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Infrastructure, Entrepreneurship, and the Export Paradox: A Panel Data Analysis of Regional Income Divergence in Turkish Economy

Mehmet ŞAHİN[1]
https://orcid.org/0000-0002-7170-3198
Department of Social Services, Çanakkale Onsekiz Mart University, Türkiye
mehmetsahin@comu.edu.tr

Özge UYSAL ŞAHİN
https://orcid.org/0000-0002-1422-4123
Department of Health Management, Çanakkale Onsekiz Mart University, Türkiye
ozge@comu.edu.tr

Shafa ALIYEV
https://orcid.org/0000-0002-4997-7563
Sumgait State University, Sumgait, Azerbaijan
shafa.aliyev@sdu.edu.az

Irada BAGIROVA
https://orcid.org/0009-0001-9326-3322
Nakhchivan State University, Nakhchivan, Azerbaijan
iradebagirova@yahoo.com

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Abstract

Türkiye's regional income gap is large and persistent. In 2023, the richest province earned roughly 4.6 times the per-capita income of the poorest. Yet whether trade, entrepreneurship, or infrastructure drive this divergence - and how stable these associations are across macroeconomic regimes - remains empirically unsettled. This paper addresses those questions using a balanced panel of 81 provinces over 2013–2023 (N = 890, T = 11). The empirical strategy proceeds in five steps: Pesaran (2021) cross-section dependence (CD) tests; Pesaran (2007) second-generation CIPS unit root tests; Theil T decomposition with between–within splitting; two-way fixed-effects (2W-FE) regression with HC1 robust errors; and a first-difference specification with year effects as the main robustness check. A supplementary beta-convergence regression and spatial autocorrelation analysis are also reported.

[1] Corresponding author

Three findings stand out. First, infrastructure - proxied by electricity consumption per capita - is the most consistently significant conditional correlate of provincial income (2W-FE: $\beta = 0.132$, $p < 0.001$; first-difference: $\beta = 0.109$, $p < 0.001$). Second, export intensity is negatively and significantly associated with income when measured as the log export-to-income ratio ($\beta = -0.013$, $p < 0.001$), a pattern concentrated in the pre-2018 sub-period and in Eastern provinces. Third, beta-convergence analysis reveals a statistically significant but slow convergence rate of 0.89% per year (half-life: 78 years), masking considerable heterogeneity: convergence is faster in the post-2018 period and absent in the pre-crisis years. Spatial autocorrelation in provincial income is high (average Moran's I = 0.67, $p < 0.01$ in all 10 observed years), confirming that income clustering is structural and geographically persistent. All reported associations are conditional correlates, not causal estimates.

Keywords: cross-sectional dependence; beta-convergence; Turkish economy; regional inequality; Theil decomposition; panel fixed effects.

JEL Classification: R11; O18; O47.

Introduction

Thirty years of high aggregate growth have not closed Türkiye's regional income gap. Istanbul's per-capita income stood at roughly 4.6 times that of Ağrı in 2023, a ratio virtually unchanged since the early 2000s. The persistence of this divide raises a straightforward but difficult empirical question: which provincial characteristics are reliably associated with income growth once permanent differences across provinces and common national shocks are controlled for?

Three candidates appear repeatedly in the regional science literature and in Turkish development policy: trade openness, entrepreneurial activity, and infrastructure quality. Each is theoretically plausible and measurable at the provincial level. Yet their relative importance - and whether their associations are stable across macroeconomic regimes - has not been examined in a unified panel framework for Türkiye covering the 2013–2023 decade, which includes the 2018 exchange rate crisis and the COVID-19 shock.

This paper fills that gap with four specific contributions. First, it exploits the full cross-province variation of all 81 provinces over 11 years, removing province fixed effects and common year shocks before drawing any inference. Second, it applies second-generation CIPS unit root tests (Pesaran, 2007) appropriate under the strong cross-section dependence documented in the data, rather than first-generation IPS tests that are oversized in this setting. Third, it documents beta-convergence alongside the more familiar sigma convergence and Theil decomposition, providing a direct estimate of the implied convergence speed. Fourth, it characterises the spatial structure of provincial income through annual Moran's I statistics, which show that income clustering is high, stable, and statistically significant throughout the sample, a structural pattern that is partially but not fully absorbed by province fixed effects.

The analysis focuses on conditional associations within provinces over time, not on estimating causal effects. Trade, firm density, and electricity consumption are all endogenous to income at some level. The two-way fixed-effects specification controls for province-level permanent characteristics and year-level common shocks, reducing but not eliminating bias. Causal language is avoided throughout.

1. Literature Review

1.1 Trade and Regional Income

The aggregate evidence that trade raises income is well established (Frankel & Romer, 1999), but its sub-national implications are less clear. Border regions and ports of entry disproportionately capture the static gains from trade, while hinterland provinces may experience rising inequality as factor prices diverge (Brülhart & Traeger, 2005). For Türkiye specifically, export activity is heavily concentrated in western coastal provinces, which implies that provincial-level regressions will identify a largely heterogeneous relationship. Spatial evidence further suggests that trade openness is linked to regional income inequality in Türkiye, implying that the income gains from export expansion may not be evenly distributed when productive capabilities are unequal across provinces (Şaşmaz, 2025).

