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ANALYSIS OF TURKISH TECHNOLOGY TRANSFER OFFICES' IMPACT ON LOCAL ECONOMIC GROWTH: A QUANTITATIVE APPROACH

BY

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ÖZET

Altay Oğulcan Dalkılıç, Türkiye'deki Teknoloji Transfer Ofislerinin Yerel Ekonomik Büyümeye Etkisinin Analizi: Nicel Bir Yaklaşım, Başkent Üniversitesi, Sosyal Bilimler Enstitüsü, Teknoloji ve Bilgi Yönetimi Tezli Yüksek Lisans Programı, 2023

Schumpeter'in de öne sürdüğü gibi, geçiş yaptığımız bilgi-tabanlı ekonomide inovasyon, ilerleme için çok önemli bir hal almıştır. İnovasyon ve ekonomik kalkınma arasındaki ilişki, birçok akademisyenin ve politika yapıcının odak noktası haline gelmiştir. İnovasyon ve kalkınma üzerine yapılan çalışma ve araştırmaların artmasıyla birlikte, sermaye ve yüksek vasıflı iş gücünü, inovasyonun tek belirleyicisi olarak gören bakış açısı solmuştur. İnovasyon süreci, ekonomik bir değer yaratmak için bilginin ticarileştirilmesini içerir. Son zamanlarda yapılan çalışmalar, inovasyon sürecinin mevcut bilgiyi yeniden birleştirmenin yanı sıra yeni bilgi üretmeye dayandığını da vurgulamaktadır. Bu nedenle, inovasyon yaratmayı artırmak için bilgiye dayalı bir ekonomide aktörler arasında bilgi paylaşımını desteklemek esastır.

Literatürde, bilgiye dayalı bir ekonominin ana aktörleri, üniversite, sanayi ve devlet olarak tanımlanmaktadır. Çalışmamızın çerçevesini belirlemek adına Üçlü Sarmal Modeli çerçevesi izlenmiştir. Üçlü Sarmal Modeli, bu etmenler arasındaki etkileşimleri ve bilgiye-dayalı ekonominin dinamiklerini modelleyen teorik bir çerçevedir. İnovasyon ekosistemlerinde teknoloji transferine yönelik artan farkındalık, üniversiteleri sanayi ile işbirliğine aracılık etmek üzere Teknoloji Transfer Ofisleri kurmaya yöneltmiştir. TTO'lar, akademi ve endüstriyi bir araya getirerek ve bir bilgi brokeri gibi hareket ederek teknoloji transferini teşvik eder.

Türkiye, bilgiye dayalı ekonomiye uyum sağlamak adına 1990'ların sonundan itibaren inovasyon ekosistemini geliştirmeye ve 2000'lerin başından itibaren de teknoloji transferi faaliyetlerine başlamıştır. Bu faaliyetlerin bir parçası olarak Türkiye genelinde çok sayıda TTO kurulmuştur. Bu çalışma, Teknoloji Transfer Ofislerinin şehir düzeyinde yerel ekonomik büyüme üzerindeki etkisine odaklanmaktadır. Koşullar şehirden şehre farklılık gösterdiğinden, kalkınmaya olan etkiyi belirlemek ve Türkiye'nin inovasyon ekosistemi için genellenebilir bir sonuca ulaşmak için bir dinamik panel veri analiz yöntemi olan iki yönlü iki aşamalı Sys-GMM yaklaşımı uygulanmıştır. Sonuçlarımız, TTO'ların pozitif ve istatistiksel olarak anlamlı bir etkisi olduğunu göstermektedir.

Anahtar Kelimeler: Teknoloji Transferi, Teknoloji Transfer Ofisleri, Ekonomik Kalkınma, Üçlü Sarmal Modeli, Sys-GMM

ABSTRACT

Altay Oğulcan Dalkılıç, Analysis of Turkish Technology Transfer Offices' Impact on Local Economic Growth: A Quantitative Approach, Başkent University, Institute of Social Sciences, Master's of Technology and Knowledge Management with Thesis, 2023

As Schumpeter argues, societies are transitioning into a knowledge-based economic system where innovation is crucial for progress. The relation between innovation and economic development has become the focus of many scholars and policy-makers. With the growing number of studies and research on innovation and growth, the perspective on innovation which considered capital and high-skilled labor as only determinants of innovation, has faded. The innovation process includes commercialization of knowledge to create an economic value. Recent studies emphasize that innovation process relies on producing new knowledge as well as recombining existing knowledge. Therefore, it is essential to support knowledge sharing between actors within a knowledge-based economy to increase innovation creation.

Literature identifies the main actors of a knowledge-based economy as university, industry, and government. To define the framework of our study, we follow the Triple Helix Model. The Triple Helix Model is a theoretical framework that models the interactions between these agents and the dynamics of a knowledge-based economy. The growing awareness on the transfer of technology in innovation ecosystems led universities to establish Technology Transfer Offices to mediate collaborations with industry. By bringing together academia and industry and acting as a knowledge broker, TTOs encourage technology transfer.

Turkey started improving its innovation ecosystem to adapt to knowledge-based economy in late 1990s and started its technology transfer initiatives in early 2000s. As a part of these initiatives, many TTOs were established all around Turkey. This study focuses on the impact of Technology Transfer Offices on local economic growth at city-level. Since the conditions differ from city to city, we follow a two-way two-step Sys-GMM approach, a dynamic panel data analysis method, to identify the impact and to reach a generalizable result for Turkish innovation ecosystem. Our results indicate that there is a positive and statistically significant effect of TTOs.

Keywords: Technology Transfer, Technology Transfer Office, Economic Growth, Triple Helix Model, Sys-GMM

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LIST OF ABBREVIATIONS

GMM	Generalized Method of Moments
HEI	Higher Education Institution
IP	Intellectual Property
IV	Instrumental Variable
OECD	The Organization for Economic Co-operation and Development
THM	Triple Helix Model
TT	Technology Transfer
TTO	Technology Transfer Office
TURKPATENT	Turkish Patent and Trademark Office
TURKSTAT	The Turkish Statistical Institute
TÜBİTAK	The Scientific and Technological Research Council of Turkey
UIC	University-Industry Collaboration
WIPO	World Intellectual Property Organization

1. INTRODUCTION

"The knowledge production function has become a structural characteristic of the modern economy" (Schumpeter, 1939; cf. Leydesdorff, 2010). Schumpeter's idea of innovation-lead economic growth has become a widely accepted theory in economic literature. However, the creation of innovation and the innovation creation process have often been neglected and assumed to be a process only handled by scientists and engineers (Freeman, 1994) where capital and high-skilled labor being the only determinants of it. With the growing body of studies on innovation, improving knowledge creation, and the relation between economic growth, this approach has been fading at least for over the last 40 years. Entrepreneurship and competitiveness has been a recent topic of interest for both academics and policy makers (Lamine et al., 2018). Modern evolutionary growth theories now consider knowledge production as another factor of growth and a separate production process than physical production of goods.

Oslo Manual published by the OECD and the Eurostat, defines innovation as; *"new or improved product or process (or combination thereof) that differs significantly from the unit's previous products or processes and that has been made available to potential users (product) or brought into use by the unit (process)"* (OECD, 2018, p. 20). As Leone et al. (2022) states, innovation is not only achieved by creation of new knowledge, but also triggered by knowledge recombination, thus, innovation production relies on both the size of the knowledge-base and the accessibility of this knowledge-base by the R&D personnel within the innovation ecosystem.

Triggering the production and development of new technologies requires the parallel and joint efforts of academicians, industry members, and policy-makers of an innovation environment, or an innovation ecosystem (Žmuidzinaitė et al., 2021). An innovation ecosystem can be defined as "*an evolving set of actors, activities, and artifacts (products, technologies, etc.), and the institutions and relations, including complementary and substitute relations, that are important for the innovative performance of an actor or a population of actors*" (Granstrand & Holgersson, 2020, p. 1). An innovation ecosystem that initiates the technological development that will stimulate the economy, needs to encourage research and knowledge sharing between actors of the innovation process.

Innovation requires interaction of actors of an innovation ecosystem. In the literature, main actors of an innovation ecosystem are identified as university, industry, and government (Cai & Amaral, 2021; Cai & Etzkowitz, 2020; Etzkowitz, 2008; Etzkowitz & Leydesdorff, 1995; Etzkowitz & Zhou, 2017; Leydesdorff, 2010). To understand the interactions of these actors, and to model the dynamics of a knowledge-based economy and their innovation ecosystem, Triple Helix Model (THM) framework was constructed (Etzkowitz & Leydesdorff, 1995). Following this framework and the depiction of Greenhalgh and Rogers (2010), we simplify the innovation process as follows:

Starting with its definition, innovation must lead to economic value creation (OECD, 2018). Therefore, learning new knowledge or a discovery is not an innovation without commercial use. Yet, an idea must emerge to start the process of innovation. A new idea emerges from knowledge-base, and knowledge-base is expanded by research conducted by universities and research institutes. Following the creation of an idea, the idea should be tested and implemented. This requires further research and testing by utilization of the infrastructure of the innovation ecosystem. This implies the significance of development level of the existing infrastructure. Also, innovation process should serve a demand of market. Industry plays an important role in determining these demands. Throughout the innovation process, government policies and funding schemes define the business environment and direction and density of research activities.

A broad definition of Technology Transfer (TT) belongs to (Mittleman & Pasha, 1997, p. 60); "*the movement of knowledge, skill, organization, values and capital from the point of generation to the site of adaptation and application*". In the recent related literature, the term TT refers to "commercialization of university research" (Good et. Al, 2019), so we use it in the same way as well. TT became a widely studied concept starting with the regulations of US government in 1970s and 1980s, the most known example being the "Bayh-Dole Act" that led the university research to collaborate with industry for commercialization. With these regulations, a great shift occurred in the research practices of Higher Education Institutions (HEI), and their impact on economy has been the focus of many studies in the literature (Agasisti et al., 2019; Algieri et al., 2013; Drucker & Goldstein, 2007; Kutlutürk & Orhan, 2021).

As innovation ecosystems developed and collaborations grew more complex, agents to mediate and manage these relations and collaboration processes, namely technology transfer offices, were established. Technology Transfer Offices (TTOs), are agents that connect the universities with industry to trigger technology transfer and diffusion as well as providing services to foster this process (Değerli & Tolon, 2016; Good et al., 2019; Siegel et al., 2003; Soares et al., 2020; Žmuidzinaitė et al., 2021).

Turkey started its initiatives to develop its innovation ecosystem in late 1990s and early 2000s. Turkey took quick steps towards adoption of the new entrepreneurial approach on university research and soon after scholars started studying the impact and the success of these policies (Acar, 2022; Akçakanat et al., 2010; Erkul & Kırankabeş, 2020; Görkemli, 2009; Pekol & Erbaş, 2011; Sargın, 2007). This study aims to contribute to this literature from a technology transfer standpoint by analyzing the impact of TTO's on the local economy and attempting to identify their intermediary effect on the relationship between patent applications and economic growth with a quantitative model. Section 2 explains the relation between innovation and economic growth within a knowledge-based economy as well as drawing the theoretical framework of our study. Section 3 elaborates on technology transfer and University-Industry collaboration. Section 4 explains the TTO concept, role of TTOs in Turkish innovation ecosystem and gives a detailed explanation of factors that affect TTO performance. Section 5 is our methodology and models. In section 6 we include our findings and test for the robustness of our model. Finally, in section 7 we discuss the results of our models and the underlying causes of low impact and low performance in Turkish TTOs.

2. THEORETICAL FRAMEWORK

2.1. Innovation and Economic Growth

Schumpeter defines the basis of economic progress in a capitalist society as the intrusion caused by constant competition between new and old. As new methods and products are introduced, old methods and products are replaced and all firms are forced to take part in this competition to survive, thus, to innovate (1942).

