Innovation:
Principles and Practices

Editors
Dr. Osman YILMAZ **Dr. Pınar ÇÖMEZ**

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"En İyi Akademi, Bir Kitaplıktır."

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THE IMPACT OF ENVIRONMENTAL TECHNOLOGY TRANSFERS AND CLIMATE CHANGE MITIGATION ON ECONOMIC GROWTH: EVIDENCE FROM G7 COUNTRIES

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INTRODUCTION

The natural environment has direct and indirect effects on economic activities. The direct effect of the natural environment on economic activities is the provision of resources and raw materials used as inputs in the production of goods and services. The indirect impact of the environment is the services provided by the ecosystem, such as managing flood risk, carbon saturation, and nutrient cycling. In this regard, natural resources are indispensable for economic growth both today and in the future. Economic growth can also affect environmental quality due to various factors, such as the scale of economic activities, if not supported by environmentally friendly policies. While other things are fixed, large-scale economic activities can lead to higher environmental degradation. As a result of increasing economic activities, because the level of resource use and waste generation is also increasing. (Everett et al.,2010: 7; Kinda, 2013 : 4). From this perspective, climate changes caused by environmental degradation are an integral part of the economy.

Although traditional growth theories focus on the increase in production of goods and services, they ignore the environmental effects of production. This growth process, which does not take environmental constraints into consideration, has accelerated with the Industrial Revolution. Increasing world population and needs have increased the pressure on natural resources. The urbanization process, which accelerated due to industrialization, led to an increase in housing demand. At the same time, the establishment of new industrial facilities led to the allocation of agricultural land to the relevant areas. The decrease in agricultural land leads to a decrease in agricultural production. The decline in agricultural production has revealed the situation of increasing world population's food needs. However, significant increases in industrial production have also begun to threaten both health and natural resources as well as leading to environmental pollution. In this sense, environmental factors that have not gained much attention in the growth models have begun to draw attention. Therefore, the sustainability of growth has started to be discussed. The first study in this field is the report titled "Limits of Growth" published in 1972.

According to “Limits of Growth”, when population and industrial capital exponentially increase, so will food and non-renewable resource demand and pollution. But food and non-renewable resource supply are finite. Therefore, rapid growth within limited resources causes systematic problems (Ekins, 1993: 271).

With the Brundtland report titled "Our Common Future" published in 1987, the concept of sustainable development was introduced into the literature for the first time. The report, which adopts the vision of meeting the needs of today's generation without hindering the needs of the next generation, emphasized the sustainability of the environment along with growth.

Another treaty highlighting environmental degradation is the Kyoto Protocol. The Kyoto Protocol is an international treaty which is linked to the "United Nations Framework Convention on Climate Change". The purpose of the protocol is to impose sanctions on industrialized countries to reduce emissions of gases causing global warming (climate change) and greenhouse effect. The treaty was signed in 1997 and entered into force in 2005. With the Paris Climate Treaty signed in 2016 after the Kyoto Protocol, the importance of environmental climate policies continued to attract attention during the sustainable growth process.

According to the Going for Growth 2019 report published by the OECD, the main factors slowing the economic growth of countries are globalization, digitalization, aging of the population and environmental degradation. According to the report, countries should improve productivity and competition, provide new business opportunities and implement policies that support a cleaner environment understanding to support long-term growth.

These awareness-raising reports and protocols emphasize that climate change and environmental degradation pose a threat to sustainable growth[1]. In other words, global economic growth is accompanied by severe environmental degradation. Increasing demand for natural resources with economic growth has put pressure on the already limited world resources. In this process, numerous resources such as water, fertile soils and fossil fuels quickly reached the limits of potential exploitation. Nevertheless, unexpected weather events, severe natural disasters and deterioration in the ecosystem due to climate change threaten economic activities and food safety (Stafford and Faccer, 2014: 12).

