DOKUZ EYLÜL UNIVERSITY
GRADUATE SCHOOL OF SOCIAL SCIENCES
DEPARTMENT OF ECONOMICS (ENGLISH)
ECONOMICS (ENGLISH) PROGRAM
MASTER'S THESIS

THE IMPACT OF DIGITALIZATION ON REGIONAL ECONOMIC CONVERGENCE IN TURKEY

Bengisu DURU

Supervisor
Prof. Dr. Yeşim Rabia KUŞTEPELİ

İZMİR-2022

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DECLARATION

I hereby declare that this master's thesis titled as **"The Impact of Digitalization on Regional Economic Convergence in Turkey"** has been written by myself in accordance with the academic rules and ethical conduct. I also declare that all materials benefited in this thesis consist of the mentioned resources in the reference list. I verify all these with my honour.

Date
17/06/2022
Bengisu DURU

ABSTRACT

Master's Thesis

The Impact of Digitalization on Regional Economic Convergence in Turkey

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Dokuz Eylül University

Graduate School of Social Sciences

Department of Economics (English)

Economics (English) Program

Digitalization is the effective use of digital technologies and information to increase economic growth in the world economies. It is more than just transferring papers to computers; it also creates value and new prospects, which is beneficial to all sectors of an economy. Digitalization increases mobility while decreasing the distances between people, businesses, governments, and countries. Since it simplifies reaching information, it saves time and allows the use of big data for the needs and wants of all the economic agents. It creates values and new job opportunities. However, effective use of digital technologies, enough infrastructure for reaching the internet and telephones, and certain skills of this usage are necessary for the digitalization process for empowering economic growth, thus reducing the income divergence between regions. Convergence assumes that after a while, poor and rich regions will have similar per capita income levels, under certain assumptions. This thesis aims to examine the impact of digitalization on economic convergence in NUTS-1 regions in Turkey to find the effect of digitalization on the income differences across regions in the 2012-2020 period. Three indices are used for analyzing digitalization with Principal Component Analysis (PCA): Usage (DUI), Infrastructure (DFI), and Skills (SI). For understanding the impact of digitalization on convergence, sigma convergence, beta convergence, and unit root tests are conducted including the calculations of the speed of the convergence. Empirical results conclude that there is convergence across NUTS-1 Regions in Turkey. Moreover, digitalization has a positive impact on regional convergence in the selected period. Furthermore,

while DUI has a long-term effect, per capita income levels are influenced by DFI and SI temporarily.
Keywords: Digital, Digitalization, Convergence, NUTS-1, PCA

ÖZET

Yüksek Lisans Tezi

Dijitalizasyonun Türkiye'de Bölgesel Ekonomik Yakınsama Üzerindeki Etkisi

Bengisu DURU

Dokuz Eylül Üniversitesi

Sosyal Bilimler Enstitüsü

İngilizce İktisat Anabilim Dalı

İngilizce İktisat Programı

Dijitalizasyon, dünya ekonomilerinde ekonomik büyümeyi arttırmak amacıyla, dijital teknolojilerin ve bilgilerin etkin kullanımıdır. Evrakları bilgisayar ortamına aktarmaktan daha kapsamlıdır; aynı zamanda bir ekonominin tüm sektörleri için faydalı olacak değerler ve yeni beklentiler yaratır. İnsanlar, işletmeler, hükümetler ve ülkeler arasındaki mesafeleri azaltırken hareketliliği artırır. Dijitalizasyon bilgiye ulaşmayı kolaylaştırdığı için zamandan tasarruf sağlar ve büyük verinin tüm ekonomik birimlerin ihtiyaç ve istekleri doğrultusunda kullanılmasına olanak sağlar. Değerler ve yeni iş fırsatları yaratır. Ancak, dijitalleşme sürecinde ekonomik büyümenin güçlendirilmesi ve dolayısıyla bölgeler arasındaki gelir farklılığının azaltılması için dijital teknolojilerin etkin kullanımı, internet ve telefona erişim için yeterli altyapı ve bu kullanım için belirli yetenekler gereklidir. Yakınsama, belirli varsayımlar altında, fakir ve zengin bölgelerin belli bir süre sonra benzer kişi başına gelir seviyelerine sahip olacağını varsayar. Bu tez, dijitalizasyonun bölgeler arası gelir farklılıkları üzerindeki etkisini bulmak için dijitalleşmenin Türkiye'deki Düzey-1 bölgelerinde ekonomik yakınsama üzerindeki etkisini 2012-2020 döneminde incelemeyi amaçlamaktadır. Dijitalizasyonun etkisini analiz edebilmek için üç indeks Temel Bileşenler Analizi (TBA) kullanılarak oluşturulmuştur: Kullanım (DUI), Altyapı (DFI) ve Yetenekler (SI). Dijitalizasyonun yakınsama üzerindeki etkisini anlamak amacıyla sigma yakınsaması, beta yakınsaması ve birim kök testleri kullanılmıştır, ayrıca yakınsama hızı da hesaplanmıştır. Ampirik sonuçlar, Türkiye'deki NUTS-1 Bölgeleri arasında yakınsama olduğu sonucuna

varmaktadır. Hatta, dijitalizasyon, seçilen dönemde bölgesel yakınsama üzerinde olumlu bir etkiye sahiptir. Ayrıca, DUI uzun vadeli bir etkiye sahipken, kişi başına gelir seviyeleri DFI ve SI'den geçici olarak etkilenmektedir.

Anahtar Kelimeler: Dijital, Dijitalizasyon, Yakınsama, Düzey-1, TBA

THE IMPACT OF DIGITALIZATION ON REGIONAL ECONOMIC CONVERGENCE IN TURKEY

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ABBREVIATIONS

ADF	Augmented Dickey-Fuller
DFI	Infrastructure
DUI	Usage
GDP	Gross Domestic Product
ICT	Information Communication Systems
ICTA	Information and Communication Technologies Authority
IPS	Im, Pesaran, and Shin
NUTS	Nomenclature of Units for Territorial Statistics
OECD	Organization for Economic Co-operation and Development
PCA	Principal Component Analysis
PP	Philips-Perron
PDF	Portable Document Format
SI	Skills
TUIK	Turkish Statistical Institute

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INTRODUCTION

Digitalization is a relatively more recent notion than convergence in the global economy, yet it is another critical issue. Digitalization may be considered only as digitalizing the information into computers. It is, however, a considerably broader concept than this description. It is described as the process of digitalizing information to boost economic growth by making production, distribution, and daily lives of individuals easier. Therefore, its impact on decreasing the disparities between regions is essential in an economy.

Digitalization is sometimes misidentified or used as synonymous vocabulary due to similar meanings of the other concepts, such as digitization, digital transformation, and the digital divide. Digitization is a process of converting analog data into computers, such as transferring the documents in archives into portable document format (PDF) or word documents defined as digitization. Digital transformation is another concept that means the whole process of digitalizing information. However, it is more individual-based than digitalization, and it includes the transformation of enterprises and strategies. Lastly, the digital divide is the disparities in accessing Information Communication Systems (ICT) and using the internet (Acılar et al., 2011: 3).

There is numerous research on convergence and how to reduce differences between regions by utilizing other variables and policies. Briefly, convergence is growing per capita income levels at higher rates in poor areas than in relatively rich ones. Therefore, under certain assumptions, the income levels of poor and wealthy economies will eventually equalize. The most common methods for measuring the convergence across regions are sigma convergence, beta convergence as absolute and conditional convergences, and the unit root test.

Contrary to studies on convergence, there are a few studies about the effect of digitalization on convergence in the global economy and regional economies in the literature (such as Köksal and Anıl, 2013; Park et. al, 2015; Rath, 2016; Celbis and de Crombrugghe, 2018; Bera, 2019). However, because these two notions are vital for building an economy, they must be examined together to determine ways to improve the regions.

The aim of this thesis is to understand the impact of digitalization on convergence in NUTS-1 regions in Turkey from 2012-2020. Sigma convergence, absolute convergence, conditional convergence, and the unit root test are the methods that are employed to analyze this relationship. Principal Component Analysis (PCA) is used to compute three indices for digitalization. The indices are Usage (DUI), Infrastructure (DFI), and Skills (SI). DUI is the usage statistics for telephones and the internet in NUTS-1 regions and includes the number of fixed telephony access, mobile telephony subscriptions, broadband subscriptions, and the proportion of internet users. DFI has the data about the infrastructure capacity for telephones and internet lines with santral capacity for fixed telephony and the length of the fiber. For understanding the ability to use the internet and telephones, SI contains the data for 15 years of age and over and literate and the upper secondary education gross enrollment rate.

Convergence is measured as the real GDP per capita in TL in NUTS-1 (2009 is the base year). Furthermore, the effects of the unemployment rate and urban population on convergence are also analyzed in the models.

The empirical analysis clearly showed that sigma convergence, and absolute and conditional beta convergence may be found in twelve locations, and digitalization has a positive effect on convergence in Turkey between 2012 and 2020. Furthermore, the unit root test reveals that, whereas DFI and SI had temporary impacts on per capita income, DUI is stationary in level, implying that it has a long-term impact in Turkey during this period.

The thesis is organized as follows: Chapter One examines the theoretical background of convergence and digitalization. Chapter Two analyzes the literature review on convergence theory, convergence across regions in Turkey, digitalization, the digital divide, and studies on the impact of digitalization on convergence. Chapter Three describes the data and methodology. Furthermore, it shows the empirical results of the study. Lastly, the conclusion summarizes the findings of the study and provides policy implications according to the results.

CHAPTER ONE
THEORETICAL BACKGROUND ON CONVERGENCE AND DIGITALIZATION

Convergence and digitalization are two essential components of the global economy. Convergence is a measure that assumes growing per capita income levels of poor economies at higher rates than rich economies. Therefore, income levels of relatively poor economies and rich economies are approaching the same level, under some assumptions over time. Also, digitalization is the practice of digitizing data to improve economic growth. It has spread in every area of the business, workplace, and daily life to ease the business models, production, and life.

In this chapter, the theoretical background of convergence and digitalization are provided in detail.

1.1. CONVERGENCE

Because of the many techniques for measuring convergence, analyzing it is a complex process. In the neoclassical growth models, many economists (such as Ramsey, 1928; Solow, 1956) stated that the growth of the poor is faster than rich economies, under the assumptions of being a closed economy and having similar preferences and technology (Barro and Sala-i Martin, 1992: 224). Therefore, according to neoclassical models, if two nations have the same savings rate, population growth rate, and exogenous technology rate, but one of them is poorer, they would have identical per capita income growth in the long run. However, before the 1980s, the convergence hypothesis had received only a little attention. In the late 1980s, it attracted many economists due to two reasons: convergence was recommended as an important criterion for modern economic growth theories and the data for GDP was available in the mid-1980s to compare GDP levels of countries (Sala-i Martin, 1996: 1019).

In terms of convergence, the terms sigma convergence, unconditional (or absolute), and conditional beta convergence have mostly been used in the literature. Briefly, Sigma convergence is the reduction in the disparity of per capita income levels among economies over time. There are different measures to understand sigma convergence such as maximum to minimum ratio, standard deviation, coefficient of variation, etc. (Sala-i Martin, 1996: 1020; Kindap and Doğan, 2019: 6). Beta convergence is a concept that assumes the per capita income of economies approaching each other in a certain period. There are two approaches for this form of convergence: absolute (or unconditional) and conditional beta convergence. Absolute convergence is the long-run convergence of countries' per capita income levels on the assumption that the only difference between them is their initial conditions. Conditional convergence demonstrates the convergence of economies with similar technology levels, savings rates, and population growth rates but differing beginning levels by selecting a variable as a condition and the others remaining constant. Besides, the beta coefficient is also a tool for the speed of convergence across selected regions in a country or countries.

In addition to sigma and beta convergence methods, panel unit root tests have lately been used to analyze convergence to avoid omitting any information and to better analyze relatively shorter periods. Also, it is essential while using panel data analysis to understand the stationarity levels of variables. There are different tests for testing stationarity, such as Im, Pesaran, and Shin (IPS), Fisher Augmented Dickey-Fuller (ADF), and Fisher Philips-Perron (PP).

1.1.1. Sigma Convergence

Sala-i Martin (1996: 1020) defines this type of convergence as the distribution of real income levels per capita across regions or groups decreasing over time. He showed real per capita GDP as:

$$\gamma_{i,t,t+T} = \frac{1}{T} \log \left(\frac{y_{i,t,t+T}}{y_{i,t}}\right) \quad (1)$$

where $\gamma_{i,t,t+T}$ is the GDP growth rate between time t and t+T in region i. Therefore, the equation for the convergence is for sigma convergence is:

$$\gamma_{i,t,t+T} = \alpha - \beta \log (y_{i,t}) + \varepsilon_{i,t} \quad (2)$$

To observe convergence in Equation 2, the sig The β coefficient should have a negative sign and be statistically significant.

One of the two methods for measuring sigma convergence is the standard deviation. Applying Equation 3 to explain sigma convergence, where σ_t is the standard deviation real per capita GDP in t over i regions/groups:

$$\sigma_{t+T} < \sigma_t \tag{3}$$

Shankar and Shah (2001: 3) describe simple coefficient of variation and weighted coefficient of variation as two methods for calculating the coefficient of variation. First, the simple coefficient of variation is:

$$CV_u = \frac{\sqrt{\sum_i \frac{(y_i - \bar{y}_u)^2}{N}}}{\bar{y}_u} \tag{4}$$

where y_i is the economy's per capita income and the number of regions is N. $\bar{y}u$ is the mean value of per capita income which is calculated as $\overline{y_u} = \frac{1}{N} \sum_i y_i$.

Equation 4 can be used for regional sigma convergence in countries but in regional sigma convergence across countries, it is not enough to calculate the coefficient of variation due to the limited number of regions in the equation (Shankar and Shah, 2001: 4). Therefore, another way to measure is the weighted coefficient of variation as:

$$CV_w = \frac{\sqrt{\sum_i (y_i - \bar{y})^2 \frac{P_i}{P}}}{\bar{y}} \tag{5}$$

where P denotes the total population of the country and P_i is the population in country i.

CV_u is varied from 0 to $\sqrt{N\text{-}1}$. If the coefficient of variation is 0, it shows perfect equality across selected regions but if it equals to $\sqrt{N\text{-}1}$, one region has all the per capita income. For CV_w is the between 0 to $\sqrt{\frac{P\text{-}P_i}{P}}$. If the coefficient of variation is 0 in this method, it means there is perfect equality and if it is $\sqrt{\frac{P\text{-}P_i}{P}}$, there is perfect inequality where one country has all per capita income.

1.1.2. Beta Convergence

1.1.2.1. Absolute Convergence

According to Galor (1996: 1056), there is absolute beta convergence in economies if their per capita income levels tend to be at the same level in the long run, regardless of their initial condition. This form of convergence is also identified by Sala-i Martin (1996: 1020), who claims that poorer economies expand at a faster rate than wealthy economies. To show this relation, it can be stated that in terms of analyses of Barro et al. (1991: 108), Barro and Sala-i Martin (1992: 225), and Sala-i Martin (1996: 1020):

$$\gamma_{i,t,t+T} = \alpha - \beta \log (y_{i,t}) + \varepsilon_{i,t,\ t+T} \quad (6)$$

where $\gamma_{i,t,t+T}$ is an economy i's growth rate between the time t+T and t so it is shown as $\gamma_{i,t,t+T} = \frac{1}{T} \log \left(\frac{y_{i,t,t+T}}{y_{i,t}}\right)$. Therefore, $\beta>0$, will be evidence of the existence of absolute β-convergence.

Sala-i Martin (1996: 1022) stated that if there is absolute convergence, there may be also sigma convergence, but it is not a necessary condition. According to him, suppose that there are two countries, Country A is relatively richer than Country B. There are three possibilities for the relation between sigma and absolute beta convergence. First, Country A and Country B may converge to the same level over time due to having sigma convergence and absolute beta convergence at the same time. Second, while Country A is growing more, Country B may shrink at time t+T. Therefore, there will be divergence, rather than sigma convergence and absolute beta convergence. Lastly, Country B may grow faster than Country A so, at t+T, Country B may become richer than Country A. Since the difference between these countries is not decreasing, there will not be sigma convergence even if there is absolute beta convergence in this case. Therefore, in some cases, these two concepts may not exist together. Sigma convergence is about the decrease in the income distribution across economies throughout time. Absolute convergence is about converging the income of individual economies to world income.

1.1.2.2. Conditional Convergence

Barro et al. (1991: 112), Barro and Sala-i Martin (1992: 226), and Sala-i Martin (1996: 1027) suggest that poor regions may expand faster than rich ones if their beginning levels of capital are different. It assumes an increase in capital stock in growing economies will decrease the growth rate until it becomes zero and reached to steady-state, which is known as conditional β-convergence. It is shown as:

$$\gamma_{i,t,t+T} = \alpha - \beta \log (y_{i,t}) + \psi X_{i,t} + \varepsilon_{i,t,\ t+T} \tag{7}$$

as $\gamma_{i,t,t+T} = \frac{1}{T} \log (\frac{y_{i,t,t+T}}{y_{i,t}})$and $\beta = \left(\frac{(I - e^{-\beta T})}{T}\right)$.

Also, $X_{i,t}$ is a set of variables that keep the economy i's the steady-state constant. To see Equation 7 in detail:

$$\frac{1}{T} \log \left(\frac{y_{i,t+T}}{yi,\ t}\right) = \alpha - \left(\frac{(I - e^{-\beta T})}{T}\right) \log \left(y_{i,t+T}\right) + \psi X_{i,t} + \varepsilon_{i,t,\ t+T} \tag{8}$$

where there is a negative correlation with the logarithm of income level at time t and growth rate at t+T. If $\beta > 0$ with $X_{i,t}$ constant, there is conditional beta convergence in selected economies.

1.1.3. The Speed of Convergence

The beta coefficient, according to Sala-i Martin (1996: 1019), in the convergence equation may be used to estimate the rate of convergence of each region in a steady-state. Supposing the equation is:

$$\frac{1}{T} \log \left(\frac{y_{i,t+T}}{yi,\ t}\right) = \alpha - \left(\frac{(I - e^{-\lambda T})}{T}\right) \log (y_{i,t+T}) + \varepsilon_{i,t,\ t+T} \tag{9}$$

where $\beta = \left(\frac{(I - e^{-\lambda T})}{T}\right)$ and $\lambda = -\left(\frac{1}{T}\right) \ln(\beta+1)$. Since a higher β means to have a higher coefficient, if λ is higher, the speed of convergence in economies will be higher in the selected period.

1.1.4. Panel Unit Root Tests

Unit root tests are used to determine if a series is stationary or not within the specified period. Evaluating for a unit root in panel data is a relatively new idea used by researchers such as Phillips and Perron (1988), Maddala and Wu (1999), Maddala (1999), Choi (2001), and Im et al. (2003), when the data is heterogeneous and nonstationary (Baltagi, 2005: 237).

