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Innovation, Relatedness and Complexity in Turkey: A Regional Analysis for 1978-2017

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Abstract

The paper aims to explore innovations and smart specialization opportunities in Turkey's regions. Patent applications measure innovations. Relatedness density and regional complexity measure prospects for smart specialization. The data is from OECD RegPat data (January 2020) for the 1978 – 2017 period. Following the approach outlined in smart specialization literature, the paper demonstrates geographic distribution of patents, average relatedness density and complexity of Turkey's regions.

There are four main results of the paper. Firstly, patent applications in Turkey during the 1978-2017 period are mostly low-tech products. Secondly, regional distribution of patent applications and relatedness density is uneven. Thirdly, regional knowledge complexity index became uniform over time, indicating that creating unique regional positions became harder. Fourthly, the potential of regions for smart specialization is higher in west of Istanbul-Ankara-Adana axis.

JEL Codes: R10, R11, R58

Keywords: Relatedness, complexity, smart specialization, patents, Turkey.

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Türkiye'de Yenilik, İlişkililik ve Karmaşıklık: 1978-2017 için Bölgesel Bir Analiz

Öz

Bu makalenin amacı, Türkiye'de bölgesel yenilik ve akıllı uzmanlaşma fırsatlarını ortaya koymaktır. Yenilikler, patent başvuruları ile ölçülmüştür. Akıllı uzmanlaşma fırsatları ise, ilişki yoğunluğu ve bölgesel karmaşıklık değişkenleri ile ölçülmüştür. Veriler, 1978–2017 dönemi için OECD RegPat'den (Ocak 2020) alınmıştır. Çalışma, akıllı uzmanlaşma literatürü yaklaşımı çerçevesinde Türkiye bölgelerinde patent başvurularını, ilişki yoğunluğunu ve karmaşıklığını göstermektedir.

Makalede dört ana sonuca varılmaktadır. İlk olarak, 1978-2017 döneminde Türkiye'deki patent başvuruları çoğunlukla düşük teknolojili ürünlerdir. İkinci olarak, patent başvuruları ve ilişki yoğunluğu düzensiz bir bölgesel dağılım göstermektedir. Üçüncü olarak, bölgesel bilgi karmaşıklığı endeksi zamanla bölgeler arasında tek tip hale gelmiş ve rekabet eden bölgeler arasında özgün konumlar yaratmak zorlaşmıştır. Dördüncü olarak, bölgelerin akıllı uzmanlaşma potansiyeli İstanbul-Ankara-Adana ekseninin batısında daha yüksektir.

JEL Kodları: R10, R11, R58

Anahtar kelimeler: ilişkililik, karmaşıklık, akıllı uzmanlaşma, patentler, Türkiye

1. Introduction

The distribution of innovative activities is not equal in space (Dosi, 1988; Feldman, 1994). Innovation is a major driver of regional development where innovative capacity of the firms and policies that encourage innovative investments are key notions (Antonelli, 2003; Stehr, 2007; Pekkarinen & Harmaakorpi, 2006). Regional innovation systems with close links and networks are essential for regional competitiveness and development (Cooke, 2005a).

Geographical distribution of innovations and industrial districts as well as spatial innovation networks has been a topic of particular interest by the scholars working on innovative milieu (Camagni, 1991; Cooke and Morgan, 1994) and regional innovation systems (RIS) (Cooke et al., 1997). Place-based innovation strategies bring out the importance of the notion of creating clusters for high-value added and innovative investments that require intensive amount of cumulative knowledge (Widuto, 2019). Knowledge creation and use of knowledge is significant in enhancing the capabilities of the regions to create sustainable competitiveness. When creating regional capabilities, it is imperative to consider uniqueness of each region, as the regions possess dissimilar capabilities and knowledge bases (Asheim et al., 2011). There is heterogeneity of knowledge bases and distribution of innovative activities across the regions. Stehr (2007) points out that technological innovations happen in regions where the firms are able to create their own technologies, adopt new technologies or apply original ideas (innovation) for economic growth.

In addition to regional distribution of innovations, a vital question is whether the regions are flexible enough to create innovations and at the same time maintain their competitiveness concerning their technological competencies. Balland et al. (2019) demonstrates that two variables, relatedness and complexity, help us understand the regions' potential to attract new and related technologies and at the same time create a unique position among competing regions. Recent work on smart specialization and place based policy (Boschma, 2014) draws from the regional diversification literature (Hidalgo et al., 2018; Neffke et al., 2011), economic complexity literature (Hidalgo & Hausman, 2009) and smart specialization literature (Foray et al., 2009 and 2011).

Overall, the literature shows a significant relationship between regional innovations and regional economic development around the world as well as in Turkey (Adak, 2015; Yılmaz, 2019; Yavan, 2011; Şahin & Altuğ, 2017). Recent work on regional innovativeness in Turkey indicate that spatial and organizational proximity enhances regional innovation capacity (Kaygalak & Reid, 2016). Özkaya (2014) studies patent data for the 2001-2013 period and concludes that Turkey lags behind developed countries with its annual patent activity remaining below 100 patents. The studies point out that low technology sectors constitute majority in the manufacturing sector with growing trend towards medium-low and medium-high-technology sectors particularly in export products (Gezici et al., 2021).

Furthermore, Kaygalak (2013), in his study on clusters, contends that none of the identified clusters includes high-tech sectors. Kaygalak & Reid (2016) and Gezici et al. (2017) demonstrate that majority of sectoral agglomerations are in medium-low and medium-high technology sectors. Additionally, Çelik, Akgüngör & Kumral (2019) demonstrate that Turkey's industrial clusters include industries whose technologies do not demand high skills, knowledge and sophistication.

In relation to patents as an indicator of innovativeness, Özkaya (2014) points out that Turkey is among the newly industrialized countries (NICs) with increasing trend in the number of patent applications per year. Türkcan & Çelik (2020) further demonstrate uneven distribution of technological progress in manufacturing industry across Turkey's regions whereas Oğuz (2019) analyzes smart specialization capacities of the clusters based on innovation capacities, innovation outputs and openness and shows uneven distribution of regional capabilities for smart specialization.

Although the studies above focus on the regional spread of the technology level and innovations, there is little knowledge concerning how regional innovativeness in Turkey have evolved in the long run. There is also limited knowledge on how regions in Turkey have diversified over time into related technologies as well as how complexity of the regions has changed.

Understanding the evolution of patterns of innovative activities in regions is imperative in the design of smart specialization policies. It is also important to understand the regions' potential to attract new and related technologies that are comparable to their knowledge base. Relatedness shows potential for regions' branching opportunities into new and related technologies. Related technologies could be a source for creating and developing innovations. Similarly, complexity of knowledge indicates that regional capabilities are unique and hard to imitate in other regions, thus creating source of regional competitiveness.

There are two aims of the paper: The first aim is to map innovations in Turkey's regions for the 1978-2017 period using patent applications as an indicator of innovative activity. The second aim is to demonstrate developments of the regions' ability to attract innovations (relatedness) and regions' ability to stay unique in economic activities (complexity) for Turkey's regions for the 1978-2017 period.

2. Turkey's Regional Innovation Policies

Turkey's development plans (initiated in 1963) show changes regarding Turkey's regional policies (Lenger, 2008). Dulupcu & Govdere (2005) document regional economic policy elements of the plans. Until 1990s, the plans speak of "regional economic integration", "diffusion of economic development to regions", "focusing on population problems due to rapid urbanization", "removing regional differences", "development of some underdeveloped regions", "mobilization of resources for regional problems", "accelerating development by rationalizing resource allocation in less developed and potentially suitable regions". More recently, particularly after the 1990s, the plans shifted their emphasis to "overall consideration of social, administrative and financial dimensions for policy introduction", "the harmonization of regional statistics in accordance with international standards, especially with EU", "the integration of sectoral and spatial studies", "sectoral specialization of provinces", "city planning", "enhancing competitiveness". Recent plans emphasize "participatory planning", "sustainability", "more efficiency in resource allocation", and "adjustment to EU regional policy" as general principles. Recent plan (11th development plan) that covers the period of 2019 to 2023 focuses on R&D and innovation capabilities of the Turkish manufacturing industry and provides an innovation- based support structure (Kleiner-Schäfer & Liefner, 2021). Report on "National Strategy on Regional Development: 2014-2023" by Republic of Turkey Ministry of Development (currently Republic of Turkey, Presidency of Strategy and Budget) emphasizes importance of smart specialization strategies for regional development (T.C. Kalkınma Bakanlığı, 2014)

Regional development policies in Turkey started in the early years of the Turkish Republic, and most were centrally planned (Lagendijk et al., 2009). Especially in the first half of the young republic's life, development efforts were within the control of the government where State Planning Organization (SPO) was the institution in charge. The centralized mindset started to change with Turkey's candidacy to the European Union (Lagendijk et al., 2009). The policies started to decentralize with recognition that regional governance is important to help development efforts reach even the most remote areas of the country. In the beginning of 2000s, 26 Regional Development Agencies across Turkey's NUTS2 regions started to be active in regional development policies and projects. In 2011, the duties of the "State Planning Organization" were transferred to the "Republic of Turkey Ministry of Development" and then to the "Office of Strategy and Budget".

Supreme Council of Science and Technology (SCST) is the main body for science and technology policy in Turkey. Scientific and Technical Research Council (TUBITAK) is the secretariat of the SCST. TÜBİTAK's responsibility is to implement Turkey's science and technology policies as the major funding agency. Other actors that are active in research and technology policies are the Turkish Academy of Sciences (TÜBA), the Council of Higher Education (YÖK) and the Interuniversity Board (ÜK). The Technology Fund of Turkey (TTGV) operates as a funding agency for industrial research as well as seed capital provision, loans and grants (European Commission, 2006).

3. Smart Specialization Policies in Turkey

As the smart specialization policies began to unfold as successful outcomes for discovering innovation potentials and making the most efficient use out of the capabilities of regions towards production of knowledge, many other regions in the periphery of the EU started to integrate smart specialization policies into their innovation frameworks. To this end, initial steps started to emerge towards deepening cooperation for smart specialization policies between the EU and many Enlargement and Neighborhood countries, including Turkey (Gómez Prieto et al., 2019). Turkey is one of the associate countries of the Horizon 2020 program and a participant to the Horizon Europe program. Being able to take active part in the European research programs is a significant opportunity for Turkey in relation to its alignment with EU smart specialization strategies (European Commission, 2017; European Commission, 2021).

Turkey's national support system for smart specialization bases its principles on Turkey's 2003-2023 Strategy Document (TUBITAK, 2004). Since then, 10 agencies/regions among 26 developed their regional innovation strategies based on smart specialization (Şahin & Ertürk, 2021). Regional development agencies started to work on principles of smart specialization strategies (Kumral & Güçlü, 2018). Additionally, there are 10 Universities with a defined mission of regional development and specialization under the program initiated by Council of Higher Education (YÖK) in Turkey (Akgüngör, Kuştepeli & Gülcan, 2021).

TUBITAK in its 2010 report on "National Science, Technology and Innovation Strategy 2011-2016" emphasizes the importance of a triple helix cooperation model for accelerating technological sophistication in Turkey's regions. The plan introduced establishment of technology transfer centers (TTO) in universities and initiated entrepreneurial university concept. Republic of Turkey Ministry of Industry and Technology in 2015 prepared an action plan to establish an infrastructure for Public-University partnership. Technology Transfer Accelerator (TTA) as an initiative of European Investment Fund (EIF) provides support to university industry collaboration in Turkey and managed by the Ministry of Industry and Technology (Technology Transfer Accelerator, 2021).

At the heart of the smart specialization policies is the idea of creating "clusters" by enabling cooperation between regions with similar expertise (Foray & Ark, 2007). Therefore, clusters are building blocks of the smart specialization concept (Hassing & Gong, 2019). There are studies on industry clusters in Turkey with a general focus on smart specialization with an emphasis on technological composition of clusters (Çelik, Akgüngör & Kumral, 2019) as well as innovation capacities, innovation outputs and openness of clusters (Oğuz, 2019). Moreover, OECD (2013) suggests Turkey's East Marmara region as an example of an automotive cluster with smart specialization potential concerning its production volume, employment creation, and number of manufacturer and supplier companies. The region's close interaction with free zones, techno-parks, research institutions, public institutions and Organized Industrial Zones are significant indicators of its integrity as a cluster. Another area suitable for the implementation of the smart specialization policies and creation of clusters in Turkey is the agro-food industry. For example, Middle Black Sea Region of Turkey takes part in agro-food thematic partnerships of the EU's S3P Agro-food platform (Stancova & Cavicchi, 2017).

Nevertheless, as stated above, few studies exist in Turkey in which smart specialization concepts such as technological relatedness and complexity are included. For example, Lo Turco & Maggioni (2017) study technological relatedness and proximity of firms and conclude that firms with high technological relatedness to foreign firms have higher potential to engage in knowledge production. Kuştepeli, Gülcan & Akgüngör (2013) confirm that related variety is a major driver of economic growth in Turkish regions. Furthermore, Akgüngör, Kuştepeli & Gülcan (2021) study smart specialization potential of İzmir by exploring technological relatedness and complexity of industrial activities in İzmir by using patent data (OECD Regpat database) and demonstrate that food chemistry, biotechnology and environmental technology are potential industries as good candidates for smart specialization in Izmir. Abay & Akgüngör (2021) display Turkey's knowledge space and demonstrate high number of patent applications in electrical engineering with strong network ties across electrical engineering field with other technology fields, such as mechanical engineering, instruments and other fields. Abay & Akgüngör (2021) further demonstrate that there is considerable heterogeneity across the cities in relation to patent applications and regions' relatedness density has a positive impact on regional innovativeness as measured by patent applications. However, there is a need for further knowledge that systematically presents the regional distribution of patents and regional relatedness and complexity over time. In order to provide better understanding of Turkey's regional smart specialization opportunities and the evolution of smart specialization opportunities over time, this study aims to demonstrate the profile of patents as well as relatedness and complexity since 1978. The paper is descriptive in nature and aims to provide background knowledge for the design of Turkey's smart specialization policies.

The following section demonstrates the conceptual framework on smart specialization based on the work by Balland et al., (2019) with roots from regional diversification literature (Hidalgo et al., 2018; Neffke et al., 2011) and economic complexity literature (Hidalgo & Hausmann, 2009). The argument is that key concepts of spatial policies are relatedness and knowledge complexity (Boschma, 2014). The theory is consistent with the view that regional advantage depends on the conditions on the use of regions' core knowledge and competencies.

4. Conceptual Framework

4.1. Regional Innovativeness

Innovations relate closely with regional competitive advantage and patents are good proxies for innovation capabilities (Griliches, 1990; Jaffe et al., 1993). Patents are compatible with other measures of innovation (Hagedoorn & Cloodt, 2003) and are reliable measures of innovative activity (Acs, Anselin & Varga, 2002; Guerrero & Sero, 1997; Narin et al., 1987). The paper follows the concept that activities related to technological innovations are key (Stoehr, 1988), application of original ideas (innovation) for economic growth are closely correlated with patenting activities where patents are significant indicators of innovations (Griliches, 1998; Siegel, Westhead & Wright, 2003; Ejermo, 2009; Buerger, et.al., 2012).

A commonly used measure to explore the distribution of innovations across regions is regional dispersion of patents (Basberg, 1987). Patents are good indicators of technological progressiveness as they encourage the promotion and spread of innovations across regions (Breschi & Malerba, 1997; Encaoua et al., 2006). Kroll (2015) states that regional innovation systems have four structural features with possibility of analysis through patent analysis. The first is the level of general technological activity, the second is the role of the state and private sector in patenting, the third is technological specialization and sectoral focus, and the fourth is the outward orientation. In his study, he examined whether the increasing patent applications were the true reflection of technological development and found that most of the technological inventions of the regions were politically encouraged. Evidence on significant relationship between GDP growth and patenting is presented in literature (see, for example, Carvalho, Beijo & Salgado (2020), Raghupathi & Raghupathi (2017)) as well as relationship of patents and regional development (Guerrero & Sero, 2010). Ginarte & Park (1997) further argue that countries greatly benefit from strong protection of patent rights.