Environmental degradation has led countries to seek solutions for sustainable growth within the framework of technological transfers and

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[1] William Nordhaus and Paul Romer won the 2018 Nobel Prize in economics for work in integrating technological innovations and climatic change into long term macro economics. This award also highlighted the role of technological innovations and climate change mitigation on the economy.

climate change mitigation innovations. On the other hand, eco-innovation strategies are needed to overcome market barriers to adaptation and mitigation technologies. Therefore, more creative and globally integrated innovation strategies need to be identified to mitigate the impacts of climate change. Climate innovation policies are effective in accelerating the impact of technological developments and reducing costs. Therefore, green environmental policies focus on innovations. Innovations in environmental technologies reduce the costs of inputs and production whereas increasing production rates and attractiveness of goods in the market. In this context, protection of climate change technologies with intellectual property rights has gained popularity in recent years (Ghulam and Manzoor, 2011: 472-473)

Developing and disseminating technologies to improve living standards, reduce poverty by minimizing the adverse effects of global warming and weather conditions is a fundamental requirement. The role of intellectual property rights, particularly patents, in the regulation of the environment and climate change cannot be denied. Patent applications, one of the main indicators of technological development, are also the result of innovation policies implemented. Patent laws offer a wide range of rights through scientific innovations, including in the field of climate mitigation technology (Rimmer, 2019: 1-2).

G7 countries, consisting of Canada, France, Germany, Italy and Japan, are the most developed and industrialized countries in the world. These countries represent more than 62% of the world's wealth and over 46% of global GDP based on nominal values (WPR, 2019). Therefore, the climate policies to be implemented by these major economies are of global importance. In this context, the main purpose of this study is to investigate the effects of environmental technological transfers and climate change mitigation on economic growth in G-7 countries over the period 1999-2016.

The structure of the paper as follows: section 2 reviews relevant literature, section 3 describes model and data, and also presents methods and results, and section 4 concludes.

1. LITERATURE REVIEW

Solow (1956: 66) argues that innovation directly affects economic growth. Many studies also empirically support for this claim (Segerstrom, 1991: 826; Grossman and Helpman, 1994:24; Freeman, 2002:193; Wong et al., 2005:335; Hasan and Tucci, 2010:1264; Bayarçelik and Taşel, 2012:744; Bektas et al., 2015:461). The link between economic growth and ecosystems has been extensively studied through statistical models using different variables and approaches. The vast majority of studies examine the relationship between environmental sustainability and economic growth at the country level (Almeida, et al., 2017:120).

Climate change is one of the main concerns caused by the increasing use of innovation and technology (Mytelka, 2007:3). Therefore, in this rather extensive literature, we focus on how sustainable technological innovations contribute to economic growth in terms of climate change. In this framework, there are studies indicating that innovation and technology transfer may have different impacts on the environment (Mytelka, 2007:4). However, the findings obtained do not provide definitive results (Tucker, 1995:215; Jaffe and Palmer, 1997:610; Dong et al., 2014:78; Albrizio et al., 2017:207). The reason for this is that Arbolino et al. (2018a:282) base environmental innovations from other technological innovations. Empirical evidence also shows that innovations in green production play an important role in improving environmental improvement without reducing economic growth (Arbolino et al., 2018c: 130; Carlucci et al., 2018:60; Bosetti et al., 2008:1313). There are many studies focusing on the role of innovation to reduce environmental effects that lead to climate change. The most important part of this process is that governments create programs that enable the development and spread of technologies that minimize the impact of climate change (De Marchi and Grandinetti, 2013: 580; Hall and Clark, 2003:343; Jong et al., 2016:1347; Watson et al., 2015:387). Blazejczak et al. (2000:126) and Haselip et al. (2015:364) argues that sustainable technologies that support economic growth should be created. Solomon et al. (2009:1704) states that environmental innovations play an important role in combating climate change and supporting sustainable economic growth. Industrial activities create greater environmental externalities, especially in less developed economic systems. Thus, the sustainability of economic activities is seen as a critical environmental policy for cleaner production and also to mitigate climate change (Yiğitcanlar, et al, 2019a:148). Ferreira et al. (2020: 2) investigates whether technology transfer, climate change mitigation and environmental patents have an impact on economic growth among European countries. The study involved examining environmental water adaptation technology and the effects of climate change mitigation patents on gross domestic product. Ferreira et al. (2020: 3) examined the relationship between technology transfers and economic growth for 23 countries between 2000 and 2013 using unbalanced panel regression analysis. It concludes that technological innovations can adapt to changes in basic climatic conditions and contribute to sustainable economic growth without harming the environment (Ferreira et al., 2020:7). Similarly, Wiesenthal et al. (2012:130) supports the evidence that climate change mitigation technology will have positive effects on sustainable economic growth. Fankhaeser et al. (2008:421) showed that the struggle to mitigate the effects of climate change has positive effects on employment, innovation and economic growth.

