence regarding the local impact of rural roads, studies on their intra-regional market access effects remain largely limited to household-level analyses. The objective of this paper is to estimate the income and growth effects of village roads within this

framework through reduced form specifications. For this purpose, the study uses a panel dataset of Turkish provinces covering the period 2011-2021.

Turkey provides a unique case to explore this topic as the Special Provincial Administration Law No. 5302 (Republic of Turkey 2005) and the National Rural Road Master Plan (General Directorate of Rural Services 2001) standardised village roads across provinces. However, the 2012 Administrative Reform Law No.6360 (Republic of Turkey 2012) abolished Special Provincial Administrations within metropolitan provinces. This effectively shifted metropolitan transport towards municipality-managed urban systems, while rendering village roads a part of non-metropolitan rural infrastructure. This study evaluates the impact of village roads under these policies on income levels and growth, proxied by the level and growth rate of GDP per capita, respectively, in the latter group of provinces.

Redding and Venables (2004), in the absence of wage data, use the level of gross domestic product (GDP) per capita as a proxy. This approach is further validated in Head and Mayer (2004). Following the literature, this paper utilises the latter indicator as the dependent variable. However, within the New Economic Geography framework, temporary shocks can alter agglomeration patterns (Head & Mayer 2004). Mion (2004) identifies market frictions as a factor creating shock persistence that requires adjustments in this trajectory. To address potential shock persistence in the dependent variable, adopting the strategy in Mion (2004), this paper applies a dynamic panel data model within a system generalized method of moments (GMM) framework. Furthermore, the growth rate of GDP per capita is utilised as an additional dependent variable, to ensure that the results are robust to such dynamic effects.

This study models the market access effects of village roads through the interaction between this variable and the urbanisation rate. The latter serves as a proxy for the size of urban markets, which becomes more accessible to rural locations, as the village road network expands. The «interaction» term captures the non-linearities in this process. Within this framework, the system GMM estimator controls for potential endogeneity in the relationship between regressors and the dependent variables.

The remainder of this paper is organised as follows: Section 2 provides the literature review, Section 3 outlines the empirical model, Section 4 describes the data, Section 5 presents the econometric methodology, Section 6 shows the empirical results, and Section 7 discusses the findings. The final section offers concluding remarks and outlines the study's limitations.

2

Agglomeration effects of transport infrastructure

Key drivers of agglomeration are Marshallian externalities, such as labour pooling, intermediate input sharing, and knowledge spillovers. These lead to increasing returns to production as resources become denser within a location (Ciccone 2002). New Economic Geography models further demonstrate that increased demand, due to the enlargement of market size, is an additional pull factor that facilitates agglomeration, while driving up the nominal wage rates (Krugman 1991, Fujita *et al.* 2001). A critical factor in this process is transport costs, and thus, transport infrastructure. On the supply side, the latter is linked to increased private sector productivity (Aschauer 1989, Banerjee *et al.* 2020), and market efficiencies through expanding the size of arable land (Atack & Margo 2011), while, on the demand side, it is positively associated with the scaling up of market size (Atack *et al.* 2011), and higher population densities and urbanisation (Atack *et al.* 2010).

On the demand side of the economy, transport infrastructure facilitates agglomeration, by boosting «market access». This concept is rooted in the market potential formula of Harris (1954), who defined it as the sum of regional markets weighted by the inverse of distance to them. New Economic Geography theory (Krugman 1991, Fujita *et al.* 2001) refined this definition by incorporating regional price index. In the empirical literature, studies employing reduced-form wage equations typically measure «market access» using Harris- or Krugman-style distance-weighted indices (Roos 2001, Mion 2004, Hanson 2005, Brakman *et al.* 2006, Kosfeld & Eckey 2010). Furthermore, because market access is fundamentally unobservable, it is also estimated through structural equation systems (Redding & Venables 2004, Knaap 2006, Hering & Poncet 2010, Donaldson & Hornbeck 2016, Baum-Snow *et al.* 2020). These estimations utilise various measures of market size, including GDP (Baum-Snow *et al.* 2020), regional price indices (Kosfeld & Eckey 2010), aggregate household disposable income (Mion 2004), and population (Donaldson & Hornbeck 2016, Baum-Snow *et al.* 2020). As factors influencing trade costs, researchers incorporate alternatives to physical distance, such as freight rates (Donaldson & Hornbeck 2016), travel time to major ports, and highway quantities (Baum-Snow *et al.* 2020). Finally, within quasi-experimental research designs, shifts in market access can be measured by changes in institutional barriers or border policies that restrict entry to regional markets (Redding & Sturm 2008).

Increases in demand resulting from improved market access typically lead to higher nominal wages (Mion 2004, Hanson 2005, Brakman *et al.* 2006, Hering & Poncet 2010, Kosfeld & Eckey 2010, Baum-Snow *et al.* 2020), GDP (Baum-Snow *et al.* 2020), and GDP per capita (Redding & Venables 2004). Beyond income benefits, enhanced market access is positively associated with population growth (Redding & Sturm 2008, Baum-Snow *et al.* 2020), and rising agricultural land values (Donaldson & Hornbeck, 2016).

Regarding Turkey, Karahasan and Bilgel (2020) and Karahasan *et al.* (2016) estimate the gains in human capital and the manufacturing wage rate associated with increased inter-provincial market potential, respectively. Because their approach links provinces across the country, they use spatial econometric methods alongside the standard ordinary less squares (OLS) techniques. Their findings support the positive impact of market potential on these variables in Turkey.

There is overwhelming evidence in favour of the positive impact of inter-regional market access on local development. However, market-access approach, as a demand-side mechanism, can be extended inwards to explore the effect of rural-urban connectivity. Evidence from micro-level household studies in low- and middle-income countries suggests a positive link between road accessibility and household income (Escobal & Ponce 2008, Khandker *et al.* 2009, Zhang *et al.* 2023), income growth (Wondemu & Weiss 2012), consumption (Escobal & Ponce 2008, Gibson & Olivia 2010, Warr 2010, Lancelot *et al.* 2015, Kamaludin & Qibthiyyah 2022, Anega & Alemu 2023), and welfare (Nguyen *et al.* 2017, Nakamura *et al.* 2020). There is also emerging evidence regarding their effect through market access on household income growth (Takada *et al.* 2021). This link is further correlated with increased access to labour activities (Gachassin *et al.* 2010). Furthermore, evidence in Asher and Novosad (2020) indicates that rural roads enable individuals to seek employment in cities. Overall, the findings in the household literature suggest that income gains from rural roads are linked to interactions with urban markets. This justifies shifting the focus from inter- to intra-regional market access frameworks.

