Journal of Emerging Economies and Policy

Araştırma Makalesi ● Research Article

Innovation Dynamics in Türkiye: Is There Any Convergence?*

Türkiye'de İnovasyon Dinamikleri: Yakınsama Var Mı?

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ÖZ

Bu çalışma Türkiye'deki bölgesel inovasyon yakınsamasını Phillips ve Sul (2007, 2009) kulüp yakınsaması yöntemi ile incelemektedir. Betimsel sonuçlara göre (varyasyon katsayısı) bölgeler arasında sigma yakınsaması yoktur. Log t regresyon sonuçlarına göre 81 il arasında mutlak inovasyon yakınsaması da bulunmamaktadır. Aksine, bölgeler kendi durağan durum değerlerine yakınsayan iki inovasyon kulübü oluşturmaktadır. Nispeten gelişmiş batı bölgeleri Kulüp 1'i oluştururken, Kulüp 2'yi daha çok doğu bölgeleri oluşturmaktadır. Ek olarak, kulüpler kendi aralarında da yakınsama göstermemektedir. Ampirik sonuçlara göre, Türkiye'de inovasyon bölgeler arasında heterojen dağılmıştır. İnovasyon kulüplerinin varlığı, tüm bölgeleri kapsayan politikalardan ziyade bölgeye özgü politikalara duyulan ihtiyacı göstermektedir.

ABSTRACT

This study examines regional innovation convergence in Türkiye by employing Phillips and Sul (2007, 2009) club convergence algorithm. Descriptive results show that the relative dispersion (coefficient of variation) of innovation signals no evidence of sigma convergence. Moreover, log t regression results confirm that absolute convergence does not exist among 81 provinces. Instead, regions form two innovation clubs which converge to their respective steady-states. Regions from the relatively developed west form Club 1 whilst Club 2 mostly consists of eastern regions. Furthermore, innovation clubs do not demonstrate a convergent behaviour among themselves. According to the empirical results, innovation is heterogeneously distributed across Turkish regions. The existence of innovation clubs indicates the need for region-specific policies rather than "one-size-fits-all" policies.

1. Introduction

Innovation serves an important role for sustained growth of nations. It has been seen as an engine for long-term growth in the leading theoretical models (Romer, 1990; Aghion and Howitt, 1992; Grossman and Helpman, 1994; Coe and Helpman, 1995; Howitt, 1999) which paved the way for empirical studies focusing on the prominence of knowledge. As technology and global competition advance, innovation-creating and innovation-absorbing capacities have become a

key determinant. Hence, nations are prioritizing knowledge-creating activities both at the national and regional level. However, knowledge creation of regions tends to be nonhomogeneous, which leads to concerns about possible further disparities.

Türkiye, a developing country, made substantial efforts to increase its R&D activity and innovation capacity (TurkStat, 2024). In the last decade, highest R&D investment took place in West Anatolia (TR5), East Marmara (TR4), and

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Istanbul (TR1) each year, developed regions with high industrial activities and high volumes of international trade. These regions have a significant share of Türkiye's innovation activity with R&D centers of leading firms, major universities, technology parks among many others. Hence, innovation capability tends to accumulate faster compared to peripheral provinces. As each region has varying levels of absorptive capacity and access to knowledge networks, innovation-creating activities are heterogeneously dispersed. Therefore, examining the distribution and the dynamics of the innovation becomes important for a better understanding of regional innovation.

This paper investigates innovation convergence patterns among NUTS-3 level Turkish regions between the years 2007-2023 with a nonlinear time-varying clustering algorithm developed by Phillips and Sul (2007, 2009). Prior to examining convergence dynamics, we employ generalized method of moments (GMM) methodology by Arellano and Bover (1995) and Blundell and Bond (1998) to analyze innovation-growth nexus. This research aims to make a notable contribution by testing sigma convergence, absolute convergence, and club convergence, and by identifying new evidence on innovation convergence patterns at the regional level. Thus, it contributes to the existing literature on the regional innovation dynamics.