Kallioras & Petrakos (2010) show that EU accession-phase trade integration had uneven regional-industrial effects in EU new member-state regions during 1995–2004, as more developed regions absorbed proportionally more of the market-access gains. A similar mechanism is plausible in Türkiye: in provinces where exports depend heavily on imported intermediates, higher export volumes need not translate into higher local value added or income. The export-to-income ratio used in the robustness specification below is designed to capture this composition effect more precisely than log export volume alone.

1.2 Entrepreneurship and Firm Formation

Schumpeterian growth theory (Aghion & Howitt, 1992) assigns a central role to firm creation in productivity growth, through creative destruction and the reallocation of factors toward more productive uses. At the regional level, Audretsch and Fritsch (2002) find that firm birth rates in German regions predict employment growth with a lag of five to seven years, while Sternberg and Wennekers (2005), drawing on Global Entrepreneurship Monitor data, document that the determinants and effects of new business creation differ systematically across stages of development and depend on the availability of complementary factors.

A common observation in the entrepreneurship literature is that in lower-income regions a larger share of new firms reflects necessity-driven rather than opportunity-driven entrepreneurship, with weaker downstream productivity effects (Sternberg & Wennekers, 2005). This distinction matters empirically: necessity entrepreneurship is less likely to generate productivity-raising innovations and more likely to dissipate rather than accumulate income. Eastern Türkiye's provinces fit this profile, which is consistent with the finding below that firm density is insignificant in the two-way FE specification that identifies within-province variation, but significant in the first-difference model that captures short-run cyclical comovement.

1.3 Infrastructure: The Proxy Problem

Physical infrastructure reduces transaction costs, widens market access, and complements private capital investment (Aschauer, 1989; Röller & Waverman, 2001). These channels are theoretically well grounded and empirically documented across a range of developing economies (Chakravarty & Mitra, 2009; Seethepalli et al., 2008).

This study uses electricity consumption per capita as a proxy for infrastructure due to its consistent provincial availability in Türkiye. However, because electricity use may also reflect economic activity, potential reverse causality is acknowledged. To assess robustness, the analysis is replicated without this variable (Section 4.3).

1.4 Regional Convergence in Türkiye

Gezici and Hewings (2004) documented a declining trend in Türkiye's regional income inequality during 1980–1997. Önder et al. (2015) report persistent provincial income differences and partial convergence patterns through the early 2010s, with the western NUTS-1 regions consistently outperforming the rest. More recent work by Karahasan and Pınar (2022) on the role of human-capital investment in provincial inequality, and by Doğan & Kındap (2019) on regional convergence and spatial spillovers in Türkiye, suggests that convergence dynamics are highly heterogeneous across sub-periods and that the East–West between-group component of inequality has remained large. Türkcan and Uğurlu (2023) point to the 2018 macro-financial shock as a candidate disruption point in the convergence path observed in the 2009–2017 window.

Two recent contributions are particularly relevant for situating the present study. Korkmaz et al. (2025) document that economic complexity contributes positively to regional growth in Türkiye, yet long-standing East–West disparities prevent less developed provinces from benefiting equally from complexity gains. Cüre (2025) provides a classification of left-behind regions in Türkiye, supporting the persistence of territorially concentrated regional underperformance - a pattern that is broadly compatible with the cumulative-causation reading invoked in the spatial analysis below.

2. Data and Methodology

2.1 Data

The dataset is a balanced panel of all 81 Turkish provinces (il) over 2013–2023, yielding 891 potential province-year observations. One observation is missing due to a gap in the export series (0.1% of the panel), leaving N = 890 for regressions that include the export variable. All provincial demographic and economic statistics are drawn from the Turkish Statistical Institute's provincial database (TÜİK, 2024). Real per-capita GDP is constructed by deflating the nominal provincial series using the World Bank's linked GDP deflator (NY.GDP.DEFL.ZS.AD; World Bank, 2024); base year is set to 2009 for consistency across the panel. Electricity consumption per capita, firm counts, and export values are taken directly from TÜİK administrative registers. Table 1 provides definitions, descriptive statistics, and variance inflation factors.

Table 1: Variables, Descriptive Statistics, and Multicollinearity Diagnostics (N = 890)

Variable	Description	Mean	SD	Min	Median	Max	VIF (2W-FE)
ln_gdppc	Ln(GDPpc, 2009 USD)	7.973	0.757	5.943	8.067	9.670	(dep. var.)
ln_export	Ln(real exports, 2009 USD)	11.35	2.841	0.909	11.34	17.94	2.31
ln_export/GDP	Ln(export / GDPpc)	2.75	2.72	−2.86	2.67	8.27	2.48
ln_firms	Ln(registered firms)	11.26	0.847	8.985	11.27	14.04	1.89
ln_elec	Ln(electricity pc, kWh)	7.670	0.555	6.155	7.741	9.306	2.07

Note: Real GDP per capita and exports are deflated to 2009 prices using the World Bank GDP deflator (NY.GDP.DEFL.ZS.AD). VIF values, computed from the main two-way fixed-effects model (M1), are all below 2.5 = no serious multicollinearity. The export-to-GDPpc ratio measures provincial export intensity relative to real per-capita income. *Source*: TÜİK ADNKS, World Bank (2024).