3

Model specification

This section explains the rationale for adopting a dynamic framework and justifies the choice of control variables. For the dependent variables, this paper uses the level of GDP per capita as a proxy for wage income (Head & Mayer 2004, Redding & Venables 2004). It further employs the growth rate of this variable to ensure the robustness of results to shock persistence in the agglomeration trajectory, in addition to utilising a dynamic panel data model. Shock persistence, often caused by market frictions, can lead to prolonged adjustment periods in moving towards equilibrium, biasing results if they left unaccounted for (Head & Mayer 2004, Mion 2004). In this study, the consistency of results between the empirical specifications for the level and growth rate of GDP per capita provides an additional diagnostic tool to ensure the findings are robust to such shocks.

3.1. Market access effects of village roads

According to the New Economic Geography framework (Krugman 1991, Fujita *et al.* 2001), an increase in market size, or a reduction in regional transport costs, stimulates labour demand, while lowering the price index, by expanding the variety of products and improving their accessibility. This, in turn, raises both nominal and real wages. Within an intra-provincial context, this process occurs via village roads, which reduce transport costs, by mitigating physical barriers between rural areas and urban markets. This bolsters agglomeration in the city centre, expanding the market size in these locations and driving higher income levels.

However, marginal income gains from transport cost reductions are a decreasing function of agglomeration (Fujita *et al.* 2001: 72), which, in advanced stages, implies that transport costs are already relatively low. Thus, income gains from further cost reductions in such locations are smaller than those in more dispersed core-periphery structures. This suggests a non-linearity in the relationship between transport costs and income levels. Consequently, a robust method to capture the market access effects of village roads is to include an interaction term between this variable and urban markets. Although data regarding urban markets are unavailable, they are expected to be correlated with the urbanisation rate, which serves as a proxy for market size in this study.

According to this market access framework, the coefficients for village roads and the urbanisation rate are expected to be positive, as these factors drive income levels upwards, by contributing to centripetal forces of agglomeration. However, the sign of their interaction is expected to be negative, because the marginal income gains from increased village roads are likely to diminish, as the level of urbanisation rises and transport costs decline.

3.2. Control variables

The intra-provincial effects of village roads rely on localised labour mobility. However, within a sub-national framework, labour also moves between provinces. To isolate the effects of rural-urban connectivity, this paper includes the net internal migration rate. Because the sample excludes the metropolitan provinces, this indicator captures external demographic shocks, as well as non-systemic spatial effects.

An important element of agglomeration is the accumulation of human and physical capital (Head & Mayer 2004). However, few studies that adopt the market access approach include these as control variables (Hanson 2005), as they are often highly correlated with market access measures (Mion 2004, Brakman *et al.* 2006). Nevertheless, they remain essential components in augmented models of agglomeration (Ciccone 2002). This paper includes these measures because, in an intra-provincial context, both human and private capital are factors that facilitate and complement the agglomeration process. Regarding private capital, due to the lack of investment data at the provincial level, the model uses industrial electricity consumption per capita as a proxy for private capital (Elburz & Cubukcu 2021).

To capture the impact of human capital, this paper utilises the share of females with secondary education as a proxy. Female education indicators, as opposed to male-centric metrics, are closely linked to increased productivity through both technology absorption capacity and reduced fertility rates (Barro 2013), while yielding positive externalities for children's health and education (Summers 1994). At the secondary and tertiary levels, growth estimations report higher productivity effects for female, relative to male education (Hill & King 1995). In the Turkish context, tertiary education attainment is likely to over-represent younger cohorts, due to the increase in the number of higher education institutions since 2006, accompanied by policies that lowered barriers to entry. Post-estimation diagnostics from preliminary results — available on request — provide further support that the share of females with secondary education is the most robust in satisfying over-identification and under-identification tests, compared to aggregate population or tertiary-based indicators.

An additional factor that affects the agglomeration process is the housing stock. Increased demand through agglomeration puts upward pressure on wage rates, which creates a centripetal force. Meanwhile, rising housing prices results in a centrifugal force that provides an incentive for dispersion. Consequently, in addition to transport costs, housing stocks are a key factor in determining the distribution of resources across space (Helpman 1998). Thus,

total housing units are frequently included as a control variable in the empirical literature of market access (Mion 2004, Hanson 2005). This paper uses residential occupancy permits as a proxy for the supply of housing stock.

3.3. Model dynamics

To account for shock persistence in the agglomeration process (Mion 2004), the model incorporates an autoregressive process of the second order, AR(2). In the context of this study, including the second lag of GDP per capita ensures the consistency of the GMM estimator and satisfies post-estimation diagnostics regarding serial correlation. In the income regressions, the first lag captures short-run persistence, whereas the second lag controls for the presence of correcting or diverging effects in the long run.

In the growth regressions, the first lag typically captures «conditional convergence» (Solow 1956, Barro 1991, Mankiw *et al.* 1992, Bond *et al.* 2001). However, in an AR(2) framework, the lags of GDP per capita may exhibit opposite signs in a stable dynamic equilibrium, which does not readily translate to a standard convergence framework. Consequently, this study reports the sum of the lagged coefficients as an additional parameter reflecting the long-run convergence process. This sum also serves as an indicator of the long-run stability of the agglomeration trajectory for both the income and growth specifications. The expected magnitudes of these coefficients are discussed in the subsequent section.

3.4. Regression model

Equations (1a) and (1b) present the empirical specifications for the income *(I)* and growth *(G)* models:

$$ln\, y_{it} = \alpha_1^I\, ln\, y_{it-1} + \alpha_2^I\, ln\, y_{it-2} + \beta_1^I\, ln\, VR_{it} + \beta_2^I\, ln\, URB_{it} + \beta_3^I\, ln\, VR_{it} \times ln\, URB_{it} + \theta_1^I\, ln\, IECPC_{it} + \theta_2^I\ ln\, SWSED_{it} + \theta_3^I\, ln\, OP_{it} + \theta_4^I\, ln\, NMR_{it} + u_{it}^I \quad (1a)$$

$$\Delta ln\, y_{it} = \alpha_1^G\, ln\, y_{it-1} + \alpha_2^G\, ln\, y_{it-2} + \beta_1^G\, ln\, VR_{it} + \beta_2^G\, ln\, URB_{it} + \beta_3^G\, ln\, VR_{it} \times ln\, URB_{it} + \theta_1^G\, ln\, IECPC_{it} + \theta_2^G\ ln\, SWSED_{it} + \theta_3^G\, ln\, OP_{it} + \theta_4^G\, ln\, NMR_{it} + u_{it}^G \quad (1b)$$

where $u_{it}^s = \mu_i + \eta_t + \epsilon_{it}^s$ for $s \in \{I, G\}$, with I and G denoting income and growth specifications, respectively. The indices i and t represent the province and year. The term u_{it} is the composite error, consisting of province-specific fixed effects (μ_i), time effects (η_t), and

the idiosyncratic error component (ϵ_{it}^{s}). Panel fixed effects are eliminated through first-differencing within the system GMM framework, while time effects are captured by year dummies.