The structure of this study is as follows. Section 2 briefly discusses theoretical models and summarizes relevant empirical literature on innovation convergence. Section 3 presents research data and methodologies. Section 4 gives the results of the analyses. Finally, Section 5 concludes this paper.

2. Literature Review

In the growth literature, convergence has been the focus of economists over a substantial period. Theory of Solow (1956) can be considered as the leading convergence study. In Solow's model, capital has decreasing returns. Poorer nations grow faster than richer nations due to diminishing returns which causes convergence. Technology, which is related with factor productivity (Solow residual), is taken as exogenous. In other words, technology does not depend on countries' capital stock, saving rate or growth of population. Growth of per worker output stems from exogenous technological advancement. Countries with same level of saving, population, and technology converge to same steady state. Conversely, endogenous growth theories (Romer, 1986; Lucas, 1988) endogenizes growth by including human capital to their models. In the study of Romer (1986), human capital shows increasing returns because knowledge has nonrival properties. Technical advancement is endogenously caused by R&D investment. Innovation creation through R&D investment leads to permanent growth due to public good nature of knowledge. Therefore, divergence rather than convergence results due to non-diminishing returns to human capital. These models led to more research on endogenous technology (Aghion and Howitt, 1992; Howitt, 1999; Howitt, 2000; Aghion et al.,

2005). Empirically, convergence is typically assessed using beta convergence and sigma convergence measures. Furthermore, club convergence analysis, which implies convergence to varying steady-state points due to similar initial conditions, is employed (Durlauf and Johnson, 1995; Quah, 1996).

The study of Kolasa (2008) demonstrates the important role of innovation in helping nations catch up to advanced economies. While most of the studies have examined innovation's impact on economic performance, studies examining the convergence of innovation indicators such as R&D expenditure, the number of R&D workers, and patents are limited. Given the shared economic and policy dynamics within the European Union, convergence of innovation among European regions is focus of the existing literature (Mulas-Granados and Sanz, 2008; Markowska and Strahl, 2012; Bednář and Halásková, 2018; Barrios et al., 2019; Blanco et al., 2020; Kijek et al., 2022; Banyuls and Vides, 2024). Mulas-Granados and Sanz (2008) examine sigma-convergence of R&D investment and patent applications per capita along with per capita income for 1990-2002 period. Between 1990 and 2002, EU regions converge both in measures of innovation and per capita income. Furthermore, they concluded that there is contribution from convergence in patents to convergence in per capita income. Sigma-convergence of innovation in EU regions is further examined by Markowska and Strahl (2012) with innovation input and output indicators for 1999-2008 period. The findings show that regional differences in innovation indicators have decreased across Europe. Similarly, Bednář and Halásková (2018) examine beta- and sigma-convergence between 2009 and 2012 in Western European regions. They found that regional differences in innovation performance persist. While convergence is observed in some regions, lagged regions diverge.

Club convergence methodology of Phillips and Sul (2007) is employed by Barrios et al. (2019), Blanco et al. (2020), Kijek et al. (2022), and Banyuls and Vides (2024) to investigate EU convergence. Barrios et al. (2019) use patents per capita as an innovation measurement for 2002-2012 period. Results of log t test demonstrate seven innovation clubs rather than full convergence of regions. European regions seem to be separated into several types of innovation clubs, ranging from those that are at the front of innovation (regions of Germany, France, Ireland among others) to those that are falling behind (regions of Eastern European countries). However, they conclude that the distance between different innovation clubs decrease towards the end of the examined period as they converge to the average. Results demonstrate that the innovation differences across regions decreased during research period. The existence of innovation clubs is also confirmed by Blanco et al. (2020), Kijek et al. (2022), and Banyuls and Vides (2024) for various periods. Moreover, Cattaruzzo (2020) investigates innovation convergence for various firms with log t test. Results indicate that firms form convergence clubs for 2000-2017 period. Also, there is a

relative convergence of R&D intensities of companies.