2.2 Econometric Strategy

The identification strategy has five steps. All relationships are interpreted as conditional within-province associations, not causal effects.

Step 1 - Cross-section dependence. Pesaran's (2021) CD test is applied to each variable. Rejection of cross-section independence motivates the use of second-generation unit root tests and HC robust standard errors rather than classical GLS corrections.

Step 2 - Unit root tests. The CIPS statistic of Pesaran (2007) augments each province's Dickey–Fuller regression with cross-section means and their lagged values, which filters out the common factor driving the strong CD. The critical value at the 5% level for T = 11 (constant only) is −2.25.

Step 3 - Theil decomposition and beta convergence. The Theil T index is computed annually across 81 provinces and decomposed into East–Central–West between-group and within-group components. Beta convergence is assessed via the standard Barro cross-provincial regression: average annual growth over the full sample period is regressed on the log of initial (2013) per-capita income, with a negative coefficient implying unconditional convergence.

Step 4 - Main estimation. The benchmark is the two-way fixed-effects model:

$$ln\_gdppc_{it} = \alpha_i + \lambda_t + \beta_1\, ln\_export_{it} + \beta_2\, ln\_firms_{it} + \beta_3\, ln\_elec_{it} + \varepsilon_{it} \quad (1)$$

Province effects (α_i) absorb all time-invariant provincial characteristics; year effects (λ_t) absorb all shocks common to every province in a given year, including both the 2018 exchange-rate crisis and the COVID-19 pandemic. HC1 heteroskedasticity-consistent standard errors are used throughout. The Hausman test (H = 116.8, df = 3, $p < 0.001$) strongly rejects random effects in favour of fixed effects. Specification M2 replaces log export volume with the log export-to-GDPpc ratio, which controls for province size and captures export intensity rather than export scale.

Step 5 - Robustness. The first-difference specification (Δln_gdppc regressed on Δln_export, Δln_firms, and Δln_elec, after year-demeaning) removes province fixed effects through differencing and tests whether year-to-year changes in the regressors predict year-to-year income changes. This provides a check against spurious levels associations. An additional robustness regression excluding ln_elec is also reported to assess how sensitive the other coefficients are to the infrastructure proxy.

Spatial autocorrelation. Annual Moran's I statistics are computed on provincial GDPpc using a KNN-5 spatial weight matrix constructed from provincial centroid coordinates (row-standardised). The statistics characterise the degree of spatial clustering in income levels. A panel FE-SAR model is also estimated to test whether spatial lag dynamics persist after province and year fixed effects are controlled for.

Dynamic model. A two-stage IV specification using L2 and L3 lagged income as instruments for L1 was estimated. The lagged dependent variable coefficient (−0.038, p = 0.65) is statistically indistinguishable from zero, indicating negligible income persistence once province and year effects are absorbed. The dynamic specification is therefore dropped from the main tables and relegated to a note; M3 (first-difference with year effects) serves as the preferred dynamic robustness check.

3. Inequality: Theil Decomposition and Beta Convergence

Table 2 reports annual Theil T values and they're between–within decomposition. Over the full sample, Theil T declined from 0.060 in 2013 to 0.056 in 2023, a modest but sustained narrowing of the overall income distribution across provinces. Three episodes interrupt this trend. The 2018 exchange rate shock pushed Theil T to its sample peak (0.067), reversing three years of convergence in a single year; this episode is consistent with broader characterisations of 2018 as a disruption point in Türkiye's regional convergence path (Türkcan & Uğurlu, 2023). The 2020 COVID-19 year produced the lowest Theil value of the sample (0.054), plausibly because pandemic-related income losses were more proportionally severe in high-income, high-tourism western provinces, temporarily compressing the distribution. The 2021 rebound then pushed inequality to 0.067, as western provinces recovered faster than eastern ones.

The between-region component fluctuates between 44% and 56% of total inequality over the sample. This stability implies that roughly half of provincial income inequality is attributable to the persistent East–Central–West structural divide, and about half reflects within-region heterogeneity. Neither component shows a strong trend, which suggests that regional policy has not substantially narrowed the structural divide during this period.

Table 2: Theil T Decomposition: Annual Provincial Income Inequality, 2013–2023

Year	Theil T	Between-region	Within-region	CV(GDPpc)	Between/ Total	Notes
2013	0.060	0.030	0.030	0.359	49.6%	Baseline
2014	0.061	0.032	0.029	0.358	52.4%	—
2015	0.059	0.033	0.026	0.352	55.4%	—
2016	0.059	0.032	0.027	0.352	53.8%	—
2017	0.058	0.030	0.028	0.348	51.2%	Pre-crisis low
2018	0.062	0.034	0.029	0.363	53.7%	Crisis peak
2019	0.058	0.030	0.028	0.347	51.5%	—
2020	0.054	0.024	0.030	0.336	44.4%	COVID trough
2021	0.067	0.032	0.035	0.378	48.2%	Rebound peak
2022	0.065	0.036	0.029	0.369	55.3%	—
2023	0.056	0.032	0.025	0.349	56.4%	End-of-sample

Note: Theil T computed with equal provincial weights: $T = (1/N)\ \Sigma_i\ (y_i/\mu)\ \ln(y_i/\mu)$, where y_i is province i's per-capita income and μ is the cross-province unweighted mean. Between-region component: West (24 provinces, TR1–TR3), Central (34 provinces, TR4–TR9), East (23 provinces, TRA–TRC). CV = cross-province coefficient of variation of per-capita income.