In Equations ($1a$) and ($1b$), $\ln y_{it}$ represents the logarithm of GDP per capita, while $\Delta ln\, y_{it}$ denotes its growth rate, respectively. The terms $ln\, y_{it-1}$ and $ln\, y_{it-2}$ reflect the first two lags of GDP per capita. Because $\Delta ln\, y_{it} = ln\, y_{it} - ln\, y_{it-1}$, in the absence of divergent effects of shock persistence, the structural slope coefficients (α^{s}, β^{s}, and θ^{s}) become identical across models, except for the coefficient for the first lag, which follows the identity $\alpha_1^G = \alpha_1^I - 1$. This implies that, for a realistic output production, which relies on persistent capital stocks, the stability of both the level and growth rate of GDP per capita requires that $0 < \alpha_1^I + \alpha_2^I < 1$. This condition also ensures long-run convergence in the growth rate of GDP per capita, as it is equivalent to $-1 < \alpha_1^G + \alpha_2^G < 0$.

The remaining notation is defined as follows: the variables $ln\, VR_{it}$ and $ln\, URB_{it}$ are the logarithms of village road length and the urbanisation rate, while $ln\, VR_{it} \times ln\, URB_{it}$ is the interaction term. Control variables expressed in logarithms include industrial electricity consumption per capita *($ln\, IECPC_{it}$),* the share of females with secondary education *($ln\, SWSED_{it}$),* and occupancy permits *($ln\, OP_{it}$).* The last control variable is NMR_{it}, which is the net migration rate between provinces. A full list of variables with explanations is provided in Table 1.

Variable	**Explanation**
$\Delta ln\, y_{it}$	Growth rate of GDP per capita
$ln\, y_{it}$	Logarithm of GDP per capita
$ln\, y_{it-1}$	First lag of the logarithm of GDP per capita
$ln\, y_{it-2}$	Second lag of the logarithm of GDP per capita
$ln\, VR_{it}$	Logarithm of village roads
$ln\, URB_{it}$	Logarithm of the urbanisation rate
$ln\, VR_{it}$ $\times\, ln\, URB_{it}$	Interaction term
NMR_{it}	Net migration rate
$ln\, OP_{it}$	Logarithm of occupancy permits
$ln\, IECPC_{it}$	Logarithm of industrial electricity consumption per capita

$ln\,SWSED_{it}$	Logarithm of the share of females with secondary education

Table 1
Variable explanations

4

Data

The data source for all variables is the Regional Statistics database of Turkish Statistical Institute. The «share of females with secondary education» refers to women aged fifteen and over, while the «urbanisation rate» is defined as the proportion of individuals residing in city and district centres relative to the total provincial population. The «net migration rate» represents the ratio of the difference between the internal migration inflows and outflows to the total population. «Occupancy permits» are measured in square metres and correspond to real estate for residential use. Finally, «industrial electricity consumption per capita» is measured in kilowatt-hours (kWh). This study utilises a panel of 51 non-metropolitan provinces, spanning the 2011-2021 period. The sample is limited to these dimensions based on the availability of data for the variables of interest.

Village roads are measured in kilometres and as previously mentioned are physically standardised across provinces according to the Special Provincial Administration Law No. 5302 (Republic of Turkey 2005) and the National Rural Road Master Plan (General Directorate of Rural Services 2001). Following the implementation of the 2012 Administrative Reform Law No. 6360 (Republic of Turkey 2012), data for village roads have become available exclusively for non-metropolitan provinces. The National Rural Road Master Plan (General Directorate of Rural Services 2001, p. 11) defines the variable as «roads that lie outside the state and provincial road networks, connecting villages and their settlements to each other, as well as to provincial, district, and sub-district centres and the state and provincial road systems».

Turkish output series used in this paper are considered to have positive biases that arise from a base year that coincides with the 2008-2009 global financial crisis, and the weights given to construction and service sectors (Bakış 2018, Boratav *et al.* 2018). The econometric technique employed in this paper produces results robust to potential biases in the Turkish GDP

series that are common across years and provinces by controlling for time and panel fixed effects.

Descriptive statistics for the variables in both levels and logarithmic forms are provided in Table 2, which reports the mean, the standard deviation and the minimum and maximum values for the overall sample. Additionally, this table presents standard deviations and extreme values for both between and within panels. The maximum and minimum values between panels reflect the provincial means, while those within panels are the highest and lowest observations after adjusting for the group and overall sample averages.

Variable		**Mean**	**Std. dev.**	**Min**	**Max**	**Observations**
$\Delta ln\, y_{it}$	overall	−0.01	0.07	−0.22	0.20	$N = 561$
	between		0.01	−0.04	0.01	$n = 51$
	within		0.07	−0.23	0.19	$T = 11$
y_{it}, USD	overall	7,508.38	2,273.63	2,871.00	15,332.00	$N = 561$
	between		2,068.27	3,393.27	12,533.18	$n = 51$
	within		983.88	4,986.20	10,307.20	$T = 11$
$ln\, y_{it}$	overall	8.88	0.31	7.96	9.64	$N = 561$
	between		0.28	8.12	9.43	$n = 51$
	within		0.13	8.56	9.20	$T = 11$
$ln\, y_{it-1}$	overall	8.89	0.30	7.98	9.64	$N = 561$
	between		0.28	8.15	9.43	$n = 51$
	within		0.12	8.57	9.18	$T = 11$
$ln\, y_{it-2}$	overall	8.89	0.31	7.93	9.64	$N = 561$
	between		0.28	8.14	9.44	$n = 51$
	within		0.12	8.52	9.16	$T = 11$
VR_{it}, km	overall	3,425.54	1,867.05	426.00	9,837.00	$N = 561$
	between		1,832.30	485.18	9,384.18	$n = 51$
	within		434.13	1640.00	7,025.45	$T = 11$
$ln\, VR_{it}$	overall	7.99	0.56	6.05	9.19	$N = 561$
	between		0.55	6.18	9.15	$n = 51$
	within		0.12	7.35	8.86	$T = 11$
NMR_{it}	overall	0.00	0.02	−0.13	0.13	$N = 561$
	between		0.01	−0.03	0.01	$n = 51$

