A Nexus Among Technology Input, Research Activity, Innovation, and Economic Growth: A vis-à-vis Analysis between Asia and Europe

Maneesh Kumar Pandey[1], **Komal Kanwar Shekhawat**[2], **Irina Sergeeva**[3], **Olga Orlova**[4]

[1] ITMO University,
9, Lomonosov str., St. Petersburg, 191002, Russian Federation.
E-mail: maneeshban@gmail.com

[2] Akal University Talwandi Sabo,
Bathinda, Punjab, India
E-mail: kshekhawat599@gmail.com

[3] ITMO University,
9, Lomonosov str., St. Petersburg, 191002, Russian Federation.
E-mail: igsergeeva@gmail.com

[4] ITMO University,
9, Lomonosov str., St. Petersburg, 191002, Russian Federation.
E-mail: oporlova@itmo.ru

This study attempts to analyze the influence of technological infrastructure development and the spill-over effect of dynamic growth of technological innovation on the Asian and European economies. Compared to European countries, the economic infrastructure of Asian countries has transformed significantly during the last three decades. Technological progress and higher growth of available engineers and researchers have become pivotal endogenous determinants in the aggregate production function and eventually became the key drivers of economic growth. Compared to European countries, rapid investment in technology import

Maneesh Kumar Pandey – Doctoral Student (Ph.D.), Faculty of Technological Management and Innovations.
Komal Kanwar Shekhawat – Assistant Professor, Department of Economics.
Irina Sergeeva – Professor, Faculty of Technological Management and Innovations.
Olga Orlova – Doctoral Student (Ph.D.), Faculty of Technological Management and Innovations.

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and a higher number of technologically competent available workforce galvanized uplifted and speedy productivity rates, causing positive economic growth in the Asian economy. The interrelation between technological progress and economic growth is summarized and analyzed by using quantitative methods. The paper studies the nexus between technological progress, the availability of engineers and researchers, and economic growth by applying the dynamic Generalised Method of Moments (GMM) method to the available quantitative data (2013–2017) of chosen Asian and European countries. The Econometric results show a significant effect of technological progress and innovation on economic growth. The empirical insight is of particular interest to policymakers as it helps to enhance internal and external technology and innovation development policies for sustainable economic growth in Asian and European countries.

Key words: technology import; workforce; patents; economic growth; Asia; Europe.

JEL Classification: O0, O3, O4, O5.

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1. Introduction

Over the recent few decades, Asia shifting from resource-driven, export-led economies to innovation-driven and sustainability-oriented ones is riding on human capital development and new technology advancements. It poses both a challenge and an opportunity for European companies regarding employment, investment decisions, and trade patterns. By introducing new products, processes, or managerial practices, innovation would lead to improved uses of capital and labor, enabling firms to enter new markets and grow [De Nicola, Chen, 2022]. Contrary to popular belief, however, innovation is not only about ground-breaking technology and advancing the global technological frontier. Most new products or processes stem from the adoption of existing technologies that have been developed elsewhere, possibly with some customization to serve better the demand of the local market [EBRD, 2014].

Asian companies have increasingly become more innovative, which forces European companies to innovate. One of the main reasons behind Asian emergence is support from governments which is steadily building the needed social support and service system, often inspired by the earlier developed countries. The arrival of technological changes has the potential to put on hold some of the policy initiatives, services, and institutional trends that willingly or unwillingly were following the paths of the developed world. It makes Asia an intriguing and exciting region to examine [Li, Piachaud, 2019].

The driving forces behind innovation are crucial to creating value for consumers, society, and shareholders. These forces are essential to maintain competitive advantage and leadership for companies. Prominently, consumers are demanding more personalized products with affordability and value for money. Channel dynamics are changing due to more digitized platforms and better global supply chain networks. Governments, shareholders, and venture capitalists demand innovation to enable higher returns from companies they support amidst rising competition in all industry sectors. New entrepreneurs are taking advantage of this pull and are accelerating the innovation cycles through the agile delivery of relevant products and services quickly. More innovation may originate from greater collaboration between SMEs and large firms, industry-government cooperation in R&D, university-industry R&D collaboration, and financial and technical aid provided by state and central governments [Kumar, Subrahmanya, 2010]. Along these lines, Gupta and Barua (2016) suggest that the establishment of supportive government policies, allocation of funds for R&D activities, and training of unskilled workers at government institutes will positively influence firm-level innovation.