Awaworyi Churchill et al. (2020) examine innovation convergence in OECD countries for 1870-2015 period. Results indicate that R&D intensity converges to the same steady state. However, convergence clubs existed prior to World War II, which suggest that there were significant R&D spillovers across countries in post war period. Similarly, Chawla (2020) investigates sigma convergence of R&D statistics in selected OECD countries for 1981-2012 period. Sigma convergence is examined separately for both R&D intensities (R&D expenditures as a percentage of GDP) and R&D expenditures (GERD). In the period of 1981-2012, it is seen that the dispersion in R&D intensity (coefficient of variation) has decreased significantly. Although coefficient of variation increased in 2011 and 2012, results demonstrate convergence in R&D intensity. Convergence is also seen in the distribution of R&D expenditures for the period 1981-2012.

Škare et al. (2022) examine innovation convergence in selected 29 countries for 1995-2017 period. Accordingly, full convergence is rejected, and there are significant differences in innovation dynamics across countries. Countries form two innovation convergence clubs. They argue that that innovation convergence exhibits a deterministic behavior at the firm and sectoral level. Furthermore, innovative activity within the advanced nations in the sample demonstrates a slowdown while there is a catch-up in new EU members. They argue that innovation singularity might be a limiting factor for growth. Barrios Gonzalez et al. (2023) investigate technology convergence in fifty states of U.S. for 1997-2010 period. Results demonstrate convergence clubs exist, and R&D expenditure and science and engineering degree play an important role in the transition to higher state domestic product convergence clubs. The findings highlight the importance of encouraging R&D and science and technology investments for states' economic development. Using data from U.S. Patent and Trademark Office, Hardy and Sever (2023) examine innovation convergence across manufacturing sectors in 32 countries between 1976 and 2006. Results support convergence in patenting rates, quality, and efficiency over time, which is strengthened by financial development and institutional quality.

Jimenez-Moro et al. (2023) employ club convergence methodology to examine innovation convergence in China using patent applications for 1987-2020 period. They divide their analysis into three subperiods to account for temporal variations. Results indicate that regions form innovation clubs in each period. Though club dynamics differ for varying periods, innovation in regions does not demonstrate absolute convergence but rather innovative activity develops at different speeds according to their similar characteristics. Cui and Tang (2023) examine innovation convergence for China with log t test for 2010-2018 period. Results indicate urban agglomerations do not indicate full convergence but rather form four innovation clubs which converge to their unique steady states.

Studies on innovation convergence remain limited for Türkiye. The existing studies focus on the effects of innovation on economic variables. Innovation measured by R&D investment or patents positively affects macroeconomic performance according to existing findings (Adak, 2015; Bozkurt, 2015; Tarı and Alabaş, 2017; Gür, 2017; Dereli, 2019; Köse, 2020; Şenol and Onaran, 2022). There are also micro-level studies that examine innovations' impact on firm performance, which focuses on how innovative efforts stimulate productivity and profitability (Ayaydın and Karaaslan, 2014; Ulku and Pamukcu, 2015; Öztürk and Zeren, 2015; Kiracı et al., 2016). Despite prevalent research on innovation from various perspectives, examining whether innovative activity demonstrates convergence remains crucial due to the current gap in the literature.

3. Research Data and Empirical Methodology

3.1. Research Data

Innovation activity is commonly measured with R&D investment, R&D personnel, scientific publications, and patent proxies. We choose to employ granted patents per capita to measure innovation due to limited data availability of the remaining proxies at the provincial level (NUTS-3) in Türkiye. Employing provincial data yields more robust results for within-country convergence analysis as NUTS-1 and NUTS-2 level data already include a clustering itself. Furthermore, although the use of patent statistics has its limitations, it provides a crucial basis for measuring innovative output empirically (Griliches et al., 1986). Patent data at the provincial level (81 provinces) is obtained from Turkish Patent and Trademark Office (TurkPatent). It is converted to per capita terms with population data from Turkish Statistical Institute (TurkStat). Analysis covers 2007-2023 period as regional population statistics are not available prior to initial year. From 2007 to 2023, total of 27914 patents are granted within Türkiye, and highest province averages (per capita terms) belong to Istanbul, Bursa, and Ankara, respectively. Summary statistics are demonstrated in Table 1 for Türkiye, west, and east. Regional classification is done as Karaca (2004).

