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ARAŞTIRMA MAKALESİ | RESEARCH ARTICLE

# ANALYZING SECTORAL AND AGGREGATE GDP GROWTH PATTERNS IN TÜRKİYE: A MIXED-EFFECTS MODELLING APPROACH

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## Abstract

This study utilized growth curve analysis, which is a mixed-effects modeling approach, to examine regional and provincial income convergence in Türkiye. Unlike traditional convergence tests, growth curve analysis provides the opportunity to track changes over time in more detail. The main objective of this study is to examine regional income convergence by analyzing total and sectoral GDP growth trends in the NUTS-2 regions and provinces of Türkiye from 2013 to 2019, as well as to investigate the sources of these inequalities. Descriptive statistics reveal significant disparities in public investment and economic output across provinces. The empirical findings show that although both aggregate and sectoral GDP grew during the study period, significant differences were observed in the initial GDP levels across regions. The incorporation of region-level controls into the models improved the models' fitness, which reflects meaningful variations in initial GDP levels. However, in general, time-region interaction terms are not statistically significant, indicating that most regions experienced similar growth trajectories. These results underline the need for region and sector-specific development policies to reduce structural disparities and to achieve more balanced regional development. Further research could explore province- and region-specific factors that contribute to the persistence of income inequality among provinces and regions.

**Keywords:** Regional growth, Income convergence, Mixed-effects modeling, Growth curve analysis.

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# TÜRKİYE'DE SEKTÖREL VE TOPLAM GSYH BÜYÜME EĞİLİMLERİNİN ANALİZİ: KARMA ETKİLİ MODELLEME YAKLAŞIMI


## Öz

Bu çalışmada, Türkiye'de bölgesel ve il düzeyinde gelir yakınsamasını incelemek için karma etkili modelleme yaklaşımına dayanan büyüme eğrisi analizi kullanılmıştır. Büyüme eğrisi analizi, geleneksel yakınsama testlerinden farklı olarak, zaman içindeki değişimleri detaylı bir şekilde izleme imkanı sunar. Bu sayede, iller ve bölgeler arasındaki başlangıç koşullarındaki eşitsizliklerin yanı sıra büyüme hızlarının nasıl farklılık gösterdiği daha belirgin şekilde gözlemlenebilmektedir. Çalışmada, 2013-2019 dönemini kapsayan 26 Düzey 2 bölgesi ve 81 ilden elde edilen veriler kullanılmıştır. Betimleyici istatistikler, iller arasında kamu yatırımı ve ekonomik çıktı açısından önemli farklılıklar olduğunu ortaya koymaktadır. Ampirik bulgular hem toplam hem de sektörel reel GSYH'nin büyüdüğünü; ancak bölgeler arasında başlangıç GSYH seviyelerinde anlamlı farklılıklar bulunduğunu göstermektedir. Bölge kontrol değişkenlerinin modellere dahil edilmesi başlangıç GSYH düzeylerindeki farklılıkların dikkate alınmasını sağlayarak model uyumunu iyileştirmiştir. Ancak genel olarak, zaman-bölge etkileşim değişkenleri istatistiksel olarak anlamlı değildir; bu da çoğu bölgenin benzer büyüme patikasına sahip olduğunu göstermektedir. Bu sonuçlar, Türkiye'de genel ekonomik büyümeye rağmen bölgesel eşitsizliklerin devam ettiğine işaret etmektedir. Çalışma, bölgeler arası farklılıkların azaltılması ve dengeli bölgesel kalkınmanın teşvik edilmesi için sektöre özgü politikaların geliştirilmesinin önemini vurgulamaktadır. Bu çalışma alanı, iller ve bölgeler arasında gelir eşitsizliğinin sürmesine neden olan il ve bölgeye özgü faktörleri de içerecek şekilde geliştirilebilir.


**Anahtar Kelimeler:** Bölgesel büyüme, Gelir yakınsaması, Karma etkili modelleme, Büyüme eğrisi analizi.

## Introduction

The investigation of the factors behind the substantial differences in economic growth across countries has been the focus of many scientific studies. Various theoretical and empirical models (Koopmans, 1963; Barro, 1991; Barro and Sala-i-Martin, 1992; Mankiw et al., 1990; Solow, 1956) have been developed to explain how changes in exogenous variables affect the endogenous variable in the growth and development framework. In this context, a vast empirical literature exists on world income distribution and growth rates. However, many of the studies conclude with different results for the same problem. The main reasons for this diversity are the methodology, data set, time interval, and variables used in the research.

Do the substantial disparities in the standard of living of nations, which are generally measured by GDP per capita, continue to exist or diminish over time? The investigation of this fundamental problem has been a persistent theme not only in cross-country studies but also in the regions of individual countries. The neoclassical growth models state that after controlling for some country-specific characteristics (education, fiscal and monetary policies, preferences, technology, etc.) the countries with low initial GDP per capita tend to grow faster than countries with high initial GDP per capita. This phenomenon is known as conditional convergence in the growth and development literature. The literature on the convergence-divergence framework can be classified into two main categories. One of the categories investigates the cross-country convergence dynamics, while the other focuses on regions or provinces of the same country.

