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# The Green Economy and Environmental Upgrading in Turkey: A Situation Analysis

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**ABSTRACT**

**Purpose:** The aim of this study is to review rising green economy agenda in a theoretical framework and further examine the capacity of Turkey to participate in the implementation of green growth.

**Methodology:** The innovation and R&D index is calculated by using Grey Relational Analysis (GRA) Method. The index is calculated by using 12 indicators under the 3 main categories as R & D and Innovation infrastructure, R & D Competence and University -Industry Cooperation, patents, design applications and technology-based exports.

**Findings:** Relying on a mapping of the research and development (R&D) efforts of Turkish industrial clusters, the most innovative firms are highly agglomerated in particular geographies in Turkey.

**Practical Implications:** The results of the study will lead the further analysis of economic geography and environmental innovations of manufacturing

**Originality:** The argument is that supplier firms of developing countries in global networks have potential to gain environmental upgrading opportunities in their production processes. This research is an original one that shows environmental upgrading efforts in Turkey in many traditional sectors through green economy.

**Keywords:** Ecological Economics, Regional Economic Activity, Technological Innovation, Environment and Development

**JEL Codes:** Q57, R11, Q55, Q56

# Yeşil Ekonomi ve Türkiye'de Çevresel İyileşme: Bir Durum Analizi

**ÖZ**

**Amaç:** Bu çalışmanın amacı, yükselen yeşil ekonomi gündemini teorik bir çerçevede incelemek ve Türkiye'nin yeşil büyüme uygulamalarına katılım kapasitesini incelemektir.

**Yöntem:** İnovasyon ve Ar-Ge endeksi Gri İlişkisel Analiz (GRA) Yöntemi kullanılarak hesaplanmıştır. Endeks Ar-Ge ve İnovasyon altyapısı, Ar-Ge Yeterliliği ve Üniversite-Sanayi İşbirliği, patentler, tasarım uygulamaları ve teknolojiye dayalı ihracat olmak üzere 3 ana kategori altında 12 gösterge kullanılarak hesaplanmaktadır.

**Bulgular:** Türk sanayi bölgelerinin teknolojik araştırma ve geliştirme (Ar-Ge) çabalarının haritalandırılmasına dayanarak, en yenilikçi firmaların Türkiye'deki belirli coğrafyalarda yüksek oranda kümelendiği görülmektedir.

**Sonuç ve Öneriler:** Çevresel iyileştirme kapasitesi en yüksek firmalar belirli coğrafyalarda kümelenme göstermektedir. Son dönem veri seti ile yapılan analizlere göre bu kümelenmenin daha da derinleştiği görülmüştür. Çalışma sonuçlarının, kümelenme görülen coğrafyalarda çevresel iyileştirme kapasitesini etkileyen dinamiklerin tespitini derinlemesine inceleme üzerinden tespit edecek çalışmalara kaynaklık etmesi öngörülmektedir.

**Özgün Değer:** Ana argüman, küresel ağlar üzerinden, gelişmekte olan ülkelerin tedarikçi firmalarının, üretim süreçlerinin çevresel iyileştirme fırsatı kazanma potansiyeline sahiptirler. Bu araştırma, birçok geleneksel sektörün eski teknolojilerden ekolojik girişimcilik ve temiz enerji teknolojilerine geçiş süreci konusunda Türkiye'nin deneyimini ortaya koyan özgün bir çalışmadır.

**Anahtar Kelimeler:** Ekolojik Ekonomi, Bölgesel Ekonomik Faaliyetler, Teknolojik Yenilik, Çevre ve Kalkınma

**JEL Kodları:** Q57, R11, Q55, Q56

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## 1. Introduction

The prevailing regional development discourses have been in transition from an economic growth focus towards a recognition of environmental issues since the aftermath of the 2008 global financial and climate crisis. There are many claims that the current situation of economic growth is socially and ecologically unsustainable (Gibbs and O'Neill, 2014; Ferguson, 2015). This viewpoint has come forward via the counter neo-liberal agenda against the deepening and widening of capitalism and rising unevenness (Brewer, 2011). This emerging agenda calls for a shift in regional development discourse in such a way as to recognize the problems of rising social exclusion, environmental degradation, and the weak conceptualization of sustainability (Vachon and Klassen, 2008; Bristow, 2009).

Considering the environmental concerns, the global consensus points to the emergence of a new discourse that integrates economic and industrial development objectives with environmental concerns. This discourse about a green economy has been on the agenda since 2008 (Gibbs and O'Neill, 2014). The concept has involved attempts to reduce greenhouse gas emissions and the development of a low-carbon economy. It is defined as follows: "low carbon, resource efficient, and socially inclusive growth in income and employment should be driven by public and private investments that reduce carbon emissions and pollution, enhance energy and resource efficiency, and prevent the loss of biodiversity and ecosystem services" UNEP (United Nations Environment Programme) 2011, p.F16. Low carbon policies have targeted a shift to a greener future and sustainable development and alternative modes of economic development (Dovì et al., 2009).