4.2. Smart specialization: Relatedness and Complexity

A stream of literature with a special emphasis on innovations is smart specialization. Smart specialization builds upon the idea that it will be more beneficial for a country or region to invest in research areas that are complementary to its existing capabilities rather than allocating their resources to a broad range of unrelated fields. Therefore, an efficient innovation strategy should aim to increase regions' expertise around a specific scientific field by encouraging research activities in areas related to their yielding competencies (Foray & Van Ark, 2007; Foray et al., 2009).

Shortly after its development, the concept of smart specialization became the basis of the EU's innovation policies. In fact, the primary objective of the smart specialization - smart, sustainable and inclusive growth- are well integrated into the EU's "EU 2020

Agenda". For the application of these objectives, a platform of Services, European Commission established the platform on "Research and Innovation Strategies for Smart Specialization" (RIS3) (Foray et al., 2011; OECD, 2013).

The smart specialization framework draws from regional innovation systems (RIS) literature (Freeman, 1995; Cooke et al., 1997) and learning regions literature (Morgan, 1997; Lundvall & Johnson, 1994). In regional innovation system approach, Cooke, 2005b) points out that innovation is the process of new knowledge through means of networks, learning, and interactions. Cooke (1994) defines RIS as, "RIS is what determines the effectiveness and the efficiency of regional knowledge building/ transfer among the different integrating parts of the system, including individual firms, sectoral/value-chain clusters business consultants, technology centers, R&D centers, University departments, laboratories, technology transfer and utilization of R&D centers, development agencies."

Recently, Löfsten et al. (2020) highlight the significance of human capital and entrepreneurship within the networks of the regional innovation system. In another stream of literature of regional innovation, Kleiner-Schäfer & Liefner (2021) mention the significance of firm-level attributes (Ernst & Kim, 2002; Henderson & Clark, 1990; Malecki, 1991; Zeschky et al., 2011). Control of internal capabilities of the firms are important to increase their absorptive capacities (Lin et al., 2002).

Boschma (2014) proposes that relatedness concept corresponds to the idea that knowledge creation is the combination of existing ideas. Foundations of knowledge and innovation are re-construction of the components of core ideas and therefore an evolutionary process. Frenken & Boschma (2007) further argue that diversification of the economic activities is a branching process and the emergence of new technologies is not random and rather depend on past knowledge. Innovations and new technologies come from existing set of capabilities (Boschma, 2017).

In addition to the significance of relatedness for branching opportunities, regions tend to have competitive advantage when the technologies are unique and hard to copy. What is highly valuable for sustainable regional growth is the ability to create knowledge that tends to be complex. Knowledge complexity resulting from valuable and tacit knowledge is difficult to imitate and access by others (Hidalgo & Hausmann, 2009). Balland & Rigby (2017) demonstrate that complexity correlates with the long run patterns of economic performance and innovativeness where regions develop based on their existing knowledge cores.

5. Data and Methods

5.1. Data

To identify technological fields and compute measures of relatedness and knowledge complexity, we use OECD-REGPAT database January 2020 Edition. OECD-REGPAT contains patent data for regions with information on addresses of the applicants and inventors. Regional patent data covers more than 5500 regions across OECD countries. In this study, we use patent data for the years 1978-2017.[1] We cleaned and grouped the data according to World Intellectual Property Organization (WIPO) technology classification “New concept of technology classification, update May 2008” (Schmoch, 2008). According to May 2008 classification, IPC codes form 5 technology classes and 35 sub-technology classes. We use the latest version (July 2019) of WIPO IPC-Technology Concordance Table to group IPC codes of the patents into WIPO technology classes.

5.2. Methods

5.2.1. Measuring relatedness

We measure *relatedness* using the method following Boschma et al. (2015) and Rigby (2015). The method counts the number of patent claims for a given period that contains a co-class pair of technologies, i and j. The method then standardizes this count by the total number of patents that contain i and j. Relatedness between technologies i and j (φ_{ij}) is a standardized measure of the frequency with which two IPC classes appear on the same patent. This paper follows the method outlined in Balland et al. (2019). We use Balland (2017) EconGeo R package.

We demonstrate relatedness across space by the knowledge structure of Turkey’s NUTS3 regions. Following the method demonstrated in Balland et al. (2019) and use of EconGeo R package, we calculate the density of technology production near individual technologies i for each NUTS3 region (r) in Turkey. Relatedness density operationalizes the relatedness of the regions.

As specified in Balland et al. (2019), the relatedness density of industry i, in region r at time t is presented below:

$$RD_{i,r,t} = \frac{\sum_{j \epsilon r, j \neq i} \varphi_{ij}}{\sum_{j \neq i} \varphi_{ij}} * 100$$

$RD_{i,r,t}$ is the relatedness density of technology i to all other technologies j where the region r has relative technological advantage (RTA) at time t. φ_{ij} is technological relatedness of technology i with technology j. RTA is a binary variable that takes the value 1 when the region has higher share of patents in technology i in comparison to the share of patents in technology i in the country; and 0 otherwise (similar to the notion of location quotient).

Relatedness density is therefore the technological relatedness of technology i to all other technologies j in which the region has relative technological advantage (RTA),

[1] 2017 was the latest complete data available for Turkey in the OECD REGPAT database during the time of data download (OECD, REGPAT database, January 2020)

divided by the sum of the technological relatedness of technology i to all other technologies in Turkey at time t.

We use *average relatedness density* variable to measure regions' potential for branching into new and related technologies. Average relatedness density of regions represents technological flexibility (the structure of the knowledge base) of the regions as demonstrated in Balland, Rigby & Boschma (2015) with calculation procedures outlined in EconGeo Package (Balland, 2017). Average relatedness density (technological flexibility) represents the average relatedness of the technologies present in the region to all technological classes that are not yet in the city. Using average relatedness density variable, we are able to develop a variable that measures regions' branching opportunities and potential to diversify into new and related technologies in Turkey's NUTS3 regions.

5.2.2. Measuring complexity

Complexity measures the quality of the knowledge created in the region. Knowledge is valuable if it is difficult to replicate outside the geography. Knowledge that is tacit and sticky in the field is a source for competitive advantage in regions.

This paper follows the method proposed by Hidalgo & Hausman (2009) and further developed by Balland et al. (2019). The method connects the regions to technologies in which they have RTA. The complexity is determined by the range and ubiquity of the technologies that the regions use. The variable that measures complexity of knowledge in regions is knowledge complexity index (KCI).

KCI has two components. Diversity is the number of technology classes in which the region (r) has relative technological advantage. Ubiquity is the number of regions that exhibit revealed technological advantage in a given technology (Balland & Rigby, 2017).

$$\text{Diversity} = K_{r,0} = \sum_i M_{r,i}$$

Where $M_{r,i}$ is a binary variable that represents whether the region r has RTA in the production of technology i.

$$\text{Ubiquity} = K_{i,0} = \sum_r M_{r,i}$$

Where $M_{r,i}$ is a binary variable that represents the number of regions with RTA in the production of technology i.

The KCI combines the information obtained from the diversity and ubiquity variables following the iterations outlined in Hidalgo & Hausmann (2009). The method includes sequentially combining the diversity of regions and ubiquity of technological classes and simultaneously computes the following 2 equations over a series of n iterations:

KCI(regions) = $K_{r,n} = \frac{1}{K_{r,0}} \sum_i M_{r,i} K_{i,n-1}$

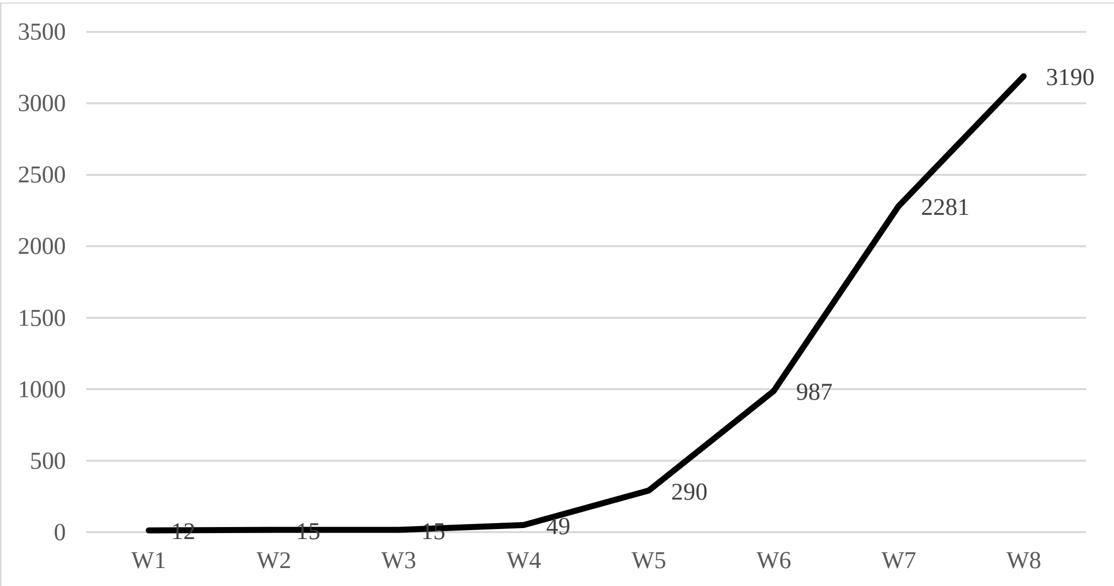
KCI (technologies) = $K_{i,n} = \frac{1}{K_{i,0}} \sum_i M_{r,i} K_{r,n-1}$

6. Findings

The findings section first demonstrates Turkey's total number patent applications and distribution of patent applications according to WIPO classes.[2] We then present the distribution and growth of patent applications across Turkey's NUTS2 regions. Third, the paper demonstrates distribution of regions according to their ability to produce and use tacit knowledge that is difficult to replicate outside the geography (knowledge complexity). The paper then continues to demonstrate the regions' ability to show technological flexibility (average relatedness density) and observe whether the regions are able to attract new technologies that are not part of their regional portfolio and diversify into related economic activities.

The findings contain eight 5-year period intervals (windows: W) during the 1978-2017 period (W1 through W8).[3]

Figure 1: Total number of patent applications (1978-2017)



Note: W1: 1978-1982: W2: 1983-1987; W3: 1988-1992; W4: 1993-1997; W5: 1998-2002; W6: 2003-2007; W7: 2008-2012; W8: 2013-2017

[2] Note that the patent application data is from OECD, REGPAT database, January 2020.
[3] W1: 1978-1982: W2: 1983-1987; W3: 1988-1992; W4: 1993-1997; W5: 1998-2002; W6: 2003-2007; W7: 2008-2012; W8: 2013-2017

Source: Authors’ own calculations from OECD, 2020.

6.1. Patent applications:

The number of patent applications indicates the size and strength of the technology market in the country (Uzun, 2001). Figure 1 demonstrates that over the 1978-2017 period, there has been an increase in total number of patent applications in Turkey. While the number of total patent applications was 12 during the 1978-1982 period (W1), the patent applications increased to over 3100 in 2013-2017 period (W8).

The increase in number of patent applications is particularly faster after W4 (1993-1997) period and onwards). This increase corresponds to the period during and after which State Planning Organization (SPO) and TUBITAK prepared the first published document on innovation policies “Science Policy of Turkey: 1983-2003” (Turkish Science Policy: 1983–2003 (in Turkish), T.C. Devlet Bakanligi, Ankara, 1983.). After the document, the Supreme Council for Science and Technology (SCST) evolved as a new institution with a mission to oversee the science and technology policies in Turkey. Mid-1990s is a turning point for the science and technology policies in Turkey with a shift from “building a national research & development infrastructure” to “innovation-oriented national policies” (Uzun, 2001). Furthermore, policy papers such as, ‘Science and Technology Human Resource Strategy and Action Plan (2011-2016)’[4] developed by ‘The Supreme Council for Science and Technology’ (SCST) with the coordination of the Ministry of Science, Industry and Technology, the Scientific and Research Council of Turkey (TUBITAK) contributed to development of National innovation policies in Turkey. Among the top national priorities of the plan are: (a) promoting research and development careers and support human resource development; (b) increasing the mobility of researchers within the European Research Area; (c) encouraging the involvement of Turkish institutions in international consortiums under Horizon 2020 programs; (d) fostering a research and innovation culture in Turkey.

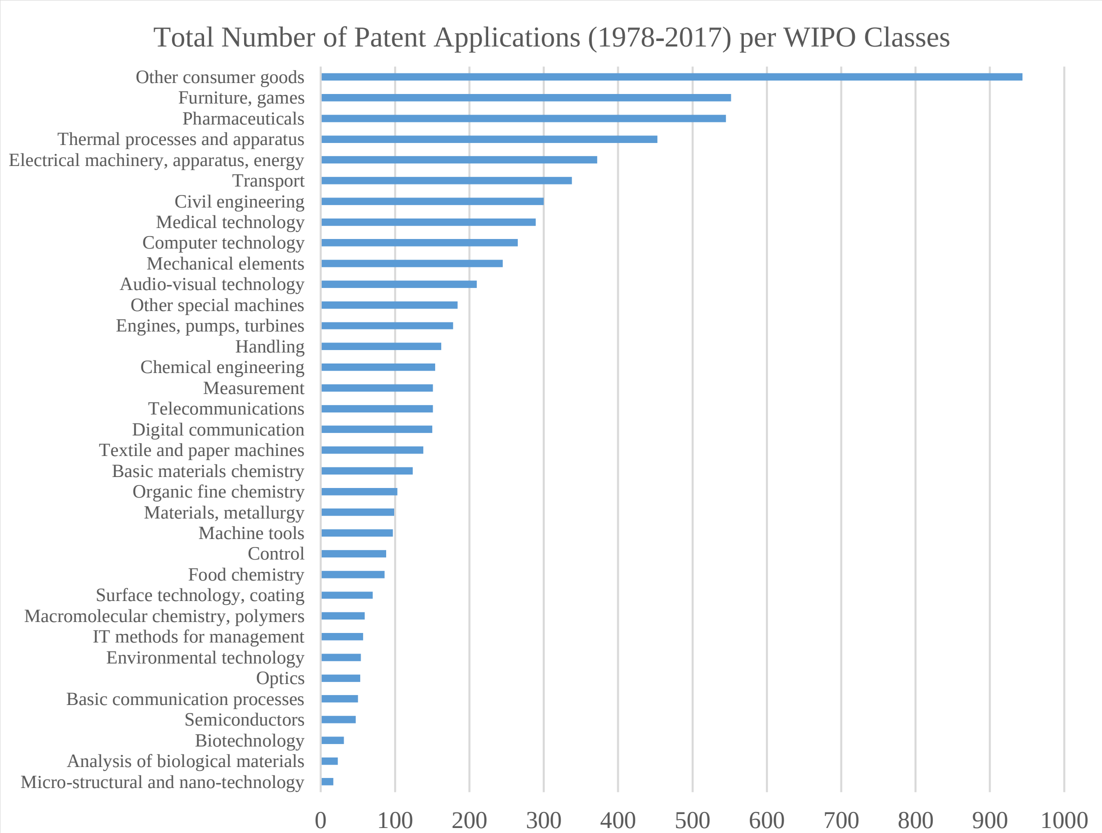
Other innovation plans include ‘Vision 2023’ project where the main theme is to create a welfare society that has a command of science and technology, uses technology consciously and can produce new technologies, and has the ability to transform technological developments into social and economic benefits. Priorities were determined to create a comprehensive innovation policy (TUBITAK, 2004). Turkey’s preparation for integration to the EU with programs to increase research and development activities provided further stimulus for Turkey’s innovation policies (Dereli & Durmus, 2009).