	within		0.02	−0.13	0.13	$T = 11$
OP_{it}, m^2	overall	434,152.10	286,631.70	4,849.00	1,917,974.00	$N = 561$
	between		247,609.60	41,560.45	1,110,674.00	$n = 51$
	within		148,128.60	−256,031.90	1,241,452.00	$T = 11$
$ln\, OP_{it}$	overall	12.69	0.89	8.49	14.47	$N = 561$
	between		0.79	10.57	13.86	$n = 51$
	within		0.43	10.28	14.60	$T = 11$
$IECPC_{it}$, kWh	overall	1,316.79	1,612.92	3.00	9,582.00	$N = 561$
	between		1,581.14	13.09	6,303.00	$n = 51$
	within		382.29	−286.21	4,595.79	$T = 11$
$ln\, IECPC$	overall	6.40	1.47	1.10	9.17	$N = 561$
	between		1.44	2.38	8.73	$n = 51$
	within		0.34	4.50	7.88	$T = 11$
$SWSED_{it}$, %	overall	17.87	4.18	7.06	28.59	$N = 561$
	between		3.33	10.03	24.06	$n = 51$
	within		2.58	11.61	28.67	$T = 11$
$ln\, SWSED_{it}$	overall	2.85	0.26	1.95	3.35	$N = 561$
	between		0.21	2.27	3.18	$n = 51$
	within		0.16	2.46	3.53	$T = 11$
URB_{it}, %	overall	64.45	10.25	34.83	88.16	$N = 561$
	between		9.83	38.02	86.55	$n = 51$
	within		3.19	52.43	77.78	$T = 11$
$ln\, URB_{it}$	overall	4.15	0.17	3.55	4.48	$N = 561$
	between		0.17	3.64	4.46	$n = 51$
	within		0.05	3.93	4.36	$T = 11$

Table 2

Descriptive statistics

Table 3 presents the pairwise correlation coefficients for the explanatory variables. Among these, the highest correlation coefficient is between the lags of GDP per capita (0.95).

These variables also have correlation coefficients of 0.58 and 0.60 with industrial electricity consumption per capita *($ln\, IECPC_{it}$)*. Similarly, $ln\, IECPC_{it}$ has a correlation of 0.59 with occupancy permits. Nevertheless, the magnitude of these correlation coefficients remains at relatively acceptable levels, not exceeding 0.60 (excluding the lags). Regardless, to address potential multicollinearity that might stem from lagged variables, the models include a parsimonious number of indicators and instruments added in a gradual manner. According to this approach, the consistency in coefficients between models validates results against potential multicollinearity.

	$ln\, y_{t-1}$	$ln\, y_{t-2}$	$ln\, VR$	$ln\, URB$	NMR	$ln\, OP$	$ln\, IECPC$	$ln\, SWSED$
$ln\, y_{it-1}$	1.00							
$ln\, y_{it-2}$	0.95	1.00						
$ln\, VR_{it}$	−0.07	−0.04	1.00					
$ln\, URB_{it}$	0.25	0.31	−0.02	1.00				
NMR_{it}	0.35	0.36	−0.02	0.18	1.00			
$ln\, OP_{it}$	0.30	0.35	0.28	0.42	0.17	1.00		
$ln\, IECPC_{it}$	0.58	0.60	0.07	0.44	0.26	0.59	1.00	
$ln\, SWSED_{it}$	0.41	0.50	−0.03	0.50	0.31	0.34	0.47	1.00

Table 3

Pairwise correlation coefficients between variables

Figures 1 and 2 provide the regional outlook for the key indicators presented in Table 2. Figure 1.*a* shows the variation in average GDP per capita among non-metropolitan provinces from 2011 to 2021, while Figure 1.*b* illustrates the average growth rate of GDP per capita for the same period. Finally, Figure 2 presents the regional distribution of village roads and urbanisation rates. In general, well-off western regions appear to exhibit slower growth rates than their poorer Eastern counterparts. Furthermore, relatively less urbanised northern provinces seem to possess more extensive village road networks than urbanised locations in the west and south.

The system GMM requires mean stationarity in the data series for robust results, which is a weaker assumption than panel stationarity. Results and discussions regarding the stationarity of the data are provided in Tables A.1 to A.3 in Appendix A.

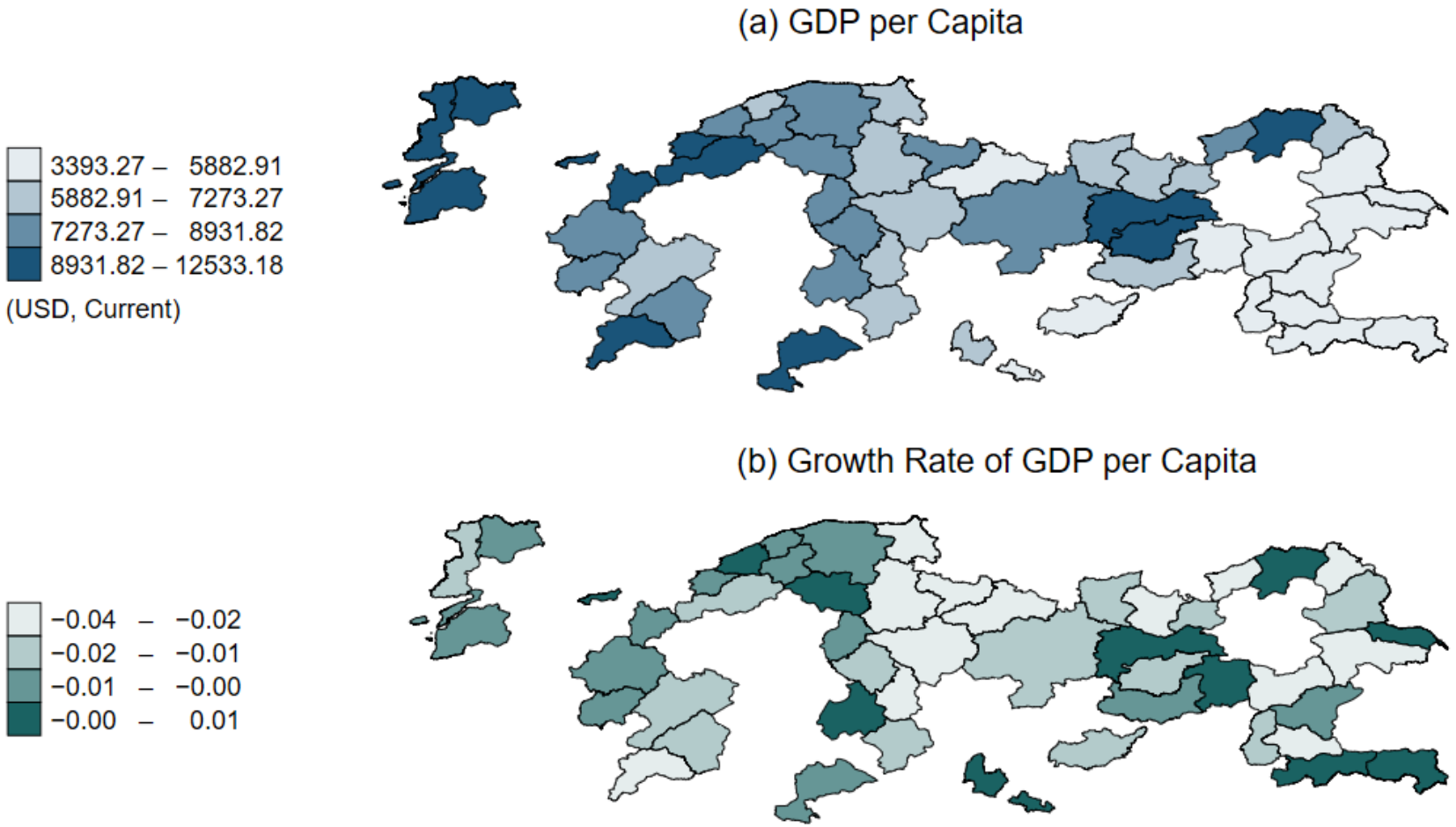


Figure 1

Level and growth rate of GDP per capita across 51 non-metropolitan Turkish provinces, 2011-2021