The green economy has also been acknowledged and promoted by international policymakers, international institutions, and many (the G20) countries (Barbier, 2012; Ferguson, 2015). The World Bank (2012), the organization for Economic Cooperation and Development (OECD, 2015), the International Monetary Fund (IMF), the World Trade Organization (WTO), and UNEP have proposed reports on green economy/green growth and offered funding for green economy initiatives (Death, 2014; Ferguson, 2015). There have been many global meetings and conferences to promote the green economy. By the time of the Rio +20 conference, in 2012, the green economy had been an important issue within policy discourse towards the end of the 2000s (Bina, 2013). In 2008,

the 20th *United Nations Conference on Environment and Development (UNCED)*, held in Rio de Janeiro, was designed to promote global consensus on a green economy. The outcome document of the UN Rio +20 was named *The Future We Want* (Goodman and Salleh, 2013). The 15th conference of Parties to the United Nations Framework Convention on Climate Change (UNFCCC) in Copenhagen in 2009 was the arena leading to the emergence of Brazil, China, India, and South Africa as key players and policy leaders in debates about climate change, conservation, and deforestation. These attempts of countries and corporations have been described as identity building, nation branding, and demands to get first-mover advantages (Barbier, 2012; Death, 2014; Ferguson, 2015).

These attempts at a green economy have been motivated by green growth concerns. Noticeably, the discourses fostering economic growth, development, innovation, and new economic opportunities within the green economy have been inclusive manifestations of green growth (Bina, 2013). The green economy discourse consists of different aspects, ranging from the transition studies that are 'all change' to sustainable future to the green growth and to the business cases for economic growth that are 'business as usual'(Bina, 2013; Gibbs and O'Neill, 2014; Ferguson, 2015). It is argued that green growth "is efficient in its use of natural resources, it minimizes pollution and environmental impacts and is resilient in that it accounts for the role of environmental management and natural capital in preventing physical disasters" (UNEP 2011; The World Bank, 2012, p.1; OECD, 2015). In this manner, it is strongly related to the environmental upgrading efforts of production. These efforts are defined as ecological modernization, which sustains innovation, technology, and progress to respond to environmental concerns (Gibbs and O'Neill, 2014; Ferguson, 2015).

Within the context of environmental upgrading and the green economy, the focus has been mainly the shift from the old technologies in many traditional sectors through green investments, ecological entrepreneurships, clean energy technologies, and green job creation (Barbier, 2012). The green economy concept reflects the emerging environmental discourse in relation to economic development and global production responding to the environmental concerns and to the environmental upgrading of firms and organizations that production processes are greener, resource efficient, less damaging to the environment, and more socially inclusive. Therefore, the R&D innovations in production processes

in environmental manner are may be an important operational part of green economy (Danish and Ulucak, 2020; Wang et al., 2021). Although environmental technologies play a fundamental role in green growth, further investigations are required to understand whether and how environmental technologies affect green growth in developing countries.

Under these circumstances, knowledge about the restructuring of the production of suppliers in developing countries in a greener way is still lacking. The environmental upgrading efforts and the restructuring of production of supplier firms in developing countries represent an important research agenda. This research agenda is important due to its effects on the production process and industrial developments of developing countries like Turkey. This study aims to contribute to environmental upgrading agenda by focusing on the new trends on greening efforts of Turkish manufacturing activities. The environmental upgrading efforts of supplier firms in Turkey is illustrated by creating a R&D and innovation performance index and mapped to detect the spatial agglomerations across Turkey. The index is calculated by using Grey Relational Analysis (GRA) using web-sourced database of the Turkish State of Statistics, Ministry of Industry and Technology and Online Thesis Center of Turkish Council of Higher Education (Yurtseven and Tandoğan, 2012; Belgin and Avşar, 2019).

Relying on the environmental upgrading agenda, the next sections comprise of a brief description of theoretical background examining global value chain and the role of lead firms and the contribution of this research to the agenda; study area and methodology parts, findings of GRA and discussion of the findings in conclusion part respectively.

## 2. Theoretical Background

### *2.1. Global Value Chain and Environmental Upgrading*

Regional development approaches changed as a result of global economic development processes from the 1980s to the late 2000s. Efforts to explain the regional development dynamics have focused on the local capacity of regions during the 1980s. The emergence of industrial clusters has been on the agenda. The strength of endogenous growth and localization trends against the forces of globalization and its circumstances have been reported. Through the end of

the 1990s, the approaches focused on the weaknesses of path-dependency and endogenous growth due to the lock-in effect of focusing regional capacity since production was geographically fragmented. The focus on endogenous growth had begun to cut the regions' competitive capacity and to cause stagnation. As production was geographically fragmented and coordinated via global networks by the 2000s, being articulated to global networks to connect with external knowledge and creating and capturing value–added products were important objectives for regions (Gereffi, 1999; Dicken, 2014).

By the 2000s, the production, distribution, and consumption of commodities, goods, and services were set geographically through complex webs of production networks. The GVC is an approach involving both coordination and collaboration between globally dispersed and complex production (Gereffi and Memedovic, 2003). GVC literature has focused on the governance structure of the value chains, the power relations between chain actors, and the role of lead firms in fostering regional development (Gereffi, 1999; Bettiol et al., 2011). Joining to the global production network is seen to bring upgrading and development opportunities to regions. Lead firms have the major role in fostering upgrading and regional development (Gibbon, Bair and Ponte, 2008; De Marchi and Grandinetti, 2013; Jakobsen and Clausen, 2016).