Another initiative to improve innovation activities in Turkey is the establishment of a platform to facilitate university-industry collaboration with an aim to produce

[4] Science and Technology Human Resource Strategy and Action Plan (2011-2016), TUBITAK, 2010.

innovative activities to increase international competitiveness of Turkey (Üniversite Sanayi İşbirliği Merkezleri Platformu, 2021). Moreover, university techno parks started to have an important place in the innovation system (Pekol & Erbaş, 2011). Additionally, signing a partnership agreement with the European Patent System at the end of 2000 can be another reason for the increase in number of patent applications where an integration across Turkish and European Patent System is reinforced thus providing a push for the development of the innovation capacity of the economy (Karaöz & Albeni, 2004).

Figure 2: Total number of patent applications (1978-2017) per WIPO classes



Source: Authors' own calculations from OECD, 2020.

Figure 2 presents the distribution of patent applications according to WIPO technological classification. The highest number of patent applications during the 1978-2017 period cover "other consumer goods", followed by "furniture, games" and "pharmaceuticals".[5]

[5] According to WIPO classification:
34: Other consumer goods include IPC classes A24#, A41B, A41C, A41D, A41F, A41G, A42#, A43B, A43C, A44#, A45#, A46B, A62B, B42#, B43#, D04D, D07#, G10B, G10C, G10D, G10F, G10G, G10H, G10K, B44#, B68#, D06F, D06N, F25D, A99Z;
33: Furniture, games include IPC classes A47#, A63#

Overall, “Other consumer goods”, according to WIPO classification, includes products such as tobacco, wearing apparel, jewelry, textiles, treatment of textiles, refrigeration and cooling all of which are low technology products. These products in this field primarily represents less research-intensive sub-fields. “Furniture, games” includes furniture; domestic articles or appliances; coffee mills; spice mills; suction cleaners in general and sports; games; amusements all of which correspond to low-tech products. Pharmaceuticals include devices and methods for medical, dental, or toilet purposes.

Pharmaceuticals correspond to high-tech sectors as defined by EUROSTAT while other consumer goods and furniture, games correspond to low-tech sectors (EUROSTAT, 2020).[6] Other high-tech sectors such as “micro-structural and Nano-technology, “analysis of biological materials” and “biotechnology” are low in number of overall patent applications. WIPO Codes and technology classification of the economic activities are in the appendices (Appendix 1 and Appendix 2).

Moreover, the type and number of patents changed during the 1978-2017 period. As demonstrated in Table 1, 25.0% of the patent applications in W1 (1978-1982) is WIPO class 31 (Mechanical elements) and 20.0% of the patent applications in W2 (1983-1987) is WIPO class 30 (Thermal processes and apparatus). In W3 (1988-1992), 46.7% of the patent applications is WIPO class 16 (Pharmaceuticals). After a high share of patent applications in pharmaceuticals during the 1988-1992 (W3), the patent applications in pharmaceuticals decreased and its share ranged between as low as 2.1% to a maximum of 13.2%.

In W4 through W8 (during the 1993-2017 period), the highest share of patent applications is on WIPO classification 34 (other consumer goods) with percentage shares of 12.2%, 15.5%, 19.5% and 16.3% and 10.3%. Overall, the patent applications in Turkey during the period of investigation covers mainly low-tech products.

16: Pharmaceuticals include IPC classes A61K not A61K-008:
“PREPARATIONS FOR MEDICAL, DENTAL, OR TOILET PURPOSES (devices or methods specially adapted for bringing pharmaceutical products into particular physical or administering forms A61J 3/00; chemical aspects of, or use of materials for deodorisation of air, for disinfection or sterilisation, or for bandages, dressings, absorbent pads or surgical articles A61L; soap compositions C11D” not “Cosmetics or similar toilet preparations”.

[6] https://ec.europa.eu/eurostat/cache/metadata/FR/htec_esms.htm (access 21.04.2021) and Eurostat indicators on High-tech industry and Knowledge – intensive services

Table 1: Percentage Distribution of Patent Applications According to WIPO Codes

WIPO codes	Periods							
	W1	W2	W3	W4	W5	W6	W7	W8
1	16,7	6,7	0,0	6,1	4,1	6,1	4,9	5,7
2	0,0	0,0	0,0	0,0	0,7	4,6	3,2	2,8
3	0,0	0,0	0,0	4,1	1,4	2,0	1,6	2,8
4	0,0	0,0	0,0	0,0	0,7	0,9	1,5	3,3
5	0,0	0,0	0,0	0,0	0,3	1,5	0,7	0,6
6	0,0	0,0	0,0	2,0	1,0	2,9	2,6	5,4
7	0,0	0,0	0,0	0,0	0,7	1,1	0,4	1,1
8	0,0	0,0	0,0	0,0	0,0	0,4	0,8	0,8
9	0,0	0,0	0,0	0,0	0,3	0,0	0,3	1,4
10	0,0	0,0	0,0	2,0	0,0	1,9	1,3	3,2
11	0,0	6,7	0,0	0,0	0,0	0,2	0,3	0,4
12	0,0	0,0	0,0	4,1	0,7	1,9	0,8	1,4
13	8,3	0,0	0,0	4,1	4,8	1,7	4,5	4,8
14	0,0	0,0	0,0	0,0	4,1	1,2	1,4	1,5
15	0,0	0,0	0,0	0,0	1,0	0,2	0,3	0,6
16	0,0	6,7	46,7	4,1	2,8	2,1	13,2	6,4
17	0,0	0,0	13,3	0,0	1,0	0,4	0,8	1,0
18	0,0	0,0	6,7	2,0	1,0	0,9	1,6	1,1
19	8,3	0,0	6,7	0,0	3,1	0,9	1,0	2,6
20	0,0	0,0	0,0	2,0	3,4	1,4	1,1	1,5
21	0,0	0,0	0,0	6,1	1,4	1,1	1,1	0,9
22	0,0	0,0	0,0	0,0	0,0	0,0	0,2	0,4
23	8,3	0,0	0,0	0,0	3,4	1,8	2,0	2,5
24	8,3	6,7	0,0	0,0	2,1	0,7	0,6	0,8
25	0,0	13,3	6,7	8,2	4,5	1,7	2,1	2,4
26	0,0	6,7	6,7	2,0	1,4	1,2	1,7	1,2
27	8,3	0,0	0,0	6,1	4,1	3,0	2,5	2,4
28	0,0	0,0	0,0	0,0	2,8	1,6	1,4	2,6
29	8,3	6,7	0,0	10,2	4,1	1,8	2,6	2,7
30	25,0	0,0	0,0	2,0	5,2	8,9	7,7	5,4
31	0,0	20,0	6,7	4,1	3,1	3,3	3,5	3,7
32	0,0	20,0	0,0	4,1	2,1	4,3	3,1	6,7
33	0,0	0,0	6,7	8,2	14,5	12,4	8,7	5,8
34	0,0	6,7	0,0	12,2	15,5	19,5	16,3	10,3
35	8,3	0,0	0,0	6,1	4,5	6,1	4,4	3,9
	100	100	100	100	100	100	100	100

Note: W1: 1978-1982: W2: 1983-1987; W3: 1988-1992; W4: 1993-1997; W5: 1998-2002; W6: 2003-2007; W7: 2008-2012; W8: 2013-2017

For WIPO codes, see, Appendix 1

Figure 3: Distribution of patents according to NUTS3 regions

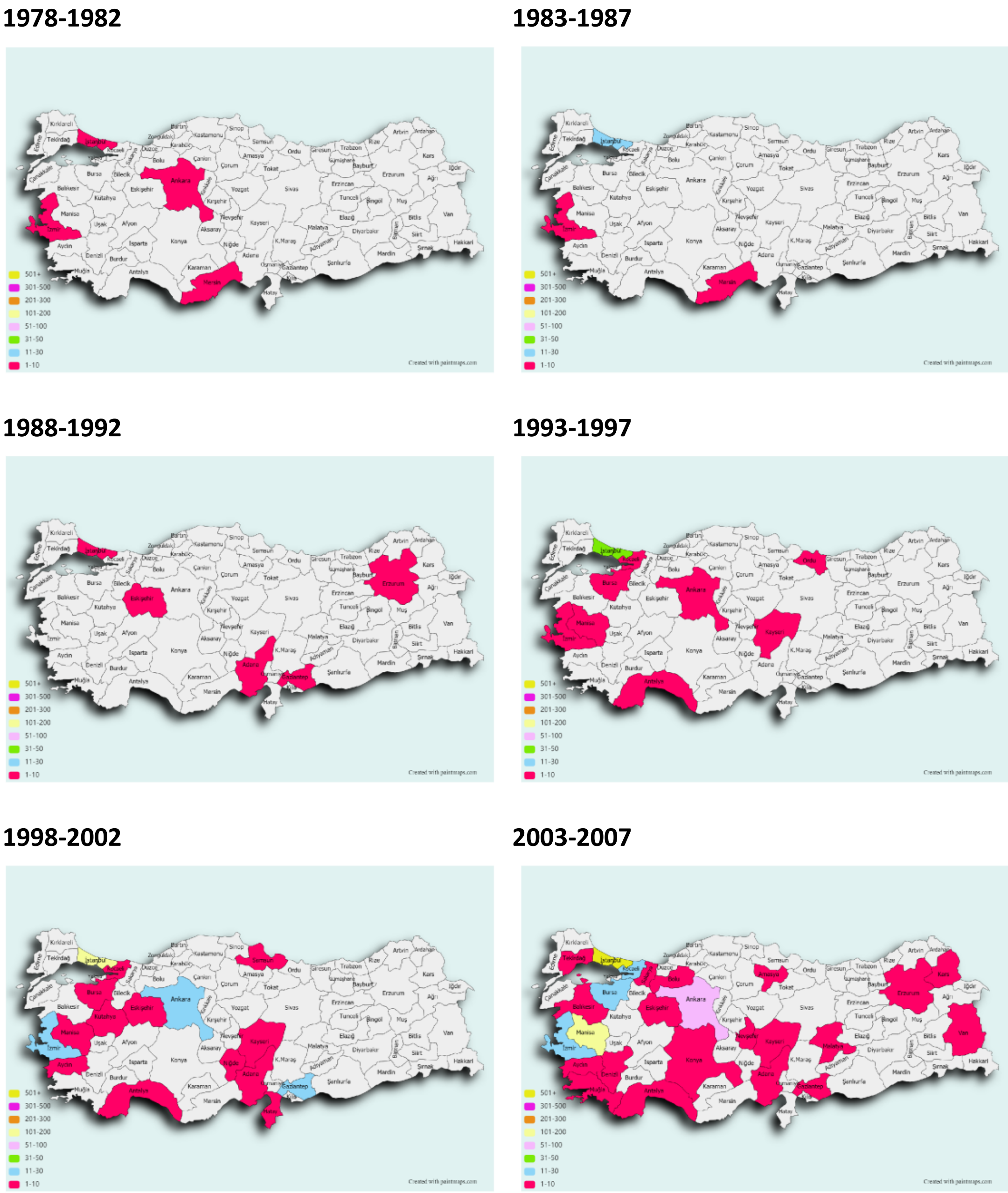
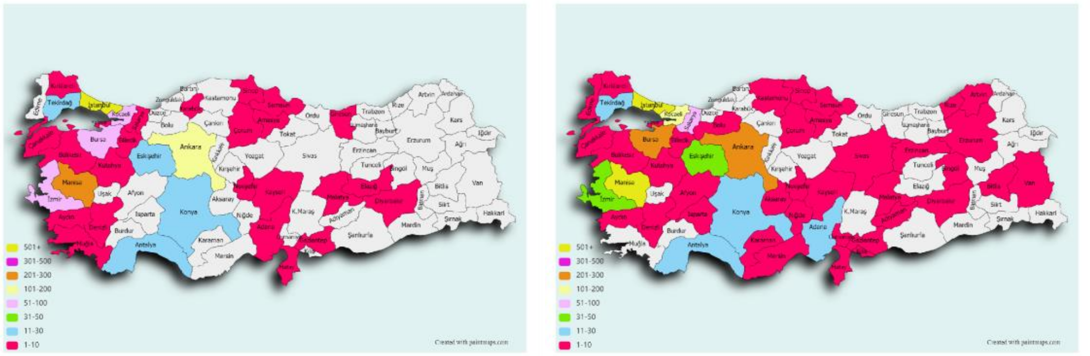


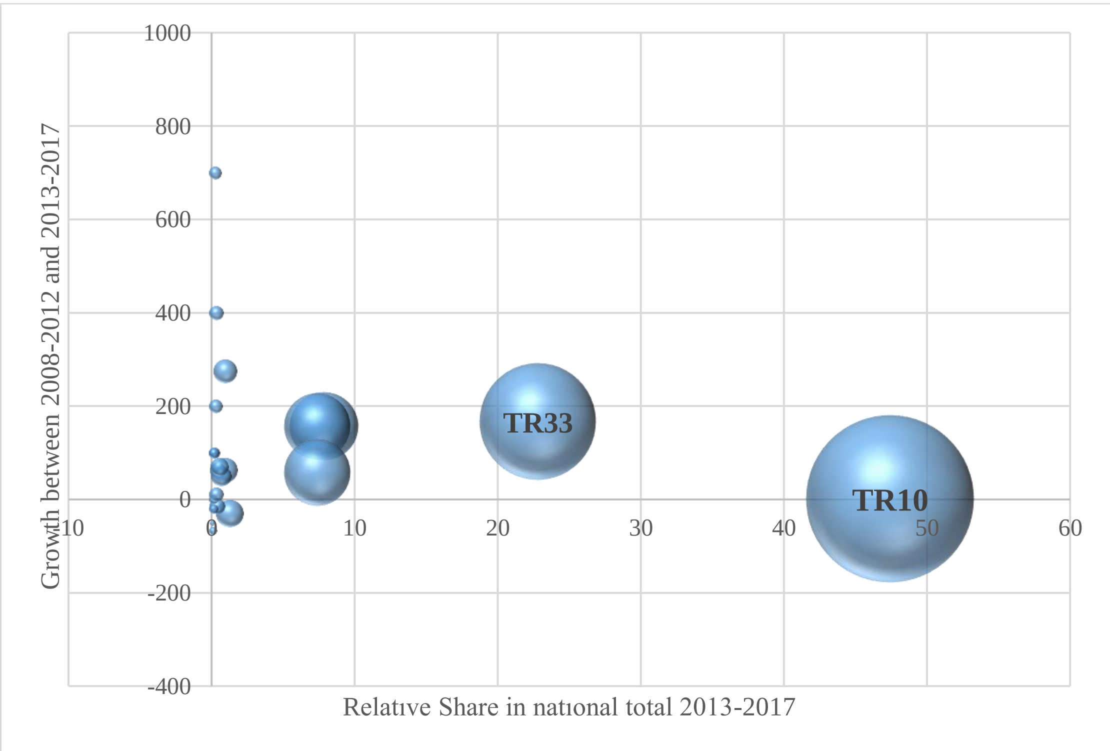
Figure 3 (Cont.):

2008-2012 **2013-2017**



The regions with no color denote no patent applications.
Source: Authors' own calculations from OECD, 2020.

Figure 4: Growth rate and share of patents (percentage) (NUTS2 regions) (2013-2017)



Source: Authors' own calculations from OECD, 2020.

6.2. Regional distribution of patents:

As demonstrated in Figure 3, a notable number of patent applications are in Turkey's three largest metropolitan cities, Istanbul, Ankara and Izmir, showing that large metropolitan areas create patents. The figure further points out that distribution of patent applications is generally higher in the western part of Turkey, most of which are in Istanbul and Manisa, while eastern provinces start to show increase in patent applications.