There is seemingly no shortage of innovative ideas and entrepreneurship in Europe. Though most new European companies, despite doing well in the start-up phase, eventually shift their bases out of Europe. Companies like Skype, Beddit, Shazam, and Minecraft are just a few well-known examples. A few key factors behind this trend are the lack of substantial long-term investment in cutting-edge innovations, fragmented rules and regulations, taxes and standards across the EU countries, and apparent deterrence in the European Union to use new technologies from young innovative companies.

Asia's success story largely stems from a consistent broadening and deepening innovation culture. By applying different innovation strategies, they have advanced their economies. In China and India, in particular, innovative strategies helped to tap global knowledge, develop reverse engineering, exploit the skills of their population diaspora, and develop information and communication technologies, which were able to accelerate the innovation process [Dahlman, 2009]. Asian companies are creating value through collaborative innovation, including strategic and technical alliances, joint ventures, and patent collaborations that allow them to combine their competencies with those of other firms. Maintenance of macroeconomic stability, financial sector development, and human capital development promote innovation and technology transfer, thus reaping economic and social benefits. Government policies to provide fiscal incentives to FDI and enhance FDI spillovers are particularly significant for basic research that provides the early seeds for a variety of innovations by many firms in the region.

In contrast, European economies struggled to recover growth momentum in the past decade. While European companies still account for one-quarter of total industrial R&D in the world, over the past ten years, US companies have continued to increase their share, reinforcing their leadership position, and China and South Korea have been catching up. The such competition challenges the ability of Europe to sustain its growth model over the long term [Moncada-Paternò-Castello, Hernandez, 2018]. Fragmentation in Europe is one of the biggest challenges as it hinders the seamless diffusion of technology across the supply chain, complicates data sharing, deters standardization, and restricts the availability of skilled resources. Large and more homogeneous markets in the United States and China ease fast scale-up and create instant demand from tech-enthusiastic consumers. Europe’s national markets lack in size by comparison, making it difficult for new players to offer the same scale despite the European Union’s efforts to create a Single Market [World Economic Forum, 2021].With this backdrop, the key objective of this paper is to take a comparative look at technology import and diffusion, movement of skilled resources, and macro-economic landscape for their impact on the innovation index and their subsequent implications on the overall economic growth in Asia and Europe economies. The paper studies the nexus between technological progress, the availability of engineers and researchers, and economic development by employing the dynamic Generalised Method of Moments (GMM) method on the available quantitative data (2013–2017) of the chosen Asian and European countries. It is critical to understand the fundamental components of the innovation engine, such as the High-Tech-Import percentage, engagement of the Scientists and Engineers Index, and patent churn, so that one can observe their impact on overall growth in the respective countries. This analysis can be instrumental in understanding their complex relationship and addressing the opportunity areas for policymaking.

To the authors' best knowledge, comparative studies that analyze these parameters in detail for Asian and European countries are limited. We believe this paper could contribute significantly to the existing body of literature. We aim to present an analysis of the innovation paradigm between Asian and European markets in the overall growth framework to foster debate, identify areas for further cooperation, and enhance the visibility and strengths of future policymaking. The subsequent sections of the paper will delve into the reviews of available relevant literature in section 2, an illustration of the data and model specification used in the study in section 3, and a discussion of findings, a conclusion combined with policy recommendations drawn from them, are presented in section 4.

2. Literature Review

One of the core features of high-tech companies is their innovativeness, as the development of the high-tech industry is a process related to technological innovation [Ze-Lei, Xin-Ya, Fei, 2017].

The innovation and research sector relations draw broader attention at the beginning of the 90s [Aghion, Howitt, 1992]. Growth theory established long ago that technological improvements affect long-run growth [Romer, 1990; Aghion, Howitt, 1998]. In developing countries, the international transmission of knowledge occurring through several channels – foreign partners, foreign suppliers, clients, or the direct trade in technologies through licensing – can be vital for technological adoption across firms [Hoekman, Javorcik, 2006].