In addition to the positive impact of environmental innovations on the environment, they can also have negative effects on economic performance (Arbolino, et al., 2017:115, 2018b:221). Machado et al. (2001: 411) states that the economic system can suppress ecological systems and, as a result, damage their own sustainability. Metz, et al. (2007:11) indicates that regulations to reduce carbon emissions lead to a decrease in gross domestic product in many countries. There are also studies that argue that with the development of carbon-neutral technologies, revenues from carbon taxes may reduce the problem of falling GDP (Jaffe et al., 2003:610; Popp, et al, 2010:873; Golosov et al., 2014:41; Acemoglu et al., 2016:52).

Kemp and Pearson (2007:15) remarks that environmental innovations are measured by patent data in the literature. In this sense, patent data has important advantages: For example: (i) these data, based on the international patent classification (IPC), contain information about the industry in which innovation occurred; (ii) this data is accessible to everyone; (iii) longer time is considered for panel analysis, and; It is not characterized by sample selection problem (Aldieri, et al., 2019: 2). Therefore, empirical evidence based on patent data is widely available in the literature (Aldieri ve Vinci, 2017:868; Peres-Ortiz, 2018:176; Quatraro ve Scandura, 2019:260). Ferreira et al. (2018: 206), using environmental-related technology patents data to analyzes environmental management, water-related adaptation and climate change mitigation between Portugal and Australia. The results show that Australia has more environmental patents than Portugal, but with both countries fall behind by the OECD average. The authors suggest that these environmental patents do not have any statistically significant effect in predicting the economic growth. Ferreira et al. (2019: 1505) similarly, it focuses on the impact of environmental patents on economic growth through technology transfers and institutional factors. It compares the continents of Europe and Oceania, which differ in terms of climate and economic sustainable policies. In this way, it contributes to the literature on intercontinental technology transfer policies by examining how environmental patents affect the economic growth rate of continents. Their results show that irrespective of the institutional and technology transfers have a positive impact on the economic growth of both continents..Ferreira et al. (2020: 4) predicts that the effect of environmental patents on GDP has a statistically significant effect based on the relationship of countries' locations with environmental patents. According to this study, the relationship between environmental patents and gdp growth is statistically significant and positive for the European countries, but this relationship is not statistically significant in the Eurozone.

When the related literature is analyzed, it is seen that environmental innovations are determined according to technological classifications and divided into categories (Aldieri ve Vinci, 2017:868; Marin ve Lotti, 2017:125). Many studies focusing on cleaner production issues (Hossain et al., 2019:976; Salim et al., 2019:1445; Souza Fairas et al., 2019:746) are seeking the answers to basic questions such as the determinants of environmental innovations and what are the economic effects of these innovations (Aldieri et al., 2019: 3).

In our study, we focus on the economic effects of environmental innovations which are less in the literature. To fill this gap in the literature, this paper aims to identify empirical evidence for the relationship between environmental technology transfer, climate change mitigation and economic growth.

2. DATA, METHODOLOGY AND ESTIMATION RESULTS

This work employs annual panel data from 2000 to 2016 for G-7 countries and reminding that the main objective of this paper is to estimate endogenous relationship between economic growth and the growth in various types of patent numbers in climate change mitigation that are related to (i) transportation, (ii)production or (iii)processing goods and energy generation, transmission or distribution. These variables, their descriptions, sources and descriptive statistics are illustrated in Table 1.

Table 1. Variable Description

Variable		Mean (%)	Std. Dev.(%)	Min (%)	Max (%)	Obs	Description	Source
GGDP	Overall	1.4705	2.0362	-5.8661	6.6431	119	GDP Growth (% change)	World Bank
	Between		0.7882	0.2759	2.6811	7		
	Within		1.8998	-5.5703	5.4325	17		
$GCME$	Overall	5.6572	20.2086	-94.098	57.6423	119	Climate change mitigation technologies in the production or processing of goods (% change)	OECD
	Between		3.24286	0.0992	9.08826	7		
	Within		19.9824	-96.846	54.8944	17		
$GCMT$	Overall	4.0324	15.2619	-94.098	43.0158	119	Climate change mitigation technologies related to transportation (% change)	OECD
	Between		2.6227	0.9919	7.5592	7		
	Within		15.0659	-96.846	43.3318	17		
$GCMP$	Overall	1.3424	14.5104	-62.755	41.3976	119	Climate change mitigation technologies in the production or processing of goods (% change)	OECD
	Between		19.6525	-1.9509	4.0773	7		
	Within		14.3949	-64.234	39.919	17		