Figure 4 presents the relative shares and growth rates of patent applications during the 2013-2017 period.[7] TR10 (Istanbul) and TR33 (Manisa) together constitute more than half of Turkey's patent applications, with shares 47.4% and 22.8%, respectively. The rest of the patents are distributed across Turkey's other regions, where TR41 (Bursa), TR42 (Kocaeli) and TR51 (Ankara) are the next highest in share of patents (7.8%, 7.4% and 7.3, respectively) with a total growth rate of less than 10% over 5 years. Growth rates of patent applications for the regions with already low share of patents are low. Conversely, growth rates of patent applications for the regions with already high share of patents are high; indicating that the gap across regional distribution of patent applications is likely to increase in favor of regions with already high number of patent applications.

6.3. Knowledge Complexity of the Regions

The number of patents is only one indication of the innovativeness of the region. In order to be innovative and at the same time sustain competitiveness, the quality of the knowledge created in the region should be among key concerns. Knowledge is valuable if it is difficult to replicate outside the geography. Knowledge that is tacit and sticky in the field is a source for competitive advantage for the regions. As explained in the methods section, the variable that measures complexity of knowledge in regions is knowledge complexity index of the region (KCI regional). Figure 5 shows the knowledge complexity indices of Turkey's NUTS3 regions.

It is possible to follow the knowledge complexity of regions from maps in periods of five years during the 1978-2017 period. The maps demonstrate that there is no variability in the first four maps; therefore, it is not possible to make sound comments.

As the number of patent applications and geographic variability increases as of 1998-2002 period, we observe that the provinces on the western part of Istanbul-Ankara-Niğde-Hatay axis have higher complexity. Complexity decreases as we move to the Eastern provinces.

[7] To make the graph visually simpler, we aggregated the data to NUTS2 regions in Figure 4.

Figure 5: Knowledge Complexity of the Regions (NUTS3 Regions)

1978-1982

1983-1987

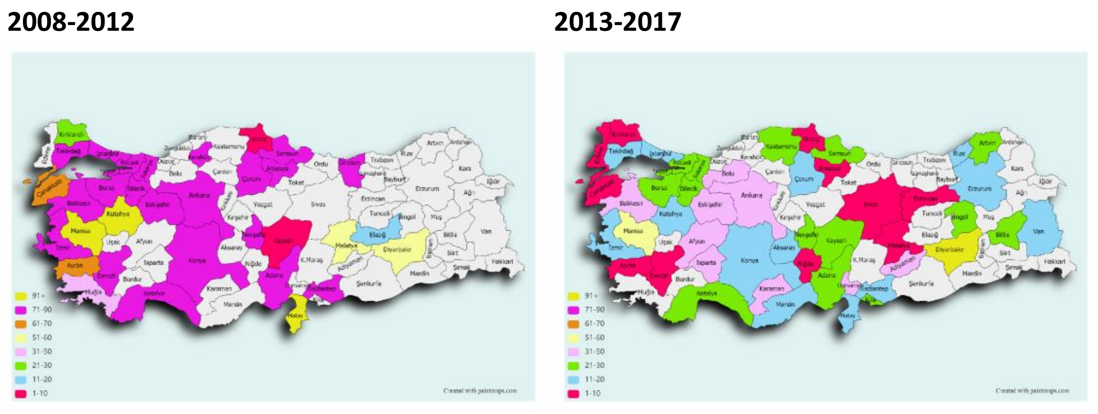
1988-1992

1993-1997

1998-2002

2003-2007

Figure 5 (Cont.):



The regions with no color denote no patent applications.
Source: Authors' own calculations from OECD, 2020

Complexity of Istanbul decreased after 2003 and we see that Konya and Malatya started to increase in complexity, followed by Erzurum. Eastern provinces surpassed western part of the country during the 2003-2007 period with Kars and Van joining as highly complex regions.

After 2008, the pattern changes again in favor of western provinces where Manisa, Kütahya and Hatay increased in complexity. During the 2008-2012 period, western regions in terms of complexity became more homogeneous while in the East, the complexity declined. During 2013-2017, it is possible to say that complexity became homogenous across the country, with Diyarbakır having the highest index for knowledge complexity.

Overall, during the 1978-2017 period, the regional complexity was mostly higher in western provinces until 2012. During the 2013-2017 period, the regional knowledge complexity index became uniform across the regions, indicating that ability to keep unique and hard-to-imitate knowledge in the region became harder. Consequently, the possibility of limiting imitations/replications outside the geographies became lower.

6.4. Average Relatedness Density of the Regions

The emergence of new technologies in the regions is not random and innovations and new technologies depend on existing set of capabilities (Boschma, 2017). Frenken & Boschma (2007) propose that diversification of the economic activities is a branching process and the emergence of new technologies is reliant on past knowledge.

Figure 6: Average Relatedness Density of the Regions (NUTS3 Regions)

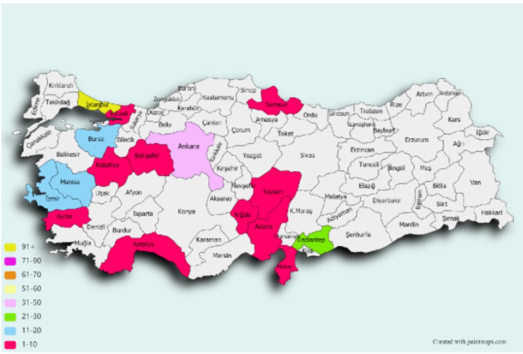
1978-1982

1983-1987

1988-1992

1993-1997

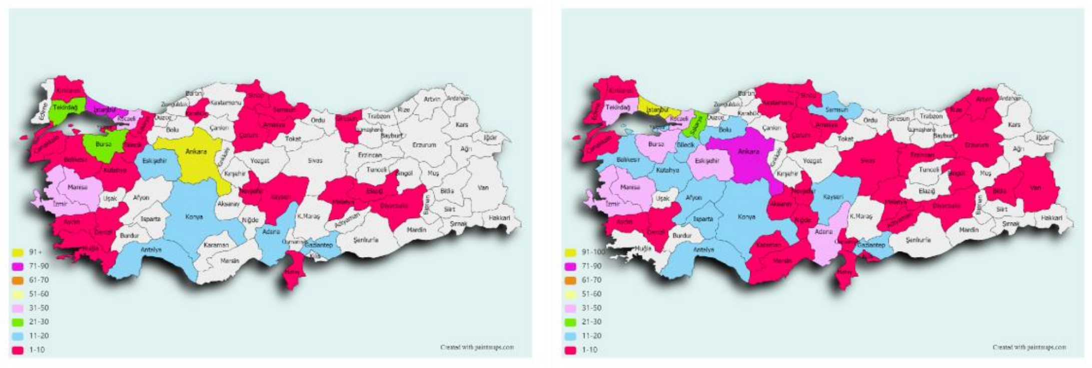
1998-2002



2003-2007

Figure 6 (Cont.):

2008-2012 **2013-2017**



The regions with no color denote no patent applications.
Source: Authors’ own calculations from OECD, 2020.

In order to show the regional branching opportunities in Turkey, we present changes in average relatedness density of the regions during the 1978-2017 period. Average relatedness density shows the potential of new and related technologies to enter the region.

Figure 6 shows regional branching opportunities in Turkey. We observe that relatedness density increases in the western provinces, particularly in Istanbul and Ankara, then in Bursa, Kocaeli, İzmir, Manisa while Tekirdağ and Muğla start to follow. Overall, we see that the average relatedness density is higher in the western provinces particularly on the western side of the Istanbul-Bursa-Ankara-Adana axis.

7. Conclusion

The paper reveals developments in innovative activities in Turkey with presenting patent applications and regional distribution of patents during the 1978-2017 period. The paper further explores how Turkey’s regions have evolved concerning knowledge complexity and relatedness density, where complexity corresponds to the ability of regions’ uniqueness and possess tacit and valuable knowledge. The complexity of the region shows that the regional knowledge is difficult to access and region is able to keep and sustain competitiveness. Relatedness density reveals the regions’ ability to attract new and related technologies with a potential to evolve into innovative (related) new products and processes.

Overall, the results show four major outcomes:

First, we see that patent applications in Turkey during the 1978-2017 period are mostly low-tech products where highest patent applications are for “other consumer goods”, and “furniture and games”. Although “Pharmaceuticals” is the third highest share of technology group in total patent applications, the high share is due to the five-year period, 1988-1992 where the pharmaceutical share was 46.2%. After 1992, the share of pharmaceuticals decreases to levels between 2.8% to 13.2%. During the last five 5-year periods, “other consumer goods”, a group consisting of low technology products, continue to have the highest share in total patent applications.

Second, the distribution of patent applications, knowledge complexity and relatedness density are uneven across space in Turkey. In general, we see that the western regions are better in innovativeness.

Third, until 2012, the knowledge complexity of the western regions increased indicating presence of tacit technologies that are difficult to access. However, the distribution of complexity index became uniform after 2012. During the 2013-2017 period, the difference between western and eastern provinces became less visible. Diyarbakır became the highest technologically complex region in the country.

Fourth, for all five-year periods, the ability of the regions to attract related technologies is higher for the western provinces. This means that the western provinces (west of Istanbul-Bursa-Ankara-Adana axis) have potentially higher ability to create innovative products and processes that are compatible to their existing knowledge bases. The results show that smart specialization policies would work better for the provinces that are on the western part of Turkey, where patent applications and relatedness density are higher. It would then be possible to create regions that are more technologically complex and difficult to imitate for sustainable competitiveness.

The next step is to investigate and verify the connection between innovativeness with relatedness density and technological complexity in Turkey. Although the paper is a preliminary attempt to show long run patterns of innovative activities, the paper reveals uneven regional distribution of smart specialization patterns and conditions to attract potential new technologies to the regions are diverse across Turkey. The paper supports the idea that smart specialization policy based on the relatedness framework is not a one-size fits all policy and all regions ought to focus on their existing portfolios to draw new economic activities.

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Appendix 1: WIPO codes

	Area, field	IPC code
I	**Electrical engineering**	
1	Electrical machinery, apparatus, energy	F21#, H01B, H01C, H01F, H01G, H01H, H01J, H01K, H01M, H01R, H01T, H02#, H05B, H05C, H05F, H99Z
2	Audio-visual technology	G09F, G09G, G11B, H04N-003, H04N-005, H04N-009, H04N-013, H04N-015, H04N-017, H04R, H04S, H05K
3	Telecommunications	G08C, H01P, H01Q, H04B, H04H, H04J, H04K, H04M, H04N-001, H04N-007, H04N-011, H04Q
4	Digital communication	H04L
5	Basic communication processes	H03#
6	Computer technology	(G06# not G06Q), G11C, G10L
7	IT methods for management	G06Q
8	Semiconductors	H01L
II	**Instruments**	
9	Optics	G02#, G03B, G03C, G03D, G03F, G03G, G03H, H01S
10	Measurement	G01B, G01C, G01D, G01F, G01G, G01H, G01J, G01K, G01L, G01M, (G01N not G01N-033), G01P, G01R, G01S; G01V, G01W, G04#, G12B, G99Z
11	Analysis of biological materials	G01N-033
12	Control	G05B, G05D, G05F, G07#, G08B, G08G, G09B, G09C, G09D
13	Medical technology	A61B, A61C, A61D, A61F, A61G, A61H, A61J, A61L, A61M, A61N, H05G
III	**Chemistry**	
14	Organic fine chemistry	(C07B, C07C, C07D, C07F, C07H, C07J, C40B) not A61K, A61K-008, A61Q
15	Biotechnology	(C07G, C07K, C12M, C12N, C12P, C12Q, C12R, C12S) not A61K
16	Pharmaceuticals	A61K not A61K-008
17	Macromolecular chemistry, polymers	C08B, C08C, C08F, C08G, C08H, C08K, C08L
18	Food chemistry	A01H, A21D, A23B, A23C, A23D, A23F, A23G, A23J, A23K, A23L, C12C, C12F, C12G, C12H, C12J, C13D, C13F, C13J, C13K
19	Basic materials chemistry	A01N, A01P, C05#, C06#, C09B, C09C, C09F, C09G, C09H, C09K, C09D, C09J, C10B, C10C, C10F, C10G, C10H, C10J, C10K, C10L, C10M, C10N, C11B, C11C, C11D, C99Z

20	Materials, metallurgy	C01#, C03C, C04#, C21#, C22#, B22#
21	Surface technology, coating	B05C, B05D, B32#, C23#, C25#, C30#
22	Micro-structure and nano-technology	B81#, B82#
23	Chemical engineering	B01B, B01D-000#, B01D-01##, B01D-02##, B01D-03##, B01D-041, B01D-043, B01D-057, B01D-059, B01D-06##, B01D-07##, B01F, B01J, B01L, B02C, B03#, B04#, B05B, B06B, B07#, B08#, D06B, D06C, D06L, F25J, F26#, C14C, H05H
24	Environmental technology	A62D, B01D-045, B01D-046, B01D-047, B01D-049, B01D-050, B01D-051, B01D-052, B01D-053, B09#, B65F, C02#, F01N, F23G, F23J, G01T, E01F-008, A62C
IV	**Mechanical engineering**	
25	Handling	B25J, B65B, B65C, B65D, B65G, B65H, B66#, B67#
26	Machine tools	B21#, B23#, B24#, B26D, B26F, B27#, B30#, B25B, B25C, B25D, B25F, B25G, B25H, B26B
27	Engines, pumps, turbines	F01B, F01C, F01D, F01K, F01L, F01M, F01P, F02#, F03#, F04#, F23R, G21#, F99Z
28	Textile and paper machines	A41H, A43D, A46D, C14B, D01#, D02#, D03#, D04B, D04C, D04G, D04H, D05#, D06G, D06H, D06J, D06M, D06P, D06Q, D99Z, B31#, D21#, B41#
29	Other special machines	A01B, A01C, A01D, A01F, A01G, A01J, A01K, A01L, A01M, A21B, A21C, A22#, A23N, A23P, B02B, C12L, C13C, C13G, C13H, B28#, B29#, C03B, C08J, B99Z, F41#, F42#
30	Thermal processes and apparatus	F22#, F23B, F23C, F23D, F23H, F23K, F23L, F23M, F23N, F23Q, F24#, F25B, F25C, F27#, F28#
31	Mechanical elements	F15#, F16#, F17#, G05G
32	Transport	B60#, B61#, B62#, B63B, B63C, B63G, B63H, B63J, B64#
V	**Other fields**	
33	Furniture, games	A47#, A63#
34	Other consumer goods	A24#, A41B, A41C, A41D, A41F, A41G, A42#, A43B, A43C, A44#, A45#, A46B, A62B, B42#, B43#, D04D, D07#, G10B, G10C, G10D, G10F, G10G, G10H, G10K, B44#, B68#, D06F, D06N, F25D, A99Z
35	Civil engineering	E02#, E01B, E01C, E01D, E01F-001, E01F-003, E01F-005, E01F-007, E01F-009, E01F-01#, E01H, E03#, E04#, E05#, E06#, E21#, E99Z

Note: This table is available in Excel format on: *www.wipo.int/ipstats/en/statistics/patents*

Source: WIPO IPC-Technology Concordance Table.

Appendix 2: Technology and Knowledge Classification[8]

Technology Classification

High technology
Manufacture of basic pharmaceutical products and pharmaceutical preparations. Manufacture of computer, electronic and optical products.
Medium-high technology
Manufacture of chemicals and chemical products. Manufacture of electrical equipment. Manufacture of machinery and equipment n.e.c. Manufacture of motor vehicles, trailers and semi-trailers. Manufacture of other transport equipment.
Medium-low technology
Manufacture of coke and refined petroleum products. Manufacture of rubber and plastic products. Manufacture of other non-metallic mineral products. Manufacture of basic metals. Manufacture of fabricated metals machinery and equipment; products, except machinery and equipment Repair and installation of machinery and equipment.
Low technology
Manufacture of food products, beverages, tobacco products, textile, wearing apparel, leather and related products, wood and of products of wood, paper and paper reproduction of recorded media. Manufacture of furniture. Other manufacturing

Knowledge Classification

Knowledge intensive services
Water transport. Air transport. Publishing activities. Motion picture, video and television programme production, sound recording and music publish activities. Programming and broadcasting activities. Telecommunications; computer programming, consultancy and related activities; Information service activities (section J). Financial and insurance activities (section K).