Before the knowledge-based approach to economic growth and development, the neoclassical models of growth considered knowledge as a byproduct of capital accumulation (Akcigit, 2017). The last two hundred years brought significant technological progress that impacted the world economy, and now the role of R&D and innovation is considered central in the development of the world technology frontier. However, neoclassical approaches have very little focus on catching the impact of technological progress on economic growth in their models, so in the early 90s, studies started shifting towards an innovation-based growth approach (Akcigit, 2017). This new approach assumed the source of innovation as "ideas". "Ideas" is a function of the size of the knowledge-base in the system and the number of researchers that produce and process it. As Acemoglu et al. (2016, p. 11483) explain, innovation is sourced by past accomplishments, which they summarize with Newton's phrase "standing on giants shoulders".

As studies progress, the question of "What has led to economic growth?" started to find its answer in knowledge production, and now left its place to the question "How knowledge leads to economic growth?" Akcigit (2017, p. 4) briefly summarizes this process in two steps; first, the investment in theory-oriented and abstract "basic research" that leads to production of "fundamental, essential, first-stage background knowledge in the form of theories and equations" which is usually carried out by universities or public research labs; second, innovators and companies, the industry members who seek profit, invest in end-product-oriented "applied research". This approach further emphasizes the significance of interaction and knowledge sharing between agents of the innovation ecosystem for economic growth, or in other words, Technology Transfer.

However, literature argues that the impact of innovative or entrepreneurial activities differs for countries that have different levels of development. Entrepreneurial activities require developed institutions and networks of technology transfer to be successfully transformed into economic value (Akcigit, 2017; Stel et al., 2005; Zelenkov & Lashkevich, 2020). Further developments of economic growth models focus on macro level growth analysis with micro level data, enhancing the micro foundations for more accurate positive predictions. Innovation is not only based on newly produced theoretical knowledge, but also on recombination of previous innovation which is previously combined knowledge. Enabling such a level of combination is what creates the necessity of management and governance of interaction and networks. This necessity can be fulfilled by effective policies that aim to create an environment that nurtures innovation production.

2.1.1. Understanding and modelling Knowledge-Based Economy

Knowledge-based economy has become a very common term to define the economic dynamics of our age since it has been first used in OECD 1994 (Leydesdorff, 2010). A knowledge-based economy refers to "*trends in advanced economies toward greater reliance on knowledge, information, and highly-skilled labor*" (Aparicio et al., 2023, p. 318). One of the key ideas behind knowledge-based economy is that the tradability of knowledge when it is codified. Codifying knowledge into abstract system of symbols decontextualizes it and enables it to be shared, exchanged (Dasgupta & David, 1994) and explained for different areas of experience (Leydesdorff, 2010).

> *"Many international and multi-national programs of the UN, the OECD, the World Bank, and the European Union assist economic development by relying on academic-industry-government relations to achieve their goals. Thus, a new mode of production is emerging based on linkages among academia, industry, and government." (Etzkowitz & Leydesdorff, 1995, p. 3)*

Leydesdorff and Etzkowitz (1996), emphasize two characteristics of the new economic system identified in the literature. First is that the firms and technologies are evolving together, as development of technologies means the development of knowledge infrastructure and development of the knowledge infrastructure enable the development of firms' capacity to grow. Second is the relation between academia and industry at an institutional level. Based on these perspectives and findings, Leydesdorff and Etzkowitz further derive three main dynamics of the knowledge-based economy: "the economic dynamics of the market, the internal dynamics of knowledge production and the governance of the interface at different levels".

"The metaphor of a knowledge-based economy appreciates the increased importance of organized R&D in shaping systems of innovation. The knowledge production function has become a structural characteristic of the modern economy." (Leydesdorff, 2010, p. 2)

To explain the interaction between science and markets, Leydesdorff and Etzkowitz (1996), refer to Braverman's "transformation of science itself into capital" claim (1998), and Marx's (Marx, 1953; cf. Leydesdorff & Etzkowitz, 1996) argument that this transformation will become the new source of industrial growth instead of land, labor, and capital. However, Leydesdorff and Etzkowitz also point out the institutional differences between the main actors in a knowledge-based economy, "the functional differentiation between sciences and markets, and the institutional difference between private and public control". Due to such differentiations and the increase in the number of interactions, structures started to form as a result, such as strategic alliances between firms and centers in universities (Leydesdorff & Etzkowitz, 1996) (we would like to point out that this is where TTOs take part in this framework), which also increase the complexity of the economic system even further as well as the necessity of governance. With such a complex and ever-evolving system to understand, Leydesdorff and Etzkowitz construct a model representing the three institutions; academia, industry, and government; as helices; the Triple Helix Model.

2.1.2. Triple Helix Model

Triple Helix Model is a theoretical framework constructed by Etzkowitz and Leydesdorff (1995), to model the dynamics in a knowledge-based economy. According to Cai and Amaral (2021, p. 217), the Triple Helix model explains "the dynamic interactions between academia, industry, and government that foster entrepreneurship, innovation, and economic growth in a knowledge-based economy". The model builds upon the idea of three main actors that interact with each other in an innovation ecosystem, which are university, industry, and government (Etzkowitz & Leydesdorff, 1995). In his 2010 study, Leydesdorff restates the sub-dynamics of these interactions that form the knowledge-based economy as:

1) Wealth generation in the economy,

2) Novelty generation by organized science and technology,

3) Governance of the interactions among these two dynamics by policymaking in the public sphere and management in the private sphere.

The model acknowledges that the participating agents are constantly interacting with each other to adapt to changing conditions and opportunities as well as to each other, while resulting in observable events such as patents (*Figure 2.1*) (Leydesdorff, 2010; Leydesdorff & Etzkowitz, 1996). In line with this view, our first hypothesis is as follows:

H_1: Number of patent applications have positive and statistically significant effect on local per capita GDP.

Leydesdorff (2010) states that these interactions, or functions as he refers, should be analyzed in terms of "transformative dynamics". The dynamics of a knowledge-based economy are in a constant state of change. These transformations are a form of adaptation of helices, or spheres, to the changing conditions, such as changes in other dynamics or technological developments, to sustain the interactions. Therefore, the states of a helices at a given time is always dependent on states of helices in the previous time, including itself. This constant transformation idea is also similar to Schumpeter's constant competition and "turmoil" characteristics of a capitalist society.

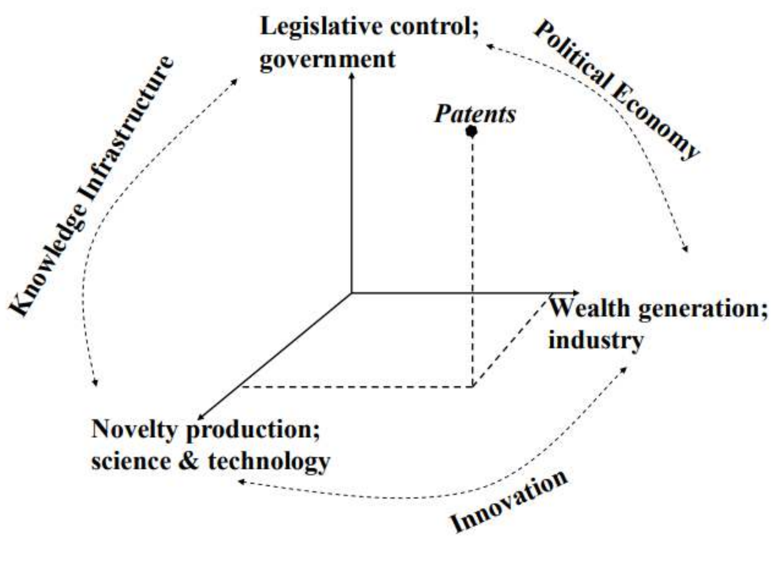

Figure 2.1 Patents as events in the three-dimensional space of Triple Helix interactions. (Leydesdorff, 2010)

Besides the main three actors, THM also includes secondary agents such as legal firms, non-governmental agencies, and intermediary agents (Cai & Amaral, 2021). With such a level of interaction comes the necessity of knowledge sharing channels and methods (Leydesdorff & Etzkowitz, 1996). Leydesdorff (2010) emphasizes the differences in used “language” between agents from different helices, and the need to overcome them. In a system that relies on knowledge trading, communication is an essential ability that institutions and agents must have. This ability can be developed over time by engaging in multi-disciplinary projects, or it can be outsourced from intermediary organizations, such as TTOs. Further, communication must also be enabled by communication networks or platforms, by the governing agent.

Within such a system that knowledge plays a key role, production of knowledge also becomes more important, as so the main producers of knowledge, universities. Triple Helix Model realizes this as one of its assumptions as a shift of role of universities from a secondary status in industrial societies, to a primary status with their enhanced relevance to technology transfer, firm-formation, and regional development in a knowledge-based societies (Cai & Amaral, 2021; Cai & Etzkowitz, 2020). On top of teaching and research, this new entrepreneurship mission of universities, the third mission, lead universities to seek collaboration with other two agents.

As for firms, THM suggests that firms should embrace a new hybrid characteristic, combining public and private as its investors, stakeholders, or shareholders (Etzkowitz & Zhou, 2017, p. 80). These new triple-helix-firms that form out of the interactions between helices can access a wider range of resources, even from multiple helices. This diversity of resources enables firms to play a more direct role in innovation.

Triple Helix also brings government forward as an active participant to the innovation process. As an active agent, government can not only regulate the innovation ecosystem as a policymaker, but also as support the innovation creation as an investor and enhance the innovation process by regenerating sources of productivity by acting cooperatively with other agents since government is more involved in the process itself (Cai & Amaral, 2021; Etzkowitz & Zhou, 2017).

These new assigned roles for university, industry, and government in a THM ecosystem bring forth the mechanism of “taking the role of the other” for all participating agents (Cai & Amaral, 2021; Etzkowitz, 2008). Successful adoption of this mechanism is the one of the main sources of innovation in a Triple Helix system (Cai & Etzkowitz, 2020). As agents embark on non-traditional roles, such as universities commercializing knowledge along with their teaching and research activities, firms providing high-level training and conducting research as well as continuing their production, or government providing venture capital especially for high-risk enterprises while managing the infrastructure, the agents become creative and contribute to the primary role of not only themselves but also the performance of other agents (Etzkowitz, 2008).

3. TECHNOLOGY TRANSFER AND UNIVERSITY-INDUSTRY COLLABORATIONS

3.1. Technology Transfer

Technology transfer (TT) is a concept that has been defined by many in literature in various ways. Değerli and Tolon (2016, p. 198) follows the definition “the process of transferring, sharing and disseminating knowledge, skills, scientific discoveries, production methods and other innovations among universities, research organizations, government agencies, private firms, industry/industry and other relevant organizations”. Žmuidzinaitė et al. (2021, p. 222) on the other hand, defines TT as “commercializing technologies resulting from university research by the collaboration of universities and industry” and states that it has a stimulant effect on economic growth and is necessary for national competitiveness. As cited from Bengoa et al. (2021), Autio and Laamanen (1995)’s definition of TT is “an intentional and goal-oriented process of interaction between two or more social entities during which the technology and the knowledge related to it is transferred”. In their TTO regulation in 2020, The Scientific And Technological Research Council Of Turkey (TÜBİTAK) defines TT as “identification of new technologies with the aim of further development and commercialization of research results and scientific findings carried out within the university and/or technology development zone, transferring it to another organization, including the processes of protecting it by appropriate methods, such as patents, copyrights, etc. of intellectual property rights of these technologies, marketing or licensing the said technologies to the public or private sector, or establishing new companies based on these technologies”. Within the framework of this study, the definitions from the literature are redacted to “transfer of technical or technological knowledge to commercialize, utilize or combine with other knowledge to form an economic output”.

In the literature, TT has been studied at three levels: macro, meso, and micro levels (Cunningham & O’Reilly, 2018). Cunningham and O’Reilly (2018) claims that categorization of the TT studies under these levels, shaped the methods of evaluating, analyzing, and interpreting the data and findings of the studies, enabling the contents of this ever-growing body of knowledge to be both synthesizable and comparable.