Source: authors' calculations from TÜİK data (TÜİK, 2024).

The beta-convergence regression complements the Theil decomposition by providing a direct estimate of the speed at which lower-income provinces close the income gap. For the full sample (2013–2023, N = 81), the OLS coefficient on initial log income is −0.0085 (robust SE = 0.0032, $p = 0.010$), implying a convergence rate of 0.89% per year and a half-life of approximately 78 years. This estimate is small but statistically significant, consistent with the slow sigma convergence in Table 2. Sub-period estimates reveal marked heterogeneity: the pre-2018 beta coefficient is small and insignificant (−0.005, $p = 0.62$), while the post-2018 period yields a substantially larger and significant estimate (−0.023, $p < 0.001$, $R^2 = 0.19$). The implication is that convergence, such as it is, has been compressed into the post-2018 years and is partly a mechanical consequence of the crisis depressing high-income provinces disproportionately rather than reflecting sustained structural catch-up.

4. Regression Results

4.1 Diagnostics

Table 3: Cross-Section Dependence and CIPS Unit Root Tests

Variable	CD stat.	CD p-val.	CIPS	Decision	Interpretation
ln_gdppc	187.77	<0.001	−2.616	I(0)***	Stationary in levels
ln_export	125.62	<0.001	−2.267	I(0)***	Stationary in levels
ln_firms	168.04	<0.001	−1.339	I(1)	Near-unit root; FD specification preferred
ln_elec	139.96	<0.001	−3.309	I(0)***	Clearly stationary

Note: CD denotes the Pesaran (2021) test for cross-sectional dependence, while CIPS refers to the Pesaran (2007) panel unit root test. The IPS test is omitted because it is invalid under strong cross-sectional dependence. The near-unit-root behaviour of *ln_firms* (CIPS = −1.34) justifies the first-difference specification (M3) as a robustness check, whereas M1 and M2 retain the level specification with province fixed effects. *** $p < 0.001$.

All four variables exhibit strong cross-section dependence (CD statistics ranging from 125 to 188), confirming that common factors - monetary policy, the business cycle, exchange rate movements - drive co-movement across provinces. This renders the IPS test inappropriate and motivates the use of CIPS throughout. ln_gdppc, ln_export, and ln_elec are stationary at the 5% level; ln_firms sit on the unit-root borderline (CIPS = −1.34 against a critical value of −2.25), which is a further reason to report first-difference results alongside levels specifications.

4.2 Panel Regression Results

Table 4: Panel Regression Results - Dependent Variable: ln(GDPpc, 2009 USD)

Variable	M1: 2W-FE (log export)	M2: 2W-FE (export/GDP)	M3: FD + Year FE	M4: Robustness (no elec proxy)
ln_export (log volume)	−0.005 (0.003)	—	0.001 (0.004)	—
ln_export/GDP (intensity)	—	−0.013*** (0.003)	—	—
ln_firms (2W-FE) / Δln_firms (FD)	0.086† (0.051)	0.071 (0.051)	0.240** (0.091)	0.115* (0.061)
ln_elec / Δln_elec	0.132*** (0.020)	0.127*** (0.019)	0.109*** (0.029)	—
Province FE	Yes	Yes	Absorbed (FD)	Yes
Year FE	Yes	Yes	Yes	Yes
R^2(within)	0.060	0.076	0.030	0.011
N	890	890	809	890
Hausman test (H, p)	116.8, <0.001	—	—	—

Note: HC1 heteroskedasticity-consistent standard errors are reported in parentheses. *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$; † $p < 0.15$. M1 is the baseline two-way fixed-effects model; M2 uses the export-to-GDPpc ratio instead of export volume; M3 estimates first differences with year dummies; and M4 excludes ln_elec as a robustness check. The dynamic AB-2SLS model is omitted because the lagged dependent variable is insignificant (p = 0.65). Results indicate conditional associations rather than causal effects.

Four observations are worth stating clearly. First, electricity consumption per capita carries a positive and highly significant coefficient in every specification: a 10% increase in electricity per capita is associated with a 1.3% higher provincial income in the 2W-FE model (M1), 1.3% in M2, and 1.1% in first differences (M3). The association disappears with electricity excluded (M4, where R^2 falls to 0.011), which confirms that electricity is doing real work in the model. Whether this reflects infrastructure quality, industrial composition, or a combination of both cannot be determined from these data alone.