1.1.4.1. Im, Pesaran and Shin Test

The null hypothesis for the IPS test may be used for testing convergence (Baltagi, 2005: 237). Im, et al. (2003: 53) proposed testing for dynamic heterogeneous panels focused on the mean of individual unit root statistics and t-test statistics according to the ADF average across groups. The null and alternative hypotheses are:

$$H_{1,0}: \begin{cases} \rho_i < 0 \text{ for } i=1,2,\ldots,N_1 \\ \rho_i = 0 \text{ for } i=N_1+1,\ldots,N \end{cases} \tag{10}$$

where the H_0 claims that the series are not stationary, and the alternative hypothesis demonstrates stationarity in certain series. The t-statistics for the IPS test are defined as:

$$\bar{t}=\frac{1}{N}\sum_{i=1}^{N} t_{\rho_i} \tag{11}$$

where t_{ρ_i} is for testing H_0: $\rho_i = 0$ for all regions I for N number of cross-sections. As Baltagi (2005: 243) stated, IPS indicates $\bar{t}$ has N(0, 1) distribution. Since N → ∞ and T → ∞ in panel data with combining Werner integral and Lindeberg-Levy central limit theorem:

$$t_{IPS}=\frac{\sqrt{N}(\bar{t}-\frac{1}{N}\sum_{i=1}^{N} E[t_{iT}|\rho_i =0])}{\sqrt{\frac{1}{N}\sum_{i=1}^{N} var[t_{iT}|\rho_i =0]}} \Rightarrow N(0, 1) \tag{12}$$

as $E[t_{iT}|\rho_i =0]$ and $var[t_{iT}|\rho_i =0]$ are calculated for T and ρ_i.

1.1.4.2. Augmented Dickey-Fuller Test

ADF is a Fisher-type unit root test where balanced panel data is not required, and different lag lengths can be used in each ADF regression. (Maddala and Wu, 1999: 636). Choi (2001: 252) describes the model as follows:

$$y_{it}=d_{it}+x_{it} \tag{13}$$

$$d_{it}=\beta_{i0}+\beta_{i1}t+\ldots+\beta_{im_i}t^{m_i} \tag{14}$$

$$x_{it}=\alpha_i x_{i(t-1)}+u_{it} \tag{15}$$

where i=1,…,N and t=1,…,T. y_{it} is a component that summarizes the nonstochastic and stochastic processes as d_{it} and x_{it} respectively. The null hypothesis is:

$$H_0 : \alpha_i=0 \tag{16}$$

for i regions, it implies series are nonstationary. Under this hypothesis where N → ∞ and T → ∞:

$$P_m=-2\sum_{i=1}^{N} \ln(p_i) \tag{17}$$

where the p test is identified as P → p^{∞} and P has a chi-square distribution. (λ^2) where the degree of freedom is 2N. Applying Lindeberg-Levy central limit theorem to Equation 17:

$$P_m \Rightarrow N(0, 1) \tag{18}$$

Also, the Z test may be used since it is invariant as N → ∞. Therefore, without any changes in Equation 17, it tests the null hypothesis (16) as:

$$Z \Rightarrow N(0, 1) \tag{19}$$

1.1.4.2. Philips-Perron Test

Phillips and Perron (1988: 335) provided a methodology for evaluating time-series stationarity. As the ADF test, PP also uses p-value, $\lambda^{2,}$ and Z-test to test the stationarity. For analyzing PP in panel data, Choi (2001: 255) modified the Z test with the same null hypotheses in (16):

$$H_0 : \alpha_i=0 \tag{20}$$

where the null hypothesis implies unit root in series. The model for the Z test is:

$$Z=\frac{1}{2\sqrt{N}}\sum_{i=1}^{N} (-2\ln(p_i)-2)=-\frac{1}{\sqrt{N}}\sum_{i=1}^{N} (\ln(p_i)+1) \tag{21}$$

as $E(-2\ln(p_i))=2$, $var(-2\ln(p_i))=4$ and $Z \Rightarrow N(0, 1)$.

1.2. DIGITALIZATION

In the literature, there are numerous definitions of digitalization, such as employing digital technologies to enhance business models to increase revenue and value-proceeding prospects, as well as using digital technology and information to improve business operations, individuals, and regions (Bloomberg, 2018: 3; Parida, 2018: 24). In this section, definitions of digitalization and assessment methodologies for evaluating digitalization's impacts are compiled. According to various researchers, its effects throughout the world and in Turkey are also being investigated.

1.2.1. Digitalization and Measurement Methods for Digitalization

Digitalization is not only a process to transfer documents into computers, but also of creating values and new opportunities, and sustainability in business and society (Parida, 2018: 24; Reis et al., 2020: 448). Especially because of the invention of the personal computer and the acceleration of its development with Industry 4.0, developments in technologies such as the internet, 2G, 3G, 4G, and 5G telephones, fixed and mobile broadband, cloud, the Internet of Things, social media, and artificial intelligence has been speeded up (Muro et al., 2017: 5). Digitalization has been changing the entire economy, individuals, firms, industries, governments, and all regions in the world. Processes in digitalization make individuals' life easier, shorten the distance between people and firms, enhance mobility, allow to use of big data, increase customer satisfaction, find new opportunities for investment, innovation, new businesses, and jobs; and create sustainable economic growth (Devereux and Vella, 2018: 550). For all these to happen, reorganization in the relations of firms and government, improvements to the decision-making procedure, encouragements for innovations and investments, and the creation of a new legislative are essential for having a more sustainable procedure for digitalization and increasing the share of the digital economy in income (Tolstykh et al., 2018: 742).

However, there is some ambiguity in describing digitalization due to the similarities between digitalization, digitization, and digital transformation. *Digitalization* may be summarized as a process of digitalizing information to make the production, distribution, and people's daily life easier, and to improve the economic growth in an economy. Besides, *digitization* means the process of transforming analog data, such as tapes and plaques, and papers into zeros and ones to collect, process, and transfer into computers (Bloomberg, 2018: 2). The main difference between *digitization and digitalization* is that digitization is about a technical change, while digitalization is an actual change in the collection, usage, and processing of information in the whole economy (Reis et al., 2020: 446). In addition to all these, *digital transformation* is a broader concept including the transformation of businesses and strategies from top to toe, and it is more individual-based, even if digitalization and digital transformation are mostly defined as the same concepts. Consequently, while digitization, digitalization, and digital transformation have similar elements, they should be considered as different phenomena.

Recent industrial revolutions have increased the value of information and technology. In Industry 3.0, the digitalization process started, but with Industry 4.0 and its follow-ups, developments in ICTs increased tremendously regarding the changes in individuals, firms, and government (Burma, 2016: 22; Parida, 2018: 26). Because it may be difficult to monitor and assess the complete effects of digitalization on economies, it is commonly measured in terms of the use of ICTs and the internet concerning the economy and society. However, over time, some variables and indices are created for this end. Table 1 shows examples of different methods to measure digitalization. Some studies recommend constructing an index to track the impact of digitalization on an economy, while other studies do not use an index but different variables to segregate factors when measuring digitalization.

Table 1: Different Methods for Measuring Digitalization

Author(s)	Indices/Variables
Dutta and Lanvin (2021)	Network Readiness Index (NRI): • Technology subindex: Access, content, and future technologies • People subindex: Individuals, businesses, and governments • Governance subindex: Trust, regulation, and inclusion • Impact subindex: Economy, quality of life, and Sustainable Development Goals contribution
İzmen et al. (2020 and 2021)	Digital Transformation Index: • Environment subindex: Political and regulatory, and business and innovation • Readiness subindex: Infrastructure, affordability, skills • Usage subindex: Individual, business, and government • Impact subindex: Economic and social

Georgescu and Kinnunen (2021)	Digital skills among the population, fixed broadband Internet subscriptions, Internet users, mobile-cellular telephone subscriptions
Mammadli and Klivak (2020)	• Ubiquity (infrastructure): Fixed broadband penetration, Mobile broadband penetration, Personal computer penetration, E-government, and Percentage of individuals using the Internet • Education: Mathematics education • Skills: ICT workers per 100
Afonasova et al. (2019)	The Digital Economy and Society Index (DESI): • Global Innovation Index • ICT Development Index • Network Readiness Index • High Technology Exports • Share of Households with Internet
Kotarba (2017)	• Digital Economy Metrics (Digital Density Index and Digital Economy and Society Index) • Digital Society Metrics • Digital Industry Metrics • Digital Enterprise Metrics • Digital Client Metrics • Digital Investment Metrics
Muro et al. (2017)	• Knowledge and Work Activities
Katz et al. (2014)	• Affordability • Infrastructure reliability • Network access • Capacity • Usage • Human capital

As shown in Table 1, Dutta and Lanvin (2021), İzmen et al. (2020 and 2021), Afonasova (2019), and Kotarba (2017) measured digitalization through the instrument of indices. İzmen et al. (2020 and 2021) calculated Turkey's Digital Transformation Index according to survey results, which are answered by business members, and many databases. There are four subindices: Environment, Readiness, Usage, and Impact which have ten subindices. The political and regulatory environments, as well as the business and innovation environments, are all included in the environment subindex. Infrastructure, affordability, and skills are readiness pillars. Individual, corporate, and government usage are the three pillars of usage. Finally, Impact covers both economic and social consequences. Kotarba (2017) compiled five main measures for digitalization as it is in Table 1, according to several researchers and his analysis:

Digital Economy Metrics (Macchi et al., 2015), Digital Society Metrics, Digital Industry Metrics (Manyika et al., 2015), Digital Enterprise Metrics, Digital Client Metrics, Digital Investment Metrics. As Digital Economy Metrics. There are two different indices: Digital Density Index (DDI) and Digital Economy and Society Index (DESI). DDI and DESI are used to investigate the digital economy. The purpose of DDI is to analyze public and private investments in the digital world to raise economic development. Therefore, it has four activity areas: making markets, sourcing inputs, running enterprises, and fostering enablers in 50 variables. Likewise, The European Commission developed the DESI to examine the economic competitiveness of European Union member states. It includes five subindices (connectivity, human capital, use of the internet, integration of information technology, and digital public services), focusing on infrastructure, quality, skills, activities, businesses, and government activities in digitalization. While DDI is concentrating on the market economy, DESI is more about understanding the economic and social impacts of digitalization.

Afonasova et al. (2019) also measure DESI, according to the reports of the OECD The five main subindices are the Global Innovation Index, ICT Development Index, Network Readiness Index (NRI), High Technology Exports, and Share of Households with the Internet. Lastly, NRI is calculated since 2016 by Dutta and Lanvin (2021). In 2021's report, the aim was to find ways to equal distribution of technology and investments for infrastructure, access, and skills, to forecast business models in the future, to understand the shift of work-life balance and the effects of COVID-19 in the globalization process, and its impacts on the environment and Sustainable Development Goals (SDG). For measuring NRI, there are four subindices: Technology, People, Governance, and Impact. Technology is the primary category and has three pillars: access, content, and future technologies. People subindex is for examining countries' skills, access, and ability to use technology with individuals, businesses, and government pillars. The Governance subindex has trust, regulation, and inclusion pillars to comprehend safety and security in the network economy. As the fourth subindex, Impact analyzes economic, social, and human impacts involved in the network economy.

In addition to these studies, Mammadli and Klivak (2020) classified variables according to the study of Katz et al. (2014). Katz et al. (2014) used affordability, infrastructure reliability, network access, capacity, usage, and human capital indicators to study the path of the digitalization process. If a country has an index score of more than 50, it is an advanced economy. Nevertheless, if it is below 20, it is a constrained economy. Furthermore, Mammadli and Klivak (2020) measured digitalization according to the ubiquity, education, and skills categories.

Instead of measuring digitalization with an index, some studies employ the effect of variables for digitalization individually. Muro et al. (2017) and Georgescu and Kinnunen (2021) analyzed factors exerting an influence on digitalization. Muro et al. (2017) analyzed knowledge and work activities separately and also created a score to calculate digitalization. They measured the score according to the Occupation Information Network survey, as stated in Equation 22.

$$\text{Digital score} = \frac{\sqrt{\text{Knowledge}_{\text{level}} \text{ x } \text{Knowledge}_{\text{importance}}} + \sqrt{\text{Work activity}_{\text{level}} \text{ x } \text{Work Activity}_{\text{importance}}}}{2} \qquad (22)$$

where Knowledge shows the information on computers and electronics, and Work Activity is the usage of computers and electronics while working. The highest possible digital score is 100.

Rather than calculating a score, Georgescu and Kinnunen (2021) examined the effect of digitalization according to digital skills among the population, fixed-broadband Internet subscription, mobile cellular telephone subscription, and Internet users, and clustering countries in terms of their development levels in digitalization.

1.2.2. Digitalization in the World and in Turkey

Developing and developed countries are using digitalization more and adapting faster, thus improving their economic growth (Mentsiev et al., 2020: 2962). Among OECD countries in 2013, although approximately 90% of the population in Luxembourg, the Netherlands, and the Nordic nations had an internet connection, only 60% or less of the residents in Greece, Mexico, Italy, and Turkey had an internet connection, with an increase to 70-95% in 2019 with the popularity of using smartphones (OECD, 2014: 76; OECD, 2020: 14).

Mammadli and Klivak's (2020) analysis of the effects of digitalization in OECD countries for the 2009-2017 period shows the most digitalized and least digitalized countries by creating an index for digitalization. While Denmark, Finland, and Japan were the most digitalized economies, the least digitalized ones were Turkey, Poland, and Slovakia. Furthermore, the results showed that a 1% rise in the level of the Digitalization Index increases GDP by 0.09% in the short term and 0.15% in the long run. Georgescu and Kinnunen (2021) examined digitalization and its effects on well-being, income inequality, and competitiveness in 121 countries in 2018 by clustering them into three groups (most developed, modest developed, and least developed). Their analysis showed that the most developed countries concerning digitalization, well-being, income equality, GDP, and competitiveness are Ireland, Luxembourg, Norway, Singapore, Switzerland, and United States. While modestly developed countries are such as Australia, Belgium, Canada, Chile, Czech Republic, Germany, Israel, Japan, Kazakhstan, Korea Rep., Oman, Panama, Portugal, Russian Federation, Spain, Sweden, Turkey, and United Kingdom; the least developed countries are mainly in Africa and South America, in addition to Albania, Algeria, Angola, Argentina, Armenia, Azerbaijan, Bosnia and Herzegovina, Georgia, Kyrgyzstan, and Ukraine.

To have an effective digitalization process in an economy, there are some challenges for citizens, businesses, and governments. The companies should adapt to new technologies for sustainability and growth in the economies (Ignat, 2017: 5). As Mentsiev et al. (2020: 2960) stated, more products and services need to be transferred to digital channels for improving customer satisfaction, and also for easing the decision-making process. Steps for tackling digitalization stated are analyzing the potential impact and deciding what is the best for the future of the company, reviewing the current situation of the company and defining the gap between the current and desired end of the transformation, and finding the needs for closing the gap in second step and actions for it to transform, implementing defined efforts and turning the other stages if it is necessary (Parviainen et al., 2017: 71). Furthermore, Mentsiev et al. (2020: 2961) indicated that governments need to measure digitalization to follow up on the investments and success of firms and to implement policies and regulations for the digital world. However, there are still more dimensions needed for improving digitalization in some areas, such as access, use, innovation, society, and trust (OECD, 2020: 16). Therefore, while individuals, organizations, and governments are developing a digitalization process, there are several challenges that they are facing. These are problems in implementing digitalization in politics, the disadvantages of digital platforms for entrepreneurship, adaption of the workforce and skills, forcing business models to digitalize, and the unperceived importance of big data and its area of usage (Parida, 2018: 25).

For measuring the digitalization level in Turkey, there are only a few studies in the literature. Yapraklı and Sağlam (2010) studied the relationship between ICT and economic growth in Turkey, using cointegration, Granger causality, and vector correction model for the 1980-2008 period. According to the results, economic growth has a positive relationship between physical capital, human capital, and employment. A 1% increase in information, on the other hand, only increases economic development by 0.07%. The NRI (Network Readiness Index) in 2016 showed that Turkey was 48th out of 139 countries with a value of 4.4, whereas Singapore and Finland had 6 with the highest ranking (Burma, 2016). According to the 2021's NRI Report, Turkey was 45th out of 130 countries with a score of 56.88, whereas the Netherlands, Sweden, Denmark, the US, Finland, Switzerland, and Singapore had scored more than 80 (Dutta and Lanvin, 2021). The port also indicates that Turkey's highest score in the Governance subindex was 63.16 out of 100, whereas the regulation pillar had a score of 65.28. It had the highest score for e-commerce legislation due to the new regulations, such as the digital services tax. The lowest subindex was technology, which is a score of 50.98, whereas the future technologies pillar's score was 31.79. It is observed that Turkey was the worst in robot density and investment in emerging technologies. Another report that analyzed Turkey's digitalization level is Turkey's Digital Transformation Index by İzmen et al. (2020). It was calculated under subindices: environment, readiness, usage, and impact, according to the range between one to five, where five is the highest level. Turkey's Digital Transformation was 2.94 in 2019 and 2020, becoming 3.06 with only a 4% increase. The best areas for digitalization in Turkey among all 64 indicators: costliness of ICT infrastructure, households have internet access, the cost for enforcing the contract, e-participation index, use of virtual social networks, fixed broadband internet subscription, literacy rate, the time required to establish a business, mobile network coverage, and prepaid mobile cellular tariff respectively. However, the worst areas are international trade in ICT services, international internet bandwidth, ICT Patent Cooperation Treaty patent applications, secure internet servers, full-time equivalent telecommunications workers, international trade in ICT services, electricity production, annual investment in telecommunication services, and the quality of mathematics and science education.

It can be concluded that the digitalization process in economies has various obstacles, and it is hard to calculate its progress. The goal of this research is to analyze the impact of digitalization on regional convergence in Turkey, using various variables about digitalization. These variables are the number of fixed telephony access, santral capacity for fixed telephony, the number of mobile telephony subscriptions, the number of broadband subscriptions, the length of the fiber, the percentage of internet users, 15 years of age and over and literate, and upper secondary education gross enrollment rate. To measure digitalization, these variables are grouped into three indices: Usage (DUI), Infrastructure (DFI), and Skills (SI). DUI refers to the individual's usage as the access to fixed telephones, mobile telephone subscriptions, fixed broadband, and mobile broadband subscription and internet users. DFI is for the capacity of fixed telephones and measuring the length of fiber-optic internet cables. Lastly, SI measures the ability of the usage of digitalization according to the literate population and upper secondary education.

Consequently, the main hypotheses of this thesis are:

Hypothesis 1. DUI reduces regional disparities across NUTS-1 regions in Turkey in the 2012-2020 period.