[8] Source: https://ec.europa.eu/eurostat/cache/metadata/FR/htec_esms.htm (access 21.04.2021) and Eurostat indicators on High-tech industry and Knowledge – intensive services (Annex 3 – High-tech aggregation by NACE Rev.2).

Legal and accounting activities; Activities of head offices, management consultancy activities. Architectural and engineering activities, technical testing and analysis; Scientific research and development. Advertising and market research; Other professional, scientific and technical activities; Veterinary activities (section M). Employment activities. Security and investigation activities. Public administration and defence, compulsory social security (section O). Education (section P). Human health and social work activities (section Q). Arts, entertainment and recreation (section R).
Knowledge intensive market eservices (excluding high-tech and financial services)
Water transport. Air transport. Legal and accounting activities. Activities of head offices, management consultancy activities. Architectural and engineering activities, technical testing and analysis. Advertising and market research. Other professional, scientific and technical activities. Employment activities. Security and investigation activities.
High-tech knowledge intensive services
Motion picture, video and television programme production, sound recording and music publish activities. Programming and broadcasting activities. Telecommunications; computer programming, consultancy and related activities. Information service activities. Scientific research and development.
Knowledge intensive financial services
Financial and insurance activities (section K).
Other knowledge intensive services
Publishing activities. Veterinary activities. Public administration and defense, compulsory social security (section O). Education (section P). Human health and social work activities (section Q). Arts, entertainment and recreation (section R).
Less knowledge intensive services (LKIS)
Wholesale and retail trade; Repair of motor vehicles and motorcycles (section G). Land transport and transport via pipelines. Warehousing and support activities for transportation; Postal and courier activities. Accommodation and food service activities (section I). Real estate activities (section L). Rental and leasing activities. Travel agency, tour operator reservation service and related activities. Services to buildings and landscape activities. Office administrative, office support and other business support activities. Activities of membership organization. Repair of computers and personal and household goods. Other personal service activities (section S). Activities of households as employers of domestic personnel.

Undifferentiated goods- and services-producing activities of private households for own use (section T). Activities of extraterritorial organisations and bodies (section U).
Less knowledge intensive market services
Wholesale and retail trade. Repair of motor vehicles and motorcycles (section G). Land transport and transport via pipelines. Warehousing and support activities for transportation. Accommodation and food service activities (section I). Real estate activities (section L). Rental and leasing activities. Travel agency, tour operator reservation service and related activities. Services to buildings and landscape activities. Office administrative, office support and other business support activities. Repair of computers and personal and household goods.
Other less knowledge intensive services
Postal and courier activities. Activities of membership organization. Other personal service activities. Activities of households as employers of domestic personnel. Undifferentiated goods- and services-producing activities of private households for own use (section T). Activities of extraterritorial organisations and bodies (section U).

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Regional Inequalities in Greece During a Time of Flux

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Abstract

Following the 2008 global financial crisis Eurozone countries and specifically countries at the periphery suffer severely reminding the rise of depression economics among the region. Originating from its fiscal troubles Greece is one of the countries which has been heavily hit by the adverse effects of the crisis. Keeping discussions on the macroeconomic fundamentals of Greece on one side, this study diverts the attention towards the extent and path of regional inequalities with specific focus on the post 2000 turmoil period in Greece. Our findings indicate the existence of a long convergence episode in Greece from 1980s and onwards with no exception during the crisis. We also find strong evidence for the existence of spatial spillovers with some cyclical behaviour. However, our additional analyses identify that spatial dependence and heterogeneity works together for the Greek case, resulting in sizable spatial variability in the speed of convergence accelerating during the post crisis period. Moreover, we discuss that observed post crisis convergence is a downward one which shifts its geographic extent reminding the possibility of a reshuffling among the Greek regions.

JEL Codes: R10, R11

Keywords: Convergence, Greece, spatial inequalities.

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Kriz Döneminde Yunanistan'da Bölgesel Eşitsizlikler

Öz

2008 küresel krizi sonrası Avrupa bölgesinde çevre ekonomileri olarak tanımlanan ülkelerin krizden daha fazla etkilenmiş olduğu görülmektedir. Bununla birlikte durgunluk ekonomisinin derin etkilerinin bölgede görülmeye başladığı tartışılmaktadır. Yunanistan'ın mali sorunları ile birlikte krizden en çok etkilenen Avrupa ülkelerinin başında geldiği de ayrıca bilinmektedir. Bu çalışma tüm bu tartışmalara ek olarak Yunanistan'da bölgesel eşitsizliklerin ilgili dönemde nasıl ilerlediğine odaklanmaktadır. Bulgular Yunanistan'da 1980'lerde başlayan ve 2000'li yıllarda hızlanan bir yakınsamanın varlığını göstermektedir. Ek olarak tüm dönem boyunca mekânsal dışsallıkların etkin olduğu görülmektedir. Ancak mekânsal bağlar ve heterojenlikler yakınsama hızında yüksek varyasyon oluşmasına neden olmaktadır. Bu yapı içinde yakınsamanın bir kulüp oluşumuna neden olduğu ve bölgelerin yakınsama patikaları ile mekânsal refahları arasında bir ilinti olduğu görülmektedir. Bu etkinin kriz sonrası dönemde daha da şiddetlendiği görülmekte ve yakınsamanın aşağı doğru bir yakınsama olduğu düşünülmektedir.

JEL Kodları: R10, R11

Anahtar kelimeler: Mekânsal eşitsizlikler, yakınsama, Yunanistan

1. Introduction

In recent years Greece has attracted much publicity and policy analysis due to its ongoing fiscal difficulties and the deep economic crisis it has experienced since 2009 – having lost almost a quarter of its GDP in the space of five years. Quite naturally, given the challenges facing Greece in relation to its Eurozone membership, attention in the relevant policy and academic debates has focused predominantly on questions that have to do with national development problems and national growth dynamics. An interesting – if not disconcerting – consequence of this has been that attention to regional evolutions and problems has been at best peripheral – especially outside the regional-scientific community in Greece. In relation to the latter, a body of work has slowly started to emerge looking at the regional economic impact of the crisis in the country (Monastiriotis, 2011; Monastiriotis and Martlelli, 2013; Psycharis et al, 2014a; Psycharis et al, 2014b; Monastiriotis, 2014; Karahasan and Monastirotis, 2017). However, a wider and more extensive study of the regional responses to the crisis and the adjustments that took place across space at the sub-national level during this period, let alone an examination for how these may link to longer-run distributional dynamics and past regional evolutions, is notably missing from the literature.

Our screening of the literature confirms that Greece has been under investigated by the literature on regional disparities in Europe. One battery of the discussions follows the ‘neoclassical convergence’ tradition. For instance, Siriopoulos and Asteriou (1998), Petrakos and Saratsis (2000), Ioannides and Petrakos (2000), Michelis et al (2004), Christopoulos and Tsionas (2004), Benos and Karagiannis (2008) and Lolos (2009) use different versions of the neoclassical convergence model and confirm the existence of a catch up effect across the Greek regions. While these studies carry out a detailed discussion on the path of the regional disparities, a related dimension of the process is examined within the spatial and distributional dynamics of income distribution. Tsionas (2002) and Alexiadis and Tomkins (2004) used different versions of Markov chain analysis and highlighted that despite continuous signs of convergence at global level different episodes from 1970 and onwards witness the formation of convergence clubs thus regional income polarization.

Despite these influential attempts to examine the regional disparities in Greece, there seems to be lack of detailed analysis of the local variations of the regional dynamics. That is both spatial spillovers as well as spatial heterogeneity can be crucial aspects of inequalities and distributional dynamics both of which are possible influences on the formation of local policies. We believe investigating the regional disparity issue and measuring the extent of spatial ties are both complementary analysis that can be even augmented by the inclusion of the examination of local variations.

Originating from this gap, in this paper we seek to make a contribution in this direction by providing a more holistic analysis of regional evolutions and growth dynamics in Greece, within a spatial economic analysis context, for the 1980-2012 period. This we believe will allow us to understand the peculiarity of the post crisis environment in Greece compared to other sub-intervals. We start by an examination of sigma- and beta-convergence, but examine simultaneously the role of space (in the form of proximity and spatial association) in conditioning the pace and extent of convergence. At this stage we aim at incorporating the impact of spatial spillovers through the use of spatial econometrics tools. However, we find it noteworthy to remark that, diverting the attention towards to the spatial variability issue is the central expected contribution of the article. Using the Geographically Weighted Regression (GWR) approach we calculate the spatial variability of the beta convergence and question whether each region of Greece realize the same level of convergence (or divergence) in terms of regional inequalities. Finally, we also examine a spatially augmented version of transition probability analyses to evaluate the extent of club convergence.

Throughout our analysis we look at the issues under study across four separate periods, starting from 1980, the year before Greece's accession to the EU, and going up to 2012, which is reasonable close to the point representing the height of the crisis.[1] This allows us to investigate in depth two issues that we see as interrelated.[2] First, the patterns of regional growth and the spatial dynamics underpinning them over the long-run period, i.e. in the 'good times' before the eruption of the crisis. Second, the regional responses to the crisis and the adjustments that took place across space at the sub-national level during the crisis period.

Our analysis reveals a number of interesting findings that have never before been considered for Greece – and are indeed rather understudied also in the international literature more widely. We find that Greek regions are undergoing a period of convergence since 1980s but also we identify that this speed of convergence has a spatio-temporal pattern that varies among different sub periods and midst different geographies. This we believe complements the previous findings/literature and also sheds new light on the understanding of regional growth processes and dynamics in the country. Additionally, we find spatial dependence as an ingredient part of the regional convergence in Greece. On the other hand, we also find strong empirical evidence on the spatial heterogeneity of regional income differences as well as the speed of convergence. Specifically, in relation to the crisis period, we further find that speed of

[1] At the national level, the rate of decline in real GDP subsided significantly after the first quarter of 2013 and was essentially reversed by the end of that year (indeed, in 2014Q1 Greece registered a positive growth rate for the first time since the start of the crisis).

[2] Our argument here, as we discuss more fully later in the paper, is that the regional responses and adjustment patterns during the crisis should not be seen as independent from the dynamics and evolutions that characterised the pre-crisis period. Studying these two in isolation (i.e., separately for the crisis and pre-crisis periods) thus reduces, in essence, the informational value of the analysis.

convergence accelerates in all parts of the country yet reversed in terms of its relative speed in some specific regions of the country, which suggests that regional problems may persist well beyond the prospective / hoped-for "Grecovery".

The structure of the paper is as follows. Section 2 starts with a presentation and discussion of our method (with more attention paid to those parts of our approach that have not been too widely applied in the literature), the case at hand (especially talking about the four periods and the Greek political-economic context in each of these) and our data (information about sources and comparability issues – basic descriptives are presented later). Section 3 presents (some descriptives and) our base results on the issue of convergence and evidence on the extent and structure of regional disparities (sigma-convergence and decomposition). Section 4 constructs the traditional beta convergence models and implements two different extensions by incorporating the role played by the spatial ties. First we augment the traditional convergence models by controlling for spatial dependence, next we aim at using spatial heterogeneity concept in order to question the local instability of the convergence. Section 5 carries out a set of transition probability analyses to understand the extent of club convergence during the period of analysis. We also consider the spatiality of the transitions in order to test whether the club formation has a distinct geographical pattern. The last section concludes with some reflections on the dynamics of regional growth in Greece and the role of the crisis – and of the prospective recovery – in these.

2. Data and Methodology

In order to better apprehend the evolutions for the post 2000 period, we decide to follow a strategy to understand the historical origins of the regional imbalances in Greece. We consider the post 1980 period by investigating the developments in four different sub-intervals. In that sense while 1980-1990 sheds light on the roots of the inequalities during the accession to European Union, 1990-2000 period summarizes the path of inequalities in Greece during its so called good times right before our focus period. 2000-2008 interval will give in-debt overview of the environment with entrance to European Monetary Union (EMU) in 2001; naturally this period will give information on the pre-crisis environment. Finally post 2008 period represents the central focus of the study on the impact of the debt crisis on the regional imbalances in Greece. Data for the pre 2000 period comes from Cambridge Econometrics (CAMECON) and for the post 2000 period we used the official statistical data base of Hellenic Statistical Authority (ELSTAT).

In general, the "convergence" framework relies on the decreasing returns principle of the neoclassic production function (Solow, 1956). Later on Barro and Sala-i Martin (1992) formalize the convergence model; that is cross country as well as regional differences can be explained based on two specific convergence measures. Sigma convergence is a dispersion figure which basically measures the cross section standard deviation. Beta convergence on the other hand constructs a relationship between the initial income level of regions with an average rate of growth for a given time interval. Equation 1 is the traditional beta convergence model, where $y_{i,0}$ is the per capita income of region i in the initial year and T is the time span of the analysis. The left hand side of equation 1 measures the growth rate of per capita income, α is the constant, $\left(1-e^{-\lambda T}\right)$/T is the coefficient of the initial income that we denote by β and finally $u_{i,t}$ is the error term. Model measures the unconditional (absolute) convergence; a negative value for β represents the absolute beta convergence. Note that it is also possible to calculate the speed of convergence and the half –life of convergence by λ and t^*.

$$\frac{1}{T}\ln\left(\frac{y_{i,T}}{y_{i,0}}\right)=\alpha+\frac{1}{T}\left(1-e^{-\lambda T}\right)\ln\left(y_{i,0}\right)+u_{i,t} \;\; ; \;\; \lambda=-\frac{\ln(1+\beta.T)}{T} \;\; ; \;\; t^*=-\frac{\ln(1/2)}{\lambda} \qquad [1]$$

While sigma and beta convergence measures are commonly used, another measure that can yield additional on the source on the inequalities is the Theil Index (Bourguignon; 1979). Theil Index (Equation 2) enables us to decompose the inequalities into inter and intra-regional inequalities by implementing a decomposition. y_i and x_i are the relative shares provincial income and population thus measures the between inequalities. Meanwhile Y_g is the region g's share in total national income and T_g is the Theil Index that measures disparities among provinces in region g.

$$T=\sum_{i=1}^{n} y_i \log\left(\frac{y_i}{x_i}\right)+\sum_{g=1}^{n} Y_g T_g \qquad [2]$$

Combes et al. (2008) pin point that spatial concentration measures can be a good proxy to underline agglomeration of economic activity. In a way rising spatial concentration can be treated as a proxy for divergence. Among different measures Moran's I spatial auto-correlation statistics is commonly used (Equation 3). *n* is the number of local units and *s* is the summation of the all elements in the weight matrix (*w*).[3]

[3] In addition to the measurement of the spatial association at the global scale, a further dimension of the spatial dependence is the local decomposition of the spatial dependence. Anselin (1995) proposed the use of Local Indicator of Spatial Association (LISA) in order to observe the local variation of the spatial dependence via; $I_i=\left(x_i-\bar{x}\right)\sum_j w_{ij}\left(x_j-\bar{x}\right)$. LISA analysis gives four major groups for local spatial association. Regions with above and below average income in spatial association forms the High-High and Low-Low clusters while regions with high income in close proximity to low income regions and regions with low income in close proximity to high income regions are represented as High-Low and Low-High outliers respectively.

$$I_i = \frac{n}{s} \frac{\sum_i \sum_j w_{ij} (x_i - \bar{x})(x_j - \bar{x})}{\sum (x_i - \bar{x})^2} \quad [3]$$

While spatial auto-correlation measure contains information on the extent of the spatial inequalities, there are additional motives embedded within spatial ties and spillovers. The neoclassic convergence model presumes that regions are isolated and no spillover among them takes place. Rey and Mountouri (1999) discuss that neglecting the impact of spatial effects may cause in biased estimates of the true speed of convergence. Indeed the convergence model introduced in Equation 1 can be further augmented by including the impact of spatial dependence. Spatial Lag Model (SAR) and Spatial Error Model (SEM) can be estimated in an unconditional way as in Equations 4 and 5 respectively.

$$\frac{1}{T}\ln\left(\frac{y_{i,T}}{y_{i,0}}\right) = \alpha + \rho W \frac{1}{T}\ln\left(\frac{y_{i,T}}{y_{i,0}}\right) + \frac{1}{T}\left(1-e^{-\lambda T}\right)\ln\left(y_{i,0}\right) + u_{i,t} \quad [4]$$

$$\frac{1}{T}\ln\left(\frac{y_{i,T}}{y_{i,0}}\right) = \alpha + \frac{1}{T}\left(1-e^{-\lambda T}\right)\ln\left(y_{i,0}\right) + \lambda W \varepsilon + u_{i,t} \quad [5]$$

Even spatially augmented versions of the convergence models earn increasing attention, recent discussions shift towards to the instability of the convergence. That is, even the spatial convergence models incorporate the spatial dependence, they neglect and fail to control for the possibility of the spatial heterogeneities and/or spatial non-stationarity. This may result in over/under representation of convergence as it is possible to observe spatial variation in the measured speed of convergence. The problem of spatial heterogeneity can be best controlled for by the use of the Geographically Weighted Regression (GWR) approach. As discussed by Brunsdon et al. (1998), Fotheringham and Brunsdon (1999), Fotheringham et al. (2002) GWR allows in the estimation of local parameter estimates. Equation 6 is a different way of measuring convergence in a GWR setting allowing for the determination of local beta estimates for each region.