Second, the sign and significance of export intensity depend critically on how it is measured. Log export volume (M1) is negative but not significant (−0.005, p = 0.13). Log export-to-income ratio (M2) is negative and strongly significant (−0.013, p < 0.001). The sign is economically plausible: provinces with high export intensity relative to their income levels tend to specialise in low-value-added commodity exports (agricultural products, textile intermediates) and are often slower-growing. This is not a statement about the aggregate gains from trade; it is a statement about which types of provinces in Türkiye export intensively and whether that activity is associated with above-trend income growth within provinces over time. In first differences (M3), the export coefficient is near zero (0.001, p = 0.80), suggesting that year-to-year changes in export activity do not predict year-to-year income changes.

Third, firm density is significant in first differences (0.240, p = 0.008) but only marginally significant in the 2W-FE levels specification (0.086, p = 0.09). Given ln_firms' near-unit-root behaviour, the first-difference result is more reliable for this variable. A 10% increase in registered firm counts is associated with approximately 2.4% higher income growth in the same year, consistent with a cyclical comovement between firm births and economic activity rather than a long-run structural relationship.

Fourth, the near-zero R^2 in M4 (without electricity) underlines the point that the 2W-FE R^2 is already low in the baseline: after removing province and year effects, only 6% of the remaining variance is explained by the three regressors. This is not unusual for within-province time-series variation in income, where persistent structural factors have already been differenced out, but it does signal that important time-varying correlates - human capital stocks, sectoral composition, public investment flows - are absent from the model.

4.3 Structural Break and Regional Heterogeneity

Table 5: Sub-Period and Regional Sub-Sample Regressions (2W-FE, M1 specification, HC1 SE)

Sub-sample	N prov.	N obs.	ln_export β (p)	ln_firms β (p)	ln_elec β (p)	R^2
Pre-2018 (2013–2017)	81	405	−0.010** (0.030)	0.008 (0.748)	0.021 (0.297)	0.018
Post-2018 (2018–2023)	81	485	0.006 (0.319)	0.205** (0.021)	0.274*** (<0.001)	0.114
Western provinces	24	264	0.004 (0.629)	−0.104 (0.291)	−0.024 (0.820)	0.004
Eastern provinces	23	253	−0.007† (0.062)	−0.001 (0.972)	0.078† (0.053)	0.051
Central provinces	34	374	n.s.	n.s.	n.s.	0.005

Note: Province and year FEs included in all sub-samples. HC1 SE. *** p < 0.01; ** p < 0.05; * p < 0.10; † p < 0.15. East: TRA–TRC NUTS-1 regions (23 provinces); West: TR1–TR3 (24 provinces);

Central: TR4–TR9. The post-2018 model absorbs the 2018 shock through the year fixed effect for 2018 itself, not through a pooled binary dummy, which avoids the D2018-versus-year-FE collinearity problem. Coefficient for Central provinces suppressed (all insignificant, $p > 0.20$ throughout).

The sub-sample results reveal substantial heterogeneity that the full-panel estimates conceal. Before 2018, export intensity is negatively associated with income and statistically significant (−0.010, $p = 0.030$); after 2018, the coefficient flips positive and becomes insignificant (0.006, $p = 0.32$). One interpretation is that the 2018 exchange rate depreciation altered the composition of export-intensive provinces: TL depreciation boosted export revenues in nominal terms but also compressed domestic purchasing power, changing the distribution of gains across provinces. The infrastructure coefficient is dramatically larger in the post-2018 period (0.274 versus 0.021), suggesting that provinces with greater electricity-proxied infrastructure capacity recovered more quickly from the crisis - consistent with the view that infrastructure quality acts as a buffer against macroeconomic shocks (Chakravarty & Mitra, 2009).

Western provinces show no significant associations whatsoever ($R^2 = 0.004$). This near-zero within-province R^2 is not a modelling failure; it reflects the structural saturation argument: western provinces' year-to-year income variation is largely driven by macro forces - financial conditions, tourism receipts, monetary policy - that year fixed effects absorb entirely. The three regressors carry no additional predictive content for this group. Eastern provinces exhibit a marginally significant negative export association (−0.007, $p = 0.062$) and a positive electricity association (0.078, $p = 0.053$), both consistent with theory: where infrastructure is scarce, marginal improvements carry larger income payoffs, and export activity tends to be concentrated in commodity sectors that add limited local value.

4.4 Spatial Autocorrelation

Annual Moran's I statistics computed on provincial GDPpc using the KNN-5 weight matrix range from 0.628 (2021) to 0.719 (2016), with an average of 0.670 across the 10 years for which complete data are available. All values are statistically significant at the 1% level (permutation inference, 499 replications). This is strong evidence of persistent geographic income clustering: provinces' income levels are highly predictable from their neighbours' income levels throughout the sample period.

A panel FE-SAR model yields a spatial lag coefficient of $\rho = 0.56$ ($p = 0.070$), marginally insignificant at the 5% level. The electricity coefficient remains significant and stable ($\beta = 0.116$, $p < 0.001$). Spatial clustering in income is largely structural - driven by permanent geographic sorting - and province fixed effects absorb it substantially. Dynamic spillovers across provincial borders exist but are modest once structural geography is controlled for. The policy implication is that geographically targeted investment in lagging eastern provinces is unlikely to generate large spillover multipliers; the structural determinants of clustering must be addressed directly.