Johns claimed that long-run growth could be possible through R&D activities [Jones, 1995]. R&D effects on aggregate production functions were tested by national research centers in the early 2000s [Sveikauskas, 2007]. It is well established that technological development and innovation capability are the main drivers of incremental growth across various industry sectors. Knowledge accumulation and its diffusion directly impact the development of abilities within firms and the evolution of industrial structures as a whole [Moncada-Paternò-Castello, 2022].

This dynamics of technological innovation and economic growth has become one of the main areas of interest for rationalizing sustainable socio-economic development of the countries. This research area has been attracting growing academic interest from many parts of the world. F.M. Scherer (1999) traces the evolution of economic growth theory from the Industrial Revolution to the present, emphasizing technological change as the most crucial dynamic force for growth. According to [Broughel, Thierer, 2019], most economists agree that economic growth and human well-being strongly depend on conditions for technological innovation in a country. The authors also underscored that regressive cultural attitudes and approaches towards technological innovation and its disruptive effects could minimize the opportunities of exploiting its benefits and thwart the sonic-economic growth of those societies and countries. Some other authors, such as [Coe, Helpman, 1995] also stated that open and liberal economies with higher shares of imports in GDP benefit more strongly from foreign R&D capital stock than more closed and conservative economies. In another study [Jalles, 2010] that performed a panel data analysis of the determinants of technological progress (Patents and Intellectual Property Rights Index) on the economic growth of 73 countries from the year 1980 to 2005, the author found that both determinants create a positive effect on the rate of economic growth in the chosen countries. The paper [Damijan, Kostevc, 2010] tried to examine the sequencing of firms' learning effect by associating with international trade links of the number of Spanish manufacturing firms [ESEE, 1991–1999] combining usual firm-level balance sheet data with the data on innovation and trade flows. The matching technique was employed to identify the exact sequencing between a firm's engagement in trade and its learning from mutual trade relations through innovation. The authors found that with the help of import activities, firms get opportunities to learn and evolve their product and process innovation activities remarkably. This close nexus between imports and innovation activities is the cause of the inception of firms' export activities which may lead to further possibilities of more innovations. Furthermore, [Worz, 2005] found that the import trade of medium and high-tech commodities has a significant positive impact on long-term economic growth through the study of African, Latin American, and other countries.

Since technology import is a vital source for enhancing research and development activity and higher factor productivity, it is crucial for boosting economic growth. To analyze this relationship, [Ming Chen, Hongbo Wang, 2021] examined the influence of imported technology sophistication on economic growth in China. The results show that the increase in the sophistication of imported technology can significantly promote the high-quality development of the regional economy, and this effect applies to both imported intermediate and final products. Consecutively, to attain high-quality economic development import of sophisticated technology is inevitable. [Shao, 2017] used the data on manufactured goods and services trade to prove that imports of technologically advanced manufactured goods and sophisticated services contributed to China's economic growth and that the driving role of service trade is high. The above finding is also substantiated by [Mehmet Adak, 2015], as this research analyzed the nexus between technological progress, innovation, and Turkish economic growth. Having accomplished an econometric analysis of the determinants, the author found that new technology investments appeared as one of the key drivers of high productivity rates leading to swift and positive economic growth. According to [Salmon, Shaver, 2005; Schneider, 2005], import spillover can occur when a firm imports a product, observes and imitates foreign production, and finally develops new products to suit the local as well as global markets. [Schneider, 2005], for example, highlighted the importance of high technology diffusion to increase domestic innovation. Countries that import technologically advanced products are likely to learn about new technology through spillover effects. In the other comprehensive study on the nexus between innovation and foreign technology by employing econometric analysis [Federico et al., 2013], the authors found a remarkable role of imported technology in innovation activity outcomes. For instance, the import of machinery and the accumulation of technical human capital contributed positively to innovation activity.

Government policies determine the innovation framework. Innovation systems depend on robust, stable, and high-quality institutions to be successful. Researchers are commenting a lot on how various governments are establishing the basis for innovation through selective investment in R&D, provision of tax incentives, subsidized loans, and human capital that promotes firms and sectors with greater ICT Exports. The Indian government has also encouraged the rise of venture capitalists as a means of funding opportunities for firms for their innovations. Additionally, the government has encouraged using foreign technologies in the ICT sectors [Crescenzi, Rodríguez-Pose, 2017]. In the case of emerging economies, corruption at the firm level of manufacturing industries and in regions having a more corrupt government has a negative association with innovation [Lee, Wang, Ho, 2020]. The authors found that the country's governance is essential in fostering innovation as firms that engage in corrupt practices exert their potential to innovate, which has a negative influence on innovation and economic growth. Furthermore, according to another study, high regulatory quality reduces information asymmetry, increases accountability, and curtails bank lending corruption [Gimenez, Sanau, 2007].