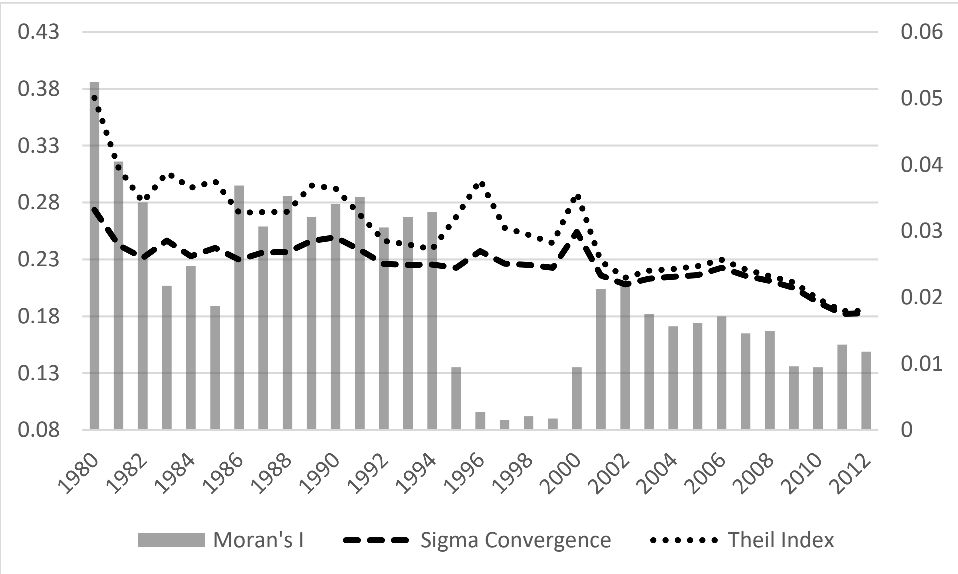
$$\frac{1}{T}\ln\left(\frac{y_{i,T}}{y_{i,0}}\right) = \alpha\left(u_i, v_i\right) + \frac{1}{T}\left(1-e^{-\lambda T}\right)\left(u_i, v_i\right)\ln\left(y_{i,0}\right) + u_{i,t} \quad [6]$$

GWR is a weighted regression where related weights are determined by the neighbour effects. The crucial item is the determination of the neighbour effects through a bandwidth and a kernel. The bandwidth which is embedded in the kernel defines the units to be considered as neighbours. Note that a kernel can be adaptive and fixed, while an adaptive kernel uses the bandwidth to consider a given number of units as connected, a fixed kernel considers units as interconnected within a fixed distance. The optimal bandwidth is selected by using different criterions such as Akaike Information Criteria (AIC), Bayesian Information Criterion (BIC) and Cross Validation (CV).[4] This recent advance in spatial econometrics finds popularity among regional scholars investigating the convergence issue. For instance, Bivand and Brunstad (2005) for Europe, Paraguas and Dey (2006) for India, Eckey et al. (2007) for Germany, James and Moeller (2013) for United States (US) and Artelaris (2015) for Europe validate sizable spatial instabilities in the speed of convergence.

3. Regional disparities and spatial dynamics: descriptive patterns

Since our study covers a long time-period, we start our analysis with a set of descriptive measures concerning three inter-related issues: the nature and evolution of regional disparities; the distribution of regional incomes and changes therein; and extent of spatial associations (clustering, hotspots) in the country.

Figure 1. Aggregate measures of regional disparity and spatial association



Notes: Moran’s I left axis, Sigma Convergence, Theil Index right axis
Source: CAMECON, ELSTAT, Authors’ own calculations

[4] See Fotheringham et al. (2002) for a detailed discussion on the background of GWR and the use of adaptive and fixed kernel functions. See also Nakaya et al. (2005) and Nakaya (2014) for further discussions on testing the variability of the coefficient estimates.

As is depicted in Figure 1, regional disparities at the NUTS3 level were reasonably high at the start of the 1980s and remained rather stable throughout the decade. Since their peak in 1990s, however, regional disparities followed a declining trend almost uninterruptedly until 2002.[5] The trend appeared to reverse in the early 2000s, but resumed more intensively since 2007, i.e., with the eruption of the crisis in Greece. This pattern is consistent across measures of inequality (standard deviation, showing sigma-convergence and the Theil index, for which the trends appear to be generally steeper) and is also consistent with findings elsewhere in the literature using other measures of regional performance (e.g., Monastiriotis, 2014).

These results are also confronted by the general structure of the distribution given in Table 1. Given a rise in the average per capita income in the pre-crisis period, there tends to evolve an overall tendency of fall in the variation of the distribution. Moreover, the range of the distribution seems to shrink, together with the rise in the min-max ratio indicating an overall improvement in terms of inequalities. Yet the fall in the average income in the post-crisis environment reminds that there is a possible reshuffling of per capita income distribution.

Table 1. Dispersion of per capital GDP (*in ln.*)

	Range	Min/Max	Mean
1980	1.493	0.852	9.037
1990	1.311	0.868	9.083
2000	0.960	0.903	9.279
2008	0.936	0.911	10.016
2012	0.914	0.913	9.891

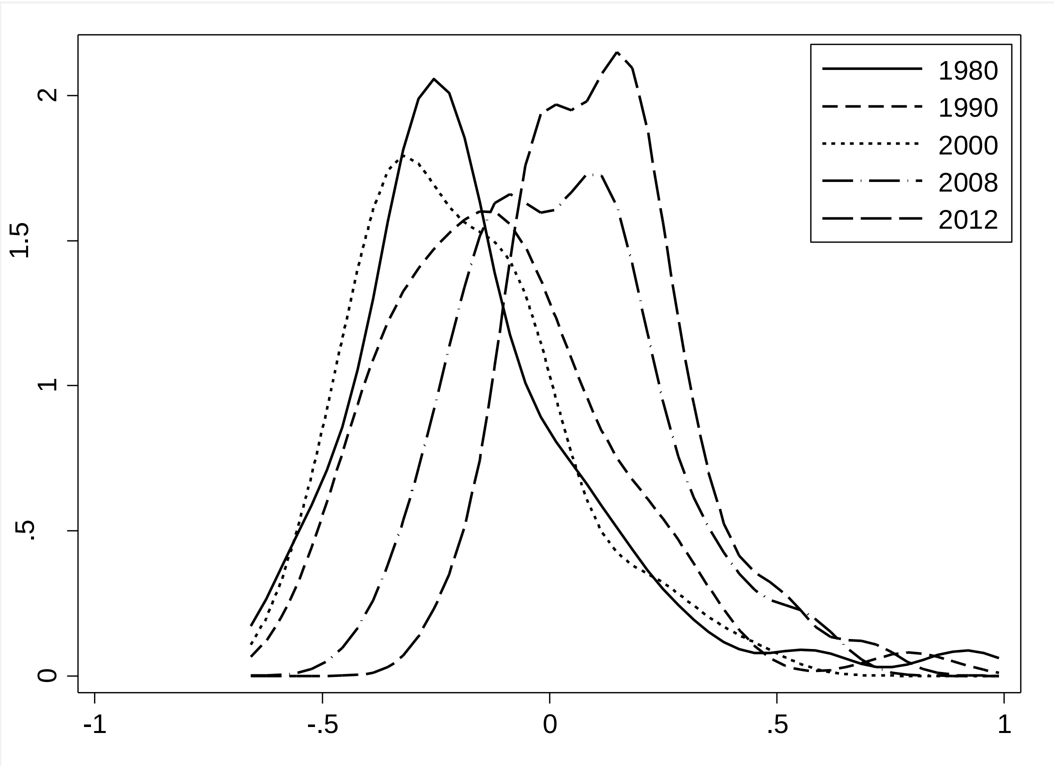
Source: CAMECON, ELSTAT, Authors' own calculations

We can examine further these movements by looking directly at the distribution of regional incomes in the country and its persistence over time / across the four periods under consideration. A convenient way to implement this is with the use of fitted Kernel density functions, as depicted in Figure 2. As can be seen there tends to be a movement towards a bi-model distribution for the post 2000 period. In a way for the pre 2000 period the distribution is rather more uniform with a tighter distribution in 1980. For both 1990 and 2000 there seems to be limited yet significant clustering in the right tails reminding the possibility of the marginalization of some high income regions. On the other hand, two post 2000 era seems to witness a relatively more dispersed pattern realizing a bi-

[5] Note that the peak in 2000 is in part related to the switch in the data sources used and should be read with caution.

modal distribution which becomes even more visible during the crisis period of post 2008. This reminds us the possibility of a club formation in a way expressing different set of regions of converging to different long run states. Additionally, it seems to be also reasonable to link this with the pattern that we detect in the acceleration of the min-max ratio for the post 2000 period. Even usual inequality measures signal possibility of a decline in regional imbalances, it is vital to note that this period of decline in inequalities especially becoming more visible during the crisis period is a way creating a somehow dual structure in Greece in terms of regional differences.

Figure 2. Distribution of regional incomes (Kernel densities)



Source: CAMECON, ELSTAT, Authors' own calculations

These observations to some extent are consistent with the picture we obtain with regard to the persistence of regional rankings using a simple Spearman rank correlation analysis given in Table 2. We find an overall persistence coefficient of 0.293 for the full 1980-2012 period. In general, between 1980 and 1990 there is sizable persistence which tends to weaken during the 1990-2000 period, yet accelerated once again after the post 2000 period. In terms of the impact of the crisis we report the highest persistence during this period.

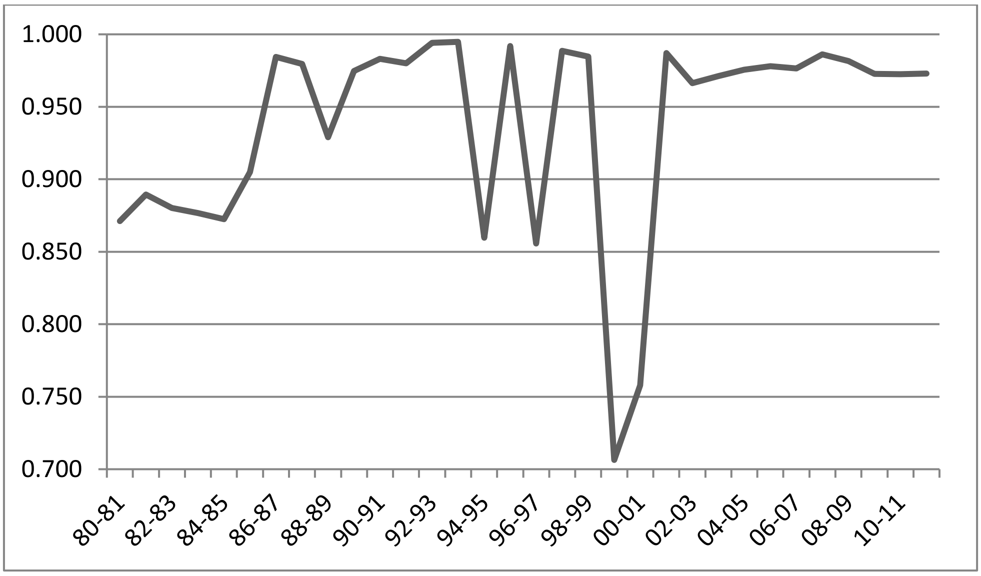
Table 2. Historical Persistence of Regional Inequalities

	1980	1990	2000	2008	2012
1980	1.000				
1990	0.780	1.000			
2000	0.344	0.566	1.000		
2008	0.317	0.507	0.762	1.000	
2012	0.293	0.431	0.747	0.939	1.000

Source: CAMECON, ELSTAT, Authors' own calculations

Year-to-year persistence is of course much higher; ranging between 0.87 and 0.98. In general, the short-run persistence of income distribution accelerates during the early 1990 and thereafter realizes a cyclical period between 1990 and 2000 and then once again a period of high but stable persistence during the 2000-2012 period. Interestingly over the whole period the lowest persistence both in terms of historical persistence (Table 2) as well as year-to-year short term persistence (Figure 3) is observed during the end of 1990s while Greece was accessing to EMU.

Figure 3. Year-to-year Persistence of Regional Inequalities

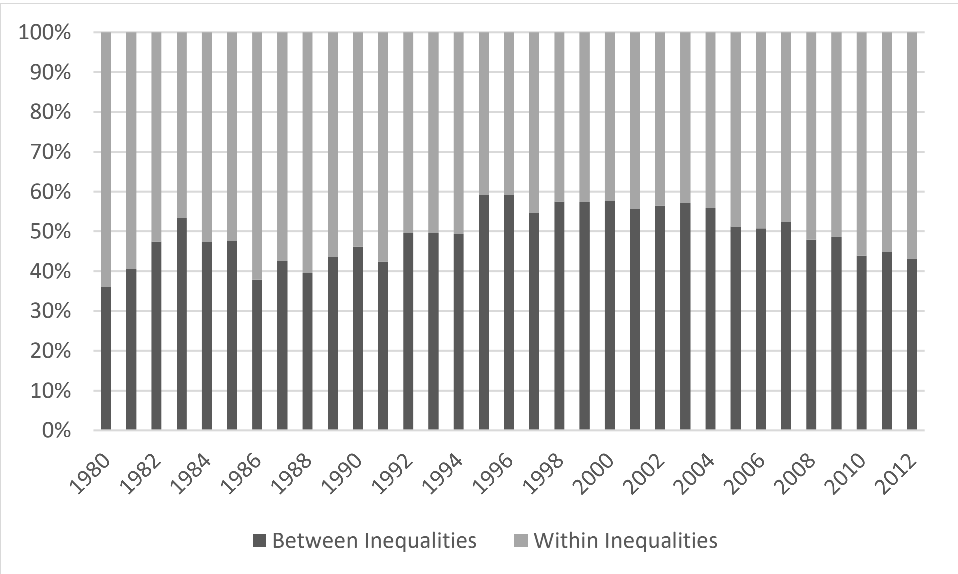


Source: CAMECON, ELSTAT, Authors' own calculations

Besides these questions concerning attributes of the distribution of regional incomes (standard deviation, max/min ratio, persistence, etc), it is also useful to examine the location of regional disparities, both in the sense of whether these concern macro-geographical versus micro-geographical (i.e., localised) patterns and in relation to the wider spatial dynamics underpinning them (i.e., spatial clustering and heterogeneity). As mentioned previously, the use of the Theil index allows us to perform a decomposition of inequalities between their intra-NUTS2 ('within') and extra-NUTS2 ('between') components.