In this work Panel Vector Autoregression (PVAR) models are used to estimate the relationship between the variables in a generalized method of moments (GMM) framework. PVAR models has an important advantage over other estimation procedures or models that is treating all variables in the model as endogenously determined by each other. This feature of a PVAR model is beneficial for revealing much-debated causal relationship between economic growth and growth in the number of patents that mitigate climate change. PVAR model to be estimated is shown as follows;

$$Y_{it} = \beta_0 + \beta_1 Y_{it-1} + \beta_2 Y_{it-2} + \cdots + \beta_p Y_{it-p} + u_i + e_{it} \qquad (1)$$

Where Y_{it} is the vector of dependent variables, u_i and e_{it} are vectors of country fixed effects and idiosyncratic errors respectively (Abrigo and Love, 2016). PVAR models presume the cross-sectional homogeneity; however heterogeneity is the common fact in practice. Introducing fixed effects allows for individual heterogeneity in the levels of variables that in turn leads biased estimation of coefficients due to correlation between the lagged values of dependent variables and fixed effects. In order to successfully overcome this problem, forward orthogonal deviation or so called "Helmert procedure" is employed (see Arellano and Bover (1995) for a detailed representation). Helmert procedure is simply the difference between mean of leading observations from current level of observation. After the orthogonality between transformed and lagged variables is ensured, lagged regressors can be employed as instruments and estimation would be made by system GMM. Effectiveness of lagged instrumental variables is controlled through Hansen test of over identifying restrictions. PVAR model will be estimated separately for the relationship between economic growth and growth in three different types of climate mitigation related patents.

The causal relationship between economic growth and growth in the number of climate mitigation related patents will be estimated through Granger causality Wald Test in which null hypothesis states non-causality. In order to affirm direction of the relationship, impulse response functions are estimated on the base of Cholesky decomposition of residual covariance matrix and ordering of the shocks are determined by Granger causality.

Table 2. Cross Section Dependence Test (CD-Test) and second generation unit root test (MADF Test)

	CD - test	MADF Test		
	CD-Test	Corr.	Abs (Corr.)	Lag (1)
$GGDP$	14.57***	0.771	0.771	199.117 **
$GCME$	11.75***	0.622	0.622	69.568**
$GCMT$	4.93***	0.261	0.297	217.835**
$GCMP$	3.97***	0.210	0.252	470.678**

***, ** and * indicates %1, %5 and %10 significance levels respectively.

Table 3. Lag order selection criteria

Lags	PVAR Model I ($GGDP$: $GCME$)			PVAR Model II ($GGDP$: $GCMT$)			PVAR Model III ($GGDP$: $GCMP$)		
	$MBIC$	$MAIC$	$MQIC$	$MBIC$	$MAIC$	$MQIC$	$MBIC$	$MAIC$	$MQIC$
1	-39.105	-14.801	-24.224	-34.979	-10.675	-20.097	-35.116	-10.812	-20.234
2	-24.195	-7.9925	-14.274	-27.116	-10.913	-17.195	-28.435	-12.232	-18.514
3	-13.205	-5.1032	-8.2441	-14.739	-6.6374	-9.7783	-13.668	-5.567	-8.708

At pre-estimation stage, stationarity of variables have to be checked by first or second generation unit root test according to of cross-sectional dependence among panel variables. At the very beginning Pesaran (2004) CD test is going to be implemented and according to the result first or second generation unit root tests are employed. Table 2 shows results of CD test and according to results all variables are found cross-sectional dependent. Evidence of cross-sectional dependency requires second generation unit root tests of series. In this work Multivariate Augmented Dickey-Fuller (MADF) panel unit root test is going to be employed among second generation tests, because number of panel units is less than of time units. According to results shown at Table 2 series are found stationary. Since series are both stationary it is appropriate to estimate PVAR model with these series. The optimal lag level is chosen through three lags selection criteria, suggested by Andrews and Lu (2001), that are Bayesian information criteria (MBIC), Akaike information criteria (MAIC) and finally Hannan and Quinn (MQIC) criteria. Optimal lag number is the one that minimizes aforementioned criteria. According to Table 3, lag order 1 is chosen as the optimal lag level. As a result 1st order PVAR model with 3 instrumental lagged for each patent variable is going to be estimated.