In the context of the nexus between human capital, social capital, and innovation [Dakhli, Clercq, 2004] performed an extensive study. The authors analyzed the influence of human and social capital on innovation activity at the country level. The research outcome showed a strong positive relationship between human capital and innovation activities. However, surprisingly a negative relationship was observed between social capital (norms of civic behavior) and one of the chosen innovation measures. Similarly, another work [Oluwatobi et al., 2016] explores the impact of human capital and institutions on innovation activities in the Sub-Saharan African region. The authors found that enhancing human capital and enabling better institutional ecosystems affect innovation outcomes significantly. At the same time, one couldn't detect many benefits from the innovation activities through foreign investment. Popescu and Diacon (2008) found that individual's abilities and skills could be improved so that in an environment where human capital is a crucial source of competitive advantage to individuals, organizations, and even societies, having a high potential for innovation induction, they could make more positive contribution to development. Apart from that [Gallié, Legros, 2012] stated in their study that all the indicators related to a firm's skills development training program for employees show that the skill development initiatives taken by the firm have a significant and positive impact on the enhancement of technological innovations. However, another study [Danquaha, Amoahb, 2017] attemptted to explore a relationship between human capital, innovation, and technology adaptation in sub-Saharan African countries. The findings show a bag of mixed results where human capital exhibits a positive and statistically substantial influence on the adoption of technology, while its effect on innovation appeared unremarkable.

3. Data and Methodology

3.1. Data and model specification

This study analyses the annual secondary data for selected Asian and European countries from 2013–2017. The countries chosen for this study represent two geographically separate groups **(1) Asian countries:** India, Israel, Kazakhstan, Iran, Kyrgyzstan, Malaysia, Oman, Pakistan, Saudi Arabia, Singapore, Thailand, Turkey, United Arab Emirates, Indonesia, Vietnam, China, Japan, Nepal, Jordan, Azerbaijan, Georgia, Mongolia, Armenia, Bahrain; **(2) European countries:** Austria, Belgium, Denmark, Estonia, Finland, France, Germany, Ireland, Portugal, Norway, Romania, Poland, Spain, Sweden, Ukraine, Czech Republic, Switzerland, Greece, Hungary, Serbia, Bulgaria, Slovakia, Croatia, Moldova, Lithuania, Latvia, Luxembourg, and Iceland.

The variables taken for this study include (1) HTI, High-Tech-Import (percentage of trade); (2) ASEI, Availability of Scientists and Engineers Index; (3) TPA, Total Patent Application; (4) GDP, Gross Domestic Product. Table 1 shows a brief overview of the data sources and data description.

Table 1.

Description of three variables along with their source and time-frame

Serial Number	Variables	Unit/Proxy	Time Period	Source
1	High-Tech-Import (Percentage of Trade), HTI	Percentage	2013–2017	World Bank Data Repository
2	Availability of Scientists and Engineers Index (ASEI)	Rank (Points)	2013–2017	World Economic Forum (Parameter) Data Collected from World Bank Data Repository
3	Total Patent Applications (ATPA including Residents and Non-Residents	Number of Applications per Year	2013–2017	World Bank Data Repository
4	Gross Domestic Product (GDP)	Nominal Rate USD (Billions)	2013–2017	World Bank Data Repository

Source: Authors Computations from World Bank Data Base 2022 (http://www.worldbank.org).

Research procedures. The research procedure/methodology is a chain of systematic steps/methods that can account for problems produced during data gathering using different procedures. Essentially, the research procedure/methodology is an algorithmic representation of a research or study [Murthy, Bhojanna, 2009].

This research work relies on a quantitative methodology. It is one of the widely employed research frameworks in the social sciences. Allen (2017) advises that in the case of scientific investigations, quantitative research counts on data that are observed or estimated for evaluating the questions about the sample population.