Hypothesis 2. DFI reduces regional disparities across NUTS-1 regions in Turkey in the 2012-2020 period.

Hypothesis 3. SI reduces regional disparities across NUTS-1 regions in Turkey in the 2012-2020 period.

CHAPTER TWO
LITERATURE REVIEW

Convergence in the global economy and thus Turkey has been the subject of various studies. However, there is only a few research in Turkey on the effects of digitalization on regional convergence in the literature. This chapter presents a literature review on convergence theory, convergence across Turkey's regions, digitalization, and studies on the impact of digitalization on convergence.

2.1. CONVERGENCE THEORY

Barro and Sala-i Martin (1990: 34, 1992: 245) found that poor economies grow faster than rich ones regardless of keeping other variables constant, except for initial per capita income. Since technologies are different across regions, there may be divergence due to the mobility of capital. Barro and Sala-i Martin (1992: 241) allowed for net migration in the model and found a positive relationship between per capita income and also little impact on convergence. Galor (1996: 1057) added capital market imperfections, externalities, non-convexities, and imperfectly competitive market structures to basic neoclassical growth models, claiming that economies can have multiple steady-state equilibria and club convergence. The augmented growth model of his indicated that countries with similar characteristics, initial levels of output, and human capital per capita but the different initial distribution of human capital may have different steady-state equilibria. Also, even if there are similar characteristics and initial levels of output and output per capita or fertility rates, the different initial distribution of income capital or physical capital may have different steady-state equilibria.

Before Barro and Sala-i Martin (1990 and 1992) and Galor (1996), Baumol (1986) analyzed Maddison's (1982) data for 1870-1979 for testing unexpected growth in productivity, GDP per capita, and exports and convergence of productivities of industrialized market economies in the history in 16 countries. A negative correlation between the productivity levels in 1970 and productivity growth in 16 countries was found. Besides, the importance of the long-run was shown, due to observing the product of path-dependent processes, since the past can affect the present. Other reasons are problems and results of policies in the short-run, ignoring forces when focusing only on the short-run, and not enough only concerning short-run to understand the long-run.

However, after Baumol (1986)'s analysis, additional issues emerged: the negative correlation between growth and initial level of productivity or real GDP per capita for convergence, a well-designed theoretical model for convergence hypothesis, and examining more countries to investigate convergence (Chatterji, 1992: 58). As a consequence, even if there is a negative association between growth and initial levels of productivity or real GDP per capita for convergence, there may be a gap between the beginning and the end of the period, which Chatterji (1992: 59) refers to as weak convergence. The question of convergence to what leads to strong convergence has two conditions: the need for a steady-state where per capita real income is equalized and dynamic forces that lead the economies to have that steady-state. As opposed to the neoclassical growth model, in shorter periods, the poorer country would have faster income growth per capita than the richer country since the poor one has lower capital stock. Therefore, in this study, exogeneity of the rate of technological progress was not assumed to equalize the level of per capita income to have strong convergence across subgroups of countries. Thuswise, Chatterji (1992: 63) found the convergences in unique equilibria for some countries. In his study, he also analyzed rich and poor nations as two clubs. In a steady-state, rich nations have higher per capita income than poor ones so the gap between these two clubs will grow eventually.

Besides these studies, Krugman (1991: 483) introduced New Economic Geography and studied the effect of the location of a region on an economy. He designed a model for the question of why and when the concentration of the manufacturing sector was only in a few regions. According to his analysis, due to transportation costs, economies of scale, and the share of nonagricultural goods in expenditure, the concentration of population and divergence in regions will occur. He suggested a two-region model with two production types: agriculture in one region and manufacturing in another region. When wage rates decrease as one region has more workforce, workers will be likely to migrate to another region so there will be regional convergence. But if wage rates increase, there will be regional divergence due to migration into another region that already has a larger workforce. Also, if there are high transportation costs, the relative wage will decline as the share of the manufacturing labor force rises, therefore there may be regional convergence or regional divergence.

Some studies found convergence in regions of Turkey, using sigma convergence, beta convergence, and/or club convergence analyses. Because poor economies tend to grow faster to try to keep up with wealthier ones, beta convergence suggests convergence across areas of an economy, whereas sigma convergence depicts the dispersion of regional income decline. Using these analyses, Ersungur and Polat (2006) and Yıldırım et al. (2009) showed convergence in NUTS-1 and Özgül and Karadağ (2015), Gömleksiz et al. (2017), and Kindap and Doğan (2019) in NUTS-2. Yıldırım and Öcal (2006), Karacuka (2020), Elmalı et al. (2021), and Öztürk and Gültekin (2021) found convergence across provinces in Turkey for different periods. However, some studies imply no convergence across selected regions in Turkey, using different types of analyses (Gezici and Hewings, 2004; Halaç and Kuştepeli, 2008; Abdioğlu ve Uysal, 2013; Duran, 2015; Konat, 2021; Yazgan and Ceylan, 2021).

Ersungur and Polat (2006) checked convergence in NUTS-1 regions in Turkey from 1987-to 2000 in Turkey. The outcome indicates that the beta convergence across NUTS-1 is statistically significant, and those regions converge by 0.07% during the 1987-2000 period. Furthermore, they found that there was a decrease in income level in economic crises, in 1994, 1999, and 2000, particularly more in high-income regions like İstanbul according to sigma convergence results, similar to the study by Yıldırım and Öcal (2006). Yıldırım et al. (2009) analyzed regional income inequality and convergence in NUTS-1, NUTS-2, four large regional groups, and an East-West distinction of Turkey for 1987-2001 in twofold: Theil coefficient of concentration with spatially disaggregated data to observe regional inequalities in these four groups of Turkish provinces and convergence analysis with Geographically weighted regression (GWR) method. Results showed that in the 1987-2001 period, there was a decline in income inequality in Turkey, even if regional disparities in three groups, not in NUTS-2. Also, according to GWR estimation, Eastern and Southeastern provinces have higher beta convergence than Western provinces. Higher fertility rates and unemployment restrain economic growth, but the level of education and real government expenditure per capita have positive effects on economic growth. Moreover, government expenditures get stronger in Central and Western provinces, so the gap between those provinces of East and West may widen when there is successive government spending.

Özgül and Karadağ (2015), Gömleksiz et al. (2017), and Kindap and Doğan (2019) analyzed convergence in NUTS-2 regions in Turkey. Sigma convergence, unconditional beta, and conditional beta convergences were analyzed in NUTS-2 in the 1990-2001 period, using welfare indicators such as per capita GDP, per person employed GDP, and development index analyzed by Özgül and Karadağ (2015). In general, there is unconditional convergence across regions in Turkey. Also, the illiterate population rate, high school graduation rate, public capital per person, and population growth rate were analyzed for their effects on welfare indicators on convergence, and there is no significant effect of them, except population growth. According to the coefficient of variation, cross-sectional OLS, and panel data for sigma-convergence, absolute and conditional beta convergences, Gömleksiz et al. (2017) investigated convergence and the role of government in convergence with regional government investments and fixed investment incentives in NUTS-2. Results concluded the importance of government incentives in decreasing income inequality, poverty, and regional development disparities. Also, government investments are essential for reducing regional economic disparities. In terms of sigma and beta convergence, Kindap and Doğan (2019) tested convergence from 2004-to 2011 in NUTS-2. Moreover, the effect of geographical proximity on economic growth and the consequence of the 2008 financial crisis on regional convergence were examined for the selected period and regions. According to cross-sectional estimation and panel data analysis to evaluate absolute beta convergence, there is regional convergence in NUTS-2 regions in Turkey for the 2004-2011 period, and poorer regions in Turkey grew relatively fast. Also, sigma convergence results indicated that those regions in Turkey experienced an increase in income inequality in expansion periods and a decrease in recessions which shows countercyclical regional economic convergence. Furthermore, findings of spatial dependence in panel models signified regions in Turkey grow faster if they have better-conditioned neighbors, so western regions and their neighbors have better growth rates when compared with eastern regions.

Yıldırım and Öcal (2006) examined income inequality and convergence in Turkey for NUTS-3 by using the Theil index and real GDP for 1979-2001. Spatial analysis results implied that the Theil index has pro-cyclical characteristics: it reduced in recession periods (in 1994, 1999, and 2001) and raised in expansions (from 1983 to 1988). Besides, there is convergence across Turkey's provinces from 1979-to 2001. Karacuka (2020) found convergence across provinces in Turkey in the 2004-2017 period and examined variables about economic growth. According to the results, foreign trade is the most efficient factor for convergence and economic growth. Therefore, regulations for specializing in trade may impact economic growth positively in all provinces. Elmalı et al. (2021) analyzed income distribution for provinces of Turkey in the 1992-2017 period, using spatial panel data analysis. GDP per capita was found to have a negative coefficient which shows convergence in all provinces. If there is progress in the distribution in the province, it also affects its neighbors. According to Elmalı et al. (2021), on a provincial basis, policymakers should consider the following policy proposals for sustainable growth and development: increasing health and public sector investments and increasing the quality of education in urban areas, providing equal opportunities to lower incomes, and appropriate regional economic policies. Moreover, Öztürk and Gültekin (2021) analyzed the 2008 crisis and the regulations introduced in the 2004-2017 period and convergence in provinces in Turkey, using beta convergence and sigma convergence analyses. According to those analyses, there is convergence across provinces in the selected period. This is because, after the 2008 crisis, growth rates declined in developed provinces (essentially located on the west side of the country) but increased in relatively less developed provinces in the east.

Some studies found no convergence across selected regions in Turkey. Gezici and Hewings (2004) examined convergence during the 1980-1997 period, using beta convergence and sigma convergence in 67 provinces and 16 functional regions, but poor cities did not grow faster than rich ones in the 1980-1997 period. Adding explanatory variables into regression did not change the results. Moran's I further revealed that GDP per capita did not distribute randomly between provinces but was clustered and spatially dependent. Therefore, there exists no convergence in Turkey's 67 provinces and regions from 1980 to 1997. Halaç and Kuştepeli (2008) used a panel unit root test to analyze income distribution across seven regions and its convergence in Turkey in the 1990Q1-2001Q4 period, but results showed no convergence in the selected period. Abdioğlu ve Uysal (2013) analyzed the hypothesis about convergence across the gross added value of 26 sub-groups in Turkey for the 2004-2008 period, using panel unit root tests. The results of the tests revealed no convergence among NUTS-2 areas. Therefore, regulations imposed in 2004 for reducing the economic divergence across them failed, and the income inequalities in Turkey existed from 2004 to 2008. Duran (2015) aimed to find poverty, its geographical distribution, and the convergence in poverty across East and West regions of Turkey, using Moran's I test for Level-1 for 2006-2013. In conclusion, since poverty rates did not fluctuate enough from 2006 to 2013, neither convergence nor divergence among 12 regions in Turkey was found. Also, considering the increase in income inequality in the past several years, as a result of globalization and technological advancement, the convergence in income inequality across NUTS-1 in Turkey was examined for the 2006-2019 period by Konat (2021). According to panel data analysis, there is no convergence in these regions in Turkey, and income inequality existed during the 2006-2019 period. Authors suggested that regulations in the labor and financial market, union policies, tax policies, and social norms about wage inequality may decrease the inequalities and converge the regions into each other. Besides, Yazgan and Ceylan (2021) found no convergence among NUTS-2 regions in 2004-2018 using the club convergence technique and indicated that the divergence among 26 regions may be permanent, since if one region is rich, it may converge with its neighbor. However, if one region is poor and its neighbors are also poor, there is a chance of staying the same or becoming worse than before.

2.2. DIGITALIZATION IN THE GLOBAL ECONOMY

Digitalization refers to the process of digitalizing an economy. The impact of digitalization on income levels at the global level and individual level, and the transparency in a country are undeniable facts (Namazi, 2020: 3). Digital technology mostly is seen as a monopoly, but it increases the economies of scale and scope in the world, because of the development of the structure of media (Mueller, 1999: 21). Therefore, it is critical to comprehend its implications on economies and convergence.

Lobanov et al. (2000), Billion et al. (2010), and Namazi (2020) studied digitalization and its effects on economies. The impact of digitalization of geo-information services and Industry 4.0, as well as a driving conceptual model to connect this impact, are examined by Lobanov et al. (2000). If a company has a great level of service and digitalization, there will be a convergence between industry 4.0 and services digitalization, and there will be both process- and customer-oriented added value. Therefore, the essential factors are customers' benefits and internal procedures in services in industry 4.0, the convergence between services digitalization and industry 4.0 for trust, ethics, and security, Internet of Things, digital cloud computing tools, and predictive analytics to support the convergence and improvements and benefits of the supply of goods, works and services to increase efficiency. Also, Billon et al. (2010) found the differences in information and communication technologies adoption, a combination of specific technologies, and explanations of the factors in 142 developed and developing countries in 2004. Results showed that variables (GDP per capita, telephone mainlines, education, the percentage of population between 15 and 64, internet price, and regulatory quality) differ while describing the countries' level of digitalization. GDP is the only variable that explains all the country groups. Besides, middle-digitalized countries are affected more by GDP, and high-digitalized countries are less affected. Namazi (2020) analyzed the effect of digitalization on income distribution in 170 countries for the 2010-2019 period, using panel OLS. Overall, 44% of the variation explains the relationship between income distribution and access to telecommunication infrastructure, education, government electronic services, knowledge output, creative output, cybersecurity, democracy, corruption, labor participation in GDP, ease of doing business, nation's development classification.

Some studies analyzed digitalization and its effects on the Turkish economy (Beceni et al., 2015; Güz, 2019; Atıcı, 2020). According to Beceni et al. (2015), new concepts for companies were introduced: transparency due to establishing information on websites, simple to archive bills and records, registered e-mail, e-notification, e-signature, e-government applications, online banking, online meetings with the

Turkish Commercial Code in 2012. Güz (2019) calculated ICT development level according to ICT access, ICT use, and ICT skills with their subgroups for the whole of Turkey and 12 regions from 2013 to 2017. İstanbul had the highest ICT development value in 2013 and 2017, then West Anatolia, Eastern Marmara, and Aegean regions followed it. However, during the 2013-2017 period, the ICT Development Index ranking in Turkey's 12 regions did not change significantly. Atıcı (2020) analyzed the effect of digitalization on emerging markets, especially in Turkey, and the game changers of the digital economy, such as cryptocurrencies, and blockchain. There is a positive expectation about digitalization in finance emerging markets due to increasing transparency in government, central bank, and businesses, increasing tax revenue, saving more with decreasing direct costs, increasing GDP and employment, increasing the productivity of firms and government, and time-saving. However, there is still a long path to confront difficulties in the digital economy, such as regulatory structure, tax collection, cyber security, fraud, and energy usage (Atıcı, 2020).

2.3. THE RELATIONSHIP BETWEEN CONVERGENCE AND DIGITALIZATION

The relationship between digitalization and convergence was analyzed for several economies. Bera (2019) examined convergence and digitalization across 17 major Indian states through 21 variables in the 2006-2016 period, calculating digitalization according to the Principal Component Method concerning infrastructure, human resources, competitiveness, diffusion, and affordability. Results showed the gap in the level of digitalization in 17 Indian states. Furthermore, when the convergence across states is examined, it is found that there is a divergence in all states included. However, when those states are divided into three groups according to their index results, there is convergence in group 1 and group 2, but not in group 3 which includes the states with low levels of digitalization. Low affordability, human resources, and diffusion rates cause divergence in lower-ranking states, so more attention is needed to these to improve the digital divide in the country particularly.

To examine the effects of digitalization in economies, Dyatlov et al. (2019) elaborated on the digital economy and the effects of digital transformation on convergence. Results showed that converged clusters are more stable due to digital transformation. According to the authors, digital transformation may create a “better world” since it helps to have sustainable growth and a better environment for working and living in the future. Moreover, Stan et al. (2020) aimed to find the relationship between digitalization and sustainable development, their effects on convergence and non-poverty, the impact of digitalization on good health and well-being, gender equality, decent work, and economic growth in Romania. Results indicated that the higher digitalization index causes higher well-being and a lower unemployment rate. Jurzyk et al. (2020) examined income inequality and COVID-19 in Asian countries as a doctoral thesis. One of the study's outcomes was: that since the government can use digital wallets, existing electronic social security, tax rosters, etc., the support for decreasing income inequality is more efficient if a country has higher levels of digital adaptation. Also, due to the development of the digital economy, it is essential to remove the legal barriers as the soonest time possible to increase the effectiveness of the digital economy, especially in urban areas (Voskresenskaya et al., 2020). Voskresenskaya et al. (2020) stated that the restrictions in digital development in Russia are the deficiency in legal regulations and institutional infrastructure, inequalities in digitalization, problems in information security, and untrained personnel. Therefore, for digital infrastructure and economic capabilities, development of free trade, ICT innovations, the infrastructure of international transactions, the rule of law for the digital economy, and financial and social infrastructure will remove the restrictions and support digital development in Russia.

The digital divide is the disparity of various socioeconomic levels according to the ability to access ICTs and use the internet for a variety of purposes (Acılar et al., 2011: 3). For instance, Chou and Huang (2007) answered the dilemma of convergence or divergence in the information era across 100 countries from 1990 to 2013, using conditional convergence growth theory and club convergence which is the threshold model for multiple equilibria. Initial income, investment ratio, the growth rate of population, and human capital are included as explanatory variables in all models in addition to the initial income level and Digital Access Index (DAI) to determine the per capita income growth rate. To analyze the digital divide, they used club convergence by grouping 100 economies into two groups based on DAI. Club convergence showed that high-DAIs have no convergence, and the sign of all explanatory variables is not significant, but low-DAIs, all variables are significant, except population growth, and economies tend to converge. The reasons for low DAIs convergence are China and India in this group and not including most less developed countries due to lack of data. Moreover, as an example of indexing, Park et al. (2015) analyzed club convergence to examine the digital divide factors affecting the global economy across 108 nations. According to them, there is a digitalization divergence among 108 countries but found the convergence member countries in three subgroups. Countries in group 3 have the lowest convergence level, but the convergence speed is highest in digitalization, and group 1 has the highest convergence level but the lowest convergence speed. If a country has GDP per capita, tertiary school enrollment, and service, it would be in a higher convergence level of group 1 or group 2, but if not, it would be in group 3. However, if a country has a higher urban population, there is a lower possibility of being in group 1 or group 2, as opposed to group 3. Also, tertiary school enrollment has the highest elasticity among other variables. Therefore, more regulations towards increasing tertiary education enrollment levels and public expenditures on education are essential. Rath (2016) examined 47 countries (28 developed and 19 emergings) for convergence of ICT development in the 2000-2012 period, analyzing through a dynamic panel model and extending the analysis of Park et al. (2015). Conditional convergence shows that emerging countries could not catch up with the developed countries. There is divergence in both developed countries and emerging countries, but in emerging countries, ICT development per capita leads to diverging more. Moreover, results showed that in all countries, per capita income level and urban population are the most influential factors in the divergence of ICT. Therefore, increasing fixed-broadband connections, providing internet facilities, and improving the quality of education are crucial to reducing divergence. Lucendo-Monedero et al. (2019) examined the regional spatial inequalities in digital development of households and individuals across Europe according to NUTS-1 and NUTS-2. According to the analysis, the usage of ICTs daily for e-commerce, e-banking, and e-government are essential for digital development levels in regions in

Europe, but the use of social networks is less for the level of digital development. Moreover, HIDDI (Index of ICT usage in households and by individuals) presents that if those regions have higher-HIDDI have as much digital development as their neighbors and vice versa.