The spatial clustering documented above has a clear interpretive structure rooted in classical regional science. Drawing on the growth-pole concept of Perroux (1955), Marmara - anchored by Istanbul and extended through Kocaeli, Bursa, Tekirdağ, Sakarya, and Yalova - can be characterised as Türkiye's dominant pole of propulsive industries (finance, automotive, chemicals, electronics, and port logistics) whose backward and forward linkages spill over into adjacent provinces through input-output relationships, daily commuting flows, shared transport corridors, and supplier-network embedding. The persistently high annual Moran's I value

(0.628–0.719) and the marginally insignificant FE-SAR spatial lag ($\rho = 0.56$) are consistent with this characterisation. Provinces adjacent to the Marmara core appear to capture spread effects, Bilecik, Çanakkale, and Eskişehir most visibly, while more distant eastern and south-eastern provinces lie outside the effective spillover radius and instead exhibit the backwash dynamics described by Myrdal (1957): selective out-migration of skilled labour and capital toward the pole, weak compensating return flows, and slow upgrading of local productive capacity. This asymmetry shapes the policy reading of the FE-SAR result. The modest residual spatial dependence after province fixed effects suggests that spillovers from Marmara are mostly already capitalised into permanent provincial characteristics - industrial structure, human-capital depth, and agglomeration economies - rather than transmitted dynamically year by year. Geographically diffuse interventions in lagging provinces therefore cannot rely on automatic spillover multipliers; they must address the structural barriers that prevent peripheral provinces from being plugged into the Marmara growth pole's value chains. The evolutionary view of regional development traps developed by Balland et al. (2025) for European regions provides a complementary lens that can plausibly be extended to the Turkish provincial setting: regions specialised in low-complexity activities tend to face self-reinforcing barriers to upgrading their productive structures, offering a useful interpretive framework for why Türkiye's peripheral provinces have not closed the gap with Marmara despite three decades of national growth.

5. Discussion

The robustness of the electricity coefficient across all four specifications - including after removing province trends, after first-differencing, and even in Eastern-province sub-samples - is the paper's most reliable finding. A 10% increase in electricity consumption per capita is associated with roughly 1.1% to 1.3% higher income, a coefficient comparable to infrastructure estimates in the development literature for similar economies (Aschauer, 1989; Chakravarty & Mitra, 2009). But the proxy limitation cannot be dismissed. Provinces like Kocaeli and Bursa consume large quantities of electricity because they host heavy industry, not because households have better access to power grids. The consistency of the electricity association with the theory of infrastructure as a growth complement (Röller & Waverman, 2001) is suggestive but insufficient for causal inference. Future work should exploit the spatial roll-out of Türkiye's fibre broadband network or motorway expansion as plausibly exogenous instruments.

The contrast between the log export volume result (insignificant) and the log export intensity result (significantly negative) speaks to a substantive economic point, not just a data construction issue. Log export volume rewards provinces that have large export sectors in absolute terms; Istanbul and Kocaeli dominate this measure. Log export intensity - exports divided by per-capita income - is high in provinces that export a lot relative to what they earn, which in Türkiye's provincial context means commodity-exporting eastern and central provinces with limited value-chain participation. The negative association between export intensity and income, concentrated in the pre-2018 period, is consistent with a terms-of-trade effect: provinces whose exports are commodity-intensive are more exposed to global commodity price cycles and TL fluctuations, and their income growth is accordingly more volatile and lower on average. This interpretation is consistent with the broader literature on the geographic concentration of export activity and on the link between export quality and growth (Frankel & Romer, 1999).

The compositional reading of this association is straightforward, and answers the question of why higher export intensity goes with lower, not higher, provincial income. Provinces with high export intensity in Turkey's lagging east and centre tend to specialise in low-complexity, labour-intensive product categories, primary and semi-processed agricultural goods, mineral and stone exports, basic textile intermediates, and unfinished metal products, whereas the high-complexity, capital- and technology-intensive baskets (automotive, machinery, electronics, refined chemicals) are concentrated in Marmara and a small number of central Anatolian industrial cities. The conceptual framework here draws on the economic-complexity literature initiated by Hidalgo and Hausmann (2009), which links export capabilities to the breadth of productive knowledge embedded in a region's firms. Provincial-level evidence for Turkey reported by Korkmaz et al. (2025) shows that, while economic complexity contributes positively to regional growth, long-standing East–West disparities prevent less developed provinces from benefiting equally from complexity gains. The negative coefficient on export intensity is therefore not a paradox in the literal sense; it is what one would expect when the share of low-value-added, labour-intensive exports in gross provincial output is large relative to the share of high-complexity exports. Within the panel, a one-log-point increase in export intensity in this composition profile is associated with slower, rather than faster, income growth - a pattern most visible in the pre-2018 window when domestic prices anchored the terms of trade more tightly than after the lira depreciation.