Studies that have a macro-level approach focus on policy-making to create an environment that supports and promotes technology transfer (Cunningham & Link, 2016; Grimaldi et al., 2011; Hall & Link, 2015; Mowery, 2011). These studies usually cover the evaluation and restructuring of policies that are aimed to bolster the production and commercialization of new knowledge in universities. One commonly studied issue is protection of intellectual property rights to make the TT environment safe for knowledge sharing. Another common topic is the formation of communication platforms that will link the industry to university, thus, accelerate the transfer process. Cunningham and O'Reilly (2018) remark that within the framework of macro-level studies, direct reapplication of policies that proven successful at certain conditions and locations, without readjustments, adaptations and understanding of causal effects, are a significant danger of such studies.

At meso level, studies focus on the operation and functioning of intermediary institutions such as Technology Transfer Offices, Incubators or Science and Technology Parks (Chapple et al., 2005; Kolympiris & Klein, 2017; Siegel et al., 2003). These studies focus on technology transfer from an organization-level perspective, conducting an in-depth analysis of the performance and impact of intermediary agents and effecting factors.

Finally, micro-scale studies analyze technology transfer at an individual-level, focusing on the TT process between individuals and the performance of individuals that take part in the TT process (Albats et al., 2018; D'este & Perkmann, 2011; O'Kane et al., 2017). Impact of individuals' or groups' cultural or educational backgrounds to their performance can be considered under this scale.

Considering the scope of the meso level studies, often they tend to overlap with micro and macro level issues, thus, can be difficult to distinguish. Especially issues that revolve around TTO performance have multiple dimensions at different scales. One dimension is the TTO personnel performance, which is a micro-level topic that has a direct impact on TTO performance. Another example would be the policies that shape the TT conditions within an environment that TTO operates in. For the context of this study, framework for meso-level issues can be defined as issues that include incentives provided to TTOs by affiliated organizations such as universities, and/or organizational policies that promote knowledge share and production. Our study conducts a macro-level qualitative analysis. However, we further extend our study to include an interpretation into the results of our analysis from a meso-level standpoint, contributing to both perspectives of the literature.

Literature is at a consensus that making the university-produced knowledge available to industry and commercialization by successful transfer of knowledge positively impacts the growth of the local economy (Agasisti et al., 2019; Cunningham & O'Reilly, 2018; Değerli & Tolon, 2016; Good et al., 2019; Link et al., 2003; Liu et al., 2022; Siegel & Wright, 2015). TT brings multiple benefits to all its participants. Knowledge sharing between academics brings knowledge from different perspectives and fields together, which as a result, accelerates the innovation production. Further, industry is considered more experienced in commercialization of technology, and they are more knowledgeable on the end-user preferences, behavior, and current demands. Thus, TT between academia and industry enables the produced technology to be reshaped and enables it to meet the demanding customer in the demanded form. This transfer of knowledge can be accomplished by bringing the raw-knowledge-producing academic researchers and commercialization-focused R&D personnel as well as making both sides aware of what is being studied or demanded on the other side. For such knowledge flow, a communication and interaction platform that connects all participants of the innovation process and a TT ecosystem that incorporates events and organizations (Spigel, 2017). Spigel (2017), defines a TT ecosystem as a collection of all cultures, social networks, investment capitals, universities and active economic policies that aim to create an environment that supports the technology transfer and innovative entrepreneurship.

3.2. University-Industry Collaboration

One key concept that is common in the majority of TT definitions is collaboration, especially between universities and industry. The concept of University-Industry Collaboration (UIC) has been a topic of debate for over 40 years, increasing in popularity after the Bayh-Dole Act, which gave the universities the rights on their research outputs.

In the late 1970's, the economic and global advantage that the United States gained after the second World War started to diminish and went into a state of inflation and recession. To reignite the economic growth, Reagan and Bush gravitated towards denationalization and deregulation policies. During this denationalization and deregulation period, it was foreseen that the process of commercialization of university research was a bottleneck and solution to this problem would create a new potential financial resource that will provide a competitive advantage at a national level as well as making industry an alternative financing source for university research (Turk-Bicakci & Brint, 2005).

In the early 1980's, the USA legislated a set of law and policy revisions to pave the way for UIC, stimulate economic growth, increase the international competitiveness of the USA and to expand the financial resources of university research. The 1980 "Bayh-Dole Act" that gives the intellectual property rights of university research financed by federal fund to universities, and the 1980 "Stevenson–Wydler Technology Innovation Act" that requires organizations that control R&D budgets to allocate %5 of their budgets to technology transfer initiatives; are two prominent examples (Turk-Bicakci & Brint, 2005). As these legislations also left universities with a much lower federal funding, universities had to change their research practices to adapt to the new competitive environment. Universities realized they could find or increase their research fundings and build their academic reputation further up; by establishing networks with industry members or strengthening existing connections (Turk-Bicakci & Brint, 2005).

The increase in numbers of patents and licenses, connections between universities and industry as well as the increase in budgets of university-industry collaborative R&D projects that followed the regulations, are argued to be strong indicators of the success of the regulations. These implications were expected to lead the university researchers to seek commercially attractive projects to be financially funded under UIC (Turk-Bicakci & Brint, 2005). Now, UIC relations are becoming "a laboratory for reshaping of the knowledge infrastructure" (Etzkowitz & Leydesdorff, 1995, p. 5).

4. TECHNOLOGY TRANSFER OFFICES

4.1. Technology Transfer Offices

As UIC became more popular, the need to manage this connection and collaboration process was realized and Technology Transfer Offices (TTO) rose to undertake this role as an intermediary agent. As it was for TT, the concept of TTO also has varying definitions in the literature due to multiple but similar methods to fulfill its intermediary role (*Table 4.1*).

Table 4.1 TTO Definitions

TTO Definitions	
TTOs facilitate technological diffusion through the licensing to industry of inventions or intellectual property resulting from university research.	(Siegel et al., 2003, p. 3)
By recognizing potentially commercializable inventions and identifying licensees and/or investors for them, the Technology Transfer Office is an intermediary between academia and industry, ensuring resources for the development and exploitation of the university's intellectual property.	(Žmuidzinaitė et al., 2021, p. 222)
TTOs are organizations that have been given the responsibility to facilitate the transfer of technology from a directly affiliated research institution (or multiple research institutions) to market by acting as a bridge between the two environments.	(Good et al., 2019, p. 3)
To define within the context of Turkey, TTO's and similar institutions and organizations, are agents that provide services to transfer the knowledge, innovation and/or technologies produced in university/research institute, to the industry with the goal of commercialization.	(Değerli & Tolon, 2016, p. 198)
An organizing unit dedicated to technology transfer acting as a "technology mediator" that allows for specialization in support services, especially in partnered research, intellectual property management and sustainable business development.	(Soares et al., 2020, p. 3)

One specifically significant definition for this study belongs to TÜBİTAK, a major actor that plays both a direct supporting and an indirect researcher role in the Turkish technology transfer ecosystem. According to TÜBİTAK, TTOs in Turkey are defined as follows; “TTOs are organizations which are responsible for contributing to the UIC within respective HEI and/or technology development zones; and transformation of knowledge produced in universities and/or technology development zones, into an economic value” (TÜBİTAK, 2020). Our study focuses on organizations that function under Turkish regulations and are defined as a “TTO” by TÜBİTAK, therefore, this definition is regarded as the main definition for our study. Following this definition, TTOs are expected to increase the commercialization of university-produced technology and transformation into economic value. Within the context of this study, we suggest that TTOs have positive and significant effect on commercialization of technology; therefore, have an intermediary effect on the economic growth, which we hypothesize as such:

H_2: TTOs have positive and significant effect on economic impact of patent applications.

The realization of significance of knowledge production led to different initiatives to encourage and support this process. Some of the similar initiatives to TTOs which can be rightfully confused with each other are “Incubators”, “Technology/Research/Science and Technology Parks” and “Technology Development Zones” and are sometimes even used interchangeably to some extent. Incubator is a relatively more general term used for any organization or agent that accelerates the TT process, arguably focused on earlier TRLs. Kolympiris and Klein (2017, p. 145) states that incubators are “facilities that assist faculty members, university graduates, community members, or other parties to start new firms that not only contribute to local economic growth, but also generate income for the university, which often holds equity positions in the incubator’s tenant firms”. Science and Technology Parks can be relatively larger than incubators and TTOs and vary in size. (Lalkaka, 2006) defines these parks, which he refers to as Technology Parks, as; “an enhanced property-based development that has a high-quality physical environment in a park-like setting; is located adjacent to or at a reasonable distance from a research institute or technical university; and emphasizes activities promoting the growth of research, technology commercialization and knowledge-based enterprises.” Finally, Technology Development

Zones are the largest of technology transfer agents, which is defined as “technocities, sites where academic, economic and social structure are combined, or technoparks, that are in or nearby of and function under a university, high technology institute or R&D center/institute; where high tech firms benefit from the infrastructure of the related university, high technology institute or R&D center/institute to produce or develop technology or software, or commercialize a technologic invention, to contribute to the regional economic development.” by TÜBİTAK (2020).

TÜBİTAK (2020, p. 4) further defines the goals, which is given below, and functions (Table *4.2*) of TTOs:

“The goals of a TTO are; commercialization of the knowledge and technology which are produced in HEIs and TDZs, by application, and support the conversion of this knowledge and technology to economic, social and cultural value; creation of collaborations between university and private sector; strengthen existing collaborations; help university and TDZs produce the knowledge and technology needed in the industry; contribute to the transfer of knowledge and technology, as well as development of concrete outcomes as a result of these collaborations.”

Table 4.2 Goals and Functions of TTOs (TÜBİTAK, 2020)

Service Group	Service
Awareness, promotion, information, and education services;	Guiding researchers in line with the needs of private sector organizations within the scope of supported TTO project activities
	Informing researchers and private sector organizations on research, technology development, innovation, and intellectual property rights, raising awareness and training on these issues
Services to benefit from incentive programs	Providing project design, application and monitoring services to organizations that incentivize national/international research, technology development, innovative entrepreneurship
	Informing private sector organizations and researchers about R&D and innovation financing, facilitation their access to fund and referral to relevant funds

Table 4.2 Goals and Functions of TTOs (Continued)

Project development/management services	"Knowledge, technology and accessing to collaboration opportunities" counseling and guidance for private sector organizations and researchers, and mediating national/international partnership agreements
	Presentation of project results
	Execution or coordination of actions such as project team building, in multi-partner projects
	Mediation of contract-based research
IP right management and licensing services	Consulting services on intellectual property rights assets, tracking intellectual right protection processes of these assets
	Managing the commercialization of the intellectual property rights by transferring these rights to public and private sector via licensing
	Collaboration with other TTOs and related organizations for intellectual property rights commercialization
Incorporation and entrepreneurship services	Providing incubation and accelerating services to commercialize university-produced knowledge by entrepreneurship
	Providing business guiding and mentorship services to these ventures
	Finding resources from inside and outside the higher education institution and making them available to entrepreneurs for prototype development at the concept validation phase of the business idea

4.2. TTO's in Turkish Case

Since the early 2000s, UIC gained significant attention in Turkey and many steps were taken for the UIC. One of the prominent examples to these advancements is the establishments of technocities and TTOs that are aimed to promote UIC and provide an infrastructure for the interaction between the two actors. Over 110 TTOs have been opened all over Turkey since the first national Development Plan that initiated these advancements (*Eighth Five Year Development Plan*, 2000; *The Eleventh Development Plan (2019-2023)*, 2018; *Ninth Development Plan 2007-2013*, 2006; *The Tenth Development Plan 2014-2018*, 2013)

The first appearance of the UIC in Turkish development plans goes back to the Eight Development Plan of Turkey, which was for the years between 2001-2005. Since then, every development plan contained actions and initiatives for betterment of UIC and TT in the Turkish innovation ecosystem. The actions and initiatives include; establishing platforms for communication between UIC members, incentives for medium-high and high tech projects conducted with UIC, and establishment of technology development centers that will bring the members of UIC together (*Eighth Five Year Development Plan*, 2000; *The Eleventh Development Plan (2019-2023)*, 2018; *Ninth Development Plan 2007-2013*, 2006; *The Tenth Development Plan 2014-2018*, 2013). Further, TÜBİTAK, one of the main regulatory authorities of Turkish innovation and technology ecosystem, promulgated the first Technology Transfer Offices Support Program Code of Practice in 2012 with only eleven pages. A strong indicator that Turkey has been put emphasis on TT and UIC is that this legislation has kept being updated and expanded to be more comprehensive, and currently is a forty-four-page long document that includes detailed explanation of definitions and project and incentive processes, as well as a comprehensive list of TTO performance indicators with descriptions. Such a resource from a regulatory authority is especially important since it can function as a guide for both academics and industry members who are less experienced in UIC processes. Considering the goals of the development plans, aggregate state of the innovation ecosystem, and the state of the high-tech private industry, the effectiveness of the actions and initiatives should be analyzed and if there is a loss of effectiveness, underlying causes must be determined.