Noticeably, since the 1980s, value chain governance has changed towards constituting a deeper modular and relational connection between lead firms and suppliers (Khattak et al., 2015). In these governance forms, suppliers are also responsible for designing products, processes, or subsystems using their own technology. Relational value chain governance is built upon a more mutual and complementary relationship of suppliers and customers. Modular value chain governance is built upon the standardizations and specifications that are set by leads firms their suppliers. However, in modular value chains, suppliers need to be able to design their processes using their own technology. Therefore, there is evidence that supplier upgrading is more likely in modular chains, wherein suppliers learn and upgrade beyond production through design and product development. However, marketing and branding innovation activities have barriers and are still under the control of lead firms (Orsato, 2006).

Value chain governance and power asymmetry is associated with environ-

mental upgrading potential for suppliers through the value chain (Geffen and Rothenberg, 2000; Bettiol et al., 2011; De Marchi, Di Maria and Ponte, 2013; Govindan et al., 2015). The new focus of the regional development approach has been on the impacts of greener and more inclusive re-structuring of global production and production nodes. Drawing on GVC approaches, this research focuses on chain level responses to environmental concerns and possibilities for environmental upgrading of suppliers in developing countries.

### *2.2. Environmental Upgrading*

The global production networks propose a knowledge-based relationship between lead firms and suppliers and have thus contributed to the development of firms and regions. The upgrading concept points to the progress of firms' and regions' positions within production networks by improving their internal capabilities and innovative activities (Ernst, 2002) in relation to new products and sustainable production processes. Upgrading issue differentiates as economic, social and environmental (Bettiol et al., 2011), this study focuses on the environmental upgrading relatedly green economy.

### *2.3. Greening the Global Value Chain by Environmental Upgrading*

Due to the rising environmental concerns, pressures of local agendas, rising global consensus on green economy, international/national regulations and actions by NGOs, global production proposes new governance models and environmental innovations through the production network (De Marchi, Di Maria and Micelli, 2013; Goger, 2013).

Environmental upgrading is defined as the technological, organizational, and institutional improvement of both products and production processes by lead firms to reduce the ecological footprint of production, such as the greenhouse effect and high rates of resource consumption (Bettiol et al., 2011). Environmental upgrading aims to achieve resource efficiency and low-carbon growth (Bina, 2013). The environmental innovation strategies of lead firms include proposing changes to produce environmental upgrading for their suppliers via new products and processes (Jakobsen and Clausen, 2016; Poulsen, Ponte and Lister, 2016).

Environmental upgrading also has market-based advantages for lead firms. Environmentally upgraded firms have attempted to transform environmental investments into sources of competitive advantage. It can be seen that lead firms focusing on environmental upgrading have also aimed to reach new markets by gaining environmental abilities as first-movers and by reducing the complexity and cost of inter-firm transactions. These inherent benefits of greening strategies have provided firms with profit and competitive advantages (Goger, 2013) and external drivers such as regulation, cooperation, and buyer demand (De Marchi, Di Maria and Micelli, 2013; De Marchi, Di Maria and Ponte, 2013).

In the environmental manner, four general competitive strategies have been proposed by leading firms (Orsato, 2006). These strategies are eco-efficiency (production process upgrading), 'beyond compliance leadership' (functional and process upgrading), eco-branding (product upgrading) and environmental cost leadership (product and inter-sectoral upgrading). Eco-efficiency leads to redesigning the internal production process of a firm to serve environmental standards. These strategies can be developed by research & development expenditures, technological innovation and human capital. The positive effects of these indicators, especially technological innovation, on green economy and green growth are showed by many scientific researches (Guo, Qu and Tseng, 2017; Guo et al., 2018; Danish and Ulucak, 2020; Wang et al., 2021).

**Table 1. The Environmental Upgrading Strategies of Lead firms**

| | Process upgrading | Product upgrading | Functional upgrading | Inter-sectoral upgrading |
|---|---|---|---|---|
| **Leadership** | eco-efficiency and beyond compliance | eco-branding and environmental cost | beyond compliance | environmental cost |
| **Impacts on the environment** | manufacturing efficiency, resource efficiency, waste and emission treatments, and energy efficiency implementations | moving into product lines with a higher unit value by innovation through new design, the use of new components and materials and a consequent green communication strategy, use of recyclable and certified raw materials, de-materialization, recyclability | reduced use of energy, substitution of polluting materials, use of certified resources | energy saving, emission reduction, recycling of removed materials |
| **Impacts on the competitiveness** | enhanced efficiency, reduction of production cost | strengthened market positioning | improved internal efficiency, new customers | enhancing cost reduction and entry into new markets |
| **Value chain implications** | increased bargaining power and deeper relationship | upgrading of strategic suppliers (design and knowledge sharing) and deep relationships | upstream vertical integration | increased bargaining power and deeper relationship |