Mıhçı and Köksal (2010) state that many regional growth studies have focused on convergence theories, which primarily examine the disparities in per capita income across regions. In contrast, there are relatively fewer studies that investigate the sources of regional

income differences. This study tries to combine the two sides of literature. Evidence shows that regional inequalities among Turkish regions and provinces have not declined over time. Therefore, examining regional economic performance from a different perspective can enhance our understanding of these disparities. The main objective of this study is to examine regional income convergence by analyzing total and sectoral GDP growth trends in the NUTS-2 regions and provinces of Türkiye from 2013 to 2019, as well as to investigate the sources of these inequalities.

The main objective of this study is to assess regional income convergence by examining total and sectoral GDP growth trends in Türkiye's NUTS-2 regions and provinces from 2013 to 2019 and to identify the sources of these inequalities. The study examined two hypotheses using the framework of Growth Curve Analysis (GCA): first, whether there were significant differences in initial GDP levels among Türkiye's regions and provinces, and second, whether there were statistically significant differences in growth trends (slopes) between these regions and provinces.

The rest of the paper is organized as follows. The next section reviews empirical studies about convergence theories and regional growth studies that investigate the determinants of regional income differences. Methodological issues, the data set, and variables are presented in Sections 2 and 3, respectively. Section 4 presents the empirical results of growth curve analysis in the regional growth framework. The last section concludes the study with some suggestions for development policies.

## 1. Literature Review

Regional growth and development have been investigated in various studies. Some of these studies focus on absolute and conditional convergence of welfare indicators (see for example, Barro and Sala-i-Martin, 1990; 1992; Bernard and Jones, 1996; Gezici and Hewings, 2004; Badinger et al., 2004; Yıldırım et al., 2009; Abdioğlu and Uysal, 2013; Özgül and Karadağ, 2015; Haaf and Koll, 2017; Gömleksiz et al., 2017; Durusu-Çiftçi and Nazlıoğlu, 2019; Bolkol, 2019; Sakarya, et al., 2024), while other studies explore the factors influencing regional income differences (Curran, 2009; Mıhçı and Köksal, 2010; Rodrigues-Pose et al, 2012; Bolkol, 2023; Centofanti et al., 2024). There are differences among the findings of these studies. The diversity in results can largely be attributed to variations in data periods, methodologies, and the geographical scope of the analysis.

Several studies have specifically examined the dynamics of regional growth and convergence using data from European countries. Curran (2009) uses spatial econometric methods to analyze British aggregate gross value added (GVA) growth from 1995 to 2004, focusing on the roles of the secondary and service sectors. The study finds that while the secondary sector is more prominent in northern regions, the service sector is heavily concentrated in the south, with a stronger impact on real GVA per capita. Similarly, Rodrigues-Pose, Psycharis, and Tselios (2012) analyze Greece regional economic growth and convergence at the NUTS 3 level between 1978 and 2007. Their findings reveal that per capita public investment positively affects long-run regional growth, though it does not contribute to convergence. Petrakos et al. (2007) investigate 249 EU NUTS II

regions from 1990 to 2003, concluding that factors such as the level of development, investment capacity in human and physical capital, economic structure, and geographical position of a region relative to EU markets are among the factors influencing regional economic growth. Rattso and Stokke (2014), focusing on 89 NUTS-4 level regions in Norway, employ kernel density functions and Markov chains to analyze the relationship between income distribution and education. Their results show convergence in income and education levels.

Other studies provide insight into regional development dynamics in non-EU countries. In Russia, Ladyaeva and Linden (2008) apply a modified Barro and Sala-i-Martin growth model to 74 regions from 1996 to 2005. The results of the study identify that initial income, the 1998 financial crisis, domestic investment, and exports are the main drivers of short-run economic growth. Badunenko and Tochkov (2010) conduct a comparative analysis of regional growth and convergence across China, Russia, and India from 1993 to 2003 using nonparametric techniques. The findings show that while physical capital accumulation drives growth in China and India, technological change is the primary source of growth in Russian regions. Furthermore, technological improvements in wealthier regions of all three countries have contributed to regional income divergence.

Literature is further enhanced by studies from various global contexts. Cravo (2010) explores regional economic growth in 508 Brazilian micro-regions from 1980 to 2004, emphasizing the critical role of SMEs (small and medium enterprises). The study finds that GDP per capita, human capital, and economic activity in neighboring regions are significant determinants of growth. Notably, the human capital embedded within SMEs plays a more vital role in fostering regional growth than the size of the sector. De Souza-Brown and Gebremedhin(2004), focusing on 38 rural counties in West Virginia for 1980 and 1990, find that poverty is a major contributor to income inequality, while human capital is associated with a reduction in inequality.