4.3. Effectiveness and Performance of TTOs

Considering the definitions in both the literature and within the Turkish innovation ecosystem, we can claim that TTOs are agents that are focused on managing the UIC process and creating a suitable environment for TT. However, effectiveness of TTO's on technology transfer is a topic of discussion in the literature (Kolympiris & Klein, 2017; Siegel & Wright, 2015; Steruska et al., 2019). Therefore, identifying if a TTO has an impact on the local economy or not, requires understanding if the TTO is performing properly.

Performance of TTOs is a complex topic that has multiple factors that aren't fully independent of each other. Numerous studies that categorize these factors can be found in the literature. Even though these categorizations differ to some extent, essentially, they are quite similar.

One other example of these categorizations belongs to Žmuidzinaitė et al. (2021), which categorizes these factors under the following six groups; Intellectual Property Strategy and Policy, Organizational Design and Structure, Human Capital, Relationship with Industry, Economic Incentives, and Cultural Aspects.

Intellectual Property Strategy and Policy

This category of performance factors includes the intellectual property (IP) rights management and IP protection support services of the connected universities. A TTO's lack of effective IP protection policies can lead to problems that reach up to academics abstaining from referring to TTOs when commercializing their studies.

Organizational Design and Structure

The characteristics of the organizational structure of a TTO affect the TT performance of the TTO. Size, experience, or the flexibility provided by the administrative support from the connected HEI are some of these characteristics.

Human Capital

Qualities of the TTO personnel are another factor of TTO performance. Education level and former work experiences are some of these human capital qualities. Further, the provided opportunities for TTO personnel to improve their skills, working motivation and personnels' understanding of the TTO structure are among the TT performance factors.

Relationship with Industry

The accessibility of the to-be-commercialized knowledge for members of the industry is of a high significance for the TT process. Thus, the relationship of TTOs with the industry and ensuring that industry members refer to TTOs when searching for the technologies they need, will highly accelerate the commercialization process. To establish successful university-industry relations, TTOs must assume the role of establishing communication and trust between the agents. Having networks that support communication and interaction is one of the prominent factors of TT efficiency.

Similar topic has been studied by Prokop and Kitagawa (2022), which follows an approach from a network perspective on TTO performance. Prokop and Kitagawa argue that networks that enable diffusion of knowledge are central for successful incubation.

Economic Incentives

This set of factors include the financial incentives provided to the organizations and start-ups hosted within the TTO. These incentives can be provided by the related HEI as well as the other actors in the innovation ecosystem, such as industry members or government.

Cultural Aspects

The work culture, traditions, and perspectives of the members within the TTO's innovation environment are under the cultural aspects. The mindset of the actors who take part in the TT process, their approach to the TT process and their cultural differences can all impact the "fit" between the actors, therefore the performance.

To analyze the TTO performance, TÜBİTAK categorizes Turkish TTOs into four groups, which all have mostly common performance parameters but also have unique ones to include their unique outcomes. These categories are simply explained by Değerli and Tolon (2016) as;

- Category 1: Units that are established under an HEI for TTO activities.
- Category 2: A company established for TTO activities, in which the higher education institution is a partner.
- Category 3: Technology development zone executive company.
- Category 4: A company established for TTO activities and in which the technology development zone management company is a partner.

5. METHODOLOGY

5.1. Data & Variables

For our dataset, we use yearly city-level data acquired from The Turkish Statistical Institute (TURKSTAT), Turkish Patent and Trademark Office (TÜRKPATENT), The Scientific and Technological Research Council of Türkiye (TÜBİTAK). The dataset includes 16 years of data for all cities of Turkey, between 2004 and 2019; Gross Domestic Product per capita, population, number of patent application, energy consumption and year of establishment of TTOs. The time period of our study was determined with respect to the beginning of GDP per capita data from TURKSTAT, until the beginning of COVID-19 pandemic. The GDP per capita in US $, population and energy consumption data was taken from TURKSTAT. Patent application data was taken from TÜRKPATENT. Then, energy consumption per capita and population growth rate were calculated. The year of establishment of TTOs are retrieved from webpages of the TTOs. We select the target population of our study as TTOs which are accepted to TÜBİTAK 1513 TTO Supporting Program. This provides us with two benefits, first, it narrows down our population for a better analysis, second, it allows us to focus on higher-performance TTOs as they are selected to the program with respect to their potential.

It is important to note that Sakarya University seems to have two separate TTOs, established in 2013, ADAPTTO, and 2018, Sakarya Applied Science University TTO. In TÜBİTAK official website the Sakarya University was accepted for the 1513 TTO Support Program in 2014 so we assume the TTO supported under 1513 Program is the former and set our model accordingly. Another point is that the Selçuk University TTO, Selçuk TTO under Konya Teknopark, has no information on the year it was established. Konya Technical University, its partner university for Konya Teknopark, established another, seemingly separate TTO, KTUN TTO, in 2020. Therefore, we assumed the year of establishment as the year it was accepted to the 1513 Program.

The Gross Domestic Product per capita is used as a dependent variable for economic growth as Sustainable Development Goals suggests (UN, 2023). Number of patent applications was used as an indicator of R&D activity in TTOs. This variable is in line with our theoretical framework and acts as an indicator for interaction between academia and industry helices. A TTO dummy variable was used to indicate the existence of a TTO in that city for a given year. However, we do not include this variable in our model directly, instead we use an interaction variable which we will explain in the next section. Population growth rate is included to capture population-related effects on per capita production and energy consumption per capita is included as a variable to capture exogenous effects.

As Weil (2014, p. 1) explains, health status of a society is "*an important determinant of economic growth*". Measures such as life expectancy are used as indicators of health status (Barro, 1996; Weil, 2014), which also have significant effects on population growth rate (Acemoglu & Johnson, 2007; Weil, 2014). We utilize population growth rate in our study, as an indicator of developments in health status. The initial effect of changes in population growth is expected to have a negative correlation with per capita GDP. By including population growth rate in our model, we absorb variations in per capita GDP that are related to health developments but aren't related to TTOs.

H_3: *Population growth rate has negative and statistically significant effect on per capita GDP.*

Energy is both a significant input and indicator of economic development, especially in developing countries (Ali et al., 2019). Lead by Kraft and Kraft (1978), the causal relation between GDP and energy has been the topic of many studies in the literature (Soytas & Sari, 2003). Even though the direction of the relation between energy consumption and GDP is a topic still debated on (Sari & Soytas, 2004), studies are at a consensus on the existence of the positive correlation between energy consumption and GDP (Emirmahmutoglu et al., 2021; Singh & Vashishtha, 2020; Soytas & Sari, 2003).

H_4: *Energy consumption per capita has a positive and significant relation with per capita GDP.*

To check the correlation between patent production and TTO, we visually represent the relationship by graphing the patent production at city-level and see if an increase of patent production is visible after establishment of TTOs. These representations are given in *Figure 5.1* to *Figure 5.13*. The years of establishment of the first TTOs in cities are represented with red columns. We further include the establishment of the first Technoparks represented as green to identify if the trends are related to Technoparks instead of TTOs. Also, the establishment of the first TTO in İzmir is added as a label since it was established before TURKPATENT was established and therefore is before our patent application dataset starts.

At first glance, in general, increase in patent production trends either starts or accelerates with establishment of a TTO. However, it should also be pointed out that the increase in trends of patent production starts at similar periods, and the correlation between increase in trends and TTO establishment can be simultaneous instead of having a causal relationship. The correlation can still be interpreted as an indication of patent production being positively affected by TTOs, these issues will be addressed and resolved in our model.

Before we proceed with our model, there are some constraints that should be addressed. The first one is the bias caused by the preference of TTO location. TTOs are much more common in larger cities of Turkey, especially İstanbul with 7, Ankara with 7 and İzmir with 3 of the total 27 TTOs we analyze. The remaining TTOs are the only TÜBİTAK supported TTOs within their city. When we rank the cities with their GDP per capita in the year 2019, 5 of the 13 cities that host TTOs are of the top 7 highest GDP per capita, which also constitutes 19 of the 27 TTOs that our study analyzes. Fortunately, when we graph the average GDP per capita growth rate over our selected period (*Figure 5.14*), there seems to be no distinct bias in the distribution of GDP per capita growth rates of cities that host TTOs.