As is shown in Figure 4, intra-NUTS2 inequalities are sizeable (typically, above 50%) and, although declining in the slow convergence period (1986-1996), they have been actually on the rise in the more recent period of fast convergence. This suggests that macro-geographical disparities (across NUTS2 regions) are only a part of the story of regional disparities in Greece – suggesting in turn that the latter is not only a story of spatial heterogeneity but rather of localised inequality. Macro-geographical disparities have further declined faster during the crisis, thus accounting for a larger proportion of the overall decline in regional disparities in this period.

Figure 4. 'Within' and 'between' components of regional disparity



Source: CAMECON, ELSTAT, Authors' own calculations

Another way of looking at the issue of regional heterogeneity is by examining the extent of spatial clustering, or association, by means of the Moran's I statistic (Figure

1).[6] Following the early remarks of Karahasan and Monastirotis (2017) we observe that the behaviour of the spatial clustering has been more cyclical, exhibiting a steep decline and then fast rise around the mid-1980s; relative stability until 1994; a sizeable deep in the years 1995-2001, which coincide with Greece's adjustment period for entry into the Eurozone; and restoration of spatial association in 2002 with a continuous declining trend thereafter. In all cases, and especially in the post-2008 period, the level of spatial association appears very low, suggesting weak and limited spatial clustering in the country – which is consistent with the results of the Theil decomposition.

Table 3. Spatial Auto Correlation Results (Per capita GDP)

	Moran's I (stats.)		**LISA Clusters (count)**				
	N2	**Inv. Dis.^2**	**Not Significant**	**High-High**	**Low-Low**	**High-Low**	**Low-High**
1980	0.462*** (0.109)	0.386*** (0.062)	44	5	2	0	0
1990	0.362*** (0.115)	0.279*** (0.066)	41	7	3	0	0
2000	0.336*** (0.124)	0.200*** (0.071)	45	5	0	0	1
2008	0.334*** (0.125)	0.167*** (0.071)	42	4	4	1	0
2012	0.260** (0.122)	0.149*** (0.070)	43	4	3	1	0

Notes: s.e. in (), ***, ** and * represents significance at 1%, 5% and 10% respectively. N2 and Inv. Dis^2 are k-nearest neighbour weight matrix (order 2) and an inverse distance weight matrix respectively.

This is further supported by more detailed analyses, derived from LISA calculations, which return only a handful (typically 3-5) of statistically significant 'hotspots' and 'spatial clusters' in any year. Table 3 gives the combined results for selected cut-off years. Note that we report the global spatial auto-correlation measure by using two different weight matrix specifications. For both we identify a fall in the spatial

[6] The statistic depicted here is based on an inverse distance spatial weights matrix.

association, yet it should be noted that in each year spatial dependence is observed to be lower for the inverse distance weight matrix with respect to a k-nearest weight matrix. This underlines the level of locality of the spatial association. Meanwhile, we also count the LISA scores of regions based on their significance as well as their magnitude by using inverse distance weight matrix.

Table 4. Persistence across Spatial Regimes

		High-High	Low-Low	High-Low	Low-High
GR113	**Rodopi**	0	1	0	0
GR115	**Kavala**	0	0	4	0
GR126	**Serres**	0	11	0	0
GR133	**Kozani**	0	0	13	0
GR134	**Florina**	0	0	5	0
GR141	**Karditsa**	0	6	0	0
GR144	**Trikala**	0	6	0	0
GR211	**Arta**	0	14	0	0
GR213	**Ioannina**	0	16	0	0
GR214	**Preveza**	0	4	0	0
GR221	**Zakynthos**	0	1	0	0
GR223	**Kefallinia**	0	10	0	0
GR224	**Lefkada**	0	2	0	0
GR231	**Aitoloakarnania**	0	1	0	0
GR233	**Ileia**	0	3	0	2
GR241	**Voiotia**	30	0	0	0
GR242	**Evvoia**	23	0	0	0
GR243	**Evrytania**	0	1	0	0
GR244	**Fthiotida**	12	0	0	0
GR245	**Fokida**	15	0	0	0
GR253	**Korinthia**	3	0	0	0
GR254	**Lakonia**	0	1	0	0
GR255	**Messinia**	0	6	0	0
GR300	**Attiki**	33	0	0	0
GR421	**Dodekanisos**	22	0	0	0
GR422	**Kyklades**	25	0	0	0

Even we detect very low number of significant spatial associations still our findings contain supportive information on the extent of the persistence. In Table 4 we count the number of years that regions are reported in given spatial regimes.[7] This will help in understanding the rigidity within the spatial regimes. In other words, this will contain

[7] We use k-nearest neighbor weight matrix for persistence analyses of the spatial regimes.

information about the possibility for one region to move to another spatial regime during the sample period. For instance, once we focus on the provinces with at least one year of observation with a significant spatial association, we identify that regions do not move within the distribution frequently. Additionally, our findings indicate that high income regions realize higher persistence with respect to low income ones. Note that there are very few cases where regions are locked in outlier geographies.

Thus, overall, our descriptive analysis leads us to a number of interesting observations with regard to regional disparities and spatial dynamics in Greece over the 30-year period under consideration. Regional disparities are relatively small and certainly declining over time. They are however significantly localised: although macro-geographical disparities are also present (and sizeable), the extent of within-NUTS2 inequality is comparatively very high. Moreover, it seems to be a case of a more bi-modal distribution for the post 2000 period, which reminds us the possibility of different spatial regimes. Still, evidence of significant localised polarisation, in the form of significant spatial 'hotspots' and 'outliers', is at best limited – as is the evidence concerning spatial clustering at large (global Moran's I) and in specific localities (LISA analysis). It all points to a pattern of 'spatial randomness', which is if anything intensifying with time / in more recent periods, in the sense that regional incomes do not follow strong distributional (disparities) or spatial (clustering) patterns. This motivates us to examine the issue of (disparities and) convergence more formally – while continuing to take into account spatial dynamics – as we do in the next section.

4. Regional Growth and Convergence

As mentioned previously, evidence on sigma convergence may mark disparate evolution in terms of growth dynamics; for example, the overall variance of the distribution of the regional income may be declining while at the same time specific regions may be experiencing cumulative growth advantage (implying essentially a tendency for club formation). This concern is also apparent via the bi-modality of the distribution during the post 2008 period as well as the high persistence detected in the local spatial association mainly among the already developed regions. Even the beta convergence is not expected to fully handle with the presence of club formation; in a way we believe our extensions for spatial heterogeneity of convergence speeds will contain sizable information on the formation of different regimes of convergence. In order to examine this, we turn to the examination of different variants of beta convergence. Table 5 gives the estimations results for the different time intervals considered in the previous section. We estimate initially the unconditional models which later we augment by controlling for population density, market size and regional accessibility. Results from non-spatial models indicate the presence of significant convergence in the entire sample in general. Only for the 1980-1990 period we report lack of significant convergence for the models conditioning for some geographical factors. Keeping this on one side, our results indicate rising speed of convergence once these regional factors are considered for the remaining intervals. However, it is remarkable that convergence tends to have a rather cyclical pattern that accelerates more during the 1990-2000 and 2008-2012 sub intervals.

As discussed before, the traditional convergence model rules out the possible impact of spatial diffusions. However, given the fall in transportation costs worldwide and based on the fact that physical and non-physical barriers to trade and connectivity diminishes during the last decades, neglecting the possible spatial spillovers may create distortions in evaluating the catch up attempt of the Greek regions. To account for the spatial dependence within convergence modeling we introduce a spatial lag and spatial error components to the convergence framework as outlined in Section 2. Our reasoning is that; spatial diffusion may work over regional growth rates or it can be the omitted factors and/or common shocks that are diffusing geographically creating some sort of a spatial spillover mechanism among Greek regions. Results given in Table 5 indicate that controlling for the impact of spatial ties does not impede the existence of convergence.[8] However, we observe that the speed of convergence is observed to be marginally lower once spatial dependence is controlled for. This is in a way in line with Rey and Montouri (1999) who reports marginal decline for the speed of convergence for US, with Arbia et al. (2005) and Arbia and Piras (2005) who demonstrate a fall in the speed of convergence once spatial lag of regional growth is included for the case of Italy and the European Union.

Even though using spatial variants of the traditional convergence model offers solutions to the spatial diffusion problem, still it does not propose a formal elucidation on the possible spatial instabilities. That is, up to this stage we presume that calculated speed of convergence may vary through time among different sub-intervals, yet we do not consider the possibility of the spatial heterogeneity which may create different convergence regimes among the Greek geography. This has been validated by the geographic variability (spatial variability) test which indicates that convergence speed for Greek regions is not dispersed homogenously. In a way this reminds us that conditioning on the spatial dependence may still underestimate the extent of the local differences. This result is parallel with Eckey et al. (2007) that demonstrates that convergence rates tend to vary geographically in Germany and more recently with Artelaris (2015) who underlines the spatial heterogeneity of convergence across the European Union countries. Inspired by these contemporary discussions and the possibility of observing local variations of convergence we extent our modelling strategy by using the Geographically Weighted Regression (GWR) approach. Our results reported in Table 5 are in supportive of our concerns; that the range between the

[8] Note that we do not report the full estimation results. These results which are available from authors upon request also show the significance of the spatial dependence (over rho and lambda) in the lag and error models. This once more validates the concerns on the existence of spatial diffusion which has been rarely considered formally within the traditional convergence model.

minimum and maximum speed of convergence varies both historically as well as geographically. For instance, during which convergence is observed to be fast there

Table 5. Regional Convergence

	1980-1990			1990-2000		
	β	λ	t^*	β	λ	t^*
Non-Spatial						
Uncd.	-0.022***	2.44%	28.45	-0.038***	4.83%	14.36
Cond.	-0.012	1.29%	53.68	-0.044***	5.78%	11.99
Spatial						
SAR	-0.017**	1.84%	37.74	-0.035***	4.28%	16.18
SEM	-0.018**	2.01%	34.44	-0.038***	4.85%	14.29
GWR						
Mean	-0.022***	2.44%	28.45	-0.039***	4.99%	13.90
1-Min	-0.033	4.01%	17.29	-0.048	6.51%	10.64
2-Max	-0.017	1.85%	37.40	-0.025	2.87%	24.15
3-Lower Quartile	-0.022	2.54%	27.34	-0.046	6.19%	11.20
4-Median	-0.018	1.96%	35.28	-0.043	5.55%	12.49
5-Upper Quartile	-0.017	1.91%	36.37	-0.034	4.18%	16.58
G. Var. Test	-30.409			-54.116		
	2000-2008			**2008-2012**		
	β	λ	t^*	β	λ	t^*
Non-Spatial						
Uncd.	-0.015***	1.64%	42.16	-0.041***	4.51%	15.38
Cond.	-0.030***	3.42%	20.28	-0.048***	5.33%	13.01
Spatial						
SAR	-0.015**	1.64%	42.34	-0.042***	4.62%	14.99
SEM	-0.016**	1.66%	41.65	-0.041***	4.45%	15.56
GWR						
Mean	-0.015***	1.63%	42.55	-0.035***	4.08%	16.99
1-Min	-0.031	3.55%	19.52	-0.044	4.79%	14.47
2-Max	-0.011	1.19%	58.48	-0.020	2.04%	34.05
3-Lower Quartile	-0.016	1.70%	40.71	-0.040	4.31%	16.07
4-Median	-0.013	1.42%	48.97	-0.036	3.89%	17.81
5-Upper Quartile	-0.012	1.28%	54.15	-0.031	3.36%	20.64
G. Var. Test	-205.082			-102.685		

Notes: ***, ** and * indicates the significance of the beta coefficient of the convergence models. For Geographically variability test (G. Var. Test) a positive value of diff-Criterion (AICc, AIC, BIC/MDL or CV) suggests no spatial variability in terms of model selection criteria. β, λ, t^* represents the coefficient of the initial per capita GDP, speed of convergence and half-life of convergence respectively.

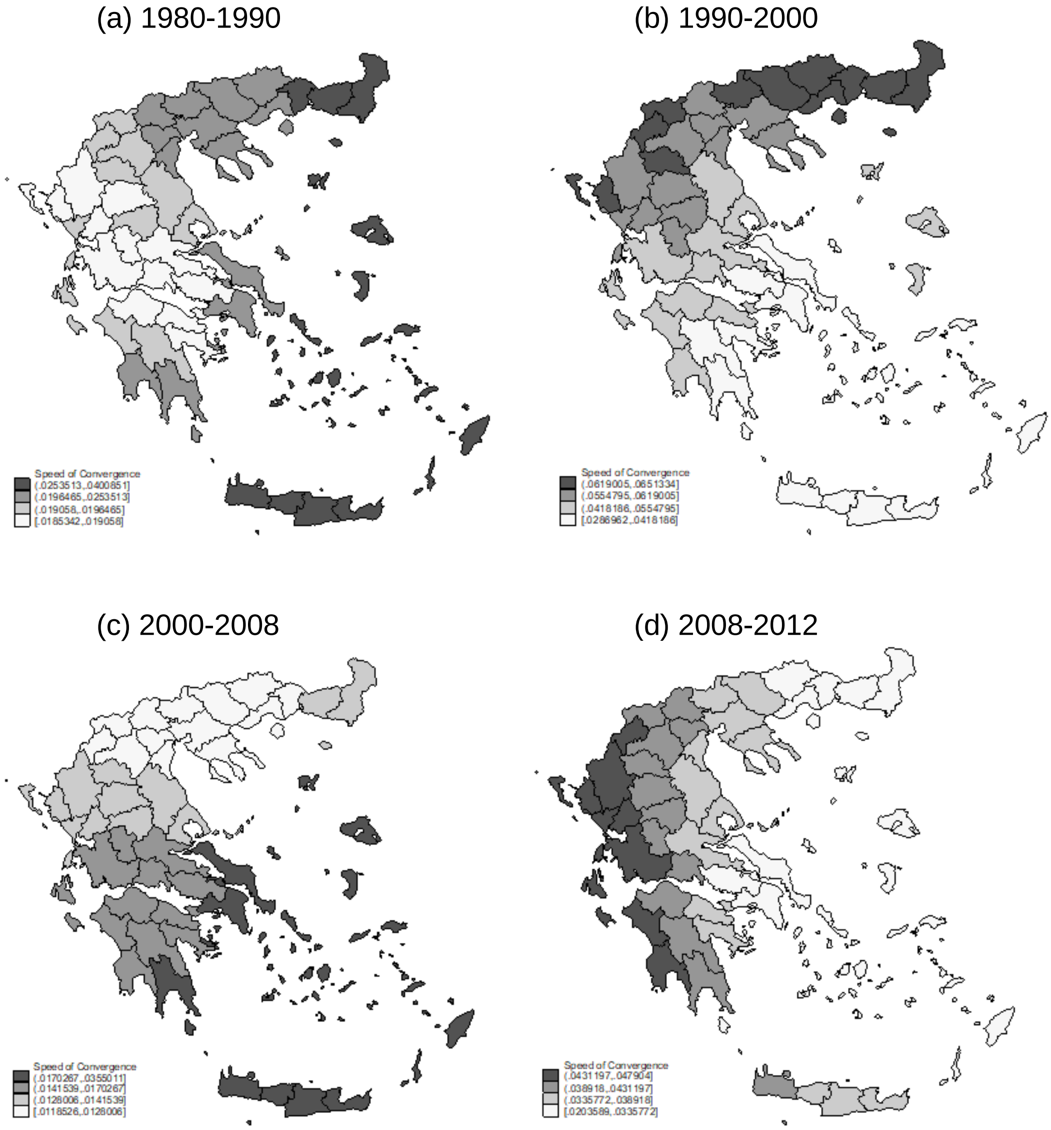
seems to be a range of 3.64% and 2.75% between minimum and maximum convergence speeds for 1990-2000 and 2008-2012 sub periods. The variation seems to be marginally smaller once the relatively slow convergence periods of 1980-1990 and 2000-2008 are considered (2.16% and 2.36% respectively). In a way during the fast convergence years (covering both 1990-2000 and 2008-2012) there are some regions in Greece that are able to close half of their gap with their steady states in 10 years but there are also some that have ability to get closer to their long run income levels by half in 34 years. In that sense our concerns on the spatiotemporal dynamics seems to prevail; not only the change in the speed of convergence through time matters but also it is a matter of fact that there are different local convergence experiences within specific time intervals.