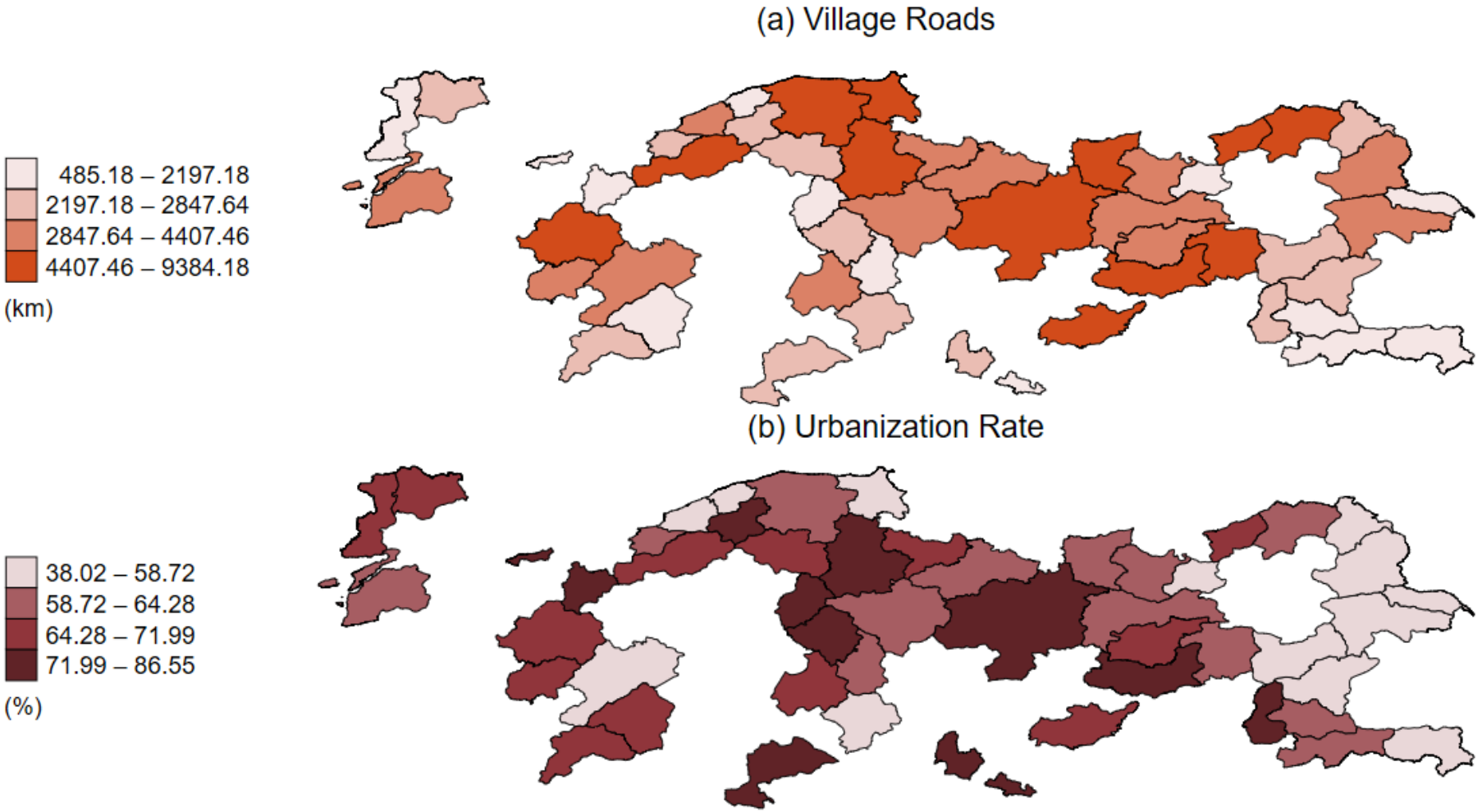


Figure 2

Village roads and the urbanisation rate across 51 non-metropolitan Turkish provinces, 2011-2021

5

Econometric technique

This study employs a dynamic panel data model, and it applies the system GMM estimator as the econometric method. This technique accounts for the endogeneity of the lagged dependent variable, as well as reverse causality between explanatory and outcome indicators. It eliminates the fixed effects without introducing Nickell bias into coefficients. Its theoretical foundations were established by Arellano and Bover (1995) and Blundell and Bond (1998), while its application was facilitated by Roodman (2009) and Kripfganz (2019). This paper utilises the latter to benefit from additional post-estimation diagnostics, such as under-identification tests, and Andrews and Lu's (2001) model and moment selection criteria. The «Results» section provides a discussion on the robustness of the findings in terms of instrument validity, Nickell bias, and potential spatial dependency.

The system GMM method estimates Equations (1*a*) and (1*b*) in levels and differences simultaneously. In this setting, the system GMM technique instruments equations in levels with lagged differences, and equations in differences with lagged levels. In its empirical application, this study follows the estimation approaches in Roodman (2009) and Kripfganz (2019).

6

Results

Results obtained from the system GMM technique are provided in Table 4. The models in this table treat all variables as strictly endogenous, including the lags of GDP per capita. While typically considered predetermined in theory (Arellano & Bover 1995, Blundell & Bond 1998, Roodman 2009, Kripfganz 2019), instrument validity here requires treating these lags as endogenous, likely due to price effects and Turkish GDP measurement biases (Bakış 2018, Boratav *et al.* 2018). Appendix D (Table D.1) provides the full list of instruments for all models in Table 4. Finally, all year dummies are modelled as strictly exogenous instrumental variables.

6.1. Baseline estimates

In columns (1)-(5) of Table 4, the dependent variable is the level of GDP per capita, while in column (6), it is the growth rate. The statistically significant coefficients of $ln\, y_{t-1}$ and $ln\, y_{t-2}$, ranging from 1.269 to 1.527 and −0.646 to −0.485 respectively, at the 1 % and 5 % levels, suggest shock persistence in the short run that dissipates over time. This is further supported by the sum of these coefficients ($\alpha_1^I + \alpha_2^I$) ranging between 0.745 and 0.880, which is less than unity.