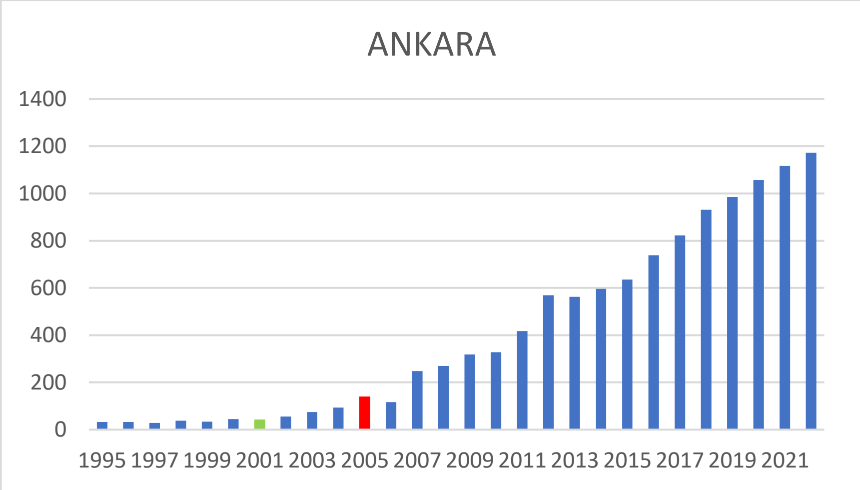

Figure 5.1 Ankara, Patent Application and TTO Establishment

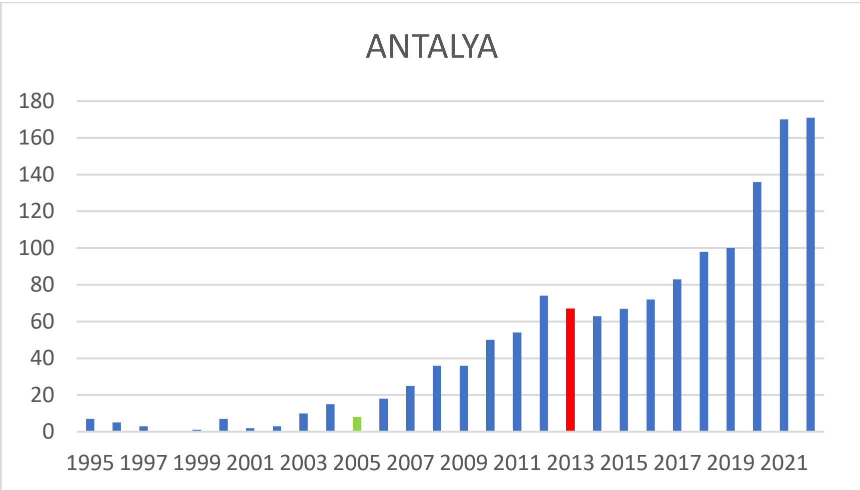

Figure 5.2 Antalya, Patent Application and TTO Establishment

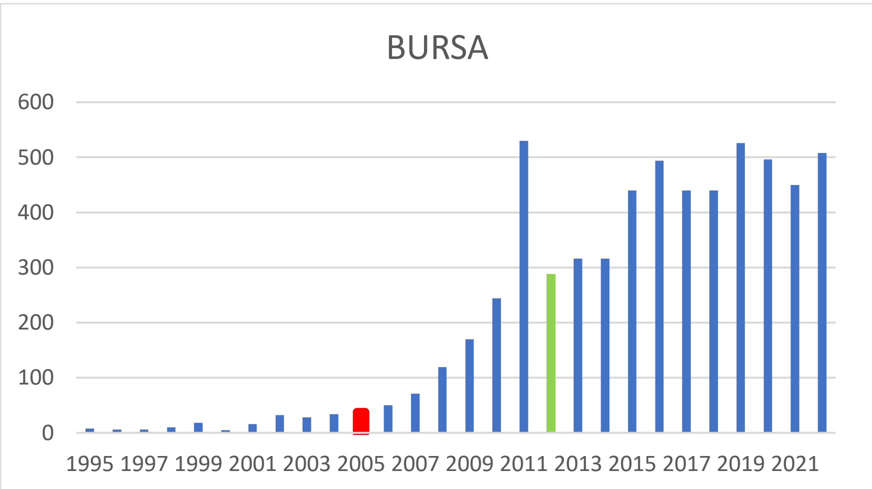

Figure 5.3 Bursa, Patent Application and TTO Establishment

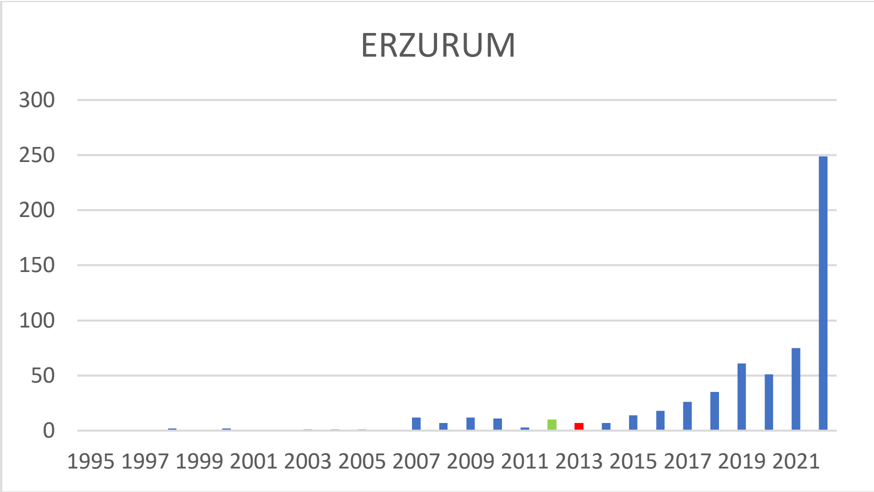

Figure 5.4 Erzurum, Patent Application and TTO Establishment

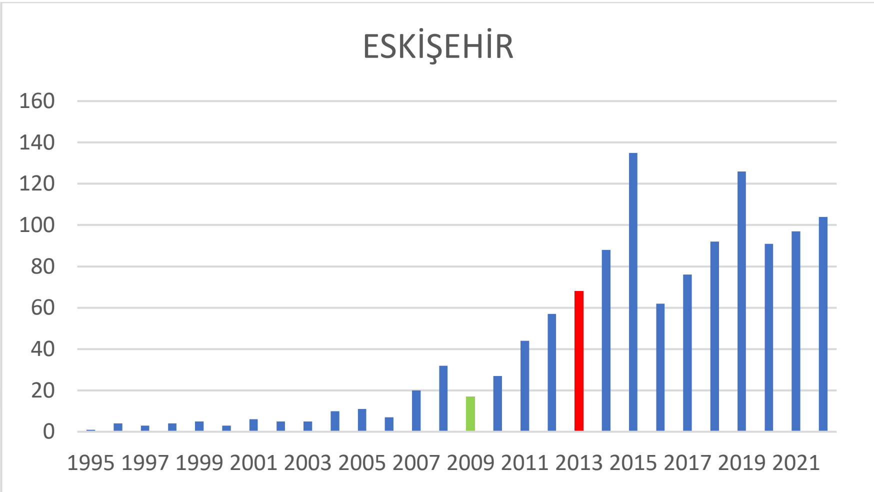

Figure 5.5 Eskişehir, Patent Application and TTO Establishment

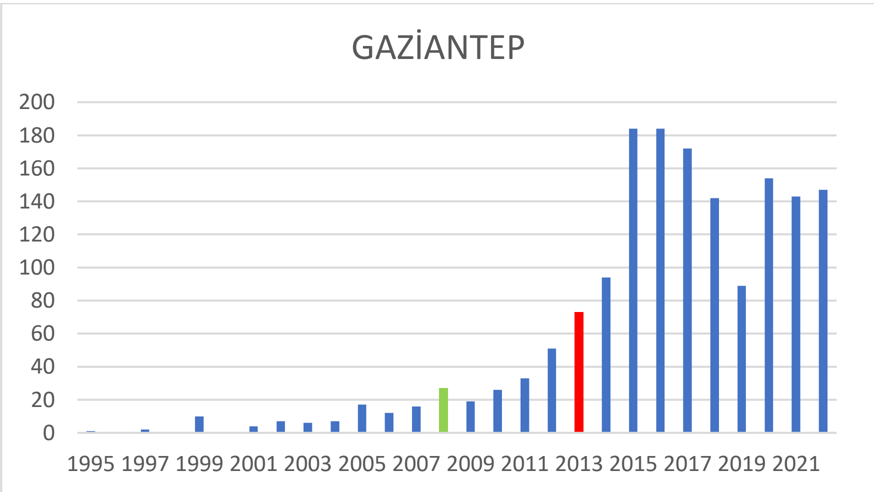

Figure 5.6 Gaziantep, Patent Application and TTO Establishment

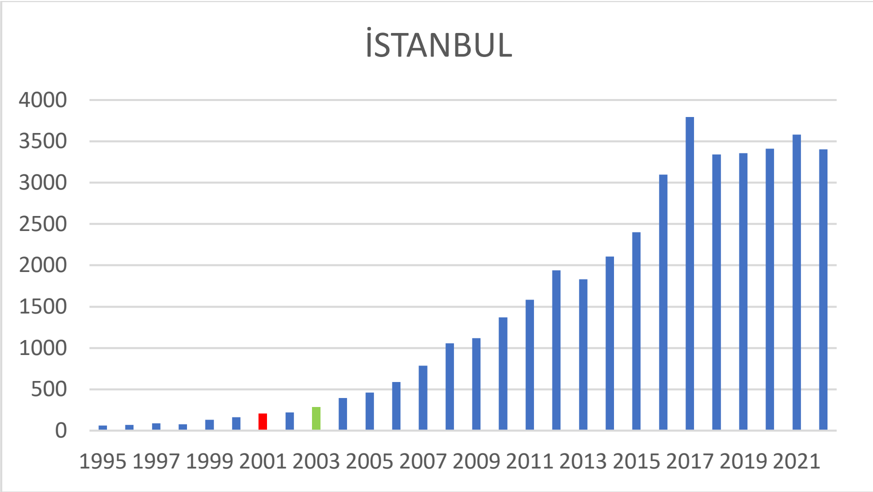

Figure 5.7 İstanbul, Patent Application and TTO Establishment

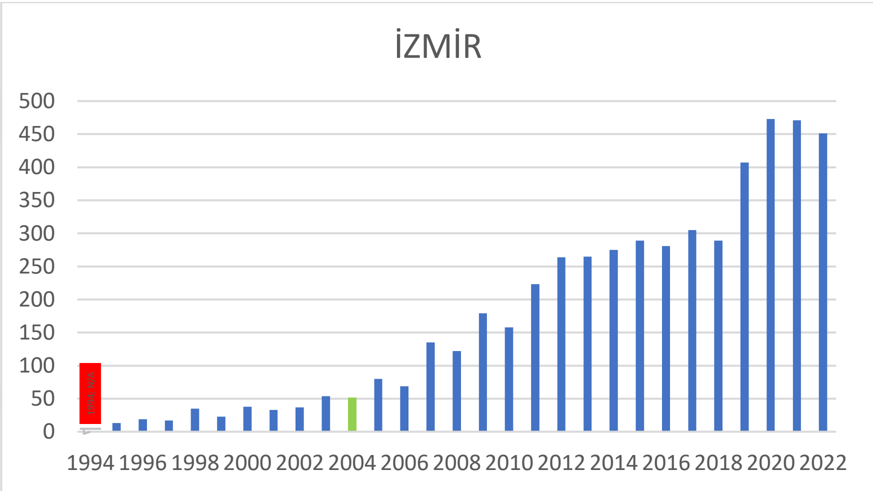

Figure 5.8 İzmir, Patent Application and TTO Establishment

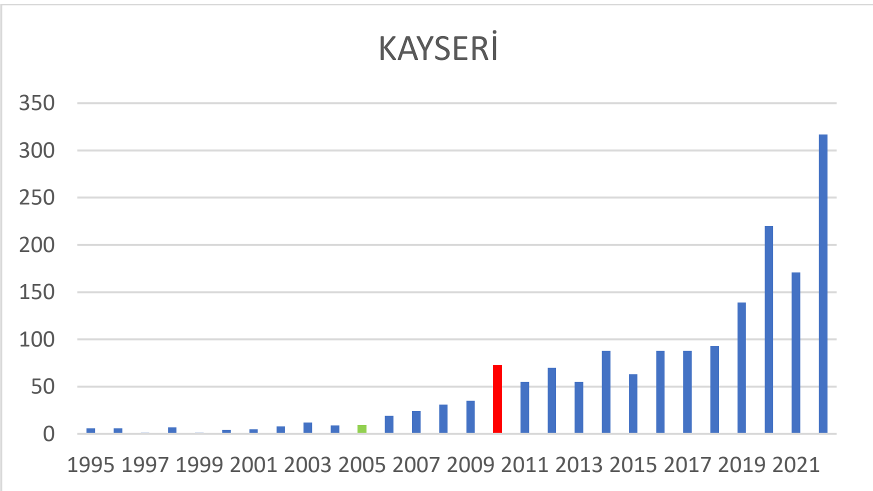

Figure 5.9 Kayseri, Patent Application and TTO Establishment

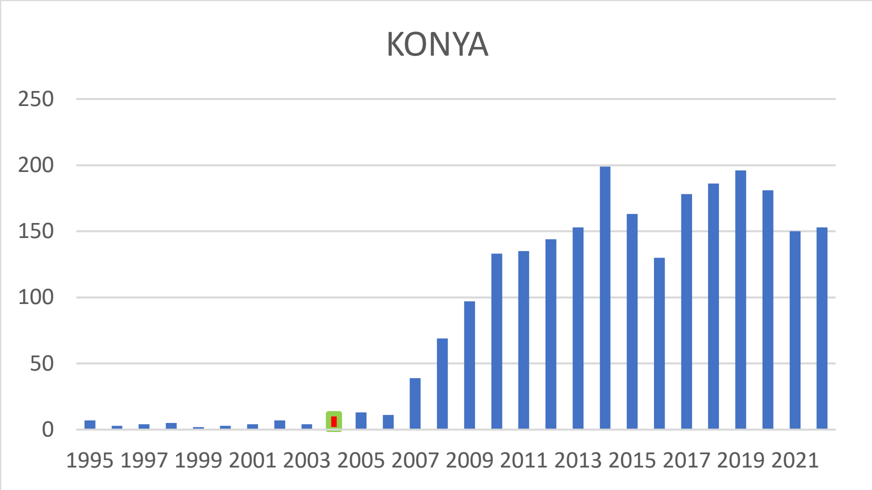

Figure 5.10 Konya, Patent Application and TTO Establishment

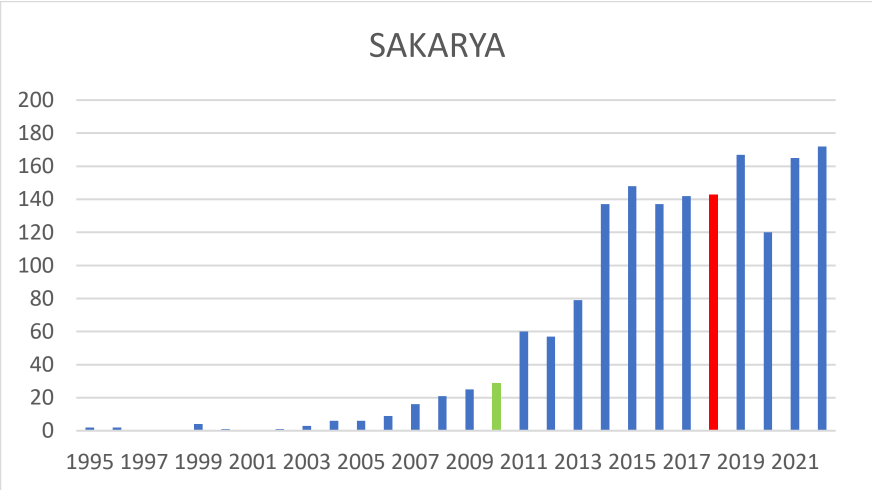

Figure 5.11 Sakarya, Patent Application and TTO Establishment

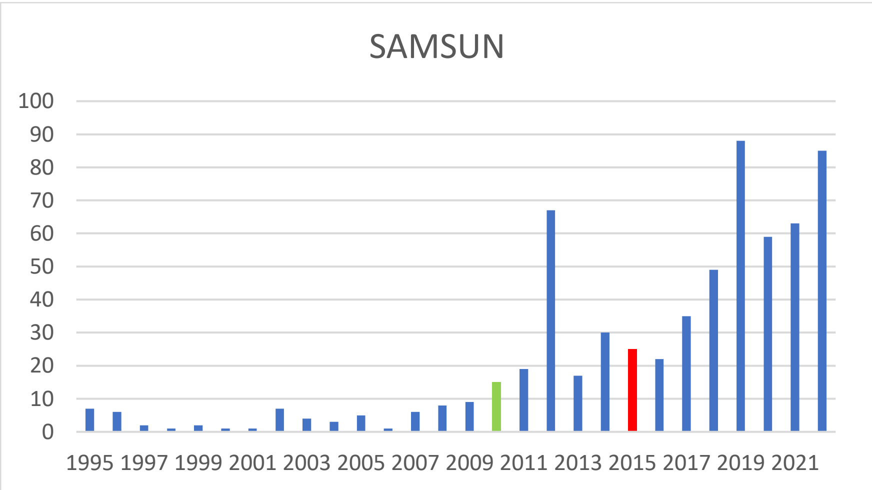

Figure 5.12 Samsun, Patent Application and TTO Establishment

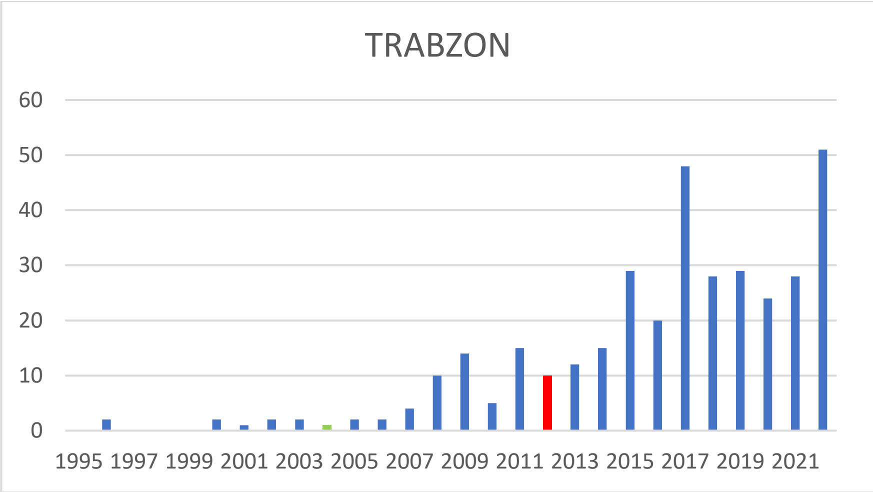

Figure 5.13 Trabzon, Patent Application and TTO Establishment

5.2. Model

Our model analyzes the relation between local economic growth and technology policies via TTO establishment impact in the Turkish innovation ecosystem at city-level. To explore the impact of TTOs on the local economic growth, we follow a dynamic panel data analysis, the two-way Sys-GMM model with instrumental variable (IV) approach adapted from the study of Agasisti et al. (2019) to our case. By using the two-way Sys-GMM, we aim to eliminate biases caused by the reverse effect of GDP growth on patent production and/or R&D activity. Further, the IV approach enables us to eliminate autocorrelation and endogeneity problems simultaneously. Finally, following the model of Agasisti et al. (2019) and modifying it to fit our research question, we construct our dynamic panel model as such:

$$\log(GDPpc_{t,i}) = \beta_1 * \log(GDPpc_{t-1,i}) + \beta_2 * \log(Patents_{i,t}) + \beta_3 * \log(PatentTTO)_{i,t} + \beta_4 * PopGR_{i,t} + \beta_5 * \log(EnConPCc)_{i,t} + \mu_i + \tau_t + \varepsilon_{i,t}$$

where *GDPpc* denotes gross domestic product per capita, *Patents* denote number of patent applications, *PatentTTO* is the interaction variable between patents and TTOs, *PopGR* is the population growth rate, *EnConPCc* is the energy consumption per capita, μ is the unobserved city-specific effects, τ are time dummies for time-specific effects and ε is the error term. i and t are the city and year subscripts, respectively. Detailed descriptions of variables are given in Table 5.1.

Since we aim to measure the effect of TTOs, we preferred an interaction variable approach between TTO and TTO performance indicator (*Patents*) variables in our model. Thus, we can measure if the patent production after TTO establishment is more impactful or not. The interaction variable in our model is the Patent * TTO (*PatentTTO*) variable. However, the TTO as a dummy variable itself is not usable in our model due to first-differencing. So, we excluded the dummy variable from the model, because first-differencing a dummy variable eliminates the dummy variable. Instead, we use the original indicator variable and interaction variable together and interpret the model accordingly.