Table 1: Summary Statistics

Patents (per capita, thousands)	Obs.	Mean	Std. Dev.	Min.	Max.
Türkiye	1377	0.0073	0.0136	0	0.1003
West	561	0.0135	0.0187	0	0.1003
East	816	0.0030	0.0050	0	0.0411

Prior to convergence analysis, we examine innovation-growth nexus at the NUTS-3 level. Economic growth (GRWTH) is measured with per capita GDP growth. We also control the share of industry (SHI) in total output as a great volume of patenting activity concentrates in sectors such as electronics, machinery, and chemicals. As we are dealing with growth rate, analysis period starts from 2008 and our number of observations is 1215 in the dynamic analysis. Variables are obtained from TurkStat.

3.2. Empirical Methodology

We initially conduct a dynamic model by employing two-step system GMM of Arellano and Bover (1995) and Blundell and Bond (1998). It uses internal instruments, and controls for endogeneity that might be caused by reverse causality, omitted variables, and unobserved heterogeneity. The general rule of thumb is to keep internal instruments lower than the number of units. Two-step system GMM uses instruments both in level and differenced equations. Lags of the level variables are used in differenced equation as instruments, and lags of differenced variables are used in level equation as instruments. It gives more efficient estimates with this duality. Furthermore, it deals with time-invariant elements which is prominent for regional analysis. To check the validity of moment conditions, we use Hansen (1982) test along with Arellano-Bond AR (1) and AR (2) autocorrelation tests. Roodman (2009) advises to check the Hansen test as it is robust to heteroskedastic disturbances.

Equation 1 depicts the dynamic model. Lag of the dependent variable (GRWTH), which includes unadded factors, is added to the model as the independent variable. We also add share industry (SHI) as control variable to our model. In GMM, it is advised to control for year effect for more robust estimates. We control for the 2008 financial crisis and 2020 global pandemic. When we include additional year controls, number of instruments exceed number of groups which violates the rule of thumb of GMM. Furthermore, we cannot add further controls to not consume degrees of freedom. Level equation (1) and first-difference equation (2) are as follows:

$$GRWTH_{it} = \propto + \gamma GRWTH_{t-1} + \beta_1 PTNTPC_{it} + \beta_2 SHI_{it}$$
$$+ \theta CRISISDUMMY$$
$$+ \vartheta PANDEMICDUMMY + a_i + u_{it} \quad (1)$$

$$GRWTH_{it} - GRWTH_{it-1} =$$
$$\propto + \gamma(GRWTH_{t-1} - GRWTH_{t-2})$$
$$+ \beta_1(PTNTPC_{it} - PTNTPC_{it-1})$$
$$+ \beta_2(SHI_{it} - SHI_{it-1})$$
$$+ \theta CRISISDUMMY$$
$$+ \vartheta PANDEMICDUMMY$$
$$+ (u_{it} - u_{it-1}) \quad (2)$$

Convergence is most widely analyzed using methodologies of sigma, beta, and club convergence in national, regional, and international contexts. Sigma convergence is assumed to occur if dispersion in economic indicators declines. Beta convergence, contrarily, examines the association between initial conditions and the following rates of growth. It suggests that nations with lower initial income levels experience higher rates of growth, implying a catch-up process. On the other hand, club convergence analysis allows distinct clubs which converge to different steady states, which is particularly important with heterogenous data. Phillips and Sul (2007, 2009) proposed an approach (hereafter PS algorithm) that groups units into clubs which converge to their own steady states. Given heterogenous innovative activity within Turkish regions, we use PS algorithm to investigate whether innovation convergence exists.