In column (6), the coefficient of $ln\, y_{it-1}$ is positive but statistically insignificant (0.323), indicating the absence of short-run shock persistence in the growth rate. However, the coefficient of $ln\, y_{it-2}$ (−0.485) is statistically significant at the 5 % level, implying conditional convergence and dynamic stability. The sum of these coefficients ($\alpha_1^G + \alpha_2^G$) is also negative (–0.161) and statistically significant at the 10 % level, lending further support to conditional convergence and a stable agglomeration trajectory in the long run.

Furthermore, note that the coefficients for all variables, except for the first lag of GDP per capita, are almost identical between columns (5) and (6). Notably, the coefficients for $ln\, y_{it-1}$ in columns (5) and (6) are 1.323 and 0.323, respectively. The latter satisfies the identity $\alpha_1^G = \alpha_1^I - 1$, as established in the «Model specification» section. This consistency across models provides further evidence for the validity of dynamic specifications in columns (5) and (6).

Regarding the market access mechanism, the variables have the expected signs. The coefficients for village roads *($ln\, VR_{it}$)* and the urbanisation rate *($ln\, URB_{it}$)* are positive, while the interaction term ($ln\, VR_{it} \times ln\, URB_{it}$) is negative with statistical significance at the 5 % level in column (4), and at the 1 % level in columns (3), (5) and (6) in Table 4. Although the coefficients for village roads and urbanisation rate increase from 0.062 to 1.001 and 0.123 to 1.830, respectively, between columns (2) and (3), the negative coefficient of the interaction term (−0.247) offsets these baseline increases, by introducing diminishing marginal returns. Notably, the magnitudes of these coefficients remain consistent between column (3) and (4), following the introduction of the net migration rate, providing evidence of robustness against potential multicollinearity. Because the market access mechanism is nonlinear, the coefficients of market access variables do not represent standard elasticities. This is discussed in further detail under the «Marginal effects» section.

The results for the net migration rate *(NMR_{it})* in Table 4 show that the level and growth rate of GDP per capita are further driven upwards by this variable. The coefficients of the net migration rate *(NMR_{it})* suggest that a one percentage-point increase in the net migration rate is associated with a 2.043 % rise in the level of GDP per capita, and a 2.043 percentage-point increase in its growth rate. Notably, the inclusion of this variable in column (5) reduces the magnitude of the other estimated coefficients, and particularly market access variables, indicating its empirical importance.

Additionally, industrial electricity consumption per capita *($ln\ IECPC_{it}$),* which proxies for private capital, appears to be positively correlated with the level and growth rate of GDP per capita. A 1 % increase in this variable is associated with an expansion ranging between 0.054 % and 0.068 % in the level of GDP per capita, and a 0.054 percentage-point rise in its growth rate. Finally, in Table 4, neither the share of females with secondary education *($ln\ SWSED_{it}$)* nor occupancy permits *($ln\ OP_{it}$)* appear to be related to either dependent variable. Potential reasons for these results are evaluated in the «Discussion» section.

	(1)	(2)	(3)	(4)	(5)	(6)
			$ln\, y$			$\Delta\, ln\, y$
$ln\, y_{it-1}$	1.362***	1.269***	1.485***	1.527***	1.323***	0.323
	(0.373)	(0.290)	(0.218)	(0.163)	(0.226)	(0.226)
$ln\, y_{it-2}$	−0.604**	−0.524**	−0.623***	−0.646***	−0.485**	−0.485**
	(0.296)	(0.244)	(0.194)	(0.149)	(0.187)	(0.187)
$ln\, VR_{it}$	0.018	0.062	1.001***	0.941**	0.899***	0.899***
	(0.123)	(0.105)	(0.348)	(0.369)	(0.310)	(0.311)
$ln\, IECPC_{it}$	0.068***	0.067***	0.061***	0.067***	0.054***	0.054***
	(0.021)	(0.020)	(0.011)	(0.011)	(0.015)	(0.015)
$ln\, SWSED_{it}$	−0.081	−0.092	−0.066	−0.019	−0.037	−0.037
	(0.062)	(0.060)	(0.058)	(0.055)	(0.084)	(0.084)
$ln\, URB_{it}$		0.123	1.830***	1.722**	1.590***	1.591***
		(0.175)	(0.647)	(0.745)	(0.585)	(0.585)
$ln\, VR_{it} \times ln\, URB_{it}$			−0.247***	−0.229**	−0.221***	−0.221***

			(0.084)	(0.094)	(0.077)	(0.077)
$ln\,OP_{it}$				−0.021	−0.001	−0.001
				(0.024)	(0.029)	(0.029)
NMR_{it}					2.043**	2.043**
					(0.981)	(0.981)
Constant	1.738*	1.053	−6.463**	−6.180**	−5.288**	−5.292**
	(1.013)	(0.921)	(2.808)	(2.813)	(2.437)	(2.440)
$\alpha_1^s + \alpha_2^{sb}$	0.758	0.745	0.862	0.880	0.839	−0.161
Std. Err.	0.16	0.16	0.08	0.09	0.08	0.08
p-value	0.000	0.000	0.000	0.000	0.000	0.060
Panel FE	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	561	561	561	561	561	561
Groups	51	51	51	51	51	51
Avg. Obs. per Group	11	11	11	11	11	11
Linear Moment Cond.	21	23	23	26	29	29
AR(1) *p-value*	0.015	0.007	0.001	0.000	0.001	0.000
AR(2) *p-value*	0.477	0.492	0.359	0.245	0.845	0.844
AR(3) *p-value*	0.840	0.851	0.861	0.865	0.477	0.407
Hansen J 2SWM[a] p-value	0.120	0.104	0.482	0.562	0.498	0.498

Hansen J 3SWM p-value	0.136	0.155	0.413	0.624	0.583	0.583
Cragg-Donald p-v.	0.082	0.059	0.020	0.028	0.035	0.035
Cragg-Donald Wald p-v.	0.067	0.042	0.026	0.000	0.000	0.000
Kleibergen-Paap LM p v.	0.038	0.018	0.003	0.002	0.016	0.016
Kleibergen-Paap Wald p v.	0.000	0.000	0.000	0.000	0.000	0.000
Andrews-Lu AIC	−1.25	−1.47	−5.52	−8.19	−9.64	−9.64
Andrews-Lu BIC	−10.91	−13.06	−15.17	−21.71	−27.02	−27.02
Andrews-Lu HQIC	−5.08	−6.07	−9.34	−13.55	−16.53	−16.53

Notes: Windmeijer-corrected and cluster-robust standard errors robust to heteroskedasticity, serial correlation and finite- sample bias are reported in parentheses.