Table 5.1 Variables used to construct the model

Variables	Definition	Source
GDPpc	Gross Domestic Product per capita at current prices (US$)	TURKSTAT
Patents	Number of patent applications	TURKPATENT
TTO	Dummy variable of TTOs presence (Included into the model indirectly)	Website of the relevant TTO
PatentTTO	Number of patent applications after establishment of TTOs	Calculated by multiplication of Patents variable and TTO dummy variable
PopGR	Annual population growth rate	Calculated from population data taken from TURKSTAT
EnConPCc	Energy consumption per capita	Calculated from population and energy consumption data taken from TURKSTAT

The coefficient of *Patents,* "β_2", and *PatentTTO,* "β_3", are the coefficients that we are interested in. Coefficient β_2, indicate the correlation between patent production overall and the local economic growth. The coefficient of interaction variable β_3, indicates the difference of economic impact of patents that are produced with and without TTOs.

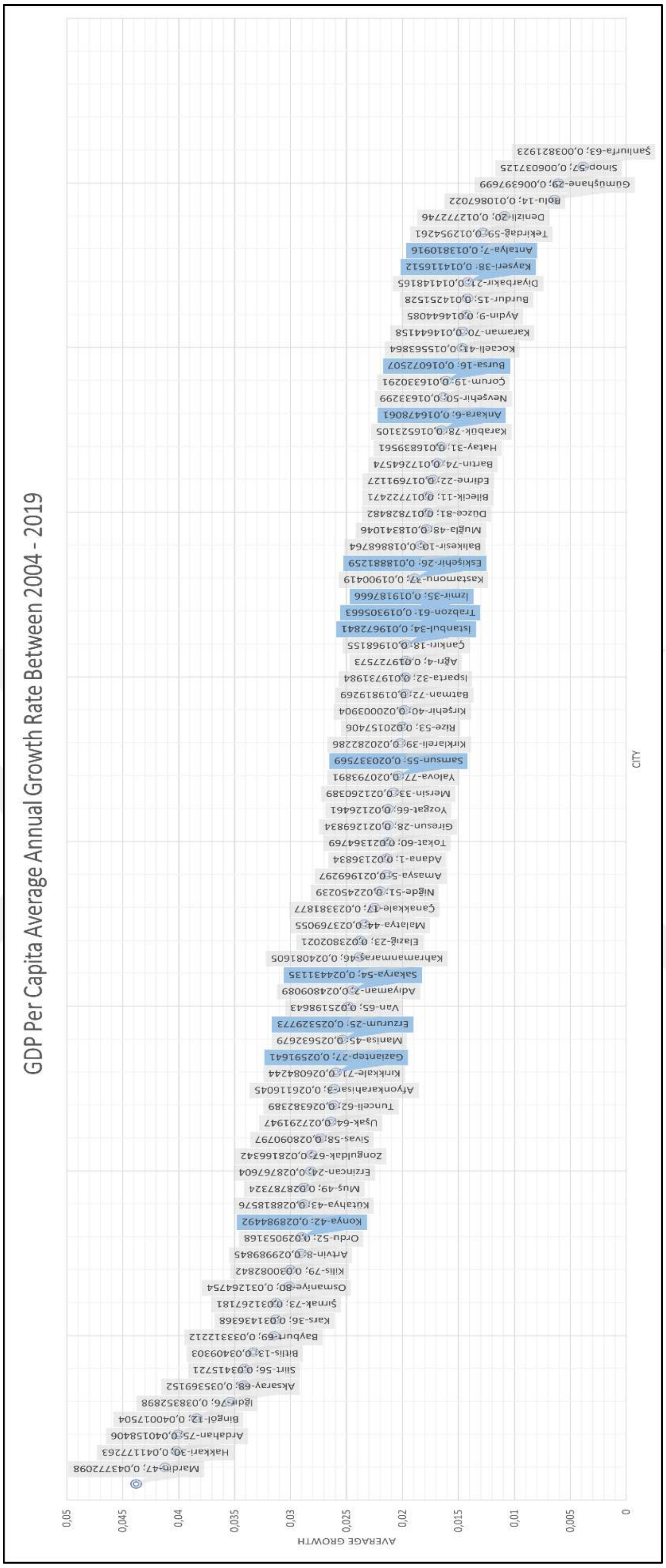

Figure 5.14 GDP per capita Average Annual Growth Rate Between 2004-2019

5.2.1. Model Selection and Sys-GMM Approach

To analyze the effect of TTO initiatives in different regions of Turkey, we need to include all regions to our model but analyze the effects within them individually and come up with a single general prediction. Therefore, we need to follow a panel data analysis method. At first, our decision was to choose from two types of panel data analysis: static and dynamic. Our first approach was to try fixed and random effect models, which are static panel data analysis methods. However, our dependent variable, GDP per capita, is an economic data, and often one of the best predictors for economic activity at a given time *t*, is the economic activity at the previous time, *t*-1. Thus, we decided to steer towards a dynamic model approach so we can include lagged values of our dependent variable.

One of the most commonly utilized dynamic analysis models is Generalized Method of Moments (GMM) which is developed by Arellano and Bond (1991) and Blundell and Bond (1998). In dynamic models, endogeneity bias, which is caused by correlation between an independent variable and the error term, is a common issue that should be addressed. Two main types of endogeneity bias that we aim to overcome with GMM are omitted variable bias and simultaneity.

As Agasisti et al. (2019) also states, the main problem faced when measuring local economic impact is the endogeneity problem caused by omitted variables and reverse causality issues. A factor affecting economic growth can also impact the performance indicators of TTOs, leading the model to a false causal relation. Further, economic growth can also push the R&D and entrepreneurial activities conducted in TTOs as well. Our model aims to eliminate these problems by a two-step two-way Sys-GMM method. Unlike Agasisti et al. (2019), we expected the impact of TTOs in the Turkish innovation ecosystem to be much less than the HEIs they study; thus, we ignore the spillover effect across cities.