Patents per population (thousands), denoted by PTNTPC, include systematic and transitory elements; that are g_{it} and α_{it}, respectively. Rewriting (3) to demonstrate transitional heterogeneity, PTNTPC is composed of common component μ_t and idiosyncratic component δ_{it}. Idiosyncratic part indicates the distance between the systematic and common elements of PTNTPC.

$$PTNTPC_{it} = g_{it} + a_{it} \quad (3)$$

$$PTNTPC_{it} = \left(\frac{g_{it} + a_{it}}{\mu_t}\right)\mu_t = \delta_{it}\mu_t \quad (4)$$

If time-varying δ_{it} converges to δ, model suggests that convergence exists. Null hypothesis of the model is stated as follows.

$$H_0: \delta_t = \delta \text{ and } \alpha \geq 0$$
$$H_1: \delta_t \neq \delta \text{ and } \alpha < 0 \quad (5)$$

Null hypothesis in (5) is tested using log t regression. First, h_{it} (transition parameter) is developed for measuring cross-unit dispersion.

$$h_{it} = \frac{PTNTPC_{it}}{\frac{1}{N}\sum_{i=1}^{N} PTNTPC_{it}} = \frac{\delta_{it}}{\frac{1}{N}\sum_{i=1}^{N} \delta_{it}} \quad (6)$$

Once the transition parameter is derived, cross-unit dispersion H_t is measured as in (7). Convergence exists when h_{it} goes to one and H_t goes to zero as t approximates to infinity. To test the convergence, log t regression in (8) is utilized in which H_1/H_t indicates dispersion ratio, and β indicates convergence speed. PS algorithm recommends to take truncation parameter γ as 0.3 for datasets with fewer time dimension. Using robust standard errors, log t test rejects full convergence for t-values lower than -1.65 at 95% confidence level.

$$H_t = \frac{1}{N}\sum_{i=1}^{i=N}(h_{it} - 1)^2 \quad (7)$$

$$log\left(\frac{H_1}{H_t}\right) - 2\log L(t) = \vartheta + \beta \log(t) + u_t$$

$$t = [\gamma T], [\gamma T] + 1 \dots, T \quad (8)$$

If full convergence within the sample is rejected, following

four steps of clustering analysis are carried out to form innovation clubs.

Step 1: Provinces are ranked based on their patents per capita in descending order.

Step 2: Core group is detected with log t analysis. If t-statistic is higher than -1.65, provinces belong to core innovation club. Log t test is continued for remaining subgroups to check whether regions can be added further to the core innovation club.

Step 3: Remaining regions are one by one sieved based on critical value c*. Regions are included to the club if t-value exceeds critical value c*. Critical value is determined based on the nature of the sample. Regions added in second and third steps form the first innovation club.

Step 4: Log t analysis is applied to the regions outside the first innovation club. If t-value exceeds -1.65, regions form another convergence club. Otherwise, first three steps are followed once again to check if subgroups converge. If any other innovation club do not exist, remaining regions diverge.

4. Empirical Results

Following endogenous growth theories, it is better to examine the impact of innovation for economic growth of Turkish regions prior to convergence analysis. In two-step system GMM, standard errors are biased downward. We utilize corrected standard errors of Windmeijer (2005) to cope with this problem. Arellano-Bond tests indicate that there is autocorrelation at order one and no autocorrelation in the second order. The Hansen test and Arellano-Bond tests confirm the validity of instruments and moment conditions. Table 2 reports system GMM results. Results demonstrate that innovation has a significant and positive effect on economic growth of Turkish regions. This signals innovative activities have the potential to increase economic performance of regions, which possibly stems from higher productivity levels caused by product and process innovations. The negative impact of the industrial share may reflect sectoral heterogeneity across regions. This may also suggest that regions' innovation absorptive capacity may change with economic structure.

Table 2: GMM Results

Dependent Variable: GRWTH	
Variables	**Coefficients**
GRWTH- LAG1	0.6968*** (0.0217)
PTNTPC	200.7732***(48.8554)
SHI	-0.3846*** (0.1165)
CRISISDUMMY	-17.0452*** (0.7479)
PANDEMICDUMMY	-2.9050*** (0.9868)
CONSTANT	31.7892*** (6.615)
Prob > F	0.000
Observation number	1215
Group number	81
Instrument number	79

Hansen test (Prob > chi2)	0.246
Arellano-Bond test AR (1) (PR > z)	0.000
Arellano-Bond test AR (2) (PR > z)	0.236

Note: *, **, and *** depict significance at %10, %5, and %1, respectively. Corrected standards errors are in parenthesis.