Acılar et al. (2011), Polat (2012), and Koramaz et al. (2019), and analyzed the digital divide in Turkey. Acılar et al. (2011) analyzed computer and Internet use for examining the digital divide in four subgroups: gender divide, age divide, rural-urban digital divide, and education level within and between Russia and Turkey in the 2004-2009 period and found the gap between them and inside them reducing in the selected period. According to Polat (2012), there are still inequalities to reach the internet, mobile phones, tablets, computers, etc., and their benefits in Turkey. Primarily, women, the elderly, rural residents, and/or uneducated people are more disadvantaged in that case due to economic/social inequalities. Koramaz et al. (2019) tested the spatial pattern in Turkey, using Getis-Ord Gi* Statistics. Gi* distribution of ICT development index results indicated that İstanbul, Ankara, İzmir, Eskişehir, Yalova, Muğla, and Antalya have the highest scores respectively.

Köksal and Anıl (2013) examined digitalization and convergence in NUTS-1 regions in Turkey in terms of the broadband adoption, usage of households and their online activities, the impact of education, age, gender, and age size on these, and the differences in broadband internet access. Factors that increase the adoption rate are the more fixed and mobile phone subscription, younger citizens, employed, educated above high school, and living in west or central regions in Turkey. Also, if a person is employed, they are more likely to use online activities such as e-mail, posting content, looking for information, getting health appointments, and e-banking, but they are less likely to use voice/video calls and social networking. The effect of internet infrastructure on regional income inequalities in Turkey’s NUTS-2 regions from 1999 to 2011 was analyzed in Turkey by Celbis and de Crombrugghe (2018). Results implied that internet infrastructure has a significant role in regional income convergence and increases convergence speeds across regions.

As it can be observed, while there are many studies about regional convergence, there are few studies in Turkey about the relationship between convergence and digitalization. Based on the hypotheses stated in Chapter One, this thesis aims to understand the relationship between digitalization and convergence in NUTS-1 areas in Turkey over the period 2012-2020.

CHAPTER THREE
EMPIRICAL ANALYSIS

3.1. DATA

In this thesis, the impact of digitalization on economic convergence in NUTS-1 regions in Turkey is analyzed. The annual data covers the 2012-2020 period for 12 regions of Turkey. Data were obtained from Information and Communication Technologies Authority's (ICTA) The Annual Statistical Bulletin at Provincial Level on Electronic Communication reports and the TUIK data portal. The Annual Statistical Bulletin at Provincial Level on Electronic Communication reports are published for every province of Turkey yearly since 2018 as 2012-2017, 2013-2018, 2014-2019, and 2015-2020 periods. The data for the number of fixed telephony access, mobile telephony subscriptions, broadband subscriptions, santral capacity for fixed telephony, and the length of fiber are obtained from these reports. Table 2 shows the regions and provinces that are included in the regions. For examining convergence, the value of GDP per capita as TL in NUTS-1 (2009 is the base year) is used from TUIK.

Table 2: NUTS-1 Regions in Turkey

Code	NUTS-1	Provinces
TR1	İstanbul	İstanbul
TR2	West Marmara	Tekirdağ, Edirne, Kırklareli
		Balıkesir, Çanakkale
TR3	Aegean	İzmir
		Aydın, Denizli, Muğla
		Manisa, Afyonkarahisar, Kütahya, Uşak
TR4	East Marmara	Bursa, Eskişehir, Bilecik
		Kocaeli, Sakarya, Düzce, Bolu, Yalova
TR5	West Anatolia	Ankara
		Konya, Karaman
TR6	Mediterranean	Antalya, Isparta, Burdur
		Adana, Mersin
		Hatay, Kahramanmaraş, Osmaniye
TR7	Central Anatolia	Kırıkkale, Aksaray, Niğde, Nevşehir, Kırşehir
		Kayseri, Sivas, Yozgat

TR8	West Black Sea	Zonguldak, Karabük, Bartın
		Kastamonu, Çankırı, Sinop,
		Samsun, Tokat, Çorum, Amasya
TR9	East Black Sea	Trabzon, Ordu, Giresun, Rize, Artvin, Gümüşhane
TRA	North-East Anatolia	Erzurum, Erzincan, Bayburt,
		Ağrı, Kars, Iğdır, Ardahan
TRB	Central East Anatolia	Malatya, Elâzığ, Bingöl, Tunceli
		Van, Muş, Bitlis, Hakkâri
TRC	South-East Anatolia	Gaziantep, Adıyaman, Kilis
		Şanlıurfa, Diyarbakır
		Mardin, Batman, Şırnak, Siirt

Source: Kalkınma Ajansları, 2021

All the variables that are used for the analysis are explained below:

1. GDP per capita (GDPPC): It is calculated by the production approach according to prices in 2009 by regions in Turkish Lira (TL).

2. The number of fixed telephony access (FIXED): Data covers the number of active fixed analog telephony access lines, voice channels equivalent to ISDN lines, fixed wireless subscriptions, number of payphones, and number of VoIP subscriptions. Data is available for the 2007-2020 period.

3. Santral capacity for fixed telephony (SANT): The overall capacity for fixed-line telephones is included. It is available for the same periods as the number of fixed telephony access in the reports.

4. The number of mobile telephony subscriptions (MOBILE): This variable includes the 2G, 3G, and 4,5G subscribers for the 2007-2020 period.

5. The number of broadband subscriptions (BROAD): It refers to the overall number of fixed broadband internet subscribers and the total number of mobile broadband internet subscriptions. The number of fixed-broadband subscriptions has these four dimensions: fiber, xDSL, cable, and other fixed broadbands. Besides, mobile broadband subscriptions include mobile broadband dedicated via data cards and standard mobile broadband. This data exists for 2011-2020.

6. The length of fiber (FIBER): It measures the length of fiber-optic internet cables as kilometers. Fiber internet provides higher speed and better reliability, can travel great

distances, and carries more data than cable internet; however, it is more expensive. It exists only for the 2012-2016 and 2016-2020 periods.

7. The proportion of internet users (INTER): All individuals and households aged 16-74 who are living in Turkey and using the internet by lasted usage are indicated in this data for the 2011-2020 period.

8. 15 years of age and over and literate (EDUC): It measures the population 15 years old or more who can read and write for 2008-2020. It is used for understanding the potential of the ability to use digital devices of Turkish citizens.

9. Upper secondary education gross enrollment rate (GROSS): It represents the proportion of all students in upper secondary education. The rate can be more than 100% because of over-age or under-age students. The data is available for 2007-2020.

10. Urban population (URBAN): According to TUIK, the urban population is defined as cities with a population of over 20001 and more from 2007 to 2020.

11. Unemployment rate (UNEMP): Employees who did not work during the reference period for different reasons are only considered employed if there is a three-month assurance of returning to work or if their employer pays them at least half of their wage or salary during their absence. People who are not considered employed are unpaid family workers and casual workers who worked for less than an hour during the reference week. It is calculated by TUIK annually according to The Labor Force Survey for 1988-2014 and 2014 to onwards, due to changes in regulations in the survey in 2014.

Selected variables for measuring digitalization are collected under three different indices: Usage (DUI), Infrastructure (DFI), and Skills (SI), similar to the indices in the studies of Katz et al. (2014) and Mammadli and Klivak (2020). It is aimed to find DUI, DFI, and SI, according to Principal Component Analysis (PCA), and their (positive) influences on convergence and minimizing regional differences. DUI includes the number of fixed telephony access (FIXED), the number of mobile telephony subscriptions (MOBILE), the number of broadband subscriptions (BROAD), and the proportion of internet (INTER) users in Turkey. DFI has the santral capacity for fixed telephony (SANT) and the length of fiber cables to measure the capacity of telephone lines and fiber internet cables (FIBER). For understanding the education level in NUTS-1 regions, SI involves 15 years of age and over and literate population and upper secondary education gross enrollment rate.

In Table 3, the descriptive statistics for selected variables are shown for the relationship between digitalization and convergence in 2012-2020 in NUTS-1 on average. According to Table 3, the mean value of GDPPC is 32361.94 TL. FIXED shows 1003021 people were accessing fixed telephones. In terms of MOBILE, 6285846 people use mobile telephones. While 4762367 people were subscribing to the fixed and mobile broadband internet, only 58.97% of the population used the internet. As infrastructure, SANT and FIBER indicate that santral capacity for fixed lines was 1741307, and the length of fiber internet was 25251.77 kilometers. The mean value of EDUC was 4739237 which is an educated population of 15 and more, whereas GROSS shows 107.74% of the population enrolled in upper secondary education. Furthermore, 6031412 people lived in the urban areas on average, and the unemployment rate was 10.16% in Turkey, as shown in URBAN and UNEMP, accordingly.

Table 3: Descriptive Statistics for Variables for all Regions

Variables	Obs.	Mean	Std. Dev.	Min	Max
GDPPC (thousand TL)	108	32.36	17.33	10.47	97.95
FIXED (million)	108	1	0.84	0.57	3.72
MOBILE (million)	108	6.29	4.89	1.48	22.4
BROAD (million)	108	4.76	4.08	0.55	20.2
INTER (percent)	108	58.97	14.16	29.44	88.68
SANT (million)	108	1.74	1.41	0.32	6.54
FIBER (thousand km)	108	25.25	11.33	7.38	60.39
EDUC (million)	108	4.74	2.72	1.31	11.4
GROSS (percent)	108	107.74	12.32	74.79	136.12
URBAN (million)	108	6.03	3.9	1.24	15.5
UNEMP (percent)	108	10.16	3.58	3.6	22.4

Source: Own calculations based on ICTA, 2018; ICTA, 2019; ICTA, 2020; ICTA, 2021; TUIK, 2021a; TUIK, 2021b; TUIK, 2022a; TUIK, 2022b; TUIK, 2022c; TUIK, 2022d; and TUIK, 2022e

The descriptive statistics for the indices DUI, DFI, and SI values are included in Table 4. Since the variables are standardized to measure indices with PCA in the analysis, their mean values are zero.

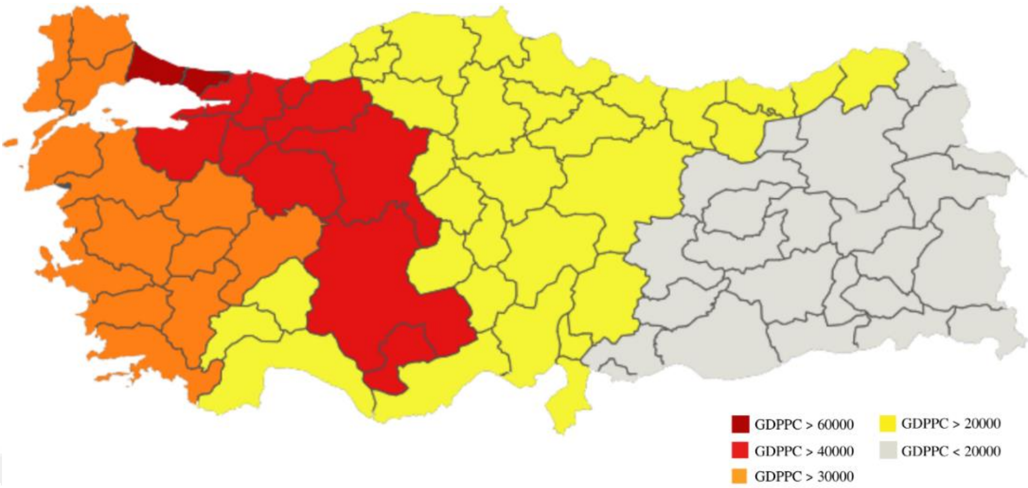
Table 4: Descriptive Statistics for Indices for all Regions

Indices	Obs.	Mean	Std. Dev.	Min	Max
DUI (FIXED, MOBILE, BROAD, INTER)	108	0	1	-1	3.22
DFI (SANT and FIBER)	108	0	1	-1.58	3.1
SI (EDUC and GROSS)	108	0	1	-2.67	2.3

Source: Own calculations based on ICTA, 2018; ICTA, 2019; ICTA, 2020; ICTA, 2021; TUIK, 2021a; TUIK, 2021b; TUIK, 2022a; TUIK, 2022b; TUIK, 2022c; TUIK, 2022d; and TUIK, 2022e

Figure 1 visualizes the GDP per capita for NUTS-1 areas from 2012 to 2020. Dark red shows the highest mean of GDP per capita, whereas grey is the lowest mean, according to the mean value of NUTS-1. Colors are determined according to the mean value of the GDPPC of Turkey. The highest mean of GDPPC is 61180.22 in Istanbul, while the lowest is 18310.22 in Central East Anatolia. After İstanbul, descending sorting is as follows: West Anatolia, East Marmara, West Marmara, Aegean, Mediterranean, Central Anatolia, East Black Sea, West Black Sea, North-East Anatolia, and South-East Anatolia.

Figure 1: Real GDP per capita TL, (GDPPC) for 2012-2020



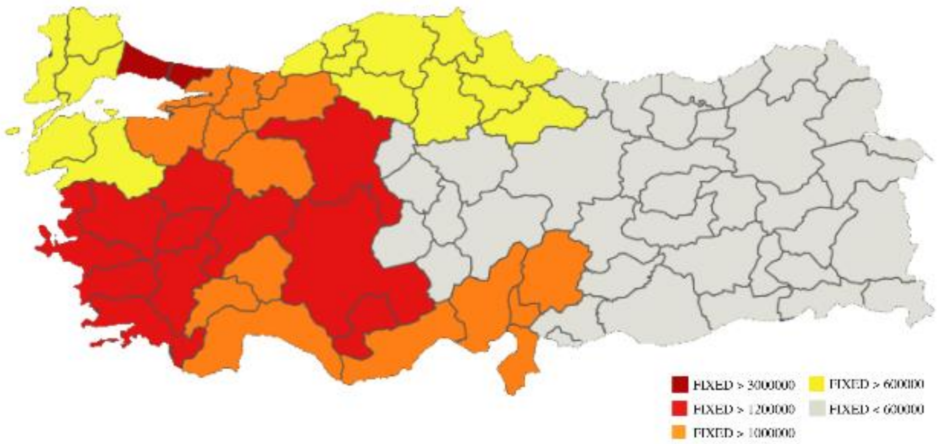
Source: TUIK, 2022a and own calculations (According to the data, the map is generated using https://pixelmap.amcharts.com/.)

Figures 2, 3, 4, 5, 6, and 7 illustrate the NUTS-1 maps for measuring digitalization, and Figures 8 and 9 show the urban population and unemployment rate in detail for the 2012-2020 period, with dark red indicating the highest value and red, orange, yellow, and gray indicating the second, third, fourth, and lowest levels. The colors and ranges for Figures 2, 4, 6, 8, and 9 were determined according to mean values in regions, and Figures 3, 5, and 7 were stated based on the highest and lowest mean values in regions.

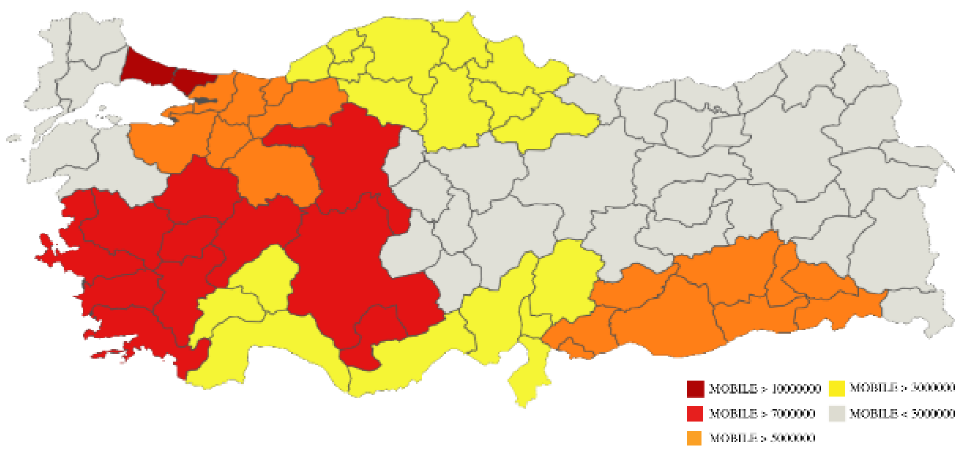
Figure 2 illustrates the NUTS-1 areas of Turkey as FIXED, MOBILE, BROAD, and INTER. Istanbul has the highest number of fixed telephony access, mobile phone subscriptions, broadband subscriptions, and a share of internet users. In FIXED, the mean number of fixed telephony access was 3292401 from 2012 to 2020 in İstanbul, with North-East Anatolia having the lowest number at 183395. Aegean, West Anatolia, East Marmara, Mediterranean, West Black Sea, West Marmara, Central Anatolia, South-East Anatolia, East Black Sea, and Central East Anatolia are the other NUTS-1 areas, in order of highest to the lowest number. While the highest number of mobile telephony subscriptions is 19767659.89 in Istanbul, the lowest number is 1636550 in North-East Anatolia. The Aegean area has the second-highest number of mobile phone subscriptions, followed by West Anatolia, East Marmara, South-East Anatolia, Mediterranean, West Black Sea, Central Anatolia, West Marmara, Central East Anatolia, and East Black Sea. The map for BROAD has a similar map as MOBILE, but the differences are Mediterranean, West Anatolia, and West Marmara. Also, according to INTER, the highest percentages of internet users are in Istanbul (73.71%) and West Anatolia (69.84%) between 2012 and 2020, while the mean for Turkey is 58.97%. In South-East Anatolia, only 47.14% of people use the internet. To summarize, Istanbul has the highest levels of DUI indicators. However, North-East Anatolia has the lowest values in FIBER, MOBILE, and BROAD, and INTER is the lowest in South-East Anatolia.