Table 4. Panel VAR Results

Response of	Response to	
PVAR Model I	$GGDP_{t-1}$	$GCME_{t-1}$
$GGDP$	0.1996 (0.1271)	-0.0024 (0.0124)
$GCME$	3.1273 (1.2999) **	0.36826 (0.2321)
PVAR Model II	$GGDP_{t-1}$	$GCMT_{t-1}$
$GGDP$	0.2002 (0.1491)	-0.0092 (0.0163)
$GCMT$	2.1843 (0.8276)***	-0.2268 (0.1205)*
PVAR Model III	$GGDP_{t-1}$	$GCMP_{t-1}$
$GGDP$	0.1807 (0.1119)	0.0101 (0.0182)
$GCMP$	0.7970 (0.7116)	-0.20330 (0.1508)

Stability Conditions of Panel VAR Systems

PVAR Model I Eigenvalue			PVAR Model II Eigenvalue			PVAR Model III Eigenvalue		
Real	Imaginary	Modulus	Real	Imaginary	Modulus	Real	Imaginary	Modulus
0.2839	-0.0216	0.2847	-0.1726	0	0.1727	-0.2232	0	0.2232
0.2839	0.0216	0.2847	0.1461	0	0.1461	0.2006	0	0.2006

All the eigenvalues lie inside the unit circle. All models satisfy stability condition.

Table 4 shows estimation results of the PVAR system after panel specific fixed effects are removed. Each panel of the table illustrates the dynamic relationship between economic growth and growth in the each patent variables. The results of Hansen overidentification test validates 4 lagged dependent variables as instrumentals. Stability of the PVAR is quite important which implies that "PVAR is invertible and has an infinite-order vector moving-average, providing known interpretation to estimated impulse response functions" (Abrigo and Love, 2016:788). Table 4 illustrates that stability conditions are verified since roots of the companion matrix are all in the unit circle.

Table 5. Granger Causality Test Results

$GCME$ does not Granger-cause $GGDP$ variable	0.038	$GCMT$ does not Granger-cause $GGDP$ variable	0.321
$GGDP$ does not Granger-cause $GCME$ variable	5.787 **	$GGDP$ does not Granger-cause $GCMT$ variable	6.965***
$GGDP$ does not Granger-cause $GCMP$ variable	0.307		
$GGMP$ Granger-cause $GGDP$ variable	1.254		

***, ** and * indicates %1, %5 and %10 significance levels respectively.

Granger causality test results are reported in Table 5. According to results, growth in GDP (GGDP) is found granger cause of both growth in climate change mitigation patents that are related to energy generation, transmission or distribution (GCME) and to transportation (GCMT), however no relation is found between GGDP and the growth in the number of patents related production or processing of goods (GCMP). However Granger causality test results show proper causal relationship between variables in the system, it doesn't inform us about the direction and magnitude of the relationship. Impulse response functions (IRF) fills the gap and "describe the reaction of one variable to the innovations in another variable in the system, while holding all other shocks equal to zero" (Love and Zicchino, 2006:194). In order to analyze the impulse-response functions their standard errors has to be calculated and confidence intervals has to be generated in order to make an assessment about significance of the relationship. Ordering of the shock is in line with as it is determined by Granger causality test and only significant relationships are going to be illustrated.

Table 6. Impulse Response Functions

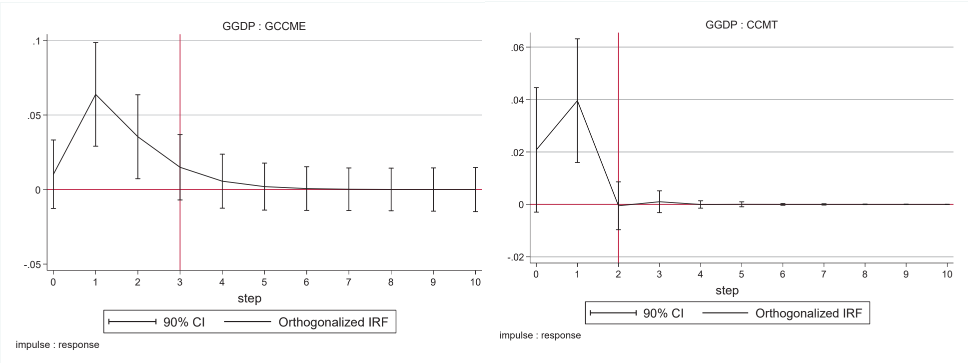

Table 6 shows the reaction of patent growth variables to the innovations in GGDP. Upper panel shows that GCME increases in response to a shock from GGDP and it is significant at 5 percent significance level however the significant effect disappears after 3th period. Lower panel illustrates that a shock from GGDP increases GCMT and it is significant at 5 percent level. This effect also vanishes after 2th period. As a result an increase in the GGDP increases GCME and GCMT at the very short-run significantly.