Transportation infrastructure and migration also emerge as significant factors in regional growth patterns. Fageda and Olivieri (2021) review multiple empirical studies on transport infrastructure investment and its economic effects. Their analysis finds mixed evidence: while cross-country studies suggest convergence, studies at the subnational level reveal increased divergence. Centofanti et al. (2024) examine internal migration in Italy at the NUTS-3 level from 2002 to 2019, concluding that internal migration by Italian citizens positively affects regional growth and may slow convergence, while no significant effect is observed for foreign citizens.

Finally, several studies provide broader regional insights with a focus on convergence. Mariš (2023) investigates conditional convergence among V4 (Czechia, Hungary, Poland, Slovakia) NUTS3 regions from 2004 to 2020, finding convergence trends but persistent disparities, with Polish regions showing the most rapid growth and Hungarian regions the slowest. Haaf and Koll (2017) analyze German regional growth and convergence from 1995 to 2014 using panel data for 16 federal states. The results indicate a gradual but significant convergence, with internal migration and structural funds supporting growth in the eastern states.

The regional disparities in Turkey have been the subject of many studies, with most concentrating on the income convergence of provinces and regions. Gezici and Hewings (2004),

examining the period 1980-1997 for 67 Turkish provinces and 16 functional regions, found no evidence for either absolute or conditional convergence based on GDP per capita. Focusing specifically on the roles of public capital stock and transportation capital stock during 1980–2001 for 26 NUTS 2 regions, Önder et al (2010) found evidence for both σ-convergence and conditional (β) convergence. Their results indicated that while per capita public capital stock reinforced convergence, transport infrastructure investments contributed to disparity. Analyzing the 1990-2006 period at the provincial level, Dağdemir and Acaroğlu (2011) found that income inequality generally increased over the whole period, as reductions between 1995-2001 did not offset the increase from 1990-1995. The researchers identified the province's capital stock, workforce, human capital, service sector productivity, and urbanization ratio as key factors explaining regional income divergence. Also examining the 1990-2001 period for 67 provinces, Yildirim (2005) used geographically weighted regression to show that convergence speeds differed significantly among provinces. Regarding the regional policies, Eastern and Southeastern provinces achieve a higher speed of convergence. Furthermore, investigating the same 1990-2001 period but focusing on welfare indicators at the NUTS II level, Özgül and Karadağ (2015) found some evidence of unconditional convergence but concluded that socio-economic factors, aside from population growth rate in some empirical models, did not significantly affect regional growth and disparities.

Research focusing on the post-2004 period also presents a mixed picture regarding convergence. Abdioğlu and Uysal (2013), examining 26 NUTS 2 regions between 2004-2008, could not find evidence of convergence in gross value added. In contrast, looking at the 2004-2014 period for NUTS 2 regions, Gömleksiz et al (2017) confirmed the convergence hypothesis and suggested that government intervention, especially through investment incentives, is crucial for reducing regional economic disparities. Bolkol (2019) examined the period from 2004 to 2017 across NUTS1, NUTS2, and NUTS3 levels and concluded that there is neither divergence nor convergence in general, although crisis periods, such as the 2008 economic crisis, temporarily reduced income disparities. Providing the most recent analysis covering the period from 2004 to 2022, Sakarya et al. (2024) used club and beta convergence methods on provincial data. They found a shift from convergence between 2004-2016 to divergence from 2017-2022, attributing this change to growth rates in sectoral GDP composition and sectoral employment shares.

Other studies have employed specific models or focused on distinct drivers of regional dynamics. Bolkol (2023) utilized an endogenous growth model for 26 regions between 2010 and 2017, focusing on human capital measured by R&D personnel. This study revealed a U-shaped relationship between R&D personnel and economic growth, suggesting that increased R&D personnel might hinder convergence in less-developed eastern regions and highlighting the need for specific policies. Analyzing the period from 1992 to 2013 for 73 provinces, Durusu-Çifçi and Nazlıoğlu (2019) found overall evidence supporting income divergence between Turkey's eastern and western regions. They also showed that while urbanization is linked to economic growth, it is insufficient on its own to achieve income convergence due to region-specific structural characteristics. Similarly, Mıhçı and Köksal (2010) analyzed a polled data set of 65 provinces from 1980-2000. They identified differences in physical and human capital accumulation,

industrial employment composition, and demographic variables as basic determinants of regional income disparity.

Despite extensive research on regional development and convergence, there are still gaps in understanding the reasons behind the persistent inequalities in Türkiye's regions and provinces throughout the study period. This study aims to contribute to this research area by examining both sectoral and total GDP data at the provincial and regional levels using a mixed-effects modeling approach.

## 2. Methodology And Data

### 2.1. Methodology

Growth curve analysis is a technique explicitly designed to assess the changes over time at group and individual level (Mirman, 2014). Growth curve analysis (here after GCA) is a multilevel regression technique designed for analysis of time course and longitudinal data. It is a rigorous means of analyzing time course data. A major advantage of this approach is that it can be used to simultaneously analyze both group level effects and individual level effects.

GCA is a multilevel regression model that allows researchers to simultaneously describe the overall group pattern and to describe how individual participants deviate from that pattern. At the first level of GCA, the development of each individual is represented by a growth trajectory that depends on a unique set of parameters. These individuals' growth parameters become the outcome variables in the second level, where they may depend on some other explanatory variables.