Figure 2: Indicators (FIXED, MOBILE, BROAD, and INTER) in DUI for 2012-2020

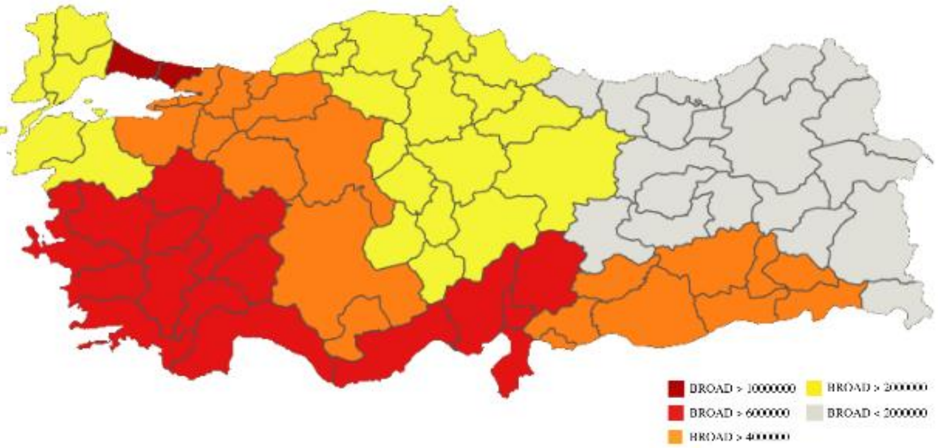
a) FIXED



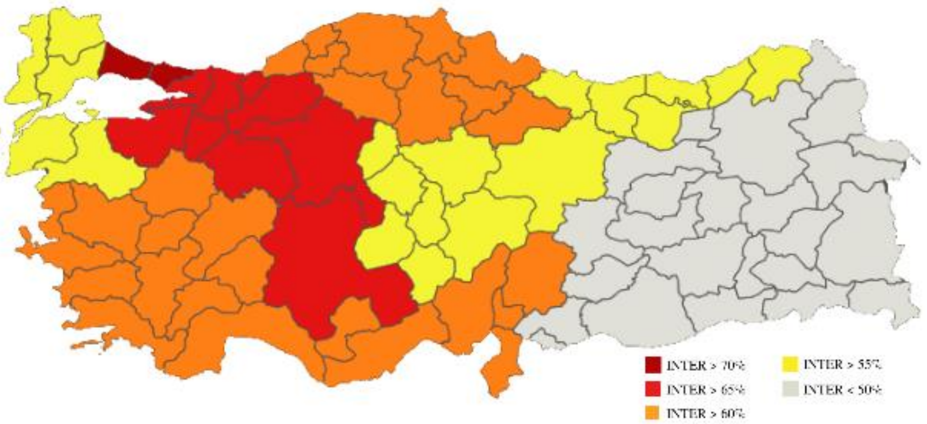
b) MOBILE



c) BROAD



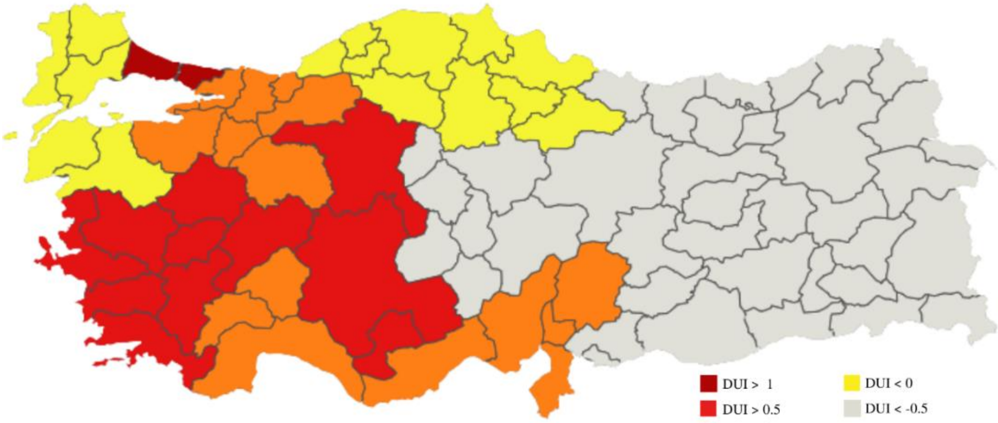
d) INTER



Source: ICTA, 2018; ICTA, 2019; ICTA, 2020; ICTA, 2021; TUIK, 2022c; and own calculations (According to the data, the map is generated using https://pixelmap.amcharts.com/.)

According to FIXED, MOBILE, BROAD, and INTER, Figure 3 indicates DUI. The highest mean of DUI belongs to İstanbul, while the lowest index is in North-East Anatolia. After İstanbul, the highest index value to lowest is Aegean, West Anatolia, East Marmara, Mediterranean, West Black Sea, West Marmara, Central Anatolia, South-East Anatolia, East Black Sea, and Central East Anatolia.

Figure 3: DUI for NUTS-1

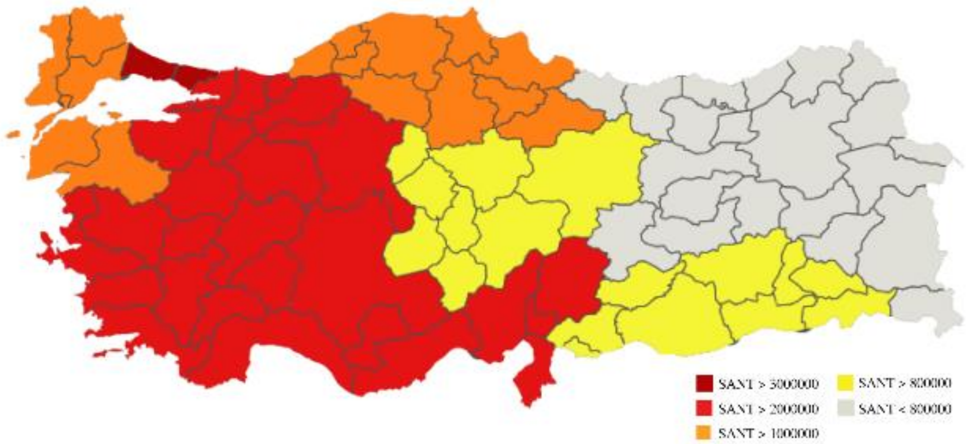


Source: Own calculations (According to the data, the map is generated using https://pixelmap.amcharts.com/.)

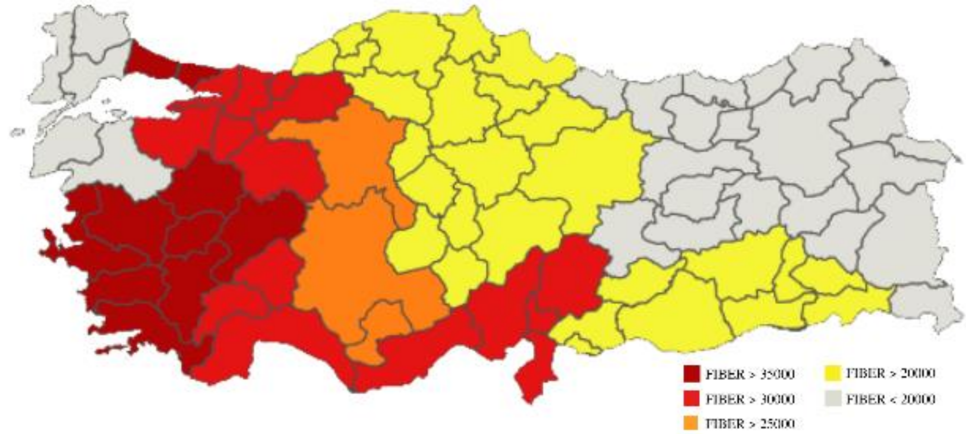
SANT and FIBER in NUTS-1 regions from 2012 to 2020 are depicted in Figure 4. In SANT, Istanbul (5255861) and the Aegean (3027952) have the highest santral capacity for fixed telephony, whereas North-East Anatolia has the lowest capacity (383080.9). After the Aegean region, West Anatolia, East Marmara, Mediterranean, West Marmara, West Black Sea, Central Anatolia, South-East Anatolia, East Black Sea, and Central East Anatolia as ranked from highest to lowest capacity. According to FIBER, the Aegean has the tallest fiber-optic internet cable length at 42449.57 km, whereas the East Black Sea only has 11393.16 km due to geographic characteristics in the 2012-2020 period. Furthermore, Istanbul (37689.43) and the Mediterranean (34842.11) have the second and third-longest internet cables, accordingly. Because the gray areas in Figure 4's FIBER map have less than 20000 km of cables, they have a lower speed than other NUTS-1 regions.

Figure 4: Indicators (SANT and FIBER) in DFI for 2012-2020

a) SANT



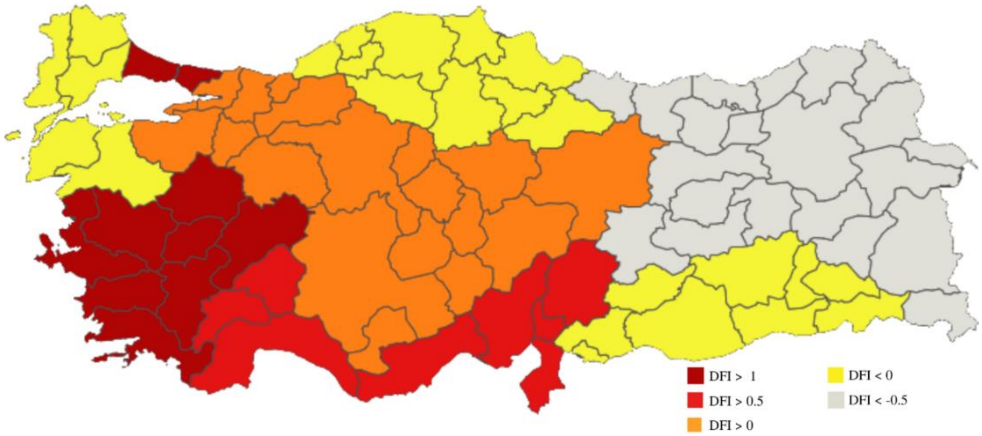
b) FIBER



Source: ICTA, 2018; ICTA, 2019; ICTA, 2020; ICTA, 2021; and own calculations (According to the data, the map is generated using https://pixelmap.amcharts.com/.)

DFI involves the santral capacity for fixed telephony and the length of fiber internet cables in Turkey. As Figure 5 shows, the highest mean of index values is in Aegean and İstanbul with 1.52 and 1.1, respectively. DFI is sorted from the highest to lowest as Mediterranean, East Marmara, West Anatolia, Central Anatolia, South-East Anatolia, West Black Sea, West Marmara, Central East Anatolia, North-East Anatolia, and East Black Sea.

Figure 5: DFI for NUTS-1

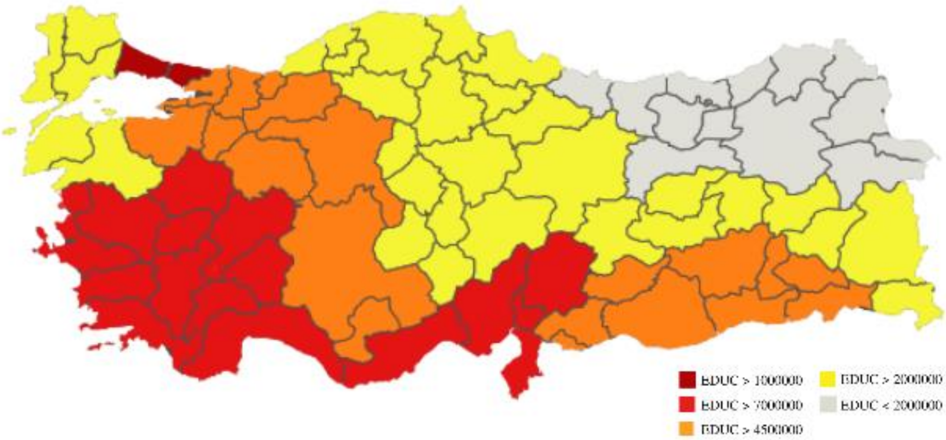


Source: Own calculations (According to the data, the map is generated using https://pixelmap.amcharts.com/.)

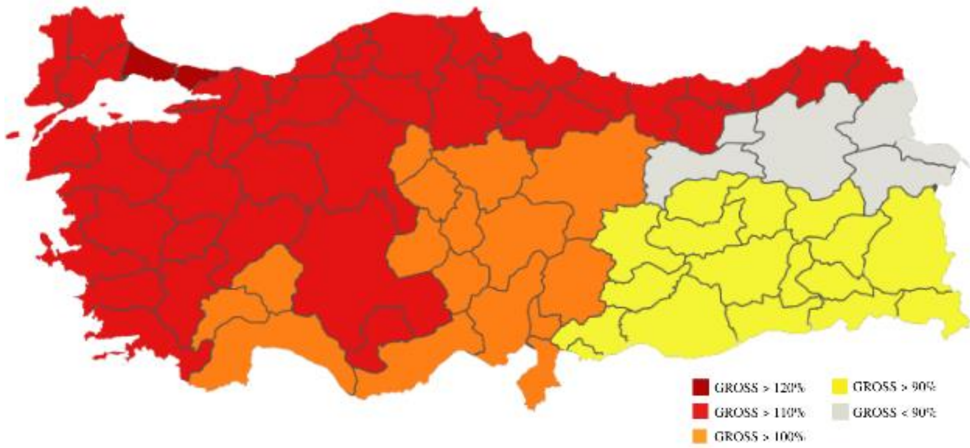
Figure 6 depicts EDUC and GROSS variables to understand human capital and the ability to use digitalization in NUTS-1 for the selected period. According to EDUC, the highest population, which is 15 years of age and over and literate is in İstanbul with 10705131.78 on average. After İstanbul, from the second largest to lowest population is as follows: Aegean, Mediterranean, West Anatolia, East Marmara, South-East Anatolia, West Black Sea, Central Anatolia, West Marmara, Central East Anatolia, East Black Sea, and North-East Anatolia regions. In GROSS, only Central East Anatolia (93.61%), South-East Anatolia (91.62%), and North-East Anatolia (89.16%) have less than 100% for upper educated students. The highest gross enrollment rate is 120.1% in İstanbul, followed by East Marmara, West Anatolia, East Black Sea, West Black Sea, Aegean, West Marmara, Central Anatolia, and the Mediterranean.

Figure 6: Indicators (EDUC and GROSS) in SI for 2012-2020

a) EDUC



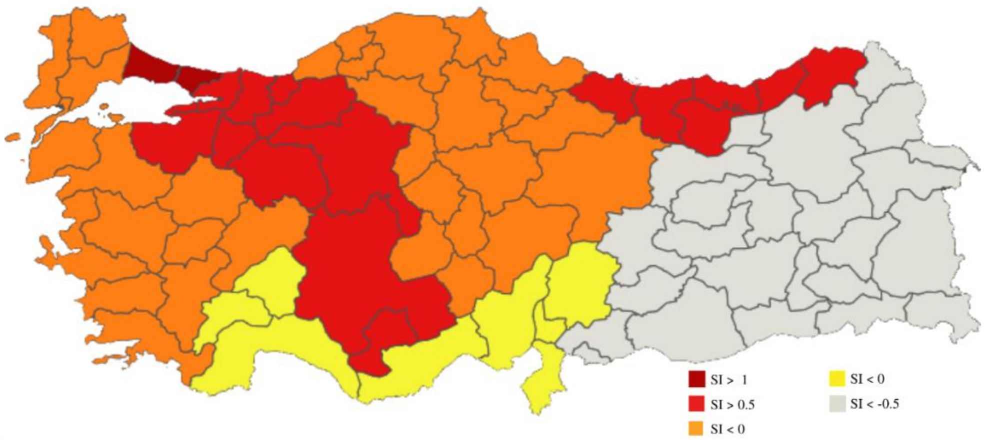
b) GROSS



Source: TUIK, 2021a; TUIK, 2022b; and own calculations (According to the data, the map is generated using https://pixelmap.amcharts.com/.)

As Figure 7 indicates, SI involves 15 years of age and over and literate and upper secondary education gross enrolment rate. The highest SI is in Istanbul, whereas the lowest is in North-East Anatolia. After İstanbul, East Marmara, West Anatolia, East Black Sea, West Black Sea, Aegean, West Marmara, and Central Anatolia have higher means of SI than other NUTS-1 regions, accordingly.

Figure 7: SI for NUTS-1

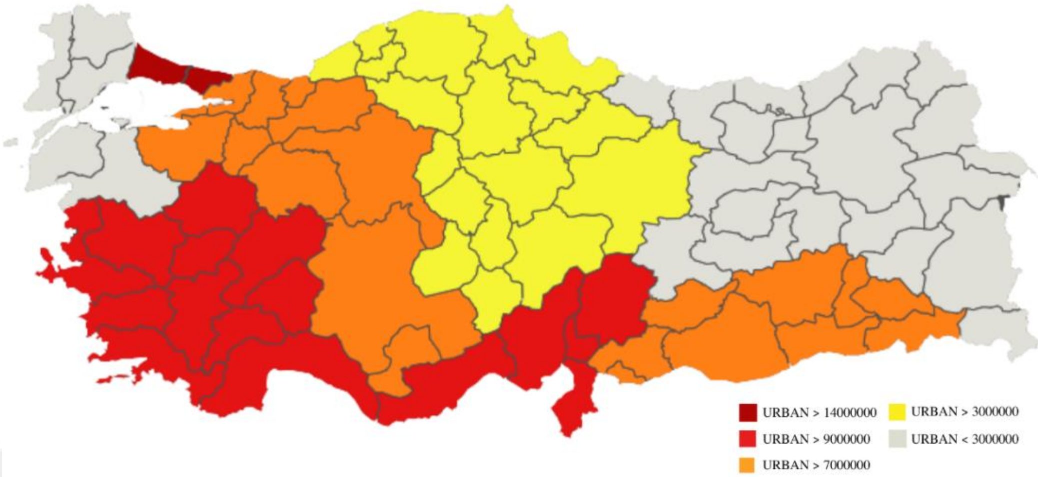


Source: Own calculations According to the data, the map is generated using https://pixelmap.amcharts.com/.)

Since most of the population lives in Istanbul, Turkey, due to better living circumstances, job opportunities, and developed infrastructure, health, and education conditions, as shown in Figure 8, Istanbul has the highest urban population in 2012-2020 (14754246.78 on average). The second-highest mean of the populated region in the urban is in the Mediterranean with 9591896 people, and the lowest populated region is North-East Anatolia with only 1510732. The Mediterranean is followed by Aegean, South-East Anatolia, West Anatolia, East Marmara, West Black Sea, Central Anatolia, Central East Anatolia, West Marmara, and East Black Sea, respectively.