The beta-convergence estimate of 0.89% per year implies a half-life of 78 years - slow by international standards but not inconsistent with the persistence of Turkey's regional divide. For comparison, the EU cohesion literature typically reports rates of 1.5% to 2% per year for NUTS-2 regions, and the World Bank documents rates of 1% to 3% for similar middle-income country contexts. The post-2018 acceleration to 2.3% is partly mechanical: the 2018 crisis disproportionately hit high-income western provinces (financial sector, tourism, import-dependent manufacturing), mechanically compressing the income distribution. Structural catch-up - in which lagging provinces invest in human capital, infrastructure, and institutional quality - requires sustained policy effort over decades rather than a crisis-induced compression.

This analysis has four principal limitations. First, endogeneity is partially but not fully controlled: all three right-hand-side variables are plausibly affected by provincial income levels. Province fixed effects remove permanent endogeneity; year fixed effects remove common shocks; but idiosyncratic time-varying endogeneity - a high-income year attracting more firms and electricity demand - is not fully addressed. Second, the panel is short ($T = 11$), which limits the power of unit root tests and structural break inference. Third, the absence of direct measures of human capital, sectoral composition, and public investment at the annual provincial level is a substantive omission that biases all reported coefficients to an unknown degree. Finally, electricity per capita is at best a rough infrastructure proxy, and results for this variable should be read as stylised facts rather than precise structural estimates.

Conclusion

Türkiye's provincial income divide is real, persistent, and only slowly narrowing. This paper documents three findings that advance our understanding of that divide.

Infrastructure endowment, proxied by electricity consumption per capita, is the most consistently significant conditional correlate of provincial income across all specifications and sub-samples. The association is larger in the post-2018 period and in eastern provinces -

where infrastructure is scarcest and its marginal contribution presumably highest - and survives first-differencing and the exclusion of other regressors. This consistent pattern suggests that physical infrastructure provision remains a binding constraint on income growth in lagging provinces and warrants priority in regional development policy.

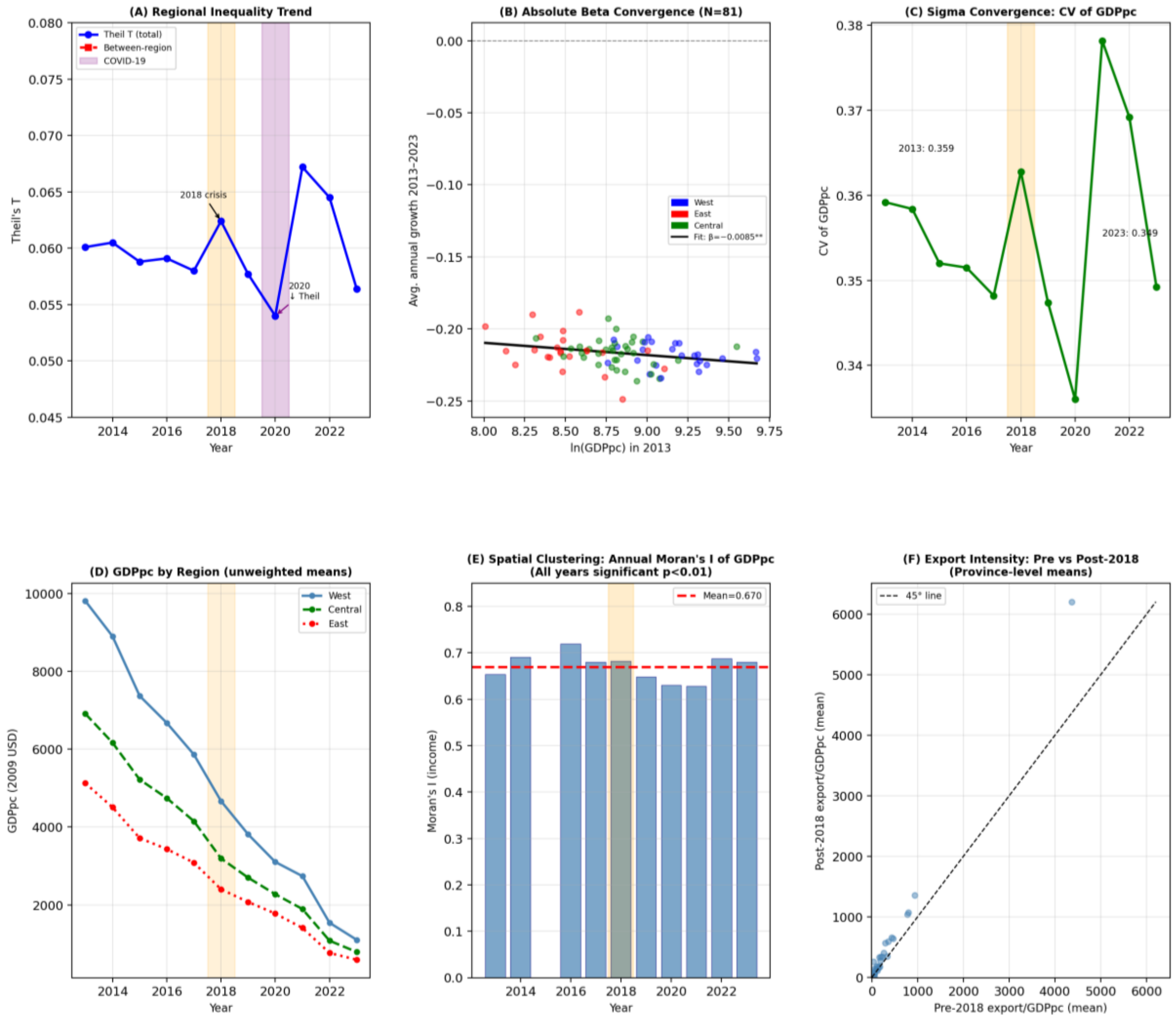
Trade openness, measured as export intensity rather than export volume, is negatively associated with provincial income, particularly in the pre-2018 period and in Eastern provinces. This finding is not a rejection of trade-led development; it is a characterisation of the type of export activity prevalent in Türkiye's lagging provinces - commodity-intensive, low-value-added, and vulnerable to exchange rate swings. Policies aimed at shifting eastern provinces up the export value chain, rather than simply expanding export volume, would target this mechanism more directly.