CONCLUSION

Climate changes, considered as a global threat, are the result of serious increases in greenhouse gas emissions, especially CO2. For a sustainable growth and future, this threat should be eliminated. Therefore, climate change mitigation policies such as improvements in energy efficiency in buildings, environmentally friendly sustainable transportation methods, promoting innovation and technology transfer and encouraging the use of renewable energy sources and should be implemented in order to reduce greenhouse gas emissions (GEF, 2019). In this sense, the goal of the study is to analyze the effects of technological strategies to minimize the negative effects of climate change, which is a major threat to sustainable growth. Therefore, the impact of environmental technology transfers and climate change mitigation on economic growth in G7 countries is investigated over the period 1999-2016.

In this paper, Panel Vector Autoregression (PVAR) models are used to estimate the relationship between economic growth and growth in the number of patents that mitigate climate in a generalized method of moments (GMM) framework. By making use of PVAR models, our objective is to estimate separately for the relationship between economic growth and growth in three different types of climate mitigation related patents. The result of study show that growth in GDP is found granger cause of both growth in climate change mitigation patents that are related to energy generation, transmission or distribution and to transportation, however no relation is found between growth in GDP and the growth in the number of patents related production or processing of goods. The results suggests that an increase in the growth in GDP increases growth in climate change mitigation patents that are related to energy generation, transmission or distribution and to transportation at the very short-run significantly. Our results provide that an increase in the growth in GDP increases growth in climate change mitigation patents that are related to energy generation, transmission or distribution and to transportation at the very short-run significantly. These results suggest the importance of further research exploring the relationship between economic growth and climate mitigation related patents.

The research & development process of an invention has serious time and resource costs. Therefore, as the economic growth of countries increases, the innovation resources reserved for new inventions is expected to increase. Accordingly, patent applications are likely to increase. According to the World Bank data, the first two sectors that cause the most CO2 emissions as well as climate change are the energy and transportation sectors, respectively. Therefore, as GDP increases in G-7 countries, it is logical to prefer patents for the energy and transport sector to reduce the effects of climate change. Since the patent application and approval process is spread over a long period, in addition, the impact of these environmental patents on economic growth can be observed in the long term. Therefore, it usual to find a causality relationship from patents to economic growth.

In the light of the findings obtained from the study, the following recommendations can be made for policymakers in G-7 countries. In their sustainable growth polices, policymakers should promote low carbon transportation such as electric vehicles, high-tech subway system, use of public transport rather than individual transport. In addition, they should encourage innovation and technology related cleaner energy.

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In this fast developing, unstable and unpredictable knowledge era; in which a lot of new concepts and components, such as artificial intelligence, big data, virtual & augmented reality, integrated systems, internet of things, cloud computing, machine learning and autonomous robots have been introduced into our lives; organizations are trying to continue their existence and maintain their competitiveness by radically changing their way of doing business.

Today, companies are operating in a world, in which they are continuously interacting in many ways. "Corona Virus" incident that was significantly influencing almost all countries in the world during the days when this book was published, showed clearly that unexpected and apparently irrelevant factors could produce substantial economic and social effects in all industries from health to education, from banking to tourism, from agriculture to retail, and thus proved once more that all industries and businesses are closely interconnected. Even companies that carry on business in local markets can easily and significantly be affected by those global factors.

One of the most crucial competencies for the companies to sustain their success and profitability in this complex and fast changing environment is to be "UNIQUE". In order to be unique, they should understand what the concept of "INNOVATION" is and how to implement and manage it properly. This book, which is edited by my dear colleagues Dr. Pınar ÇÖMEZ and Dr.Osman YILMAZ, is a very important reference on this particular subject, "innovation management", that has gained significant attention from scholars and practitioners. In this book, various topics; such as the behavioral antecedents and consequences of innovation, relationship of innovation management with human resources and organizational culture, influence of leadership on innovation capability, associations of innovation management with health management and marketing strategies, as well as innovative utilization of new technologies in education; are addressed. In addition, how innovation management can be developed and applied in various fields is also widely discussed.

By its timing, theme, content and wide perspective, I believe that this book will significantly contribute to close an important gap in innovation management field, and will provide a noteworthy guidance for academicians who want to conduct research in this field and for managers who are in the position of making strategic decisions for their organizations.

"Prof.Dr.Alper ERTÜRK
Professor of Human Resource Management & Analytics"

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