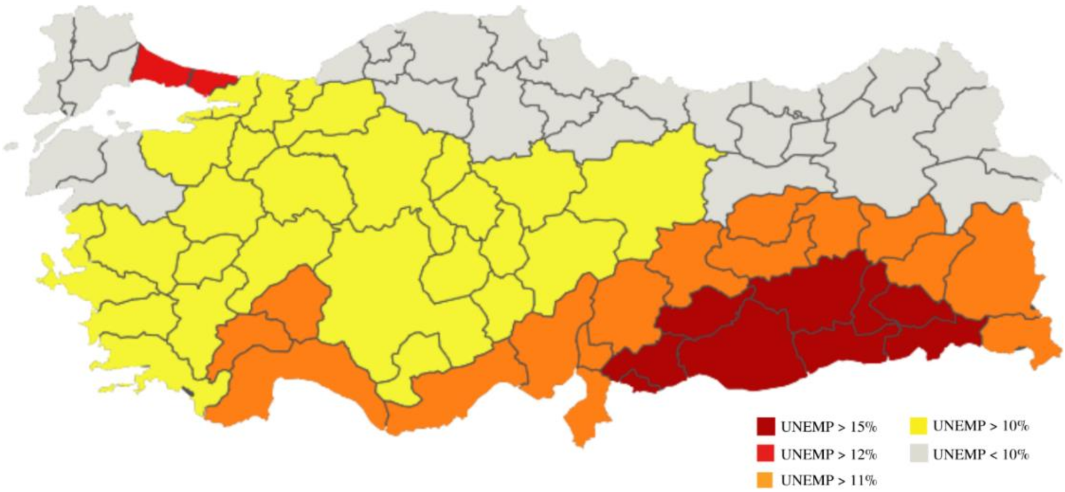
Turkey's average unemployment rate between 2012 and 2020 was 10.16%. As Figure 9 indicates, the highest unemployment rates are 22.4% and 12.98% in South-East Anatolia and Istanbul, respectively, whereas the lowest rates are 6.34% and 6.87% in East Black Sea and North-East Anatolia, according to UNEMP for NUTS-1. The mean unemployment rates in NUTS-1 are higher than the mean of Turkey in the Mediterranean, Central East Anatolia, Central Anatolia, and the Aegean. The other locations with the greatest to lowest ratings but lower percentages than the overall mean are West Anatolia, East Marmara, West Marmara, and West Black Sea.

Figure 8: Urban population for 2012-2020



Source: TUIK, 2021b and own calculations (According to the data, the map is generated using https://pixelmap.amcharts.com/.)

Figure 9: The unemployment rate for 2012-2020



Source: TUIK, 2022d; TUIK, 2022e; and own calculations (According to the data, the map is generated using https://pixelmap.amcharts.com/.)

3.2. METHODOLOGY

This study evaluates the impact of digitalization on convergence in all 12 NUTS-1 areas for the period 2012-2020. For analyzing the convergence, sigma convergence, absolute and conditional beta convergence, and unit root tests, such as IPS, ADF, and PP are used. Before convergence analysis, DUI, DFI, and SI are calculated according to PCA to minimize the dataset for digitalization.

3.2.1. Principal Component Analysis

PCA is a method for reducing a dataset's complexity while maximizing its variability, as a large data set makes it hard to detect trends and patterns (Jolliffe and Cadima, 2016: 1; Bloomer and Rehm, 2014: 1). However, it almost has the same information as the original variables (Gniazdowski, 2017: 43). Therefore, the goal of this strategy is to get rid of the dimensionality curse by establishing a new orthogonal basis by rotating the existing axis until maximum variance directions are identified. As stated by Richardson (2009), PCA helps to observe underlying trends, patterns, and outliers.

Jolliffe (2002: 6) analyzed the background and technique of PCA. As he stated, even if some researchers studied singular value decomposition (SVD) before, which is a type of PCA, Pearson (1901) and Hotelling (1933, 1936) developed the techniques of PCA firstly. Hotelling (1933, 1936) aimed to set the independent variables to maximize their variances in the dataset and called these new variables “components” (Jolliffe, 2002: 7). The covariance matrix, eigenvectors, and eigenvalues are computed to find components.

Jolliffe (2002), Richardson (2009), Abdi and Williams (2010), Bloomer and Rehm (2014), Jolliffe and Cadima (2016), and Gniazdowski (2017) improved the early versions of PCA and examined the methodology to reduce the dataset with PCA method. Richardson (2009) and Jolliffe and Cadima (2016: 2) analyzed the basic technique of PCA, assuming that there is a dataset with p variables for n individuals. Therefore, n x p data matrix, X shows the values as $x_1, x_2, \ldots, x_j$ to find the maximum variance of the X matrix with its linear combination:

$$X=\begin{pmatrix} X_{11} & X_{12} & \cdots & X_{1p} \\ X_{21} & X_{22} & \cdots & X_{2p} \\ \vdots & \vdots & \ddots & \vdots \\ X_{n1} & X_{n2} & \cdots & X_{np} \end{pmatrix} = \begin{pmatrix} X_1 \\ X_2 \\ \vdots \\ X_n \end{pmatrix} \tag{23}$$

$$\sum_{i=1}^{p} a_i\, x_i = Xa \tag{24}$$

where a is a vector of constants consisting of a_1, a_2, ..., a_p. Equation 24's variance is showed as:

$$var(Xa)=a'Sa \tag{25}$$

S is the dataset's sample covariance matrix, and a' is the transpose of the "a" vector. S can be interpreted as explaining a certain percentage of the total variation. To find the maximum variance in Equation 25, Jolliffe and Cadima (2016: 2) stated that there is a need to have a restriction, different than a'a=1, where λ is a Lagrange multiplier:

$$Sa=\lambda a \tag{26}$$

Equation 26 states the requirement as λ is the eigenvector and S is the covariance matrix. Therefore, the variance of X can be defined as:

$$var(Xa)=a'Sa=\lambda a'a=\lambda \tag{27}$$

The covariance matrix S is p x p, where there are p eigenvalues, λ_k (k equals 1, 2, …, p), and eigenvectors such as $a_k'a_k = 1$. To solve the eigenvector problem:

$$\sum_{j=1}^{p} a_{jk}\, x_j=Xa_k \tag{28}$$

where the variance is maximized.

For understanding principal components, the linear combinations of centered variables, x_j* is defined as

$$x_{ij}^* = x_{ij}^* - \bar{x}_j \tag{29}$$

where $\bar{x}_j$ is the mean of the variable j. Therefore, X* matrix which includes x_j* in columns is shown as

$$(n-1)\ S = X^{*\prime}X^* \tag{30}$$

Standardizing primary variables is essential for summing variances as orthogonal components because it ensures that standardized variables are mutually independent (Gniazdowski, 2017: 56). As Jolliffe and Cadima (2016: 6) examined, if the variables are in different units, before using the PCA method, it is common to standardize variables in case of a change in the covariance matrix, S.

$$z_{ij}=\frac{x_{ij}-\bar{x}_j}{s_j} \tag{31}$$

Therefore, the data matrix, X, is changed to a standardized data matrix, Z where n is the standardized observations in j variables. Since the dataset is standardized, the mean is zero and the variance is 1 (Jolliffe, 2002: 250).

As a result, principal components have the information from the variances of x-variables. As Richardson (2009: 8) stated, the first principal component gives the maximum variance, so it shows the highest variation possible to explain the component. The second principal component is a matrix of variables with the higher variation possible in the data, but there must be no correlation between the first and second PCs. There can be more than two principal components. However, since components are orthogonal in matrix form, the latest components have less information than others (StataCorp., 2013: 576). Furthermore, the information about a component and a variable is estimated by their correlation with eigenvalues and this relationship is referred to as loading in the PCA framework (Abdi and Williams, 2010: 442). Therefore, since it shows the correlation, loadings can be negative or positive.

As described by Abdi and Williams (2010: 442), after principal components are found, the components are rotated until the directions of maximum variation are determined. They define orthogonal rotation as a matrix where the rows indicate the original factors, and the columns represent the rotated factors. After rotating, new variables are provided to analyze with maximized variance.

Since the dataset for measuring digitalization is large, indices for Usage, Infrastructure, and Skills are calculated according to the PCA method. The indices are including:

1. DUI: The number of fixed telephony access (FIXED), the number of mobile telephony subscriptions (MOBILE), the number of broadband subscriptions (BROAD), the proportion of internet users (INTER)
2. DFI: Santral capacity for fixed telephony (SANT) and the length of fiber (FIBER)
3. SI: 15 years of age and over and literate (EDUC) and upper secondary education gross enrollment rate (GROSS)

As observed, indices include different types of measurements, so before PCA, FIXED, MOBILE, BROAD, INTER, SANT, FIBER, EDUC, and GROSS are standardized.

3.2.2. Convergence

Convergence is examined according to sigma convergence, absolute and conditional beta convergence, and panel unit root tests. Also, the speed of convergence is found, using the β coefficient.

3.2.2.1. Sigma Convergence

For sigma convergence, the β coefficient should have a negative sign and be statistically significant. The equations of simple coefficient of variation and weighted coefficient of variation are accordingly:

$$CV_u=\frac{\sqrt{\sum_i \frac{(Y_i-\overline{Y}_u)^2}{N}}}{\overline{Y}_u} \tag{32}$$

$$CV_w=\frac{\sqrt{\sum_i (Y_i-\overline{Y})^2 \frac{P_i}{P}}}{\overline{Y}} \tag{33}$$

where Y_i is per capita income in the natural logarithm in a region i and N show all regions. Besides, $\overline{Y}_u$ and $\overline{Y}$ is the sample mean of per capita income in the natural logarithm, P represents the national population, whereas P_i represents the population in region i.

3.2.2.2. Beta Convergence

3.2.2.2.1. Absolute Convergence

Absolute beta convergence implies the convergence if the $\beta_1<0$ according to Equation 34:

$$\ln\left(\frac{Y_{i,t,}}{Y_{i,t-1}}\right)= \alpha+ \beta_1 \ln(Y_{i,t-1})+ \beta_2 DUI_{i,t} + \beta_3 DFI_{i,t} + \beta_4 SI_{i,t} + \beta_5 UNEMP_{i,t} +\varepsilon_{i,t} \tag{34}$$

where $\ln\left(\frac{Y_{i,t}}{Y_{i,t-1}}\right)$ is the GDP per capita growth rate between time t-1 and t in region i. DUI, DFI, and SI are indices for Usage, Infrastructure, and Skills. As stated before, there may be sigma convergence if there is absolute beta convergence, but this is not a requirement. Therefore, there is a chance that two concepts will not be found together.

3.2.2.2.2. Conditional Convergence

This form of convergence suggests that poor regions will expand faster than rich regions, assuming that their beginning levels of income are different, such as population growth, which impact their growth rates. As examined by Rath (2016) in their analysis, the impact of the urban population in convergence is added as a condition. Therefore Equation 35 shows that:

$$\ln\left(\frac{y_{i,t}}{Y_{i,t-1}}\right)= \alpha+ \beta_1 \ln(Y_{i,t-1})+ \beta_2 DUI_{i,t} + \beta_3 DFI_{i,t} + \beta_4 SI_{i,t}+ \beta_5 UNEMP_{i,t} + \beta_6 \ln(URBAN)_{i,t} + \varepsilon_{i,t} \quad (35)$$

If $\beta_1<0$ with ln(URBAN) is constant, it means there is a conditional beta convergence in regions with the natural logarithm of income level at time t and growth rate at t+T.

3.2.2.3. The Speed of Convergence

The beta coefficient in a convergence equation also shows the speed of convergence if:

$$\ln\left(\frac{Y_{i,t,}}{Y_{i,t-1}}\right)= \alpha+ \beta_1 \ln(Y_{i,t-1})+ \beta_2 DUI_{i,t} + \beta_3 DFI_{i,t} + \beta_4 SI_{i,t} + \beta_5 UNEMP_{i,t} +\varepsilon_{i,t} \quad (36)$$

$$\ln\left(\frac{y_{i,t}}{Y_{i,t-1}}\right)= \alpha+ \beta_1 \ln(Y_{i,t-1})+ \beta_2 DUI_{i,t} + \beta_3 DFI_{i,t} + \beta_4 SI_{i,t}+ \beta_5 UNEMP_{i,t}+ \beta_6 \ln(URBAN)_{i,t} + \varepsilon_{i,t} \quad (37)$$

where $\beta_1 = \left(\frac{(I - e^{-\lambda T})}{T}\right)$ and $\lambda=-\left(\frac{1}{T}\right) \ln\left(\beta_1+1\right)$. Since a higher λ means a higher β_1, the speed of convergence will be higher in region i in the 2012-2020 period.

3.2.2.4. Panel Unit Root Tests

Unit root tests are essential for panel data analysis to determine the stationarity of the variables. Also, it is an indicator to confirm the convergence among regions. To not avoid any information and analyze better in the 2012-2020 period, IPS, ADF, and PP tests are used.[1]

3.3. EMPIRICAL RESULTS

3.3.1. Principal Component Analysis Results

Tables 5, 6, and 7 indicate the PCA results for DUI, DFI, and SI after standardizing the variables: FIXED, MOBILE, BROAD, and INTER; FIBER and SANT; and EDUC and GROSS. In Tables, part "a" shows the correlation between variables, "b" is the principal components of indices, "c" is the eigenvectors of variables, "d" indicates the principal components of indices after rotation, and "e" is the rotating components of variables.

The first step for each index is examining the correlation between variables. For all variables included in each index, variables are found to be most highly correlated with each other. Therefore, DUI, DFI, and SI may be constructed according to PCA. As shown in part b in Tables 5, 6, and 7, without rotation, the proportion of each variable in indices is not equal. Also in part b, as stated before, the first principal component has the greatest variance, indicating the greatest variation that can be used to explain the component (Richardson, 2009: 8). With rotation in parts d and e, the proportion of all variables in an index is the same. Following the rotation, new variables are presented for analysis with maximum variance.

Table 5: Steps for PCA for DUI

a. Correlation between FIXED, MOBILE, BROAD, and INTER

Variable	FIXED	MOBILE	BROAD	INTER
FIXED	1.0000			
MOBILE	0.9360*	1.0000		
BROAD	0.7973*	0.9288*	1.0000	
INTER	0.4406*	0.4843*	0.6813*	1.0000

[1] Tests are explained in Chapter One.

b. Principal components of DUI

Component	Eigenvalue	Proportion	Cumulative
Component 1	3.1726	0.7932	0.7932
Component 2	0.6681	0.1670	0.9602
Component 3	0.1504	0.0376	0.9978
Component 4	0.0088	0.0022	1.0000

c. Eigenvectors of FIXED, MOBILE, BROAD and INTER

Variable	Component 1	Component 2	Component 3	Component 4
FIXED	0.5109	-0.3918	0.6732	-0.3637
MOBILE	0.5393	-0.3167	-0.1840	0.7583
BROAD	0.5415	0.0587	-0.6578	-0.5202
INTER	0.3936	0.8618	0.2833	0.1487

d. Principal components of DUI after rotation

Component	Variance	Proportion	Cumulative
Component 1	1.0000	0.2500	0.2500
Component 2	1.0000	0.2500	0.5000
Component 3	1.0000	0.2500	0.7500
Component 4	1.0000	0.2500	1.0000

e. Rotated components of FIXED, MOBILE, BROAD and INTER

Variable	Component 1	Component 2	Component 3	Component 4
FIXED	1.0000	0.0000	-0.0000	-0.0000
MOBILE	0.0000	0.0000	1.0000	0.0000
BROAD	0.0000	0.0000	-0.0000	1.0000
INTER	-0.0000	1.0000	-0.0000	-0.0000

Note: * indicates significance at the 1%.

Source: Own calculations based on ICTA, 2018; ICTA, 2019; ICTA, 2020; ICTA, 2021; TUIK, 2022c

Table 6: Steps for PCA for DFI

a. Correlation between SANT and FIBER

Variable	SANT	FIBER
SANT	1.0000	
FIBER	0.4995*	1.0000

b. Principal components of DFI

Component	Eigenvalue	Proportion	Cumulative
Component 1	1.4995	0.7497	0.7497
Component 2	0.5005	0.2503	1.0000

c. Eigenvectors of SANT and FIBER

Variable	Component 1	Component 2
SANT	0.7071	0.7071
FIBER	0.7071	-0.7071

d. Principal components of DFI after rotation

Component	Variance	Proportion	Cumulative
Component 1	1.0000	0.5000	0.5000
Component 2	1.0000	0.5000	1.0000

e. Rotated components of SANT and FIBER

Variable	Component 1	Component 2
SANT	0.0000	1.0000
FIBER	1.0000	-0.0000

Source: Own calculations based on ICTA, 2018; ICTA, 2019; ICTA, 2020; ICTA, 2021

Note: * indicates significance at the 1%.

Table 7: Steps for PCA for SI

a. Correlation between EDUC and GROSS

Variable	EDUC	GROSS
EDUC	1.0000	
GROSS	0.4451*	1.0000

b. Principal components of SI

Component	Eigenvalue	Proportion	Cumulative
Component 1	1.4451	0.7226	0.7226
Component 2	0.5549	0.2774	1.0000

c. Eigenvectors of EDUC and GROSS

Variable	Component 1	Component 2
EDUC	0.7071	0.7071
GROSS	0.7071	-0.7071

d. Principal components of SI after rotation

Component	Variance	Proportion	Cumulative
Component 1	1.0000	0.5000	0.5000
Component 2	1.0000	0.5000	1.0000

e. Rotated components of EDUC and GROSS

Variable	Component 1	Component 2
EDUC	0.0000	1.0000
GROSS	1.0000	-0.0000

Source: Own calculations based on TUIK, 2021a; and TUIK, 2022b

Note: * indicates significance at the 1%.

3.3.2. Convergence Results

3.3.2.1. Sigma Convergence Results

Table 8 indicates the results of standard deviation, simple coefficient of variation (CV_U), and weighted coefficient of variation (CV_W) for sigma convergence. In addition, Figure 10 shows the results of indices that are used for calculating sigma convergence. In 2015 and 2016, income disparities in NUTS-1 reduced, according to standard deviation and CV_W. Even if divergence increased in 2017 Also, As shown, trends of graphs for standard deviation, $CV_{U,}$ and CV_W trends indicate a decrease in income disparities. Based on these findings, it is possible to conclude there is a sigma convergence in NUTS-1 areas in Turkey between 2012 and 2020.

Table 8: Results of Standard Deviation, Simple Coefficient of Variation, and Weighted Coefficient of Variation

Years	Std. Dev.	CV_U	CV_W
2012	0.3771	0.4727	0.5749
2013	0.3868	0.4867	0.5897
2014	0.3913	0.4843	0.5905
2015	0.3853	0.4799	0.5888
2016	0.3840	0.4802	0.5884
2017	0.3836	0.4822	0.5929
2018	0.3945	0.4887	0.5952
2019	0.3831	0.4803	0.5887
2020	0.3646	0.4646	0.5663

Source: Own calculations based on TUIK, 2022a

Figure 10: Results of Sigma Convergence

Source: Own calculations based on TUIK, 2022a

3.3.2.2. Beta Convergence Results

The results of absolute convergence and conditional convergence are presented in detail in this section. Furthermore, the Wald test for significance of explanatory variables, Wooldridge test for autocorrelation, and Hausman test for understanding the proper model in the analyses are applied. The null hypothesis for Wald Test is the set of parameters is equal to some value. The null hypothesis for autocorrelation, according to the Wooldridge test, is that the models have no first-order autocorrelation. If the null hypothesis is not rejected in the Wooldridge test, the model should be robust. When the null hypothesis in the Hausman test is rejected, the fixed-effect model is used in the equations.