We initially investigate sigma convergence with some descriptive statistics. Examining sigma convergence with coefficient of variation (CV) gives a good measure of overall dispersion trend. CV measures relative standard deviation by dividing dispersion to the arithmetic mean. Hence, it prevents the transition of changes in the mean that do not reflect change in distribution to standard deviation (Dogruel and Dogruel, 2006). The coefficient of variation of the innovation variable for East, West, and Türkiye is given in Figure 1. In 2008-2010 period, innovation dispersion decreased in Türkiye which might be caused by constrained financial access and following decline in R&D activities. In the following years, it remained relatively stable until the years of 2019 and 2020, when pandemic led to disruptions labor markets and supply chain operations. However, there is no clear trend for eastern & western regions and Türkiye implying convergence. Hence, it not possible to detect a clear convergent dynamic referring to CV, and conclude sigma convergence.

Figure 1. Coefficient of Variation of Innovation for East, West, and Türkiye (i.e. Sigma Convergence)
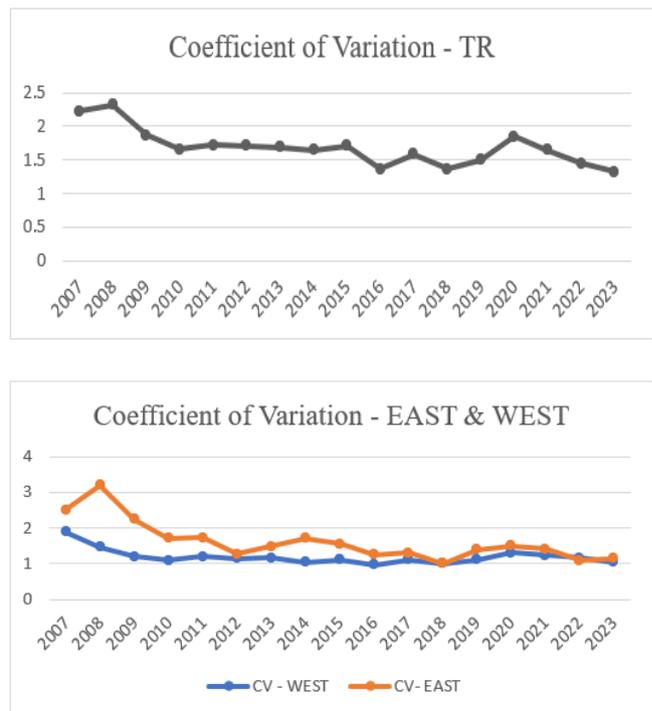
Following PS algorithm, we initially test full convergence of the sample with log t regression. Referring to Table 3, full innovation convergence is rejected as t-value is lower than critical t-statistic. Thus, we proceed to implement previously mentioned clustering steps to detect innovation clubs which converge to their unique steady-states.

Table 3: Results of the Log t Regression

	PTNTPC
Beta Coeff.	-0.5613
Std. Error	0.2206
t-statistic	-2.5435

Note: The critical t-value is -1.65 at 95% confidence level. Table demonstrates results of log t regression given in Equation (8).

Table 4 demonstrates clustering analysis results, identifying innovation clubs. Accordingly, innovation activity of 81 Turkish provinces is clustered into two innovation clubs. Following clustering analysis, we apply merging test of Phillips and Sul (2009) to examine if these two clubs can be merged further. Merging test reports that innovation clubs cannot be merged beyond this clustering. Consequently, we detect two innovation clubs converging to their own steady states.