In the context of a regression model, $Y_{it}$ states for an observer status for an individual $i$ at time $t$.

$$Y_{it} = \beta_{0i} + \beta_{1i} \times Time_t + \epsilon_{it} \quad (1)$$

where ϵit is the residual error that is assumed to be independent and identically distributed. $\beta_{1i}$ is the growth rate for the individual $i$ over the data collected period. It represents the expected change during a fixed unit of time (Raudenbush and Bryk, 2002). In level 1 each individual's development is represented by a systematic growth trajectory or growth curve plus random error. The growth curve in level 1 depends on a unique set of parameters. An important feature of level 1 is that the growth parameters vary across individuals.

Level 2 models are constructed based on level 1 coefficients $\beta_{0i}$ and $\beta_{1i}$. These individual growth parameters become the outcome variables in level 2. Hence, Level 2 models can be formulated as:

$$\beta_{0i} = \gamma_{00} + \gamma_{0c} \times C + \delta_{0i} \quad (2)$$
$$\beta_{1i} = \gamma_{10} + \gamma_{1c} \times C + \delta_{1i} \quad (3)$$

where $\gamma_{00}$ is a baseline value of $\beta_{0i}$, $\gamma_{0c}$ is the fixed effect (or structural effect) of $C$ on the intercept, and $\delta_{0i}$ is the random deviations from that baseline for individual i (Mirman, 2014). Both the intercept and the growth rate parameters can vary at level 2.

### 2.2. Data and Variables

Obtaining a time-consistent dataset for sub-regions in Turkey is challenging due to inconsistencies in data availability across indicators and periods. For example, data on GDP at the regional (NUTS 2) and provincial (NUTS 3) levels are available only from 2004 onwards. Similarly, education data are accessible from 2008, while trade data are available only from 2013. Furthermore, the Turkish Statistical Institute (TurkStat) does not publish regional or provincial investment data. However, provincial investment data are published by the Presidency of Strategy and Budget only for the period from 2000 to 2019. This condition is the binding constraint of our study. Some descriptive statistics for individual series are provided for the longest available period. However, our growth curve analysis is conducted for a panel of 26 NUTS 2 subregions spanning the period from 2013 to 2019.

**Table 1. Description of Variables and the Source of Data**

| Variables | Description | Sources |
|---|---|---|
| invit | Total Public investment, in thousand ₺, (deflated to 2009 prices) | Republic of Türkiye, Presidency of Strategy and Budget |
| gdpit | Total provisional GDP, in millions ₺ (deflated to 2009 prices) | Turkish Statistical Institute (Turkstat) |
| tgdpit | Total provisional GDP in agriculture, in millions ₺ (deflated to 2009 prices) | Turkish Statistical Institute (Turkstat) |
| igdpit | Total provisional GDP in industry, in millions ₺ (deflated to 2009 prices) | Turkish Statistical Institute (Turkstat) |
| hgdpit | Total provisional GDP in services, in millions ₺ (deflated to 2009 prices) | Turkish Statistical Institute (Turkstat) |
| seduit | Proportion of secondary education graduates (%) | Turkish Statistical Institute (Turkstat) |
| tradeit | The sum of imports and exports (US Dollar) | Turkish Statistical Institute (Turkstat) |

**Source**: Author's own work.

The investment data is obtained from the Republic of Turkey, the Presidency of Strategy and Budget, at the provincial level. The provincial-level data is aggregated to obtain NUTS 2 level regional data. The data for GDP, investment, and trade are deflated to 2009 prices. The description of variables and their sources is indicated in Table 1. To visualize the spatial dispersion of real GDP across Turkish NUTS 2 sub-regions, a set of color-coded maps is presented. Figures 1 and 2 represent real GDP for 2013 and 2019, respectively.