3.3.2.2.1. Absolute Convergence Results

As Table 9 indicates, the beta coefficient is negative (except for (2)) but not significant. Therefore, there is no absolute convergence in 12 regions in Turkey from 2012 to 2020 in all models. Moreover, since the results are not significant, the addition of indices does not increase the fitness of the model, as the Wald test statistics are not statistically significant. DFI and SI have positive impacts, however, these indices are not significant in model (1). Also, when all the indices were examined separately in models (2), (3), and (4), DUI, DFI, and SI still do not have a significant impact.

On the other hand, Table 10 shows the absolute convergence in the selected period in 12 regions since $\beta<0$ and it is significant in models (1), (2), (3), and (4) when variables are first differenced. The effects of DUI and DFI on convergence are positive in the model (1). Besides, when the impacts of DUI, DFI, and SI are analyzed in separate models, indices are found to be positively and significantly affecting the convergence in Turkey.

Table 9: Results of Absolute Convergence (Without First Differencing)

Variable	(1)	(2)	(3)	(4)
lnY (β coefficient)	-0.1195 (-0.69)	0.0080 (0.12)	-0.0419 (-0.32)	-0.0325 (-0.43)
DUI	-0.0953 (-0.83)	-0.1127 (-0.72)		
DFI	0.0300 (0.71)		0.0481 (0.72)	
SI	0.0555 (1.36)			0.0513 (1.29)
UNEMP	0.0048 (0.73)	0.0048 (0.68)	0.0033 (0.62)	0.0016 (0.47)
Autocorrelation	32.45*	94.31*	25.34*	46.07*
Wald	1.00	0.26	2.20	1.65
Fixed	Yes	Yes	Yes	Yes

Note: The significance levels at 1, 5, and 10% are indicated by the symbols *, **, and ***.
Source: Own calculations based on ICTA, 2018; ICTA, 2019; ICTA, 2020; ICTA, 2021; TUIK, 2021a; TUIK, 2021b; TUIK, 2022a; TUIK, 2022b; TUIK, 2022c; TUIK, 2022d; and TUIK, 2022e

Table 10: Results of Absolute Convergence (With First Differencing)

Variable	(1)	(2)	(3)	(4)
ΔlnY (β coefficient)	-1.0100* (-46.34)	-1.0058* (-40.71)	-1.0119* (-43.91)	-0.9647* (-31.08)
ΔDUI	0.1789* (3.20)	0.2078* (2.98)		
ΔDFI	0.0364* (2.69)		0.1942* (5.37)	
ΔSI	0.0136 (1.60)			0.0267* (3.39)
ΔUNEMP	-0.0012 (-0.47)	-0.0022 (-0.94)	-0.0036 (-1.26)	-0.0014 (-0.49)
Convergence Speed	0.0582	0.0580	0.0583	0.0563
Autocorrelation	10.86*	94.31*	9.77*	5.58**
Wald	11.15**	9.75*	8.97*	17.95*
Fixed	No	No	Yes	No

Note: The significance levels at 1, 5, and 10% are indicated by the symbols *, **, and ***.

Source: Own calculations based on ICTA, 2018; ICTA, 2019; ICTA, 2020; ICTA, 2021; TUIK, 2021a; TUIK, 2021b; TUIK, 2022a; TUIK, 2022b; TUIK, 2022c; TUIK, 2022d; and TUIK, 2022e

3.3.2.2.2. Conditional Convergence Results

Results for conditional convergence are given in Table 11, where the condition is the urban population in the equation, according to the random-effects model. All the models examine the convergence at the level and show no conditional convergence in NUTS-1 regions in the 2012-2020 period. Yet, none of the indices have a significant impact on convergence and do not increase the fitness in the models.

Table 11: Results of Conditional Convergence (Without First Differencing)

Variable	(1)	(2)	(3)	(4)
lnY (β coefficient)	-0.0526 (-0.67)	0.0209 (1.42)	-0.0053 (-0.15)	-0.0184 (-0.37)
DUI	0.0009 (0.09)	-0.0063 (-0.88)		
DFI	0.0281 (1.10)		0.0244 (1.11)	
SI	0.0260 (1.07)			0.0223 (1.00)
UNEMP	0.0054** (2.50)	0.0039* (2.97)	0.0037* (5.98)	0.0060 (2.48)
lnURBAN	-0.0470*** (-1.80)	-0.0164*** (-1.69)	-0.0397** (-2.45)	-0.0278 (-2.96)
Autocorrelation	36.91*	67.74*	30.05*	46.43*
Wald	46.41*	17.37*	36.38*	24.35*
Fixed	No	No	No	No

Note: The significance levels at 1, 5, and 10% are indicated by the symbols *, **, and ***.
Source: Own calculations based on ICTA, 2018; ICTA, 2019; ICTA, 2020; ICTA, 2021; TUIK, 2021a; TUIK, 2021b; TUIK, 2022a; TUIK, 2022b; TUIK, 2022c; TUIK, 2022d; and TUIK, 2022e

Table 12 shows the conditional convergence with the first differencing in the selected variables. DUI, DFI, and SI are positively affecting the convergence in the model (1). According to models (2), (3), and (4), the impacts of indices on conditional convergence are still significant separately. Also, the unemployment rate, urban population and/or DUI, DFI, and SI are increasing the fitness of the model. The unemployment rate is not significant in all models. Moreover, the growth of the urban population harms convergence in Turkey in the selected period in all models except (3).

Table 12: Results of Conditional Convergence (With First Differencing)

Variable	(1)	(2)	(3)	(4)
ΔlnY (β coefficient)	-1.0256* (-47.56)	-1.0231* (-44.33)	-1.0198* (-45.21)	-0.9940* (-37.94)
ΔDUI	0.1651* (3.18)	0.2023* (3.06)		
ΔDFI	0.0222*** (1.72)		0.1776* (5.05)	
ΔSI	0.0191*** (1.94)			0.0326* (3.62)
ΔUNEMP	-0.0005 (-0.19)	-0.0019 (-0.81)	-0.0034 (-1.19)	-0.0003 (-0.11)
ΔlnURBAN	-0.1039* (-2.84)	-0.0901** (-3.06)	-0.0515 (-1.04)	-0.1393* (-3.58)
Convergence Speed	0.0588	0.0587	0.0586	0.0575
Autocorrelation	7.81**	3.32***	10.54*	5.65**
Wald	26.29*	31.61*	10.73*	23.79*
Fixed	No	No	Yes	No

Note: The significance levels at 1, 5, and 10% are indicated by the symbols *, **, and ***.

Source: Own calculations based on ICTA, 2018; ICTA, 2019; ICTA, 2020; ICTA, 2021; TUIK, 2021a; TUIK, 2021b; TUIK, 2022a; TUIK, 2022b; TUIK, 2022c; TUIK, 2022d; and TUIK, 2022e

3.3.3 3. The Speed of Convergence

In Tables 10 and 12, the results indicate statistically significant convergence in NUTS-1 regions in Turkey. Therefore, the speed of convergence is calculated in terms of the beta coefficients in these models of the beta convergence, as the formulation indicated in Chapter One. In model (1), the speed of convergence is 5.82% in the absolute convergence, while it is 5.88% in the conditional convergence in Turkey. These rates mean that NUTS-1 regions of Turkey converge with each other approximately in six months in the selected period. Since a higher λ means a higher β_1, if λ was high, in the selected period, the speed of convergence of regions in Turkey might be stated to be high. Therefore, regulations for increasing digitalization in Turkey would increase the speed of convergence across NUTS-1 regions.

3.3.3.4. Panel Unit Root Tests Results

Table 13 indicates the results of unit root tests. According to the results, while there is unit root and thus no convergence with respect to DFI and SI among NUTS-1 regions in the 2012-2020 period, DUI shows stationarity in the NUTS-1 in level. Moreover, UNEMP and URBAN are stationary only in the first difference. Therefore, it can be stated that while DFI and SI have temporary impacts on per capita income, DUI has a more permanent impact in 2012-2020 in twelve regions of Turkey.

Table 13: IPS, ADF, and PP Tests Results

Variable	IPS	ADF	PP
$\ln\left(\frac{Y_{i,t,}}{Y_{i,t-1}}\right)$	2.9964 (0.9986)	5.3568 (1.0000)	101.0700* (0.0000)
lnY (β coefficient)	14.5484 (1.0000)	0.0977 (1.0000)	0.2677 (1.0000)
DUI	-9.4036* (0.0000)	252.8738* (0.0000)	46.2273* (0.0042)
DFI	7.5047 (1.0000)	0.7446 (1.0000)	0.0434 (1.0000)
SI	5.6306 (1.0000)	0.5271 (1.0000)	2.5455 (1.0000)
UNEMP	2.9752 (0.9985)	4.9852 (1.0000)	7.5875 (0.9994)

lnURBAN	0.7314 (0.7677)	30.1387 (0.1802)	453.5040* (0.0000)
$\Delta\ln\left(\frac{Y_{i,t,}}{Y_{i,t-1}}\right)$	-1.8090** (0.0352)	43.3265* (0.0091)	-
ΔlnY (β coefficient)	-6.9084* (0.0000)	206.4241* (0.0000)	122.6721* (0.0000)
ΔDUI	-	-	-
ΔDFI	4.1079 (1.0000)	33.5512*** (0.0930)	28.6934 (0.2319)
ΔSI	2.7464 (0.9970)	2.4341 (1.0000)	9.2826 (0.9969)
ΔUNEMP	-4.3289* (0.0000)	86.6939* (0.0000)	171.2420* (0.0000)
ΔlnURBAN	-2.6007* (0.0047)	115.9604* (0.0000)	-

Note: *, **, and *** denote significance at the 1, 5, and 10% levels, when the optimal lag is 2, respectively.

Source: Own calculations based on ICTA, 2018; ICTA, 2019; ICTA, 2020; ICTA, 2021; TUIK, 2021a; TUIK, 2021b; TUIK, 2022a; TUIK, 2022b; TUIK, 2022c; TUIK, 2022d; and TUIK, 2022e

3.4. SUMMARY OF EMPIRICAL RESULTS

Digitalization is the use of digital technology to enhance business models to raise revenue and value-added possibilities and improve economic growth in nations, as well as the use of digital technologies and information to improve corporate operations, individuals, and regions (Bloomberg, 2018). Since its effect on the economies is undeniable, it is essential to examine the impact of digitalization on economic convergence, especially in emerging countries, such as Turkey.

In this thesis, the relationship between digitalization and convergence in Turkey’s NUTS-1 regions is examined from 2012-to 2020. For the effect of digitalization, three different indices are generated, using FIXED, MOBILE, BROAD, INTER, SANT, FIBER, EDUC, and GROSS with the PCA method. DUI represents FIXED, MOBILE, BROAD, and INTER, DFI has SANT and FIBER, and SI has EDUC and GROSS. Also, the effect of the unemployment rate and urban population are examined in the models. The applied tests for digitalization and convergence are sigma convergence (according to standard deviation, simple coefficient of variation, and weighted coefficient of variation), beta convergence (absolute and conditional convergence), and unit root tests (IPS, ADF, and PP tests). The aim is to determine how digitalization affects economic convergence.

Results for sigma convergence confirm that regional disparities between regions are decreasing in the selected period in Turkey. Beta convergence is applied in four models, where (1) includes all the indices, DUI, DFI, and SI. Other models analyze the impact of indices separately. According to absolute and conditional convergence, there is no regional convergence in Turkey, and the impact of digitalization on convergence is not significant when the variables are at their levels. Beta convergence shows that when variables are first differenced to get rid of the individual region and time-specific effects. In that way, it is observed that there is convergence in regions of Turkey. Since variables are first differenced, the effect of change in independent variables is observed not in time t, but the next period. Also, when first differenced, DUI and DFI have a positive impact on convergence according to absolute convergence. However, SI does not since it is not significant. In Models 2, 3, and 4, each of the indices has a positive influence on convergence. Furthermore, conditional convergence examines this association, with the specified condition for convergence in the models being the urban population. Conditional convergence indicates that digitalization affects the economic convergence positively in NUTS-1 in the 2012-2020 period. While the unemployment rate has no significant impact in all models, the urban population in Turkey harms convergence. Also, the speed of convergence is calculated if convergence is found in the models. The speed of convergence in models (1) is 5.82% in absolute convergence and 5.88% in conditional convergence. Lastly, the unit root tests imply that while DFI and SI have a temporary influence on per capita income, DUI has a more long-term impact in twelve regions of Turkey between 2012 and 2020.

CONCLUSION

Digitalization refers to the use of digital technologies and information to enhance business operations, individuals, and economies. It helps time-saving, reduces the distance between people and/or businesses, and improves mobility. Also, it allows for the use of big data, increases customer satisfaction, and uncovers new opportunities for investment, innovation, new businesses, and jobs. Thus, digitalization fosters long-term economic growth. As a result, the role of the digitalization process on economic convergence in NUTS-1 regions from 2012 to 2020 is studied in this thesis.

Because digitalization is important for economic growth, it may also assist to improve economic dispersion among areas. Convergence means a decrease in economic divergence with the assumption for poorer regions' per capita income grows faster than relatively richer regions. There are different methods for understanding convergence among economies, such as sigma convergence, beta convergence, and unit root tests.

Sigma convergence is a reduction in the divergence of per capita income levels within a group of nations or regions in an economy over time and is mostly measured by standard deviation. Also, beta convergence assumes that per capita incomes of economies would approach each other in a certain period. It is calculated according to the beta (β) coefficient. If $\beta<0$, there is a beta convergence among selected regions. Furthermore, the beta coefficient is a tool for determining the speed of convergence among regions within a country or countries. Beta convergence can be approached in two ways: absolute (or unconditional) and conditional convergence. According to absolute convergence, countries' per capita income levels will eventually converge over time if the only difference between them is their beginning conditions. However, conditional beta convergence is a strategy that contends that achieving the same beginning level of revenue in various economies is unattainable, so it illustrates the convergence of economies if there are similar levels of technology, savings rates, and population growth rates but different initial points. Lastly, unit root tests imply the convergence if variables are stationary at the level or in the first difference.

The aim of this thesis is to understand the effect of digitalization on convergence in NUTS-1 in Turkey for the years between 2012 and 2020; therefore, sigma convergence (with standard deviation, simple coefficient of variation, and weighted coefficient of variation), beta convergence (absolute and conditional convergence), and unit root tests (IPS, ADF, and PP) are analyzed. For examining the impact of digitalization, three different indices are created, using Principal Component Analysis. These indices are Usage (DUI), Infrastructure (DFI), and Skills (SI). DUI covers the number of fixed telephony access (FIXED), mobile telephony subscriptions (MOBILE), and broadband subscriptions (BROAD), and the proportion of internet users (INTER). DFI contains statistics on infrastructure capacity for telephones and internet lines, santral capacity for fixed telephony (SANT), and fiber length (FIBER) in Turkey. Lastly, SI provides statistics for 15-year-olds and older who are literate (EDUC), and the upper secondary education gross enrolment rate (GROSS), to help comprehend the capacity to use the internet and cellphones. Also, the unemployment rate (UNEMP) and urban population (URBAN) are added to the models for understanding their impacts on convergence.

According to sigma convergence, beta convergence, and unit root tests, there is economic convergence in NUTS-1 regions in the 2012-2020 period. Sigma convergence results show that except CVu there is divergence across NUTS-1 until 2015, and in 2017, and 2018 overall. However, in 2015, 2016, 2019, and 2020, there is economic convergence across regions. Also, trends in graphs for standard deviation, CVu, and CVw show that economic divergence between regions is decreasing in the selected period.

The absolute and conditional convergences are examined using four models, where the model (1) focuses on all three indices. DUI, DFI, and SI are included sequentially and individually in models (2), (3), and (4). In addition, the Wald test for significance of DUI, DFI, SI, and UNEMP (also URBAN in conditional convergence) in the models, the Wooldridge test for autocorrelation, and the Hausman test for evaluating the correct model are used in the studies. The model is robust if the null hypothesis is rejected in the Wooldridge test.

Absolute convergence and conditional convergence are analyzed where indicators are at the level and in the first difference. Results showed that there is no convergence and digitalization has no effect on the models for both convergences when variables are at level. In absolute convergence, in Turkey, there is regional convergence in the selected period, when all variables are first differenced in all models and DUI and DFI have a positive effect on convergence in (1). Also, in models (2), (3), and (4), digitalization has a positive impact in this period. In absolute convergence, however, the unemployment rate seems to have no significant impact on any models. In conditional convergence, the urban population is added to models for being a condition for converging. At the level, the urban population and unemployment rate are significant, with the urban population growth having a negative influence on convergence and the unemployment rate having a positive impact. Regions are converging when variables are differenced, and digitalization has a positive effect on conditional convergence. Furthermore, except for (3), the growth of the urban population reduces convergence in Turkey during the chosen period.

Since the β coefficient also indicates the speed of convergence across regions, it is calculated if convergence is found in the models of absolute and conditional convergences. Model (1)'s speed is 5.82% in absolute convergence and 5.88% in conditional convergence.

Additionally, according to applied unit root tests, DFI and SI have unit roots at the level and in the first difference, but DUI is stationary at the level. Therefore, it can be stated that whereas DFI and SI have a short-term impact on per capita income, DUI has a long-term impact in twelve regions in Turkey between 2012 and 2020, according to the unit root testing.

As a result, between 2012 and 2020, sigma convergence, and absolute and conditional beta convergence may be demonstrated in twelve areas of Turkey, and digitalization has a significant and positive impact on convergence. Furthermore, the unit root test demonstrates that, unlike DFI and SI, DUI is stationary in level, meaning that it had a permanent influence in Turkey throughout this period.

Although empirical results indicate that there is a positive impact of digitalization on convergence in Turkey in the selected period, regions in the eastern part of Turkey still have fewer opportunities to reach and use the internet, fixed telephones, and mobile telephones, and citizens have fewer skills to use it, as it is observed in NUTS-1 maps. Therefore, to enhance the positive impact in the eastern regions, the following solutions are proposed: government programs for increasing digitalization effectiveness, increasing demand for digital technologies, improving and constructing infrastructure, applying programs for increasing digitalization skills, and implications for increasing education level. As Mentsiev et al. (2020: 2961) indicated, the government should measure digitalization for observing its impacts on economies with increasing investments and success of businesses, regulating policies and regulations to increase digital technologies in the nation. To spread the usage of digital and the potential that regions of Turkey have for digitalization, there should be a certain increase in investments in digital technologies (Güz, 2019: 135). Since digitalization decreases distances between people, businesses, and governments, public investments to improve existing infrastructure and the construction of new fiber-optic cables to reach the internet faster are other policy implications that are needed in most regions to enhance the convergence across regions (as seen in Figure 5). In addition, the analysis shows that basic skills to use digitalization should be improved. For using digital technologies, more advanced skills are needed, such as searching for information, digital literacy, and analyzing the data. Therefore, common-public education programs to inform citizens how to use these technologies effectively should be applied.