^*a* 2-step weighting matrix

^*b* The sum of coefficients of *ln_y_it*-1 and *ln y_it*-2

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 4

Baseline regression results

6.2. Robustness of results

Regarding the robustness of model specifications, Table 4 reports only the *p-values* for conciseness; full post-estimation statistics are available on request. In Table 4, the *Arellano-Bond AR*(1), *AR*(2) and *AR*(3) tests confirm the absence of second- and third-order serial correlation in the residuals. Additionally, *Hansen J-statistic p-values* for two-step and three-step weight matrices fail to reject the null hypothesis of overidentifying restrictions. Furthermore, the *Cragg-Donald and Kleibergen-Paap LM and Wald statistics* support the relevance of the instruments, indicating that the models are neither under-identified nor subject to weak identification. The *Andrews-Lu model selection criteria* further indicate that models (5) and (6) are the best fit.

An additional approach to establishing the validity of the system GMM models is to compare the estimator with coefficients obtained from the pooled OLS and fixed-effects techniques. In a dynamic panel data model, the endogeneity of the lagged dependent variable biases the pooled OLS estimator upwards and the fixed-effects estimator downwards (Nickell bias). A robust system GMM estimator should lie between these bounds (Bond *et al.* 2001). As this study employs an *AR*(2) process, Table B.1 in Appendix B confirms this relationship for the sum of the lagged coefficients in columns (5) and (6) of Table 4.

An additional factor that can bias the results is spatial spillover effects. However, certain characteristics of the sample mitigate such effects. Firstly, the exclusion of metropolitan provinces creates a non-contiguous sample, making spatial effects province-specific, while rendering standard contiguity-based weight matrices inapplicable. Secondly, village roads facilitate intra-provincial rural-urban mobility rather than inter-provincial movement. Nevertheless, Moran's I statistics, obtained from a spatial distance-based weights matrix for columns (5) and (6) in Table 4, show no evidence of systemic spatial dependence (see Appendix C, Table C.1).

6.3. Marginal effects of village roads

Given the nonlinear relationship between village roads and the level and growth rate of GDP per capita, their marginal effects provide critical insights. Table 5 and Figure 3 report these for the logarithm of the urbanisation rate *($ln\ URB_{it}$),* ranging from 3.55 (34.81 %) to 4.48 (88.23 %), based on the income and growth specifications in columns (5) and (6) of Table 4.

Note that marginal effects are almost identical between the two models, providing further validation for the dynamic specifications.

In Table 5, for a province with 34.81 % urbanisation, a 1 % increase in village roads is associated with a 0.114 % increase in the level of GDP per capita, and a 0.114 percentage-point gain in its growth rate. This impact diminishes as urbanisation rises, and at 41.26 % the marginal gain moderates to a 0.076 % increase and a 0.076 percentage-point gain, respectively, at the 5 % significance level. Between urbanisation rates of 41.68 % and 44.70 %, the returns to village roads range from 0.074 % to 0.059 % for the level, and 0.074 to 0.059 percentage points for the growth rate of GDP per capita at the 10 % significance level. Beyond 44.70 %, the association is statistically insignificant. However, for highly urbanised provinces (81.45 % and above), a 1 % expansion in village roads is associated with a decrease of between 0.074 % and 0.092 % in the level of GDP per capita and a decline of between 0.074 and 0.092 percentage points in its growth rate.

Figures 3.*a* and 3.*b* depict the statistics from Table 5 within 95 % confidence intervals for columns (5) and (6) of Table 4, respectively. According to the estimated coefficients in Table 5, the marginal effects reach zero, at an urbanisation rate of 4.06 (57.97 %) in both specifications. Statistically, however, the marginal effects become insignificant, at a threshold of 3.73 (41.68 %). Note that Figure 3 displays 95 % confidence intervals, thereby leaving out the coefficients that are statistically significant only at the 10 % level in Table 5.

Urbanisation level		**Table 4 column (5)**		**Table 4 column (6)**	
$ln\, URB_{it}$	URB_{it}, %	*dy/dx*	*std. err.*	*dy/dx*	*std. err.*
3.55	34.81	0.114**	0.047	0.114**	0.047
3.56	35.16	0.112**	0.046	0.112**	0.047
3.57	35.52	0.109**	0.046	0.110**	0.046
3.58	35.87	0.107**	0.045	0.107**	0.045
3.59	36.23	0.105**	0.045	0.105**	0.045
3.60	36.60	0.103**	0.044	0.103**	0.044
3.61	36.97	0.101**	0.044	0.101**	0.044
3.62	37.34	0.098**	0.043	0.099**	0.043
3.63	37.71	0.096**	0.043	0.096**	0.043
3.64	38.09	0.094**	0.042	0.094**	0.042

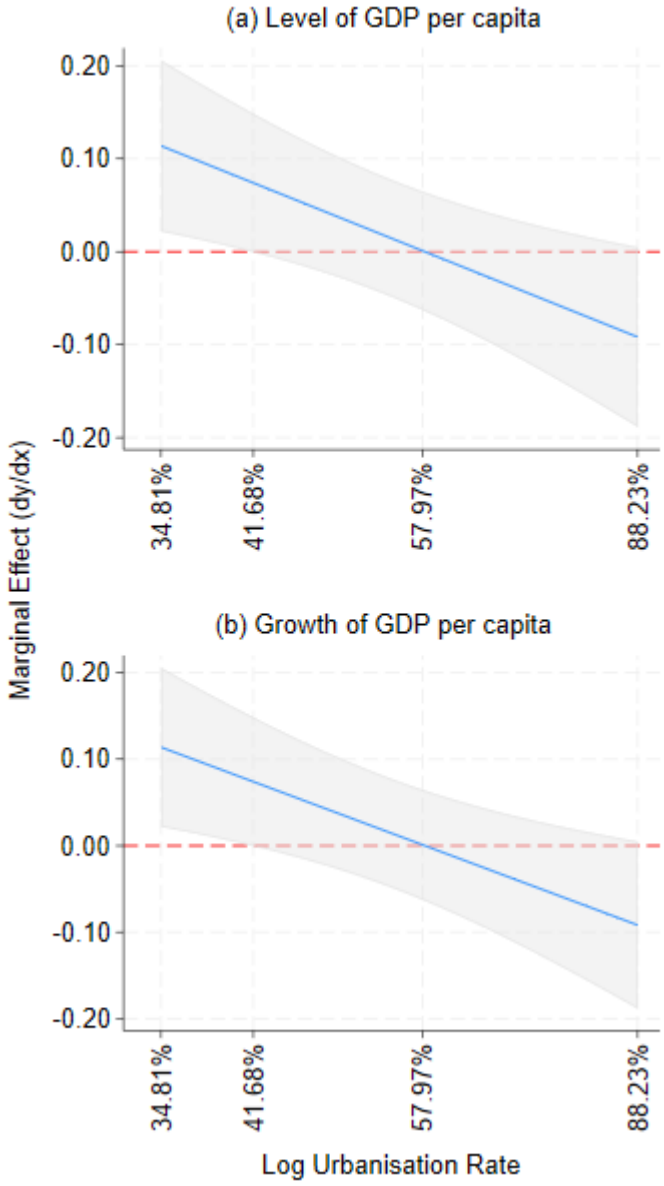
3.65	38.47	0.092**	0.042	0.092**	0.042
3.66	38.86	0.089**	0.041	0.090**	0.041
3.67	39.25	0.087**	0.041	0.087**	0.041
3.68	39.65	0.085**	0.040	0.085**	0.040
3.69	40.04	0.083**	0.040	0.083**	0.040
3.70	40.45	0.081**	0.039	0.081**	0.039
3.71	40.85	0.078**	0.039	0.079**	0.039
3.72	41.26	0.076**	0.039	0.076**	0.039
3.73	41.68	0.074*	0.038	0.074*	0.038
3.74	42.10	0.072*	0.038	0.072*	0.038
3.75	42.52	0.070*	0.037	0.070*	0.037
3.76	42.95	0.067*	0.037	0.068*	0.037
3.77	43.38	0.065*	0.037	0.065*	0.037
3.78	43.82	0.063*	0.036	0.063*	0.036
3.79	44.26	0.061*	0.036	0.061*	0.036
3.80	44.70	0.059*	0.036	0.059*	0.036
3.81-4.39	45.15-80.64	*Statistically insign.*		*Statistically insign.*	
4.40	81.45	−0.074*	0.045	−0.074*	0.045
4.41	82.27	−0.076*	0.045	−0.076*	0.046
4.42	83.10	−0.079*	0.046	−0.079*	0.046
4.43	83.93	−0.081*	0.047	−0.081*	0.047
4.44	84.77	−0.083*	0.047	−0.083*	0.047
4.45	85.63	−0.085*	0.048	−0.085*	0.048
4.46	86.49	−0.087*	0.048	−0.088*	0.048
4.47	87.36	−0.090*	0.049	−0.090*	0.049
4.48	88.23	−0.092*	0.049	−0.092*	0.050