The literature of environmental upgrading and green innovation may categorized into two mainstreams, as examining the impact of collaborative green supply chain practices and role of lead firms on manufacturing performance (Geffen and Rothenberg, 2000; Tokatli and Kizilgün, 2004; Vachon and Klassen, 2008; Özatagan, 2011; De Marchi and Grandinetti, 2013; De Marchi, Di Maria and Ponte, 2013) and measuring environmental innovativeness capacity of manufacturing firms based on firm level data and/or region-province level data (Eraydin and Armatli-Köroğlu, 2005; Yurtseven and Tandoğan, 2012; Gibbs and O'Neill, 2014; Karadeniz Yılmaz et al., 2016; De Martino and Magnotti, 2018; Guo et al., 2018; Belgin and Avşar, 2019). This study aims to contribute to the latter one examining the recent spatial pattern of innovative capacity of Turkish

firms by using national databases of Turkey. As considering the previous studies focusing on measuring innovation capacity of Turkish firms, the main contribution is the insertion of geographical manner and sectoral distribution by province level data into measurement of environmental innovativeness capacity researches in Turkey (Table 2). The limitation of this study the lack of available data and limited number of innovativeness indicators. However, this study visualizes the general trend on innovativeness capacity regarding environmental manner and relates the results with sectoral pattern of manufacturing firms across Turkey.

**Table 2. The Recent Literature Review of Measurement of Innovativeness Capacity of Manufacturing Firms**

| Authors | Study | Subject | Method | Case areA | Data | Limitations |
|---|---|---|---|---|---|---|
| Eraydin and-Armatli Köroğlu (2005) | Innovation, networking, and the new industrial clusters: the characteristics of networks and local innovation capabilities in the Turkish industrial clusters | measuring local innovation and networking capabilities of three Turkish industrial clusters by using direct and indirect innovation measures | sampling through in-depth interviews. | Denizli, Bursa, Ankara | firm level data | limited geographical data |
| Yurtseven and Tandoğan (2012) | Patterns of Innovation and Intra-industry Heterogeneity in Turkey | the patterns of innovation in Turkey | double - level factor analysis and cluster analyses | Turkey | firm level data | no geographical clustering |
| Karadeniz Yılmaz et al. (2016) | Analysis of Competitiveness of Provinces in Turkey with the Help of Innovation Index: Level-III | the competitiveness of the provinces on the level of 26 NUTS considered spatial units in Turkey | The innovation index by 22 variables and factor analysis to present the competitiveness of the provinces | Turkey | province level data | lack of sectoral data |

| | | | | | | |
|---|---|---|---|---|---|---|
| De Martino and Magnotti (2018) | The innovation capacity of small food firms in Italy | to analyze the innovation capacity of small and medium enterprises (SMEs) and micro enterprises through the influence of some internal and external resources | a structured questionnaire through the cluster analysis | Campania region, Italy | firm level data | a static view in comparison to the longitudinal analysis |
| Belgin and Avşar (2019) | Measuring R&D and Innovation Performance at Regional and Provincial Level in Turkey Using Grey Relational Analysis | to measure Turkey's R&D and innovation performance at regional and provincial level. | Grey Relational Analysis | Turkey | province level data | no geographical visualization |

## 3. Study Area and Methodology

The study area is Turkey as a developing country and as having a great ratio of manufacturing activities in the global economy. The transition process of manufacturing towards clean energy technologies is increasingly continues in Turkey (Tokatli and Kizilgün, 2004). This study aims to figure out the current spatial pattern of environmental upgrading capacity of Turkish industrial nodes and firms using innovation indicators and R&D expenditures data of national databases. The environmental upgrading strategies that are mentioned in Table 1 are recorded as innovation and R&D activities of firms and enterprises in Turkish national databases. The R&D and innovation activities are highly related with the upgrading of production process such as reduction of toxic outputs, development of recycling and reduction of use of raw materials (Guo et al., 2018).

In order to understand the innovative capacity of Turkish firms, "the innovation and R&D index" is calculated by calculating grey relational grade (GRG) of provinces based on detailed indicators from web-based national databases in terms of greening efforts in manufacturing. The data is sustained from national

database of the Turkish State of Statistics, Ministry of Industry and Technology and Online Thesis Center of Turkish Council of Higher Education. The database is comprised into three subgroups as the numbers of (1) R & D and Innovation infrastructure, (2) R & D Competence and University -Industry Cooperation, (3) patents, design applications and technology-based exports in each province of Turkey (Table 3).

*3.1. The Green Economy and Environmental Upgrading in Turkey*

The current spatial pattern of industrial nodes has been rooted in 1980s as an important turning point in economic policies in Turkey. By the 1980s, the change from protectionist attitude to liberalized trade has been occurred by reliance on foreign trade and exchange in industrial politics of Turkey. Economic transformations and the new competitive environment also enforced to occur a new spatial pattern of industrial activities and nodes. The new industrial agglomerations are in different parts of Turkey with different evolution dynamics. Some of these nodes are specialized in certain industries relying on their institutional and external/internal cooperation capacities within new flexible production systems (Eraydin and Armatli-Köroğlu, 2005). These new industrial nodes are still active manufacturing areas in Turkey and located at inner parts of the Anatolia and at the periphery of metropoles. These industrial nodes are locally mentioned as "Anatolian Tigers", "new industrial nodes" or "new industrial clusters" (Figure 1). Besides İstanbul, İzmir and Ankara, the noticeable nodes are Denizli, Gaziantep, Kayseri, Konya, Tekirdag, Çorum, Manisa in this regard. The locations and their main sector are represented in the Figure 1, as seen they are mostly located at the inner and west part of Anatolia.