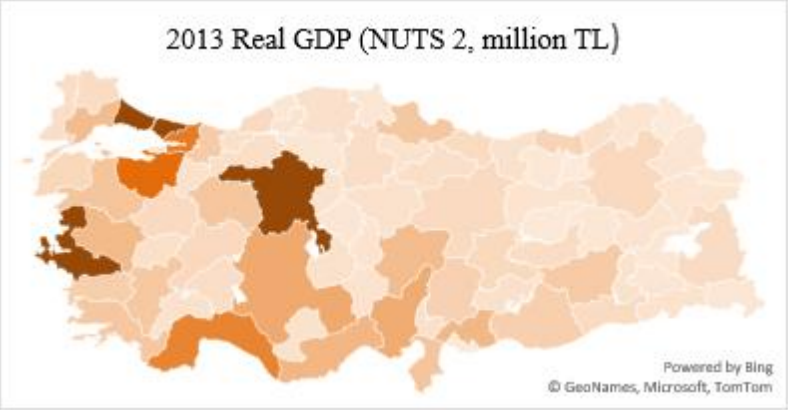



**Figure 1. 2013 Real GDP dispersion (NUTS 2, million ₺**
Source: Author's own work.

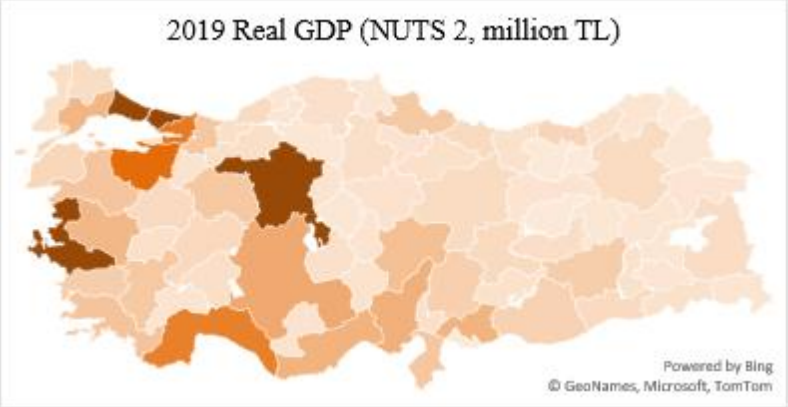



**Figure 2. 2019 Figure 1. Real GDP dispersion (NUTS 2, million ₺)**
Source: Author's own work.

The color-coded maps in Figures 1 and 2 show the regional distribution of real GDP in Türkiye for 2013 and 2019. Darker colors indicate a higher GDP, while lighter colors indicate a relatively lower GDP. While there was no significant difference in the distribution of regional GDP between 2013 and 2019, the western and central regions consistently showed higher GDP compared to the eastern regions. The general trend of higher GDP in the West and lower GDP in the East continues in both years. Therefore, although real GDP increases, no convergence is observed between the regions in general.

From the descriptive statistics presented in Table 2, we observe that total public investment (inv) has a mean of approximately 265,090 thousand ₺, but a very large standard deviation (582,776 thousand ₺), indicating significant variability in public investment across provinces during the 2013-2019 period. This high standard deviation, which is more than twice the mean, indicates a wide dispersion of investment values, ranging from a minimum of approximately 3,008 thousand ₺ to a maximum of 6,544,075 thousand ₺. Similarly, total provincial GDP (gdpit) has a mean of roughly 17.5 million ₺, with a considerable standard deviation of approximately 51 million ₺, reflecting significant economic disparities among the provinces.

**Table 2. Descriptive Statistics**

| Variable | Obs | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| invit | 567 | 265090.48 | 582776.48 | 3008.057 | 6544075 |
| gdpit | 567 | 17509338 | 50950144 | 789705.31 | 4.896e+08 |
| tgdpit | 567 | 1248853.2 | 1091577 | 162201.59 | 7274113 |
| igdpit | 567 | 5573411.4 | 15296387 | 85525.852 | 1.389e+08 |
| sgdpit | 567 | 10687073 | 35789573 | 435635.13 | 3.613e+08 |
| seduit | 567 | 22.058 | 3.831 | 11.72 | 31.55 |
| tradeit | 567 | 2715455.8 | 14401734 | 118.399 | 1.722e+08 |

Source: Author's own work.

The correlation matrix in Table 3 highlights several important relationships between the variables. Total provincial GDP shows a strong positive correlation with total public investment (invit, r = 0.776) and trade volume (tradeit, r = 0.919), suggesting that higher economic output is associated with increased public investment and international trade. The high school graduation rate is positively correlated with the total regional GDP, as well as with GDP in the service and industrial sectors. In contrast, it has a low negative correlation with the GDP in the agricultural sector.

**Table 3. Correlations**

| Variables | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|
| (1) gdpit | 1.000 | | | | | | |
| (2) agdpit | 0.151 | 1.000 | | | | | |
| (3) igdpit | 0.987 | 0.153 | 1.000 | | | | |
| (4) sgdpit | 0.997 | 0.119 | 0.973 | 1.000 | | | |
| (5) invit | 0.776 | 0.177 | 0.772 | 0.770 | 1.000 | | |
| (6) seduit | 0.168 | -0.081 | 0.198 | 0.157 | 0.104 | 1.000 | |
| (7) tradeit | 0.919 | 0.004 | 0.912 | 0.918 | 0.698 | 0.108 | 1.000 |

Source: Author's own work.

## 3. Empirical Strategy

### 3.1. Preliminary Results

Figure 3 compares the initial values of GDP and its sectoral breakdown (agriculture, industry, and services) with growth rates from 2013 to 2019. Although the slopes of the trend lines vary across sectors, there is an overall positive relationship at both the total provincial GDP and sectoral levels. Although the slope of the trend line is very low in the agriculture and services sectors, the trend lines in all four panels indicate a positive relationship between initial GDP levels and growth rates. The situation remains the same in the case of excluding the three largest cities, namely İstanbul, Ankara, and İzmir1. This suggests that cities with higher initial GDP tended to experience faster growth during this period. Therefore, this pattern indicates divergence rather than economic convergence among cities.

[1] The scatter plots excluding İstanbul, Ankara, and İzmir are not included to save space but are available upon request.