At this stage, focusing on the post 2000 period yields a number of important information. Among the investigated four sub-intervals the pre-crisis period of 2000-2008 has the slowest speed of convergence reminding us a worsening of the distribution even before the start of the debt crisis. Yet for the aftermath of the crisis this time we tend to identify a bounce back of faster convergence. That said, in all cases we continue to identify the spatial variability of the speed of convergence. This suggests that even speed of convergence has a cyclical pattern among different sub-intervals; crisis environment does not have direct influence on the extent of the overall spatial heterogeneities. This brings additional concerns on the spatial distribution of the observed speed of convergence.

In order to understand whether there is a shift in the geography of convergence we compare the spatial variability of the speed of convergence for different time intervals given in Figure 5. Figure 5 identifies the spatial variability of speed of convergence supporting the concerns that geography of convergence moves historically. For instance, considering the relatively fast convergence in sub periods 1990-2000 and 2008-2012, it seems that there exists a north dominant convergence in the late 1990s whereas it turns out to be a clear west oriented convergence during the crisis periods of post 2008. However, note that the low convergence episodes of 1980-1990 and 2000-2008 Greece witness a relatively similar spatial variability in terms of convergence speeds.[9]

[9] In addition to the local variation of the beta coefficient and the speed of convergence, we implement the analysis of the local variation of the intercept and the R^2. Our findings show that like the spatial variability of the speed of convergence, both long run steady state growth rates (intercept) as well as the fit of the relationship (R^2) realizes substantial spatial variability. These results are available upon request.

Figure 5. Spatial Variability of the Speed of Convergence



Source: Authors' own calculations

5. Distributional Dynamics

While the descriptive analysis gives information on the periodical as well as spatial path of inequalities and different variants of the convergence models focuses on the ability for poor regions to catch up with the rich ones, all suffer from giving insufficient information on the distributional dynamics. Even investigating the evolution of the distribution is possible by observing the Kernel type distribution functions; still it is not possible to distinguish regions in terms of their mobility within the distribution. For instance, it would not be possible to identify if a poor/rich region in one year moves to an upper/lower income group in the subsequent year unless transition probabilities are considered. These types of movements within the distribution can be identified by the use of Markov Chain analysis which is offered as an alternative to the traditional convergence models by Quah (1993 and 1996). Quah (1993 and 1996) for a cross section of countries and US; Lopez-Bazo et al. (1999) and Le Gello (2004) for Europe applied the Markov Chain approach and identified the possibility of club formation in a way towards polarization unlike the strong convergence finding of the traditional neoclassical convergence approach.

Quah (1996) discuss that in addition to observing the probability of transition among different income classes, it is possible to identify a long run or ergodic distribution in a way to understand the tendency of the shape of the distribution in the long run. Additionally, as underlined by Quah (1996) different properties of the evolution of the distribution can be studied from the certain properties of the transition matrix. For instance, Ponzio and Di Gennaro (2004) and Monfort (2008) underlines that an indicator of speed can be calculated by using the second eigenvalue obtained from the transition probability matrix. This speed similar to convergence framework can be used to measure half-life of convergence. Finally, stability of the distribution can also be calculated by using the transition probability matrix. As discussed in Monfort (2008) stability index yields information on the stability of the distribution; summation of the all elements of the main diagonal of the matrix is normalized by the number of pre-determined states of the distribution.

While applying the Markov Chain framework a crucial point is the detection of the income classes through which transition are going to be traced. As discussed by Quah (1993) obtaining close number of observations in the initial year can be preferred while determining the cut-off grids. Therefore, we base our income groups by grouping regions based on the 75%, 90%, 100% and 115% of the per capita income of Greece in each year, which gives us the most uniform number of regions among income classes in the initial year.[10] Results are given in Table 6.

Overall, one notable finding is the general path of inequalities which is much or less identical to the one we detect during the convergence analysis. For instance, we continue to identify falling stability during the post crisis episode, with a half-life number more than two times lower than the one detected in 1980s. That said, specific transition probabilities contain some additional findings inhibiting the source of disparities. For example, probability of having any kind of upward mobility from the lowest income group is 28% in 1980s, while same probability jumps to 75% after the crisis. More interestingly considering mobility from middle income groups (income state 3); there is 32% of chance to move to a lower income group during 1980s, while upward mobility

[10] We also try different grids with different number of income classes. As mentioned in Lopez et al. (1999) there are also differences in our transition probabilities with different grids, yet they seem to have negligible influence on the qualitative analysis.

probability is just 14%. That said after the crisis probability for a region in the middle income group to fall to a lower income group is significantly lower and around 5%. On contrary upward mobility to a higher income region group is 20%. Keeping all these in mind it is worth underlining that observing an upward mobility from any income group seems to realize decreasing probability once average income rises. For instance, during the post crisis period, probability of an upward mobility for the lowest income regions are 75% compared to 18% for the regions in the middle income group. Note that during the other sub intervals we do not observe such a divergence between low and middle income regions' upward mobility probabilities. For 1980s there is 26% chance for regions in the lowest income group to move one state upwards within the distribution while same upward mobility probability is 14% for regions in the middle income group. This make us think on the source of higher convergence after the crisis; that the fast jump of the lowest income regions upwards within the distribution, matching with the drastic fall of average income during this period both suggest the possibility of a convergence towards the falling mean of the distribution.

While transition probabilities up to this stage gives sizable information suggestive of an improvement after 2000 (unlike the downgrading of 1980s), they can be developed further by also incorporating the possibility of spatial conditioning. Following Rey (2001) we consider a spatial lag conditioning and aim at measuring the transition probabilities once more, but this time conditioned on the income level of spatial proximity.

Our concern is that any upward mobility for a region can be higher if some other high income regions are in close proximity. We group spatial proximity into three groups (high, mid and low) and test whether locating close to regions with certain income levels affects the chances of transition probabilities and thus convergence. Indeed our findings (Table 7) are supportive of this concern. For instance, in 1980s and 1990s having middle income regions in close proximity decreases half-life to convergence relative to especially having low income regions in surrounding. During the pre-crisis period this time locating spatially linked to high income regions decreases half-life to convergence. That said even more interestingly during the post crisis episode things turn out just the opposite. Regions spatially linked to low income regions have the lowest half-life values suggesting that these regions are observing an even more drastic convergence attempt which once more fits into our concerns on the reshuffling of regional income patterns. Our results from different variants of Markov Chain analyses supports the existence of convergence, partially in the form of a club formation which can be explained by the geographical and economic differences of the spatial proximity.

Table 6. Traditional Markov Chain Analysis

			1980-1990				
	1	**2**	**3**	**4**	**5**		
1	0.72	0.26	0.02	0.00	0.00	Stability Index	0.73
2	0.14	0.68	0.16	0.01	0.01		
3	0.00	0.32	0.53	0.14	0.01	Convergence Index	0.23
4	0.00	0.03	0.10	0.79	0.08		
5	0.00	0.00	0.02	0.06	0.92	Half-life to Steady State	10.33
Int. Dist	0.208	0.367	0.159	0.139	0.127		
Erg. Dist.	0.140	0.286	0.149	0.181	0.243		
			1990-2000				
		1	**2**	**3**	**4**	**5**	
1	0.88	0.10	0.01	0.01	0.00	Stability Index	0.76
2	0.13	0.77	0.09	0.01	0.00		
3	0.03	0.20	0.63	0.13	0.00	Convergence Index	0.24
4	0.02	0.02	0.19	0.70	0.06		
5	0.00	0.00	0.07	0.13	0.80	Half-life to Steady State	5.56
Int. Dist	0.251	0.296	0.182	0.182	0.088		
Erg. Dist.	0.403	0.321	0.143	0.100	0.032		
			2000-2008				
	1	**2**	**3**	**4**	**5**		
1	0.72	0.28	0.00	0.00	0.00	Stability Index	0.78
2	0.03	0.81	0.16	0.00	0.00		
3	0.00	0.02	0.59	0.39	0.00	Convergence Index	0.22
4	0.00	0.00	0.03	0.81	0.16		
5	0.00	0.00	0.00	0.03	0.97	Half-life to Steady State	5.38
Int. Dist	0.194	0.328	0.137	0.194	0.147		
Erg. Dist.	0.000	0.001	0.011	0.166	0.822		
			2008-2012				
	1	**2**	**3**	**4**	**5**		
1	0.25	0.75	0.00	0.00	0.00	Stability Index	0.66
2	0.03	0.59	0.38	0.00	0.00		
3	0.00	0.05	0.75	0.18	0.02	Convergence Index	0.39
4	0.00	0.00	0.04	0.75	0.21		
5	0.00	0.00	0.00	0.04	0.96	Half-life to Steady State	4.52
Int. Dist	0.020	0.167	0.216	0.260	0.338		
Erg. Dist.	0.000	0.004	0.030	0.165	0.801		

Notes: Int. Dist., Erg. Dist. represents initial and ergodic distributions respectively.

Table 7. Spatial Markov Chain Analysis

				1980-1900								1990-2000		
		1	**2**	**3**	**4**	**5**			**1**	**2**	**3**	**4**	**5**
Low	**1**	0.73	0.23	0.03	0.00	0.00	**Low**	**1**	0.93	0.05	0.00	0.01	0.00
	2	0.19	0.70	0.09	0.00	0.01		**2**	0.10	0.81	0.07	0.02	0.00
	3	0.00	0.37	0.53	0.05	0.05		**3**	0.00	0.29	0.71	0.00	0.00
	4	0.00	0.00	0.00	0.80	0.20		**4**	0.07	0.07	0.07	0.80	0.00
	5	0.00	0.00	0.11	0.11	0.78		**5**	0.00	0.00	0.00	0.20	0.80
	Erg.	0.25	0.34	0.12	0.11	0.15		***Erg.***	0.52	0.31	0.09	0.06	0.00
Mid.	**1**	0.68	0.32	0.00	0.00	0.00	**Mid.**	**1**	0.72	0.28	0.00	0.00	0.00
	2	0.14	0.69	0.16	0.01	0.00		**2**	0.14	0.77	0.09	0.00	0.00
	3	0.00	0.32	0.55	0.13	0.00		**3**	0.00	0.19	0.58	0.22	0.00
	4	0.00	0.06	0.13	0.63	0.19		**4**	0.04	0.04	0.30	0.59	0.04
	5	0.00	0.00	0.00	0.18	0.82		**5**	0.00	0.00	0.25	0.00	0.75
	Erg.	0.15	0.37	0.17	0.14	0.15		***Erg.***	0.23	0.40	0.16	0.08	0.01
High	**1**	0.75	0.25	0.00	0.00	0.00	**High**	**1**	0.88	0.00	0.13	0.00	0.00
	2	0.03	0.64	0.31	0.03	0.00		**2**	0.14	0.74	0.09	0.03	0.00
	3	0.00	0.29	0.52	0.19	0.00		**3**	0.08	0.18	0.65	0.10	0.00
	4	0.00	0.02	0.10	0.84	0.04		**4**	0.00	0.00	0.18	0.73	0.10
	5	0.00	0.00	0.00	0.02	0.98		**5**	0.00	0.00	0.06	0.14	0.81
	Erg.	0.01	0.13	0.13	0.25	0.45		***Erg.***	0.35	0.17	0.25	0.14	0.07
				2000-2008							**2008-2102**			
		1	**2**	**3**	**4**	**5**			**1**	**2**	**3**	**4**	**5**
Low	**1**	0.82	0.18	0.00	0.00	0.00	**Low**	**1**	0.33	0.67	0.00	0.00	0.00
	2	0.02	0.88	0.11	0.00	0.00		**2**	0.00	0.64	0.36	0.00	0.00
	3	0.00	0.00	0.54	0.46	0.00		**3**	0.00	0.00	0.76	0.18	0.06
	4	0.00	0.00	0.00	0.82	0.18		**4**	0.00	0.00	0.06	0.67	0.28
	5	0.00	0.00	0.00	0.00	1.00		**5**	0.00	0.00	0.00	0.13	0.88
	Erg.	0.00	0.00	0.00	0.00	1.00		***Erg.***	0.00	0.00	0.06	0.28	0.65
Mid.	**1**	0.68	0.32	0.00	0.00	0.00	**Mid.**	**1**	0.00	1.00	0.00	0.00	0.00
	2	0.05	0.78	0.17	0.00	0.00		**2**	0.06	0.56	0.39	0.00	0.00
	3	0.00	0.00	0.59	0.41	0.00		**3**	0.00	0.11	0.67	0.22	0.00
	4	0.00	0.00	0.05	0.86	0.10		**4**	0.00	0.00	0.06	0.82	0.12
	5	0.00	0.00	0.00	0.06	0.94		**5**	0.00	0.00	0.00	0.00	1.00
		0.00	0.00	0.04	0.37	0.57							
	Erg.	0	0	4	9	7		***Erg.***	0.00	0.00	0.00	0.00	1.00
High	**1**	0.40	0.60	0.00	0.00	0.00	**High**	**1**	0.00	0.00	0.00	0.00	0.00
	2	0.04	0.71	0.25	0.00	0.00		**2**	0.00	0.50	0.50	0.00	0.00
	3	0.00	0.04	0.62	0.35	0.00		**3**	0.00	0.00	0.89	0.11	0.00
	4	0.00	0.00	0.02	0.78	0.20		**4**	0.00	0.00	0.00	0.78	0.22
	5	0.00	0.00	0.00	0.03	0.97		***5***	0.00	0.00	0.00	0.03	0.97
	Erg.	0.00	0.00	0.00	0.12	0.86		***Erg.***	0.00	0.00	0.00	0.10	0.89

Notes: Erg. is the ergodic distribution.

6. Conclusion

Our results from different specifications of the traditional convergence models are crucial. First not the least, it seems precise that even there is a cyclical nature, Greek regions undergo a period of convergence which is fastest at the recent crisis period of post 2008. In a way it is also important to underline that even spatial ties are getting weaker we continue to detect significant and marginally slowing convergence in the spatial convergence models. However, most remarkable finding is the way that the speed of convergence varies among the geography of Greece; this proposes the existence of a spatiotemporal convergence for the Greek regions becoming more peculiar during the crisis period. Additionally, our results from different transition probability analyses confirm the existence of club formation. Remarkably the club formation has a distinct geographical pattern which validated that spatial proximity has influence on the fate of the Greek regions' mobility within the regional income distribution.

Greece experience overall gives a picture for a peripheral European country benefiting from various regional policies of EU considering the overall convergence trend. However, we identify that the fast speed of convergence detected for the 1990-2000 and 2008-2012 periods had different fundamentals. While for the former we identify the good times before the EMU accession with falling regional inequalities and rising average income; for the post 2008 period there seems to be a reshuffling among the Greek regions, which underlines a downward convergence and distinct spatial variability of the speed of convergence. This reminds that spatial regimes of the convergence are quiet divergent before and after the crisis.

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