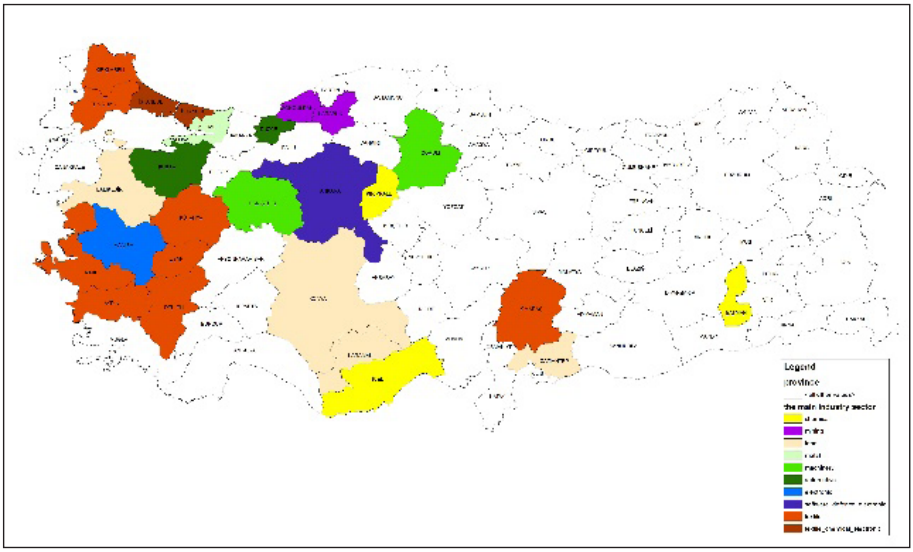


**Figure 1. The spatial pattern of main manufacturing sectors**
**Source: Author, 2021**

The spatial and sectoral agglomeration is as seen in the Figure 1. The dominant sectors are traditionally textile, automotive, machinery and food in Turkey. As seen in the Figure 1, there are specialized manufacturing nodes in traditional sectors such as at Denizli and Bursa, as well as nodes with modern and high-tech firms of different manufacturing fields such as at Istanbul and Ankara.

Along with the developments in the world economy, it is seen that plans, macro policies and strategies aim sustainable targets on economy in Turkey as well. There are increasing trend in R&D expenditures of manufacturing in Turkish firms (Özatagan, 2011; Ministry of Industry and Technology, 2021). The share of R&D expenditures in GDP has risen from 1,03% in 2018 to 1.06% in 2019 (Turkish Statistical Institute, 2019). These activities of firms have been also supported by legislative regulations in Turkey. It is achieved by the five-year development plans with the great support on green investments, ecological entrepreneurships, and clean energy technologies. The concept of green economy was first mentioned in Turkey with the 7th five-year development plan which was implemented between 1996-2000 (Turkish Statistical Institute, 2019). In this plan, the importance of environmentally responsive productions, employments

and energy efficiency are emphasized. It is aimed to support R&D investments in energy efficiency by the support of State Planning Organization. The mainstream of the plan was to increase the number of green employees and ecological entrepreneurships and to improve working conditions of employees (Başol, 2018).

In the 8th five-year development plan for 2001-2005, the green employments were defined in common with the definition of ILO (International Labor Organization). Accordingly, it was aimed to reduce greenhouse gas emissions, to sustain the sustainability of natural resources, to support the use of environmentally enhanced technologies and to increase the number of employees in these areas, and to support the green entrepreneurs (State Planning Organization, 2000). In the 9th five-year development plan for the years 2007-2013, the definition of the ILO on the concept of green employees and employments is included for the first time in development plans. The points highlighted in these plans are the advance technologies in the renewable energy sector and the employees in this sector (Official Gazette, 2006, number: 26215).

Likewise, in the in 10th five-year development for the years 2014-2018, the importance of green employments is increasingly emphasized. In the 10th five-year development plan, it is aimed not only to create green employments on renewable energy or energy efficiency, but also to improve the green production capacity of the service, agriculture, tourism, construction and manufacturing sectors, and to improve the working conditions of labors (Ministry of Development, 2016). The 10th development plan is the first development plan that emphasize not only the environmental and economic benefits but also the social benefits of the production processes.

In addition to five-year development plans, another indicator to monitor the development of green economy is the ratio of green employments in Turkey. Although the percentage of green employees in the public sector is decreasing, there is a significant increase in the number of green employments and employees in the private sector in Turkey. In 2015, more than 80,000 individuals were employed in green employments. Unfortunately, the ratio of employment is 0.30% in Turkey, while it is 2% in the European Union, 2.4% in the US and 1.5% in OECD countries (Başol, 2018).