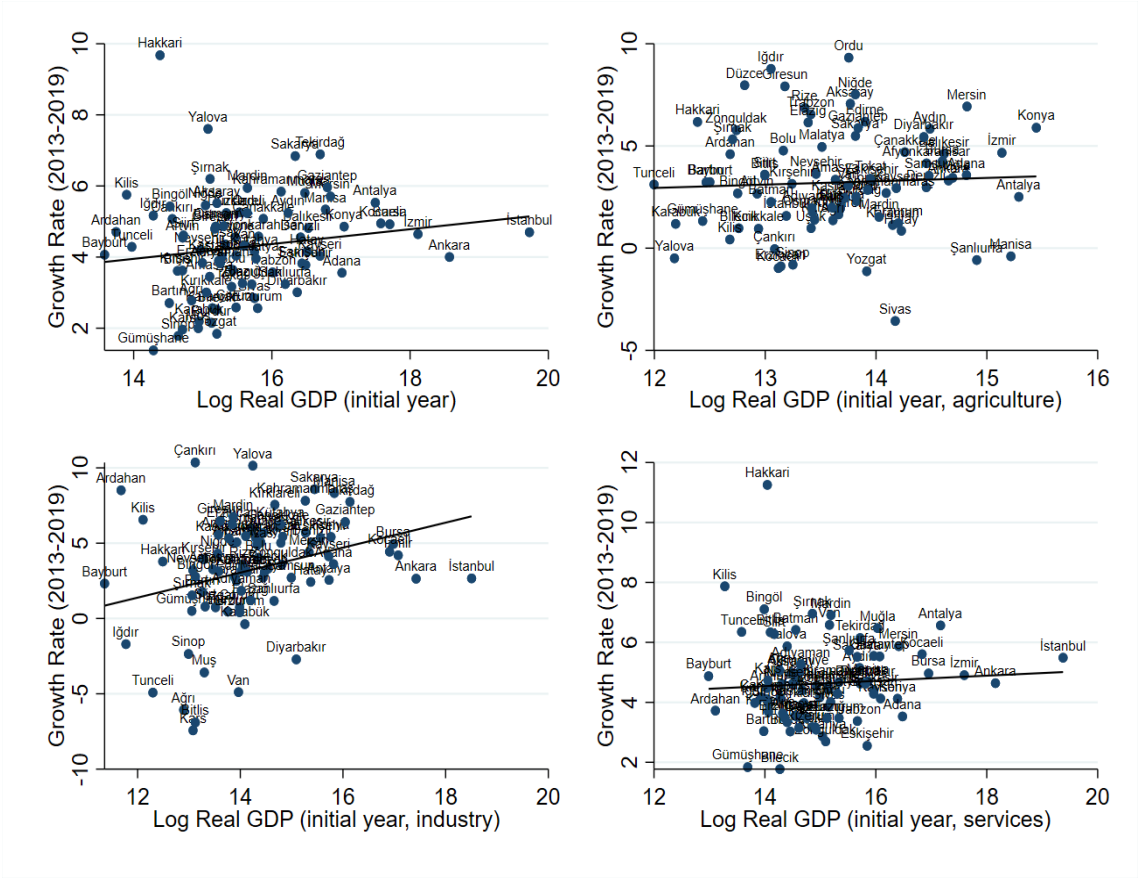
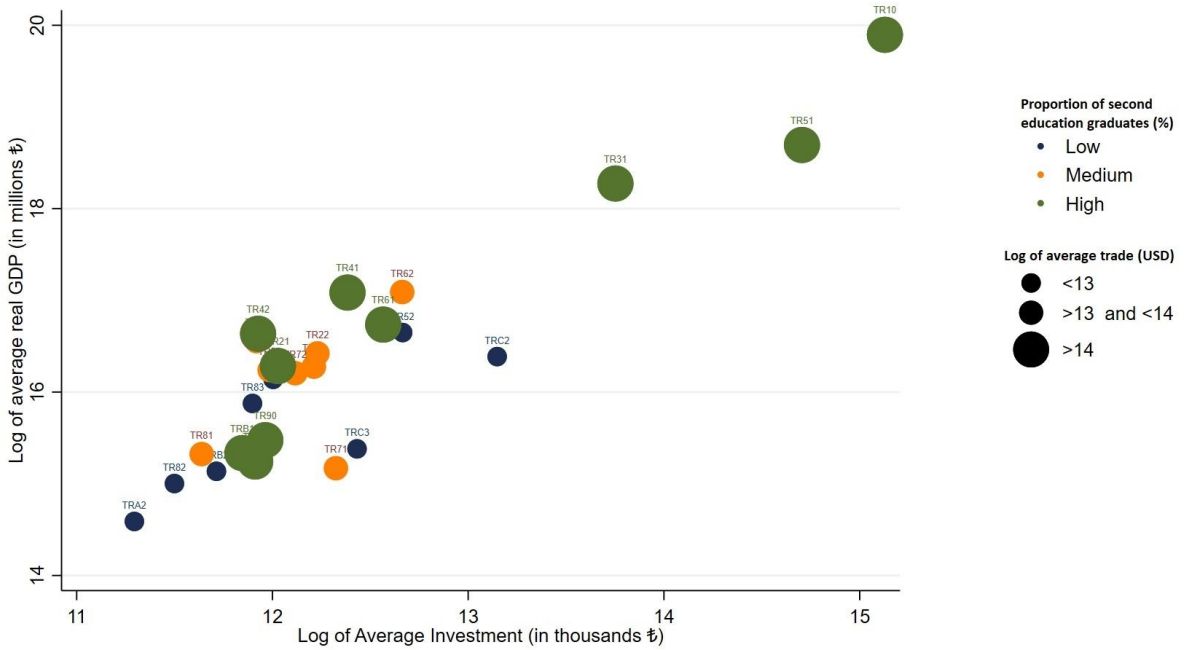