REFERENCES

Abdi, H., & Williams, L. J. (2010). *Principal component analysis*. Wiley Interdisciplinary Reviews: Computational Statistics, 2(4): 433–459.

Abdioğlu, Z., & Uysal, T. (2013). *Türkiye'de Bölgeler Arası Yakınsama: Panel Birim Kök Analizi*. Atatürk Üniversitesi İktisadi ve İdari Bilimler Dergisi, 27(3): 125-143.

Acılar, A., Markin, M., & Nazabaeva, E. (2011). *Exploring the Digital Divide: A Case of Russia and Turkey*. The XII HSE International Academic Conference on Economic and Social Development, April 5-7, 2011.

Afonasova, M. A., Panfilova, E. E., Galichkina, M. A., & Ślusarczyk, B. (2019). *Digitalization in economy and innovation: The effect on social and economic processes*. Polish Journal of Management Studies, 19(2): 22–32.

Atıcı, G. (2020). *Digital and Digitalized Economy in EMs: A Focus on Turkey*. IntechOpen.

Baltagi, B. H. (2005). *Econometric Analysis of Panel Data*. Great Britain: John Wiley & Sons.

Barro, R. J., & Sala-i-Martin, X. (1990). *Economic growth and convergence across the United States*. National Bureau of Economic Research Working Paper Series, No. 3419: 1-39.

Barro, R. J., Sala-i Martin, X., Blanchard, O. J., & Hall, R. E. (1991). *Convergence Across States and Regions*. Brookings Papers on Economic Activity, 1991(1): 107–182.

Barro, R. J., & Sala-i Martin, X. (1992). *Convergence*. Journal of Political Economy, 100(2): 223–251.

Baumol, William J. *1986. Productivity growth, convergence, and welfare: What the long-run data show*. American Economic Review, 76(5): 1072–85.

Beceni, Y., Hamzaoglu, Y., & Uzun, F. (2015). *The Digitalization of Companies in Turkey*. Turkish Commercial Law Review, 1(3): 279-288.

Bera, S. (2019). *Club convergence and drivers of digitalization across Indian states*. Telecommunications Policy, 43(8): 1-17.

Billon, M., Lera-Lopez, F., & Marco, R. (2010). *Differences in digitalization levels: A multivariate analysis studying the global digital divide*. Review of World Economics, 146(1): 39–73.

Bloomberg, J. (2018). *Digitization, digitalization, and digital transformation: confuse them at your peril*. Forbes: 1–6.

Bloomer, C., & Rehm, G. (2014). *Using principal component analysis to find correlations and patterns at diamond light source*. IPAC 2014: Proceedings of the 5th International Particle Accelerator Conference: 3719–3721.

Burma, Z. A. (2016). *4th Industrial Revolution and Innovating in the Digital Economy : World and Turkey Values for 2016 by Global Indicators*. International Journal of Research in Engineering, IT and Social Sciences, 06(12): 20–33.

Cass, D. (1965). *Optimum Growth in an Aggregative Model of Capital Accumulation*. The Review of Economic Studies, 32(3): 233–240.

Celbis, M. G., & de Crombrugghe, D. (2018*). Internet infrastructure and regional convergence: Evidence from Turkey*. Papers in Regional Science, 97(2): 387–409.

Chatterji, M. (1992). *Convergence Clubs and Endogenous Growth*. Oxford Review of Economic Policy, 8(4): 57–69.

Choi, I. (2001). *Unit Root Tests for Panel Data.* Journal of International Money and Finance, 20: 249-272.

Chou, J., & Huang, T. (2007). *Convergence or Divergence in the Information Era*. Project LINK Spring Meeting, May 14-17, 2007, Beijing, China.

Devereux, M., & Vella, J. (2018). *Debate: implications of digitalization for international corporate tax reform.* Intertax 46(6): 550–559.

Duran, H. E. (2015). *Türkiye'de Yoksulluğa Bölgesel Bir Bakış*. Dokuz Eylül Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi, 30(2): 87-103.

Dyatlov, S. A., Didenko, N. I., Lobanov, O. S., & Kulik, S. V. (2019). *Digital transformation and convergence effect as factors of achieving sustainable development*. IOP Conference Series: Earth and Environmental Science, 302(1): 1-8.

Elmalı, K., Erkal, G. ve Özer, H., (2021): *Türkiye'de İller Arası Gelir Yakınsaması: Mekânsal Ekonometrik Yaklaşım*. Atatürk Üniversitesi İktisadi ve İdari Bilimler Dergisi, 35(2): 451-468.

Ersungur, Ş. M., & Polat, Ö. (2006). *TÜRKİYE'DE BÖLGELER ARASINDA YAKINSAMA ANALİZİ.* Atatürk Üniversitesi Sosyal Bilimler Enstitüsü Dergisi, 8(2): 335–343.

Galor, O. (1996). *Convergence? Inferences from Theoretical Models*. The Economic Journal, 106(437): 1056–1069.

Georgescu, I., & Kinnunen, J. (2021). *The Digital Effectiveness on Economic Inequality: A Computational Approach*. Springer Proceedings in Business and Economics: 223-239.

Gezici, F., & Hewings, G. J. D. (2004). *Regional Convergence and the Economic Performance of Peripheral Areas in Turkey*. Review of Urban & Regional Development Studies, 16: 113-132.

Gniazdowski, Z. (2017). *New Interpretation of Principal Components Analysis*. Zeszyty Naukowe WWSI, 11(16): 43–65.

Gömleksiz, M., Şahbaz, A., & Mercan, B. (2017). *Regional economic convergence in Turkey: Does the government really matter for?*. Economies, 5(3): 1-16.

Güz, T. (2019). *Information and communication technologies development index: regional analysis of Turkey*. Pressacademia, 6(3): 128–135.

Jurzyk, E., Nair, M. M., Pouokam, N., Saadi Sedik, T., Tan, A., & Yakadina, I. (2020). *COVID-19 and Inequality in Asia: Breaking the Vicious Cycle*. IMF Working Papers, 20(217): 1-23.

Halaç, U., & Kuştepeli, Y. (2008). *Türkiye'de Bölgesel Gelirin Yakınsaması: Gelir Dağılımı Açısından Bir Değerlendirme*. Discussion Paper Series, 08/01: 1-13.

Hayrullahoğlu, B. (2021). Digital Service Tax and Its Applicability in Turkey. *Global Transformation and Differentiation II: Digitalization and the Future of Digital Society* (pp. 15-23), 12-14 March 2020, Akdeniz University.

Hotelling, H. (1933). *Analysis of a complex of statistical variables into principal components*. Journal of Educational Psychology, 24: 417–441.

Hotelling, H. (1936). *Simplified calculations of principal components*. Psychometrika, 1: 27–35.

https://pixelmap.amcharts.com/ (23.02.2022).

ICTA (2018). *The Annual Statistical Bulletin at Provincial Level on Electronic Communication 2018*. https://www.btk.gov.tr/yillik-il-istatistikleri (30.11.2021).

ICTA (2019). *The Annual Statistical Bulletin at Provincial Level on Electronic Communication 2019*. https://www.btk.gov.tr/yillik-il-istatistikleri (30.11.2021).

ICTA (2020). *The Annual Statistical Bulletin at Provincial Level on Electronic Communication 2020*. https://www.btk.gov.tr/yillik-il-istatistikleri (30.11.2021).

ICTA (2021). *The Annual Statistical Bulletin at Provincial Level on Electronic Communication 2021*. https://www.btk.gov.tr/yillik-il-istatistikleri (30.11.2021).

Ignat, V. (2017). *Digitalization and the global technology trends*. IOP Conference Series: Materials Science and Engineering, 227(1): 1-5.

Im, K.S., Pesaran M.H. & Shin, Y. (2003). *Testing for unit roots in heterogeneous panels*. Journal of Econometrics, 115: 53–74.

İzmen, Ü., Üçdoğruk Gürel, Y., & Kılıçaslan, Y. (2020). *TÜBİSAD Turkey's Digital Transformation Index*. https://www.tubisad.org.tr/en/images/pdf/tubisad_dde_endeks_report_eng.pdf, (30.12.2021).

İzmen, Ü., Üçdoğruk Gürel, Y., & Kılıçaslan, Y. (2021). *TÜBİSAD "Türkiye'nin Dijital Dönüşüm Endeksi" Raporu*. https://www.tubisad.org.tr/tr/images/pdf/tubisad-2021-dde-raporu.pdf, (27.01.2022).

Jolliffe, I. T. (2002). *Principal Component Analysis*. New York: Springer.

Jolliffe, I. T., & Cadima, J. (2016). *Principal component analysis: A review and recent developments*. Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, 374(2065): 1-16.

Kalkınma Ajansları (2021). https://ka.gov.tr/sayfalar/kalkinma-planlamasinda-istatistiki-bolge-birimleri-siniflandirmasi--24, (28.11.2021)

Karacuka, M. (2020). *İller arasi ekonomik büyüme yakinsamasina etki eden faktörler*. Journal of Business Innovation and Governance, 3(2): 103-119.

Katz, R., Koutroumpis, P. & Martin Callorda, F. (2014). *Using a digitization index to measure the economic and social impact of digital agendas*. Info, 16 (1): 32-44.

Kindap, A., & Dogan, T. (2019). *Regional Economic Convergence and Spatial Spillovers in Turkey*. International Econometric Review: 1–23.

Konat, G. (2021). *Is There Income Inequality Convergence Between Regions in Turkey? Panel Data Analysis*. Muş Alparslan Üniversitesi Sosyal Bilimler Dergisi, 9(2): 375-381.

Koramaz, T. K., Nasrollahzade, S., & Özdemir, Z. (2019). Spatial Pattern of Digital Divide in Turkey. *REAL CORP 2019: IS THIS THE REAL WORLD? Perfect Smart Cities vs. Real Emotional Cities* (pp. 685–69), Karlsruhe, Germany. 2-4 April 2019.

Kotarba, M. (2017). *Measuring Digitalization-Key Metrics*. Foundations of Management, 9(1): 123–138.

Köksal, E., & Anil, B. (2013). *Determinants of Broadband Access and Usage in Turkey: Do Regions Matter?*. SSRN Electronic Journal, 17(1): 113–132.

Krugman, P. (1991). *Increasing Returns and Economic Geography*. Journal of Political Economy, 99(3): 483–499. https://pr.princeton.edu/pictures/g-k/krugman/krugman-increasing_returns_1991.pdf

Lobanov, O., Schugoreva, V., Minakov, V., Dyatlov, S., & Putkina, L. (2019). *Convergence of digitalization of geo-information services and technologies of industry*

4.0 in conditions of digital economy. International Multidisciplinary Scientific GeoConference: SGEM, 19(2.1): 203-210.

Lucendo-Monedero, A. L., Ruiz-Rodríguez, F., & González-Relaño, R. (2019). *Measuring the digital divide at regional level. A spatial analysis of the inequalities in digital development of households and individuals in Europe*. Telematics and Informatics, 41(April): 197–217.

Macchi, M., Berthon, B., & Robinson, M., (2015). *Digital Density Index – Guiding Digital Transformations*. Accenture Strategy: 1-15.

Maddala, G.S. (1999). *On the use of panel data methods with cross country data*. Annales D'E´conomie et de Statistique. 55–56, 429–448.

Maddala, G. S., & Wu, S. (1999). *A comparative study of unit root tests with panel data and a new simple test.* Oxford Bulletin of Economics and Statistics: 631–652. https://doi.org/10.1111/1468-0084.0610s1631

Maddison, A. (1982). *Phases of Capitalist Development*. New York: Oxford University Press.

Mammadli, E., & Klivak, V. (2020). *Measuring the Effect of the Digitalization*. Informatics eJournal: 3-14.

Manyika, J., Ramaswamy, S., Khanna, S., Sarrazin, H., Pinkus, G., Sethupathy, G., & Yaffe, A. (2015). *Digital America: A Tale Of The Haves And Have-Mores*. McKinsey Global Institute: 3-107.

Mentsiev, A. U., Engel, M. V, Tsamaev, A. M., Abubakarov, M. V, & Yushaeva, R. S. E. (2020). *The Concept of Digitalization and Its Impact on the Modern Economy*. Proceedings of the International Scientific Conference "Far East Con" (ISCFEC 2020): 128(March): 10–15.

Mueller, M. (1999). *Digital convergence and its consequences*. Javnost, 6(3): 11–27.

Muro, M., Sifan, L., Whiton, J., & Kulkarni, S. (2017). *Digitalization and the American workforce*. Brookings Metropolitan Policy Program: 3-59.

Namazi, M. (2020). *The Determinant of Income Inequality: Emphasis on Digitalization* (Unpublished doctoral dissertation). New Hampshire: Southern New Hampshire University the School of Business.

OECD. (2014). *Measuring the Digital Economy: A New Perspective*. OECDpublishing.

OECD. (2020). *OECD Digital Economy Outlook 2020*. Paris: OECD Publishing.

Özgül, S., & Karadağ, M. (2015). *Regional Convergence in Turkey Regarding Welfare Indicators*. Sosyoekonomi, 24(24): 38–50.

Öztürk, A., & Gültekin, L. (2021). *Türkiye' de İller Arası Ekonomik Yakınsama: 2008 Küresel Krizinin Rolü*. Hacettepe Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi, 39 (2): 253-270.

Parida, V. (2018). *Digitalization*. Addressing Societal Challenges, 23–37.

Park, S. R., Choi, D. Y., & Hong, P. (2015). *Club convergence and factors of digital divide across countries*. Technological Forecasting and Social Change, 96: 92–100.

Parviainen, P., Tihinen, M., Kääriäinen, J., & Teppola, S. (2017). *Tackling the digitalization challenge: how to benefit from digitalization in practice*. International Journal of Information Systems and Project Management, 5(1): 63–77.

Pearson, K. (1901). *On lines and planes of closest fit to systems of points in space*. The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science, 2: 559–572.

Phillips, P. C. B., & Perron, P. (1988). *Testing for a unit root in time series regression*. Biometrika, 75(2): 335–346.

Polat, R. K. (2012). *Digital exclusion in Turkey: A policy perspective*. Government Information Quarterly, 29(4): 589–596.

Ramsey, F. P. (1928). *A Mathematical Theory of Saving*. The Economic Journal, 38(152): 543–559.

Rath, B. N. (2016). *Does the digital divide across countries lead to convergence ? New international evidence*. Economic Modelling, 58: 75–82.

Reis, J., Amorim, M., Melão, N., Cohen, Y., & Rodrigues, M. (2020). *Digitalization: A Literature Review and Research Agenda*. Proceedings on 25th International Joint Conference on Industrial Engineering and Operations Management: 443–456.

Richardson, M. (2009). *Principal Component Analysis*. University of Oxford: 1-23.

Sala-i-Martin, X. (1996). *The Classical Approach to Convergence Analysis*. The Economic Journal, 106(437): 1019–1036.

Sayifullah, S. (2021). *Testing Of Economic Convergence In The Middle Of The Covid-19 Pandemic*. Jurnal Ekonomi Pembangunan, 7(2): 113–122.

Shankar, R., & Shah, A. (2001). *Bridging the Economic Divide within Nations: A Scorecard on the Performance of Regional Development Policies in Reducing Regional Income Disparities*. Policy Research Working Paper, 2717: 1-54

Solow, R. S. (1956). *A Contribution to the Theory of Economic Growth*. Quarterly Journal of Economics, 70(1): 65-94.

Stan, S., Oprean, C., & Țîțu, A. M. (2020). *Digitalization - Sustainable Development Convergence: Metrics and Effects in Romania*. Management of Sustainable Development, 12(1): 10–18.

StataCorp, (2013). *Stata: Release 13*. Statistical Software. College Station, TX: StataCorp LP, 572-588.

Tolstykh, T., Shkarupeta, E. V., Shishkin, I. A., Dudareva, O.V., & Golub, N. N. (2018). *Evaluation of the Digitalization Potential of Region's Economy*. International Conference on Humans as an Object of Study by Modern Science, Vol. 622, 736-743.

TUIK (2021a). *Literacy (15 Years of Age and Over).* https://biruni.tuik.gov.tr/medas/?kn=130&locale=en, (20.12.2021).

TUIK (2021b). *Urban population.* https://biruni.tuik.gov.tr/medas/?kn=130&locale=en (25.12.2021).

TUIK (2022a). *Gross Domestic Product Per Capita, Value (2009 Base).* https://biruni.tuik.gov.tr/medas/?kn=116&locale=en, (21.02.2022).

TUIK (2022b). *Gross Upper Secondary Education Enrollment Rate.* https://biruni.tuik.gov.tr/medas/?kn=153&locale=en, (05.02.2022).

TUIK (2022c). *Percentage of Internet Users By Classification of Statistical Regions (Sr) Level-1 and Sex.* https://data.tuik.gov.tr/Bulten/DownloadIstatistikselTablo?p=P/d/eFVvTvtipAnAiA HQmeohR/wQ5OgBpimAvswYQtqyYt5wT4jiTxOJs0ZCPNH5, (21.02.2022).

TUIK (2022d). *Unemployment rate (2012-2013)* https://biruni.tuik.gov.tr/isgucuapp/isgucu.zul?dil=2, (21.02.2022).

TUIK (2022e). *Unemployment rate (2014-2020)* https://biruni.tuik.gov.tr/medas/?kn=102&locale=en, (21.02.2022).

Voskresenskaya, E., Vorona-Slivinskaya, L., & Achba, L. (2020). *Digital economy: Theoretical and legal enforcement issues in terms of regional aspect*. E3S Web of Conferences, 164: 1-8.

Yazgan, Ş., & Ceylan, R. (2021). *Türkiye'de Düzey-2 Bölgeleri Arasında Kişi Başı Gelir Yakınsama Kulüpleri Var Mıdır?*. Atatürk Üniversitesi İktisadi ve İdari Bilimler Dergisi, 35(4): 1497–1519.

Yapraklı, S., & Sağlam, T. (2010). *Information and Communications Technology and Economic Growth in Turkey: An Econometric Analysis (1980-2008)*. Ege Academic Review, 10(2): 575–596.

Yıldırım, J., & Öcal, N. (2006). *Income Inequality and Economic Convergence in Turkey*. Transition Studies Review, 13(3): 559–568.

Yıldırım, J., Öcal, N., & Özyıldırım, S. (2009). *Income inequality and economic convergence in Turkey: A spatial effect analysis*. International Regional Science Review, 32(2): 221–254.