Table 4: Clustering Results

	Units	**Coeff.**	**Std. Error**	**t value**
Club 1	32	-0.043	0.121	-0.354
Club 2	49	-0.571	0.607	-0.940

Table 5 summarizes regions belonging to innovation clubs. Club 1 is composed of highest innovation generating provinces with high per capita patents. Some members of the Club 1 (i.e. Istanbul, Ankara, İzmir, Kocaeli, Bursa) vary greatly in terms of innovative activity from the rest of the provinces in the sample. These highly industrialized regions comprise of various domestic and foreign firms attracting investments from their counterparts abroad. Such international contact leads to technology and knowledge transfer, and hence more innovative output. Furthermore, these regions include headquarters and factories of firms with high export volume, which heavily invest in R&D and have high innovation-absorbing capacity. Most of the provinces in the first innovation club are "industrial zones" from western part whilst Club 2 mostly consists of provinces from the eastern part of the country, that are "poorly industrialized regions" (Dogruel and Dogruel, 2011). They are relatively less advanced in terms of innovation input and outputs. Furthermore, there might be structural disadvantages such as lower access to skilled labor and limited R&D investment due to network effects. Additionally, existence of only two clubs might signal a degree of polarization, that some provinces are advancing and others are lagging. Hence, innovation activity remains clustered in certain regions. Figure 2 plots the geographical distribution of the innovation clubs and descriptive statistics of clubs are demonstrated in Table 6.

Figure 3 depicts the average transition paths of the two clubs. In the case of full sample convergence, transition paths of clubs should converge to one. Accordingly, innovation clubs (Club 1 and Club 2) do not converge to each other for 2007-2023 period. Furthermore, their trajectories seem to separate during the analysis period. This pattern demonstrates that high innovation-creating regions enhanced their innovation capabilities, and lagging regions struggled to catch-up. It led innovation gap to increase further.

Table 5: Province Details of Innovation Clubs

| **Clubs**	**Provinces**
1	Bursa, Sakarya, İstanbul, Ankara, Eskişehir, Kocaeli, Konya, İzmir, Kayseri, Rize, Gaziantep, Erzurum,
	Sivas, Tekirdağ, Siirt, Zonguldak, Trabzon, Karabük, Elazığ, Çanakkale, Kahramanmaraş, Bolu, Amasya,
	Erzincan, Karaman, Balıkesir, Kilis, Hatay, Kütahya, Tokat, Aksaray, Tunceli
2	Manisa, Bilecik, Burdur, Çorum, Düzce, Yalova, Isparta, Samsun, Kırşehir, Denizli, Antalya, Malatya,
	Bartın, Nevşehir, Edirne, Mersin, Aydın, Kastamonu, Kırıkkale, Giresun, Adana, Afyonkarahisar, Çankırı,
	Muğla, Sinop, Şanlıurfa, Ordu, Bingöl, Kırklareli, Yozgat, Ağrı, Şırnak, Osmaniye, Van, Batman, Adıyaman,
	Diyarbakır, Uşak, Niğde, Artvin, Gümüşhane, Bayburt, Kars, Iğdır, Ardahan, Muş, Bitlis, Hakkari, Mardin

Table 6: Descriptive Statistics of Innovation Clubs

	Obs.	Mean	Std. Dev.	Min.	Max.
Club 1	544	0.0126	0.0188	0	0.1003
Club 2	833	0.0038	0.0066	0	0.0999

Overall, empirical results reveal an endogenous classification of Turkish regions according to their innovation levels, without any prior condition. Referring to log t regression, full sample does not demonstrate convergent behaviour as supported by average transition paths of innovation clubs. Rather, there are two innovation clubs which converge to their own steady states. Examining the determinants of the innovation club formation is not within the scope of this study since data of the factors stimulating innovative output, namely R&D expenditure, R&D personnel, foreign trade volume among others, are not available at the provincial level for investigated period.