According to the statistical analyses upon green growth, Turkey is the 13th country among 40 OECD countries (Venables, 2006). However, Turkey puts ef-

forts on the green growth by considering measurable future targets on the manufacturing and related activities (Tokatli and Kizilgün, 2004). The development pattern of firms on either product or process upgrading is shown in the Figure 2 by using the recent data of TSI (Turkish Statistical Institute, 2019). The Figure 2 shows the percentage of enterprises with product and/or process innovation based on economic activity classification in 2016-2018. In this Figure, total of value of each line don't give 100 because an enterprise may introduce both product and process innovation and may have more than one option in economic activities.

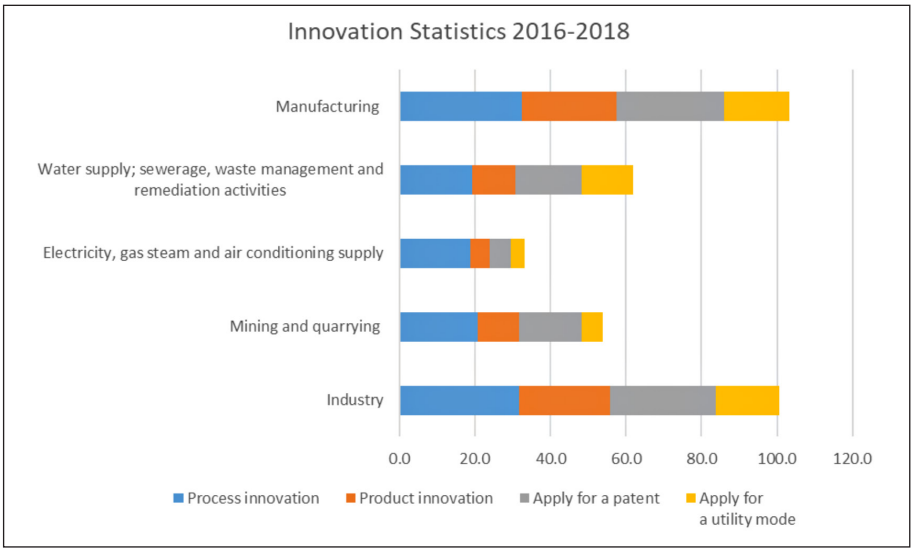


**Figure 2. The greening innovations in Turkish firms 2016-2018**
**Source: (Turkish Statistical Institute, 2019)**

Parallel to the legal regulations in Turkey, the R&D and innovation scores of firms are important indicators regarding environmental upgrading capacity of Turkish Firms (Yurtseven and Tandoğan, 2012; Yılmaz, 2017; Belgin and Avşar, 2019). Although there are academic studies that finds evidences on product and process upgrading of firms in textile manufacturing firms in Denizli and İstanbul (Tokatli, 2007a, 2007b) and automotive sector in Bursa (Özatagan, 2011), there is still room to re-generate general trends on environmental upgrading of Turkish

firms. This study aims to contribute to assess greening efforts of Turkish firms and to figure out the current pattern of environmental upgrading capacity of industrial nodes in Turkey by using innovation indicators and R&D expenditures data of national databases.

*3.2. Methodology*

In order to understand the innovative capacity of Turkish firms, "the innovation and R&D index" is calculated by Grey Relational Analyze (GRA) method using various indicators. The direct measures of innovation are identified as the number of patents, quality certificates and new or modified products and production processes introduced by a firm. On the other hand, indirect measures of innovative capacity are assumed as the share of R&D personnel in total employment and the percentage of R&D expenditures in total expenditures of a firm. In the calculation of R&D and innovation performance index, 12 indicators are used under the 3 main categories as in the Table 3. These categories are (1) R&D and Innovation Infrastructure, (2) R&D Competence and Public-University-Industry Cooperation and (3) Intellectual Property Rights and Commercialization data. The detailed data are listed in Table 3 under these categories. These data are compiled from the 2021 database of the Turkish State of Statistics, Ministry of Industry and Technology and Online Thesis Center of Turkish Council of Higher Education and as secondary data of related research papers (Yılmaz, 2017; Belgin and Avşar, 2019; Turkish Statistical Institute, 2019; Ministry of Industry and Technology, 2021; Turkish Council of Higher Education, 2021).

**Table 3. The indicators of the database (Yılmaz, 2017; Belgin and Avşar, 2019; Turkish Statistical Institute, 2019; Ministry of Industry and Technology, 2021; Turkish Council of Higher Education, 2021)**

| R & D and Innovation Infrastructure | R & D Competence and Public University Industry Cooperation | Intellectual Property Rights and Commercialization |
|---|---|---|
| Total R & D Centers in the Province | Number of R & D Projects | Number of Patent Applications in the Province |
| Total number of technology development zones in the province | Number of R & D Projects Supported by SME | Number of trademark applications in the province |
| Number of R & D Personnel in the Province | Amount of Industrial Thesis in the Province | Number of Utility Model Applications in the Province |
| R & D Expenditure of the Province | | Number of Design Applications in the Province |
| | | Number of Exports in the Province |

For this study, the value of R&D and innovation performance index for each industrial nodes are calculated based on province-level data by using GRA. GRA is one of the derived evaluation methods for index creations in multi-criteria cases. GRA is a powerful method in terms of performance grading rather than VIKOR and TOPSIS. When the studies that compare these methods are considered; it is seen that the GRA method ranks successfully in a situation where the conditions are not clear. VIKOR and TOPSIS are more about consensus building and decision making rather than ranking or performance grading (Rençber, 2019). Besides, there are studies claiming that the subjective or collective determination of the *v consensus parameter* of the VIKOR method can also cause significant changes in the ranking (Ceballos, Lamata and Pelta, 2016).