Notes: standard errors are calculated according to the Delta method.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 5

Marginal effects of village roads



Note: panel *(a)* illustrates the effect on the level of GDP per capita, while panel *(b)* shows the effect on the GDP growth rate. The *x-axis* represents

the urbanisation rate (displayed in levels on a log scale). Shaded areas indicate 95 % confidence intervals. The horizontal dashed line represents the zero-significance thresholds.

Figure 3

Marginal effects of village roads for given values of the logged urbanisation rate

7

Discussion

The results in this paper lend support to the theory that village roads are positively associated with income levels and growth through the market access channel. Additionally, there is evidence of an inverted U-shaped relationship between village roads and the level and growth rate of GDP per capita. This arises from the fact that, within the New Economic Geography framework (Krugman 1991, Fujita *et al.* 2001), a higher level of urbanisation implies lower transport costs. Therefore, reductions in transport costs have smaller positive income effects in urbanised provinces than their rural counterparts. In the context of this study, in more urbanised locations, additions to village roads are also weakly associated with income reduction, likely due to the cost of their provision and maintenance.

The results are also consistent with literature that find positive income effects of rural roads (Escobal & Ponce 2008, Khandker *et al.* 2009, Wondemu & Weiss 2012, Zhang *et al.* 2023). The findings suggest that market-integrating effects of rural roads, through increasing workers' access to labour markets (Gachassin *et al.* 2010), and enabling villagers to find employment in urban industries (Asher & Novosad 2020), capitalise into aggregate income gains in the wider region. These income effects take place if the region is below a certain urbanisation threshold.

Furthermore, the results demonstrate that the established link between inter-provincial market potential and income benefits in Turkey (Karahasan *et al.* 2016) is also present at the sub-provincial level. These findings are also consistent with the positive productivity effects of Turkish transport infrastructure reported in the literature (Akgüngör 2006, Beyzatlar & Kuştepeli 2011, Elburz & Cubukcu 2021). Additionally, the positive and statistically significant coefficient of the net migration rate aligns with the spatial dimension of Turkish

regional development identified in these studies (Karahasan *et al.* 2016, Karahasan & Bilgel 2020, Elburz & Cubukcu 2021).

According to the coefficients of the lagged GDP per capita, there is shock persistence in the short run (Mion 2004). Shock persistence in both the level and growth rate of GDP per capita dissipates in the long run, consistent with discussions in Head and Mayer (2004). These results underline the importance of temporal dependencies in the agglomeration trajectory. In this study, the similarity of the results between models that include the level and growth rate of GDP per capita as the dependent variable validates the use of dynamic model specifications.

Furthermore, the level of private capital, measured by industrial electricity consumption per capita, emerges as a significant driver of both the level and growth rate of GDP per capita. This aligns with theoretical frameworks that link private capital accumulation to higher marginal labour productivity and increased regional wealth (Ciccone 2002). They are also consistent with the literature regarding the impact of roads on productivity in Turkey (Elburz & Cubukcu 2021).

In the results, the share of females with secondary education and occupancy permits are statistically insignificant. Hanson (2005) reports statistically significant coefficients for the education indicators for sixteen years of schooling or more. Similarly, the author finds that the housing stock is statistically significant with a positive sign. In the context of this study, relatively low shares of females with secondary education in the sample suggest the prevalence of less developed provinces. Consequently, the limited absorptive capacity for skilled workers and high vacancy rates in the labour and housing markets of these provinces are likely to weaken the link between these indicators and the dependent variables, leading to statistically insignificant coefficients.

8

Conclusions and limitations

This study has examined the relationship between village roads and both the level and growth rate of GDP per capita across a panel of 51 non-metropolitan Turkish provinces from 2011 to 2021. The income and growth effects of village roads have been estimated within an intra-provincial market-access framework through reduced-form specifications. It employs a dynamic panel data model via the system GMM method. The results reveal a positive

relationship between the length of village roads and income levels and growth. However, this relationship is conditional on the level of urbanisation: the more rural a province, the higher the marginal income gains from village roads. Findings further suggest shock persistence in the agglomeration trajectory, which dissipates in the long run.

The findings yield crucial policy implications for sustainable regional development, particularly in relation to SDG 11.*a* («Support positive economic, social and environmental links between urban, peri-urban and rural areas by strengthening national and regional development planning»). Investment in village roads boosts income levels in rural provinces. However, its impact becomes statistically insignificant at an urbanisation threshold of approximately 42 %. This finding provides economic justification for the 2012 Turkish Administrative Reform (Law No. 6360), as this legislation effectively restricted village road provision to non-metropolitan provinces, where the marginal returns remain significant in the less urbanised locations.

The analysis in this paper is constrained by data availability, particularly the potential positive bias in the Turkish GDP series. This study has utilised year dummies to control for common time-specific shocks and mitigate these biases. To validate and extend these results, future research could explore the non-income effects of village roads; for example, whether improved connectivity draws manufacturing firms, or facilitates human capital accumulation by increasing access to educational facilities.

9

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10

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