Figure 2. Mapping of Convergence Clubs
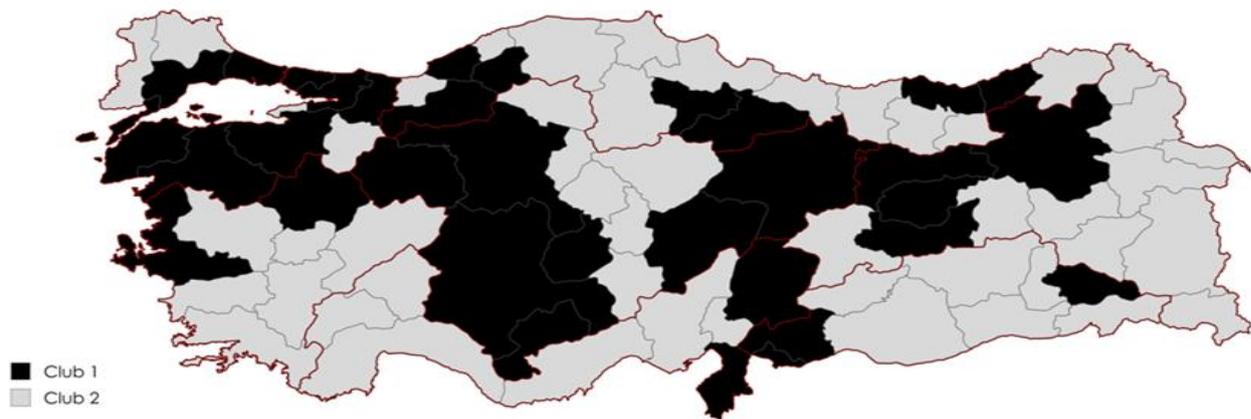
Note: Illustrated with mapchart.net

Figure 3. Average Transition Paths of Clubs
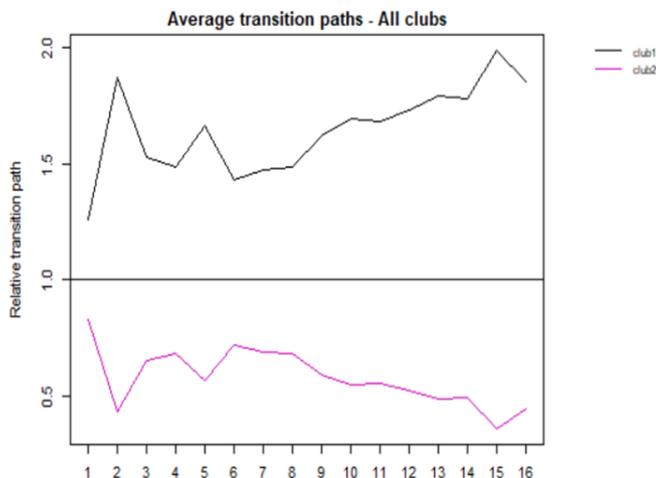
5. Conclusion

In this study, we examine innovation convergence dynamics of Turkish regions for the years between 2007-2023 using data from TurkStat regional statistics. We contribute to the literature by employing an endogenous clustering algorithm by Phillips and Sul (2007, 2009) to Turkish innovation data, and identifying new evidence on innovation clubs. We observe that there is no sigma convergence of innovation in west, east, and Türkiye. In addition, regions do not demonstrate absolute convergence. Instead, Turkish regions form two innovation clubs with their respective steady states and transition paths. Furthermore, the difference between the average transition paths appears to widen at the end of the analysis period, which depicts the divergent behaviour of the clubs. In particular, the widening innovation gap between average transition paths demonstrates unequally distributed innovation activity. Regions with high innovation performance continue to enhance their knowledge-creating capacity while lagging regions struggle

to catch-up. This might be caused by low absorptive capacity, limited access to knowledge networks, less access to skilled labor, and less R&D investment. Hence, divergent dynamics indicate the need for region-specific innovation policies. Policymakers might consider enhancing innovation absorptive capacity in lagging regions by supporting researcher mobility and innovation networks. Furthermore, they may focus on encouraging collaboration between universities and firms to further enhance absorptive capacity.

This research is subject to several limitations. First, measuring innovation with patents has its restrictions (Desrochers, 1998). However, it is the only available innovation indicator at the provincial level for Türkiye. Second, we cannot investigate a longer period that reflects innovative activity more accurately due to data limitations. Given the heterogeneous innovation dispersion across regions, the findings suggest that region-specific innovation policies might be more appropriate compared to aggregate policies. As there is a divergent dynamic between two innovation clubs, a one-size-fits-all type of policy might enlarge the gap even further. However, findings should be considered with respect to extant restrictions. There will be opportunities for future research as innovation data accumulates.

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