The main purpose of the method is to create an index where alternatives can be compared with each other. The basic idea is to determine the degree of relationship between each criterion and the reference dataset. GRA calculates a single value for every alternative by combining the attribute values that are

considered for. This process reduces the multi-criteria decision-making problems into a single-objective problem. GRA method has 3 steps as (1) normalization, (2) calculation of grey relational coefficient and (3) calculation of grey relational grade. Firstly, experimental data are normalized to values between 0-1. Secondly, grey relational coefficient expresses the relationship between ideal and current normalized experimental results. Finally, grey relational grade is calculated by averaging the grey relational coefficient values of each performance indicator (You et al., 2017; Belgin and Avşar, 2019)

For such a multi-criteria decision making (MCDM), the value of GRG is aimed to represent the greening efforts of each industrial nodes based on province-level data.

In this study, a R&D and innovation performance index is calculated by first normalization of each indicator, and then calculation of grey relational coefficient (GRC) and thirdly calculation of the GRG based on the average value of GRC records of each indicator (Figure 2).

$$x_{(k)} = \frac{X_i(k) - min\ X_i(k)}{max\ X_i\ (k) - min\ X_i\ (k)} \qquad (1)$$

$$\delta_i\ (k) = \frac{\Delta \min + \delta \Delta \max}{\Delta_{0,i}(k) + \delta \Delta max} \qquad (2)$$

$$\gamma_i = \frac{1}{n} \sum_{k=1}^{n} \delta_i\ (k) \qquad (3)$$

Where:

$\boldsymbol{x_{(k)}}$ is the original sequence,

$\boldsymbol{\Delta_{0,i}}$ is the deviation sequences of the reference sequence and comparability sequence

$\boldsymbol{\delta_i}$ is known as identification coefficient (GRC)

$\boldsymbol{\gamma_i}$ represents GRG

## 4. Findings

This study aims to figure out the spatial agglomeration of most innovative firms in greening manner in Turkey. It is calculated by index calculation using GRA

method with R&D and technological innovation indicators. R&D and innovation performance index is the standardized score of the average value of each indicator. It is calculated using 12 indicators summarized in the Table 4. The statistical results summarized in the Table 3. First of all, the correlation coefficient is 0.98 that is the evidence of the perfect linear relationship between all variables in the database. The table shows that the average R&D and innovation index is 0.13 (< 0.5), mode is 0 and the standard deviation is nearly 0.2. Since the value of standard deviation is close to the value of mean, it can be said that the total efforts of green production of firms is low across Turkey. Besides, considering these values and also skewness (positive skewed with the value of 1.49) and kurtosis (heavy-tailed distribution with the value of 2.78), it is seen that firms with technological innovation and R&D are highly accumulated in particular geographies. These indexes have insights about the transformation trends to greener economy of firms and the details of indicators can represent the upgrading capacity of firms and industrial sectors in the provinces.

**Table 4. Descriptive Statistics of GRA results**

| | |
|---|---|
| Mean | 0.130023353 |
| Standard Error | 0.022125891 |
| Median | 0 |
| Mode | 0 |
| Standard Deviation | 0.199133021 |
| Sample Variance | 0.03965396 |
| Kurtosis | 2.788827486 |
| Skewness | 1.494655942 |
| Range | 1 |
| Minimum | 0 |
| Maximum | 1 |
| Sum | 10.53189163 |
| Count | 81 |
| Confidence Level (95.0%) | 0.044031927 |

Since the distribution of data is not symmetrical and heavy-tailed, the value of indexes is spatialized using Jenks natural break classification technique to reveal the spatial agglomeration of most upgraded sectors and firms in Turkey

(Figure 3). According to the results the R&D and innovation performance is highly agglomerated in İstanbul and after that in Ankara, İzmir and Bursa city regions (Table 5 and Figure 3). Comparatively, it may be claimed that innovation capacity of İstanbul has been deepened divergently. Furthermore, through the information of Figure 1 and Figure 3, it may be said that the most upgraded sectors are textile, automotive, electronics and chemical in Turkey. Besides these nodes, these sectors mostly agglomerated at Manisa, Denizli and Tekirdağ. As İstanbul and Ankara are specialized at varied field of industrial production, the firms in these nodes have the highest degree in innovation and R&D activities.