**Figure 3. Growth Rates and Initial Level of GDP**

Source: Author's own work.

Figure 4 shows the relationship between total public investment, total regional GDP, the proportion of secondary education graduates, and trade volume for 22 NUTS 2 regions in Türkiye. In general, higher public investment is associated with higher regional GDP; see, for example, TR10, TR31, and TR51. In these regions, the proportion of secondary education graduates and trade volume are relatively higher compared to the other 22 NUTS 2 regions. Higher rate of secondary education (represented by blue bubbles) tends to be found in areas with higher regional GDP and public investment, indicating a positive correlation. Larger bubble sizes, which indicate greater trade volume, are generally associated with higher public investment and regional GDP, suggesting a positive relationship. However, some inverse conditions exist. For example, despite moderate investment, TRC2 shows relatively low GDP and low levels of education. TR81 and TR71, on the other hand, show low levels of public investment and regional GDP, and both have moderate education levels. This result indicates that, although education and trade are expected to foster economic growth, other factors may influence the outcome, resulting in deviations from the expected pattern.

**Figure 4. The Relationship Between Education, Investment, and GDP in Turkish Regions**




Source: Author's own work.

### 3.2. Emprical Results

The year variable is modified to treat 2013 as initial time (time 0) so that it corresponds to the intercept. In other words, 2013 is subtracted from the year variable. The empirical estimations are carried out based on equations 1, 2, and 3. Maximum likelihood estimation is used to fit the models. The analysis for all models is carried out in R version 3.3.1 using lme4 package version 1.1-12. The following three models are estimated separately for total GDP and its sectoral distribution.

$$\text{Model 1: } lngdp = f((1 + Time), (1 + Time|\text{City})) \quad (4)$$

$$\text{Model 2: } lngdp = f((1 + Time), NUTS2, (1 + Time|\text{City})) \quad (5)$$

$$\text{Model 3: } lngdp = f((1 + Time),\ NUTS2, Time{:}NUTS2, (1 + Time|\text{City})) \quad (6)$$

As usual, the left-hand side specifies the dependent variable, and the right-hand side specifies the set of predictors. lngdp, the natural logarithm of gross domestic product at the provincial level, is a function of two components. The first term, (1 + T), represents the fixed effect, corresponding to the intercept denoted by 1 and the slope denoted by T.

**Table 4. Results of the Nested Mixed-Effects Models**

| | Aggregate GDP | | | Sectoral GDP: Agriculture | | | Sectoral GDP: Industry | | | Sectoral GDP: Services | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Model 1 | Model 2 | Model 3 | Model 1 | Model 2 | Model 3 | Model 1 | Model 2 | Model 3 | Model 1 | Model 2 | Model 3 |
| Fixed Effects | | | | | | | | | | | | |
| Intercept | 15.64*** | 19.69*** | 19.74*** | 13.65*** | 13.37*** | 13.28*** | 14.30*** | 18.57*** | 18.56*** | 15.06*** | 19.28*** | 19.38*** |
| Time | 0.04*** | 0.04*** | 0.05*** | 0.03*** | 0.03*** | -0.003 | 0.04*** | 0.04*** | 0.03 | 0.05*** | 0.05*** | 0.06*** |
| Region Dummies | - | Many significant | Many significant | - | Several Significant | Several Significant | - | Many significant | Many significant | - | Many significant | Many significant |
| Time × Region Interactions | - | - | Nonsignificant | - | - | Several Significant | - | - | Nonsignificant | - | - | Nonsignificant |
| Random Effects Variances | | | | | | | | | | | | |
| Intercept (city) | 1.17 | 0.40 | 0.39 | 0.60 | 0.22 | 0.22 | 1.69 | 0.53 | 0.53 | 1.19 | 0.43 | 0.42 |
| Slope for Time (city) | 0.00015 | 0.00015 | 0.00008 | 0.00018 | 0.00018 | 0.00002 | 0.00089 | 0.00089 | 0.00039 | 0.00017 | 0.00017 | 0.00007 |
| Residual | 0.00132 | 0.00132 | 0.00132 | 0.01132 | 0.01132 | 0.01088 | 0.01029 | 0.01029 | 0.01029 | 0.00076 | 0.00076 | 0.00076 |
| Model Fit | | | | | | | | | | | | |
| AIC | -1315.8 | -1354.6 | -1340.1 | -409.3 | -441.5 | -436.4 | -308.0 | -346.6 | -338.2 | -1535.4 | -1570.3 | -1576.4 |
| BIC | -1289.8 | -1220.1 | -1097.0 | -383.3 | -306.9 | -193.4 | -281.9 | -212.0 | -95.2 | -1509.3 | -1435.8 | -1333.4 |
| Log-likelihood | 663.9 | 708.3 | 726.0 | 210.6 | 251.7 | 274.2 | 160.0 | 204.3 | 225.1 | 773.7 | 816.2 | 844.2 |

Notes: ** p<0.05; *** p<0.01. Source: Author's own work.