The two-step two-way System Generalized Method of Moments utilizes first-differencing the equation and instrumental variables, to overcome the aforementioned, omitted variable and reverse causality. First-differencing the model equation eliminates the unobserved city-specific effects and so the omitted variable bias. Then, the dependent variable is instrumented with first-differences and lagged values to eliminate bias caused by simultaneity.

Similar to universities' (Agasisti et al., 2019), TTO outputs and patent developments might take time to have an impact on economic growth. However, we aim to measure the impact of conducted R&D processes, stimulated and fostered under TTOs, which are expected to have a faster impact.

6. FINDINGS

To conduct our analysis, we analyzed the data in four scenarios which all use GDP per capita as the dependent variable. Scenario 1 measures the relation between number of patent applications and per capita GDP by including the lagged value of GDP per capita, patent applications, population growth, and energy consumption per capita as independent variables. Scenario 2 adds the interaction variable to Scenario 1, to see the effect of TTOs on the relation between patents and GDP and includes the lagged value of GDP per capita, number of patent applications, our interaction variable, population growth, and energy consumption per capita. Scenario 3, like Scenario 1, measures the relation between patents and GDP but with a one-year lag, and includes the lagged value of GDP per capita, patent applications with one-year lag, population growth, and energy consumption per capita. And Scenario 4 adds the one-year lagged interaction variable to Scenario 3 to measure the one-year lagged effect of both patent applications and the interaction variable by including the lagged value of GDP per capita, number of patent applications with one-year lag, interaction variable with one-year lag, population growth, and energy consumption per capita. Results are given in Table 6.1.

Table 6.1 The intermediary effect of TTOs on patents' effect on local economic growth

Variables	Scenario 1	Scenario 2	Scenario 3	Scenario 4
GDPpc (t-1)	0.9408 *** (0.0239)	0.9347 *** (0.0267)	0.9357 *** (0.0265)	0.09348 *** (0.028)
Patents	0.0026 (0.0024)	-0.0001 (0.0019)		
Patents (t-1)			0.0036 (0.0025)	0.0012 (0.002)
Patent*TTO		0.0036 ** (0.0017)		
Patent*TTO (t-1)				0.0030 * (0.002)
PopGR (t)	-0.2971 *** (0.0749)	-0.2949 *** (0.075)	-0.2966 *** (0.0744)	-0.3017 *** (0.076)
EnConPCc (t)	0.0182 ** (0.0092)	0.0228 ** (0.0109)	0.0193 * (0.0102)	0.0217 * (0.011)
Wald Test for Coefficients	p=<2.22e-16	p=<2.22e-16	p=<2.22e-16	p=<2.22e-16
Wald Test for Time Dummies	p=<2.22e-16	p=<2.22e-16	p=<2.22e-16	p=<2.22e-16
Hansen-Sargan	0.0997	0.1153	0.1094	0.1076
AB(2)	0.5948	0.4807	0.6137	0.5594
n	81	81	81	81

* P<0.10 ** P<0.05 ***0.01, Standard Errors are in parentheses

The results of our model do not support our first hypothesis on the positive and significant effect of patent application data on per capita GDP. The coefficients of patent application variable in our scenarios are insignificant, so H_1 is rejected. As for our second hypothesis, the results support our second hypothesis; H_2, on the positive effect of TTOs on economic development. Since the coefficient of the interaction variable is positive and significant, we can claim that establishment of TTOs are increasing the impact of produced patents on economic development, therefore, our findings support H_2. The results show that there is an increase in impact of application for patents on per capita GDP after TTO establishment in both equal 't's and with one-lagged post-TTO patent production (*Table 6.I: Scenario 2, Scenario 4*). In other words, TTOs increase the impact of patent production efforts on the economy. In line with the discussion in Section 5, population growth rate has negative and statistically significant effect on per capita GDP; and energy consumption has positive and statistically significant correlation with per capita GDP. So, H_3 and H_4 are supported.

Further, Sargan Test results show that besides Scenario 1, we failed to reject that our instrumental variables are valid and not overfitted as well. But Sargan Test p-value fails to reject with a p-value lower than desirable. On the other hand, Arellano-Bond test for second-order autoregression failed to reject the null hypothesis. The Sargan Test result fails to reject the validity of instrumental variables and along with the results of Arellano-Bond test showing an expected second-order autoregression, these results indicate that our instruments are valid.

6.1. Robustness and Sensitivity

To test the robustness of our model, we measure if the correlation is related to the selection bias due to the choice of establishment place for TTOs. To test it, we adapt the sensitivity test of Agasisti et al. (2019). We divide the dataset of cities into quartiles with respect to their averaged GDP per capita between 2004 and 2019. We conduct our model by, first, excluding the highest income quartile, then a second time by excluding the lowest income quartile.

6.1.1. Excluding 20 Highest Income Cities

Table 6.2 The intermediary effect of TTOs on patents' effect on local economic growth - excluding the highest-income quartile

Variables	Scenario 1	Scenario 2	Scenario 3	Scenario 4
GDPpc (t-1)	0.9237 *** (0.0465)	0.9233 *** (0.0539)	0.9266 *** (0.0490)	0.9296 *** (0.0569)
Patents	0.0003 (0.0021)	-0.0008 (0.0022)		
Patents (t-1)			0.0001 (0.0021)	-0.0006 (0.0023)
Patent*TTO		0.0025 * (0.0013)		
Patent*TTO (t-1)				0.0024 (0.0016)
PopGR (t)	-0.3284 *** (0.1015)	-0.3215 ** (0.1001)	-0.3120 *** (0.1064)	-0.3312 ** (0.1054)
EnConPCc (t)	0.0211 (0.0157)	0.0227 (0.0175)	0.0197 (0.0164)	0.0202 (0.0189)
Wald Test for Coefficients	p=<2.22e-16	p=<2.22e-16	p=<2.22e-16	p=<2.22e-16
Wald Test for Time Dummies	p=<2.22e-16	p=<2.22e-16	p=<2.22e-16	p=<2.22e-16
Hansen-Sargan	0.7373	0.8560	0.7517	0.7966
AB(2)	0.8774	0.7180	0.8804	0.8887
n	61	61	61	61
				* P<0.10 ** P<0.05 ***0.01, Standard Errors are in parentheses

After excluding the highest income quartile, we see that significance of patent production after TTO establishment in equal time *t* remains significant (*Table 6.2 Scenario 2*). The coefficient of lagged patent production in TTOs is not significant at 90% confidence but remains positive (*Table 6.2 Scenario 4*) while coefficient of patent production overall is insignificant.

6.1.2. Excluding 20 Lowest Income Cities

Table 6.3 The intermediary effect of TTOs on patents' effect on local economic growth - excluding the lowest-income quartile

Variables	Scenario 1	Scenario 2	Scenario 3	Scenario 4
GDPpc (t-1)	0.8989 *** (0.0374)	0.8977 *** (0.0372)	0.9022 *** (0.0342)	0.8936 *** (0.0393)
Patents	0.0046 (0.0031)	0.0018 (0.0021)		
Patents (t-1)			0.0060 ** (0.0027)	0.0032 (0.0022)
Patent*TTO		0.0040 ** (0.0019)		
Patent*TTO (t-1)				0.0042 ** (0.0019)
PopGR (t)	-0.2794 *** (0.0814)	-0.2748 *** (0.0789)	-0.2760 *** (0.0712)	-0.2646 *** (0.0714)
EnConPCc (t)	0.0258 ** (0.0119)	0.0286 ** (0.0118)	0.0234 ** (0.0104)	0.0279 ** (0.0117)
Wald Test for Coefficients	p=<2.22e-16	p=<2.22e-16	p=<2.22e-16	p=<2.22e-16
Wald Test for Time Dummies	p=<2.22e-16	p=<2.22e-16	p=<2.22e-16	p=<2.22e-16
Hansen-Sargan Test	0.8323	0.8455	0.8424	0.8528
AB(2)	0.5238	0.3705	0.6075	0.3486
N	61	61	61	61
* P<0.10 ** P<0.05 ***0.01, Standard Errors are in parentheses				

When the lowest income quartile is excluded, the positive effect of TTOs on transformation of patent production to economic value maintains significance (*Table 6.3 Scenario 2, Scenario 4*). What is also interesting is that the direct effect of patent production overall gains significance with a positive coefficient, even with p-value equals 0.024 when tested individually as a lagged predictor (*Table 6.3 Scenario 3*).

The tests show that our model is robust. The coefficients of *PatentTTO* remain significant in the majority of the tested scenarios (*Table 6.2 Scenario 2; Table 6.2 Scenario 2, Scenario 4*). This indicates that the positive effect of TTOs is not dependent on income level. However, the tests also show that the level of impact does increase as the income level increases. In higher income cities, we see that *PatentTTO* has a higher coefficient, therefore, the process of transforming patents into economic value can be argued to be more efficient and impactful when compared to lower income cities.

The interpretation of our results leads to three main outcomes, first is that the impact of patents on economic development is insufficient; second, TTOs are significantly impactful on patent effectiveness even though patents' effectiveness is underwhelming, third is that patents' impact on economic growth in higher income cities is significantly higher, but also TTOs in relatively lower income cities are still impactful and effective. Referring back to our TTO selection and TTO performance indicators by Žmuidzinaitė et al. (2021) and Değerli and Tolon (2016), all the TTOs are connected to a HEI and operate under TÜBİTAK TTO support program, thus, we assume that they are provided with a sufficient amount of incentive, management and mentorship services, and have access to a human capital supply. Further, considering the underwhelming effect of patents, it can be argued that the less than desirable impact level of TTOs might be due to a macro-level inefficiency rather than an organization-level drawback. Establishing an efficient triple helix ecosystem requires not one but all three helices to develop simultaneously. The increase in impact of both patents and TTOs in higher income cities can be an indicator of necessity of focusing on developing institutional level and infrastructure of the region TTOs operate in. It should also be noted that higher income cities have larger local markets as well, meaning TTOs need to reach a larger consumer base. Our further arguments and discussions are given in the following section.

7. RESULTS AND DISCUSSION

Our study models the intermediary effect of TTOs on the relation between patent applications and economic growth to identify TTOs' economic impact. The results of our model show that TTOs have a positive and statistically significant effect as an intermediary agent. This effect can be interpreted as increasing the commercialization of conducted R&D activity in universities. Further, both the effect of patent applications on growth, and the effect of TTOs are relatively higher in higher-income cities compared to cities with lower-income. However, our results also show that the patent applications' economic impact independent of TTOs, is measured to be insignificant in our main model (*Table 6.1*).

Findings of our study are interesting yet not surprising. Literature argues that the effectiveness of innovation activities is dependent on the level of development of the innovation ecosystem dynamics. Many studies in literature suggest that innovation activities in developing countries, such as Turkey, don't have an economic effect or aren't impactful.

Many studies (Almodóvar-González et al., 2020; Baumol & Strom, 2007; Content et al., 2020; Stel et al., 2005; Ulku, 2004) reach similar results for the relation between entrepreneurial activity and growth, that the effect of entrepreneurial activity on economic growth is dependent on the level of per capita income. Stel et al. (2005) for example, finds that the effect of entrepreneurial activity is positive only above 20000$ per capita income. Ulku (2004), finds that the relation between patent stock and growth is only significant in countries with larger markets. Almodóvar-González et al. (2020) who reach similar results relates this to the ability of reaching economies of scale, which Stel et al. (2005) states as lack of large firms. This insignificance of relation might also be caused by insufficient level of physical infrastructure, networks, human capital, or creation of new knowledge as well (Content et al., 2020).

As Ulku (2005) suggests, the most important factor for innovation is the knowledge stock. However, focusing on a single dimension of the triple helix structure, in our case universities, gives diminishing results. For successful transformation of knowledge into economic value, all dimensions of the innovation ecosystem should be improved simultaneously.