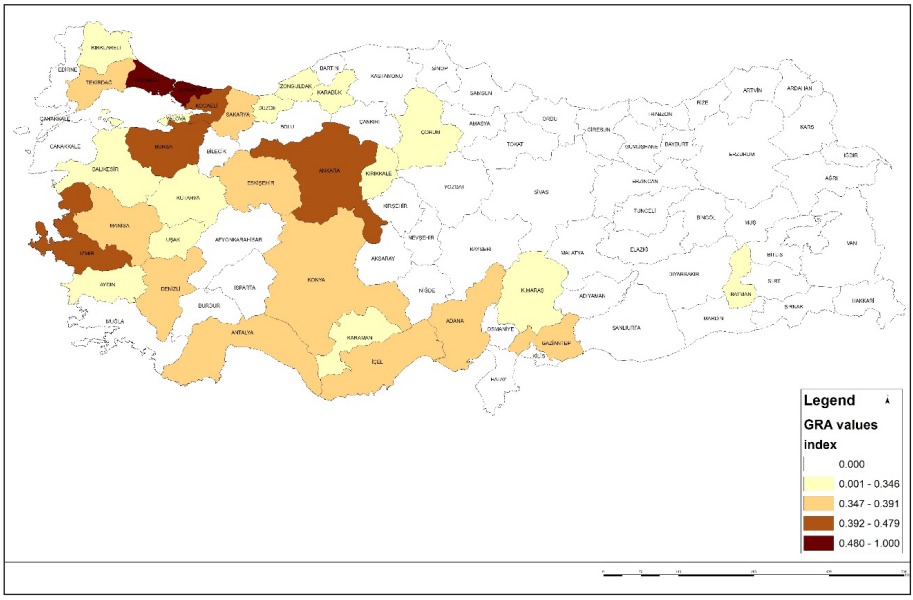


**Figure 3. The spatial agglomeration of most environmentally upgraded firms in Turkey**

**Source: Author**

**Table 5. GRA results**

| Provinces | Index | Provinces | Index |
|---|---|---|---|
| İSTANBUL | 1 | KONYA | 0.355230165 |
| İZMİR | 0.473618263 | SAKARYA | 0.353159827 |
| KOCAELİ | 0.419491692 | MERSİN | 0.352210458 |
| BURSA | 0.459588208 | ESKİŞEHİR | 0.351745327 |
| ANKARA | 0.478898639 | DENİZLİ | 0.349912949 |
| TEKİRDAĞ | 0.391080262 | BALIKESİR | 0.345804802 |
| GAZİANTEP | 0.383841277 | AYDIN | 0.345234722 |
| MANİSA | 0.373274509 | DÜZCE | 0.340926494 |
| ANTALYA | 0.365871116 | KÜTAHYA | 0.339874343 |
| ADANA | 0.363336691 | KIRKLARELİ | 0.339126296 |
| K.MARAŞ | 0.338536852 | ÇORUM | 0.334684974 |
| UŞAK | 0.337530798 | KARAMAN | 0.334299101 |
| YALOVA | 0.33592586 | KARABÜK | 0.333943923 |
| ZONGULDAK | 0.334744082 | OTHER CITIES | no data |

## 5. Conclusion

The global economy and production have experienced restructuring in the production processes since the 2008s environmental and economic crisis. Turkey is one of the developing countries that has been affected by the restructured economic conditions. The firms in Turkish industrial nodes have achieved environmental upgrading in production processes by governance networks with external and internal partnerships. Some of these industrial nodes are in the periphery of the metropolitan areas and others in the inner parts of Anatolia.

As mentioned, there are internal and external factors as the determinants of environmental upgrading. External factors are mainly governance of GVCs regulated by legal regulations, restrictions, demands of lead firms and customers, pressure of NGOs. Besides, internal factors are the innovative capacity, R&D, human capital, willingness, competitive advantage, and governance types. As seen in the many industrial sectors in developing countries, Turkish firms also have gain opportunities to environmental upgrading both benefiting from the GVCs by global relations and also by using their existing local capacities (Eraydin and Armatli-Köroğlu, 2005).

This study aims to figure out the efforts to environmental upgrading of Turkish manufacturing firms. Furthermore, it is aimed to reveal Turkey's R&D and innovation performance at provincial level. The proposed model for creating R&D and innovation performance index of provinces relies on the optimization of the 12 indicators. These indicators consist of (1) R&D and Innovation Infrastructure, (2) R&D Competence and Public-University-Industry Cooperation and (3) Intellectual Property Rights and Commercialization.

The database is mainly relying on open-sourced data from public authorities and reports by private groups. The limitations of study are lack of internal firm-level knowledge and sector specific knowledge. Although the data of national databases have limitations; it gives hints about the environmental upgrading capacity of Turkey. Turkey has an increasing trend in environmental upgrading activities at high-tech manufacturing sectors as well as at traditional sectors such as textile, electronic, chemical and defense industry. Especially traditional sectors are important to achieve environmental upgrading, due to their prevailing production capacity in Turkey. Relying on the results of GRA, it is considered that the most innovative firms are divergently located at İstanbul, Ankara, İzmir and Bursa (Figure 3). Considering earlier studies on the innovative capacity of Turkey, it is seen that the innovative capacity of Istanbul has been deepened and dramatically risen rather than Ankara, İzmir and Bursa (Karadeniz Yılmaz et al., 2016). Moreover, it is seen that Manisa, Tekirdağ, Mersin and Aydın have a relatively increased situation in terms of innovate capacity.

The results of this study aim to support further studies to highlight the firm-level and sector-level experiences and supporting factors of green growth in Turkey. Furthermore, the results of the study aim to contribute to the insights of environmental upgrading trends and efforts in Turkey.

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