Beta-convergence is statistically significant but slow (0.89% per year, half-life 78 years). The convergence process is heterogeneous across time and absent in the pre-2018 period, cautioning against reading the aggregate trend as evidence of steady structural catch-up. Spatial income clustering is high throughout the sample (average Moran's I = 0.67), structural rather than dynamic, and not substantially reduced by province fixed effects - a finding that reinforces the case for geographically targeted rather than uniformly distributed regional investment.

A direct policy implication concerns the design of Türkiye's Regional Investment Incentive Scheme, which classifies provinces into six tiers, with the least-developed eastern and south-eastern provinces grouped into region 6 and granted the most generous set of instruments - corporate-tax reductions, social-security premium support, income-tax withholding allowances, customs-duty exemptions, interest-rate support, and free land allocation. The bulk of these instruments are oriented toward firm formation and the subsidisation of private fixed investment, which target the entrepreneurship channel. Yet the panel results suggest that within-province income variation in the eastern sub-sample is most reliably associated with the infrastructure proxy ($\beta = 0.078$, $p = 0.053$) and only weakly associated with firm density once province and year effects are absorbed. To the extent that this pattern reflects a genuine structural relationship rather than an artefact of measurement, the implication is that the current incentive mix may be over-weighted toward business-formation subsidies relative to direct public investment in infrastructure. Rebalancing the package - sustaining the existing tax and social-security incentives but pairing them with a stronger pipeline of public investment in energy, transport, and digital connectivity within region 6 - would address the correlate that our panel identifies most consistently with provincial income gains.

The recent global review of infrastructure-finance trends (World Bank, 2025) underscores the importance of mobilising private and blended finance for infrastructure projects in middle-income countries, which is directly relevant for the Region 6 pipeline. A complementary adjustment would tilt firm-level incentives away from generic business-formation support and toward export-quality upgrading, helping Region 6 provinces escape the low-complexity export profile. This rebalancing is consistent with the policy directions set out in Türkiye's pre-accession economic reform programme (Presidency of Strategy and Budget, 2024), which emphasises digital and physical infrastructure, productivity-enhancing investment, and regional development as integrated priorities. It also aligns with the World Bank's (2024) diagnosis of the middle-income trap, in which sustained transition to higher income tiers requires complementary investments in productive infrastructure and a shift from input-driven to innovation-driven growth; the broader macroeconomic context for these challenges in Türkiye is documented in the OECD's (2025) most recent economic survey.

Figure 1: Regional Income Dynamics in Türkiye, 2013–2023.



Note: (A) Theil T decomposition: overall inequality with between- and within-region components. (B) Absolute beta convergence scatter (N = 81 provinces): negative slope confirms slow convergence ($\beta = -0.0085$, half-life 78 years). (C) Sigma convergence: coefficient of variation of GDPpc. (D) Per-capita income trends by region (West/Central/East). (E) Annual Moran's I of provincial GDPpc: all years significant ($p < 0.01$), average = 0.670. (F) Export intensity pre- vs post-2018 by province.

Source: authors' calculations from TÜİK (2024) and World Bank (2024).

Credit Authorship Contribution Statement

Mehmet Şahin: Conceptualisation, Methodology, Software, Formal Analysis, Writing – Original Draft, Writing – Review & Editing. Özge Uysal Şahin: Conceptualisation, Data Curation, Writing – Review & Editing, Supervision. Shafa Aliyev: Validation, Writing – Review & Editing. Irada Bagirova: Validation, Writing – Review & Editing. All authors have read and approved the final version of the manuscript.

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Conflict of Interest Statement

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Data Availability Statement

Provincial data are publicly available from the Turkish Statistical Institute (TÜİK) at https://data.tuik.gov.tr. The linked GDP deflator series (NY.GDP.DEFL.ZS.AD) is openly available from the World Bank at https://data.worldbank.org. Replication code is available from the corresponding author upon reasonable request.

Ethical Approval Statement

This study is based exclusively on the analysis of publicly available, aggregated administrative statistics from the Turkish Statistical Institute (TÜİK). No human participants, personal data, or animal subjects were involved. Therefore, ethical approval was not required.

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