7.1. The Case of Turkey

First recognition of TT in Turkey starts with the 5-Year Development Plan in 2000. Since the first initiatives of TT in early 2000s, Turkey improved its innovation ecosystem significantly. OECD indicators of science and technology such as Gross Domestic Expenditure on R&D as percent of GDP (*Figure 7.1*) or percentage of researchers in the labor force (*Figure 7.2*) have been in a consistent upwards trend in Turkey. Patent applications are increasing in almost all regions of Turkey. According to Global Innovation Index, which is an index measuring the innovation ecosystem performance of countries based on intellectual property production, that is calculated and announced by World Intellectual Property Organization (WIPO), Turkey was ranked 45 in 2007 (Dutta & Caulkin, 2007). Following a sharp decline after the 2008 crises until 2012, it was ranked 74 in 2012 (Dutta & Lanvin, 2012). Turkey then climbed even higher than its previous peak, to rank 37 out of 132 countries (Dutta et al., 2022). Overall, we see that the initiatives in improving UIC and TT taken since the early 2000s have arguably been effective.

However, even though our results as well as macro indicators from reputable organizations show positive effects of the TT initiatives, the impact of innovation efforts in Turkish innovation ecosystem is still less then desirable. Studies on entrepreneurial activity or that focus on its relation with economic growth (Acemoglu, 2008; Almodóvar-González et al., 2020; Baumol & Strom, 2007; Content et al., 2020; Stel et al., 2005; Ulku, 2004), define similar factors for such results, which are also quite similar to what TTO performance literature (Değerli & Tolon, 2016; Žmuidzinaitė et al., 2021) suggests. Studies on entrepreneurial activity suggest mainly three factors that cause inefficiency in turning knowledge into economic value; lack of a large enough market (Almodóvar-González et al., 2020; Stel et al., 2005; Ulku, 2004), insufficient level of human capital (Almodóvar-González et al., 2020; Content et al., 2020; Stel et al., 2005), and insufficient level of institutional development (Acemoglu, 2008; Baumol & Strom, 2007; Content et al., 2020).

Further, combining these assessments with the analysis of The Ministry of Industry and Technology of Turkey (*Evaluation of the Effectiveness of Technology Transfer Offices*, 2021) and Global Innovation Index Report 2022 (Dutta et al., 2022) evaluations, we reach the following conclusions on the state of the Turkish innovation ecosystem:

- Turkey needs to improve its level of institutional development, especially in regulating the business processes,
    - GII 2022 considers policies for doing business underdeveloped,
    - Ministry Report states slow bureaucratic procedures and unestablished concept of incorporated company.

- Turkey should emphasize on its human capital,
    - GII 2022 indicates strong university enrollment levels and number of R&D personnel.
    - Ministry Report shows insufficient university-industry relations.

- Turkey can focus on utilizing the market potential,
    - GII 2022 considers weak venture capital investments but strong domestic market scale and diversification.

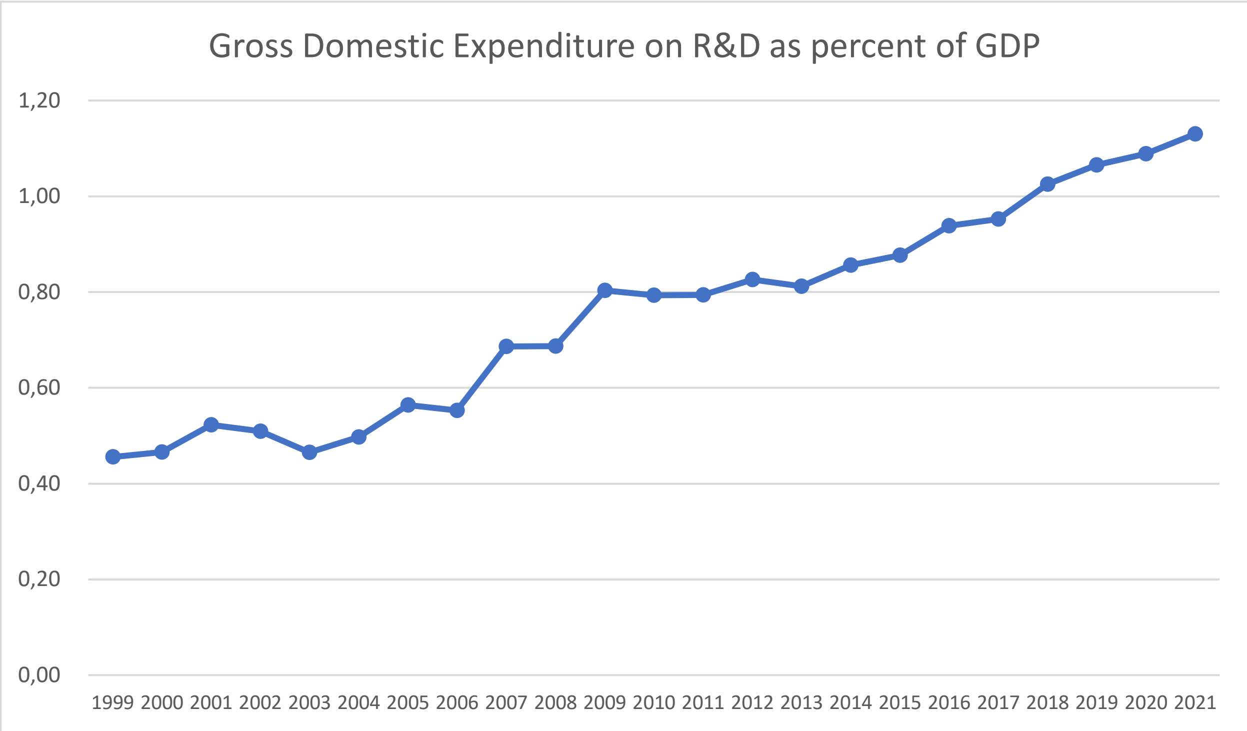

Figure 7.1 Gross Domestic Expenditure on R&D as percent of GDP (OECD, 2023)

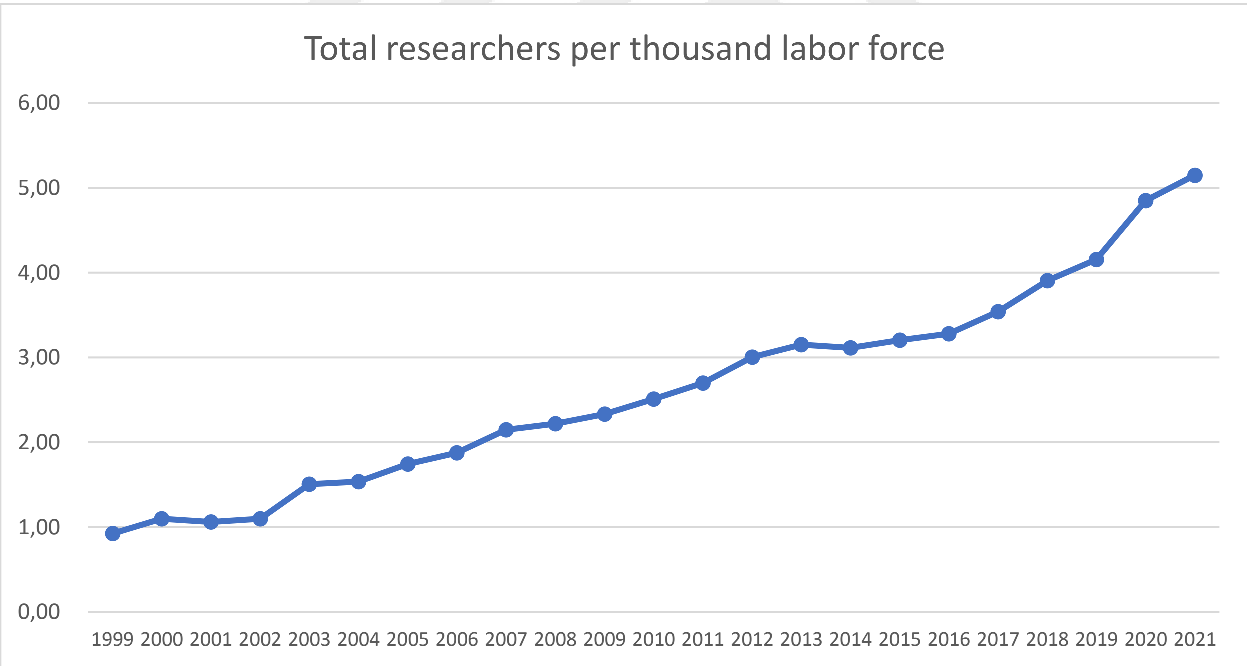

Figure 7.2 Total researchers per thousand labor force (OECD, 2023)

7.2. Policy Implications

With respect to the assessments of the related literature, we propose three main policies to enhance the innovation ecosystem of Turkey. Starting with the strengths, Turkey is increasing its knowledge stock as well as number of researchers, its human capital. This increase is an indication of future potential. To utilize this potential, Turkey should establish wide and efficient networks of communication and interaction between researchers and industry members with the help of TTOs, to increase the knowledge diffusion. The networks can be extended even internationally, to increase both the market the enterprises can reach and the knowledge stock that can be accessed.

As Baumol and Strom (2007) defines, the role of entrepreneur is “to exploit unnoticed opportunities" thus platforms to enable researchers and engineers, in other words potential entrepreneurs, to notice the opportunities that lie in other researchers’ inventions are necessary for the development of the ecosystem. Additionally, regulation and supervision of the collaborations encouraged by such networks is another field that needs attention. As stated in the report of The Ministry of Industry and Technology of Turkey as well (*Evaluation of the Effectiveness of Technology Transfer Offices*, 2021), a lack of detailed regulations was identified, and an lack of legal framework of conducting business may hinder both quality and quantity of collaborations. Finally, to improve the quality and accuracy of future studies, we draw attention to the collection of more detailed data on the indicators of innovation and technical development. Measuring innovation and entrepreneurial activity is a difficult task and patent stock is not a perfect indicator of innovation (Stel et al., 2005; Ulku, 2004). A stronger indicator of innovation is utilized by (Akcigit et al., 2021), which is patent citation. Patent citation shows both the quality of the produced patent by number of total citations, and the field of study that utilizes that patent. Thus, enables much more accurate measurement of technology transfer performance and also identification of the path knowledge follows during its transfer. Further, as one of the most important indicators of technical progress, the number of total researchers and labor force should be collected not just at macro level but also at city level.

7.3. Concluding Remarks

Our study tries to bring a quantitative approach to measure TTO impact in Turkish innovation ecosystem. Following the Triple Helix Model as a theoretical framework we identify the intermediary effect of TTOs in the relation between university R&D activities and local economic growth. For a more accurate interpretation of our results and policy proposals, the factors that affect TTO performance are taken into account. To measure the intermediary effect of TTOs, we employ a two-way two-step Sys-GMM method, which eliminates reverse causality and omitted-variable biases. Our results show that there is a positive and statistically significant effect of TTOs on the process of transforming inventions to economic value. Further, we assessed the state of Turkish innovation ecosystem according to our findings and combined with other evaluations in the literature. Our assessment showed that a simultaneous development of helices is needed to increase the effectiveness of innovation activities. Finally, we identified three main topics that Turkish policy-makers can address to improve Turkish innovation ecosystem; interaction and knowledge diffusion between agents that participates in the innovation process, enhancement of legal regulations to draw the legal framework for future collaborations, and expansion of datasets that enable more accurate identification and study of technology transfer.

7.4. Limitations and Further Studies

Our study aims to measure the intermediary effect of TTOs on innovation process, however, as the data of stronger indicators such as patent citation and city-level labor force were insufficient, we shifted towards more accessible data. Conducting this model with stronger indicators can potentially increase the accuracy of the results. Also, our model assumes cross-city spill-over effect isn’t impactful. Further studies can utilize more detailed data if it becomes available in the future. They can also compare the development of Turkish innovation ecosystem to other international actors.

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