Second term, (1+Time|City), indicates the random effects which specify city-level random variability in the baseline severity (intercept: 1) and rate of recovery (slope: Time). To account for the fixed effect of NUTS2-level regions on the intercept, the term NUTS2 is added to the base model. This modification is shown in equation 5 above. Time: NUTS2 is an interaction syntax that shows the effect of NUTS2 level regions on the linear term. Equation 6 shows this modification.

To examine patterns of economic development across Turkish regions and provinces, we estimated three nested mixed-effects models for each of the four dependent variables: aggregate real GDP, agricultural GDP, industrial GDP, and services GDP. While Model 1 is based on the baseline GDP, Models 2 and 3 incorporate regional-level variations into the baseline GDP, allowing the growth rates of regions to change over time. The results of nested mixed-effects models 1-3 are summarized in Table 4.

In all models, the findings indicate that both total real GDP and the shares of GDP in the agriculture, industry, and services sectors increased during the study period. In model 1, which includes only a fixed effect for time and random intercepts and slopes for provinces, the estimated time coefficients are positive and statistically significant. For example, the time coefficients of aggregate and sectoral GDP were found to range from 0.04 to 0.05 ($p < 0.01$), which suggests a consistent growth pattern. In addition, after adding region-level controls and time-region interactions, the services sector displayed a robust positive trend. On the other hand, the estimated growth rates in the agricultural and industrial sectors both decreased slightly and lost statistical significance when region-time interactions were included. This suggests that part of the time trend in Model 1 may be related to regional differences in these sectors.

The fixed effects for regions are examined in Model 2. The incorporation of fixed effects substantially improved model fit for all results. Based on the Akaike Information Criterion (AIC), models that included regional intercepts were preferred over simpler specifications. Most of the regional dummies are statistically significant. This reflects meaningful differences in the baseline levels of aggregate and sectoral GDP among NUTS-2 level regions.

We add time-region interaction terms in Model 3 to examine whether regions differ in their growth trajectories over time. Except for agricultural GDP, time-region interactions are not statistically significant and do not improve model fit compared to models with only regional intercepts. For agricultural GDP, time-region interactions are significant for several regions.

## Conclusion

This study aims to contribute to the existing literature by examining income convergence in Turkey at the provincial and regional levels. This study, which utilized the growth curve method, has made a methodological contribution to convergence literature. The study, which used data from 81 provinces and 26 NUTS-2 regions between 2013 and 2019, presents important findings on the overall and sectoral development of gross domestic product (GDP) at the provincial level. The results indicate a consistent upward trend in total real GDP, as well as in the agriculture, industry, and services sectors during the study period. However, significant differences in initial

GDP levels were observed between provinces, revealing that regional inequalities in Türkiye persist despite overall growth.Nested mixed-effects models were used in empirical analyses. Although the analysis reveals that the province's total and sectoral GDP have generally increased, when region-time interactions are included in the empirical models, the growth rates in the agriculture and industrial sectors lose their statistical significance. This result indicates that regional disparities affect the growth trends of these sectors. Furthermore, although some differences were observed in the growth of agricultural GDP between regions, no significant regional differences were found in any of the three sectors. In addition, models that include random intercepts for provinces provide a better fit. This finding implies that there are significant differences in the initial GDP levels among provinces. In contrast, the low variance in the random trend for the time variable indicates that when regional factors were controlled, provinces tended to follow similar growth trajectories.

In conclusion, although provinces in Türkiye experienced economic growth between 2013 and 2019, the findings reveal that significant regional disparities in initial GDP levels persist. Since the overall growth trend in total and sectoral GDP was largely similar across regions, the gap between wealthy and less-developed regions did not decrease significantly during this period. The results obtained are consistent with previous studies that have presented conflicting findings on convergence in Türkiye. Moreover, the findings highlight the importance of developing policies that consider initial differences between provinces and regions, as well as sector-based dynamics, to promote more balanced regional development. In this context, the main drivers of GDP in the western and eastern regions should be identified and differentiated incentive packages should be implemented accordingly. Additionally, the distribution of public investments should be reviewed and reorganized to eliminate initial inequalities in line with regional development goals. Further research could examine province- and region-specific factors to determine why income disparities between regions have not decreased over time. It could also evaluate the specific policy interventions that have effectively reduced these disparities in more detail.

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