By deploying quantitative methodology, in this study, different econometric tools have been applied in a stepwise manner starting with descriptive statistical analysis for summarizing the data and drawing the obtained information through particular arithmetic results like measures of central tendency (mean, median, etc.) and measures of dispersion (variance, standard deviation, skewness, and kurtosis, etc.) to make the understanding of the data better. Moreover, a graphical representation of different variables provides a better picture of the data. The second step requires a unit root test to check the stationarity of data. In statistical analysis, a unit root test examines the presence of unit roots in non-stationary time series variable data. The null hypothesis reflects the existence of a unit root. The alternative hypothesis suggests that the data would be stationary, trend stationarity, or have an explosive root – depending on the test used. The third step involves correlation analysis to measure the degree of affinity among variables. According to [Lindley, 1990], correlation is a tool for understanding the relationship between two quantities. In correlation analysis, one can understand how much the two quantities are symmetrical.

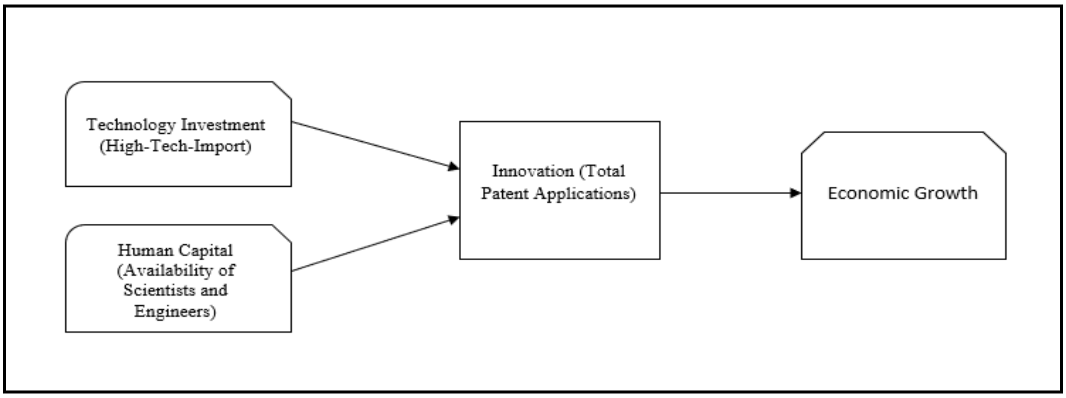
The fourth step, based on the empirical model of a research problem and possible econometric solution, uses the generalized method of moments (GMM). The GMM estimation for linear and non-linear models with applications in economics and finance was formalized by [Hansen, 1982]. It has become one of the most widely used estimation methods for models in economics and finance. OLS estimators are inappropriate in the presence of nonstationary data as they would have a consistent endogenous problem. The GMM is helpful for the estimation of panel data. Therefore, GMM [Arellano, Bond, 1991] was applied to overcome the endogenous problem. Unlike maximum likelihood estimation (MLE), GMM does not require complete knowledge of the data distribution. One needs only specified moments derived from an underlying model for GMM estimation.

Empirical model. The model is constructed in two stages, as given in Fig. 1. However, it is worth noting that this model is applied to Asian and European countries separately. Firstly, the innovation process is estimated, which one can present as suggested by equation 1.

$$TPA_{it} = f\left(ASEI_{it}, HTI_{it}\right), \quad (1)$$

where *i* = 1 is for Asian countries, *i* = 2 is for European countries, and t is for the time period. *TPA* is the dependent variable which denotes Total Patent Applications. *ASEI* and *HTI* are the independent variables that denote the Availability of Scientists and Engineers Index and High-Tech-Import accordingly.

Innovation is represented by a Total Patent Application variable (TPA). Innovation is influenced by technology investment and human capital wherein the technology level of a country is usually raised by importing new technological tools, equipment, and human capital. The latter's quality can increase based on professional and scientific training and development initiatives. New technology and human capital accumulation are closely associated with patent registration. The number of total patent applications becomes a dependent variable, while high-tech import as the annual percentage of total trade and the annual ranking of availability of scientists and engineers are chosen as independent variables.



Source: Constructed by authors.

Fig. 1. Model summary

In the second stage, total patent applications are used as independent variables in aggregate production function. The model specification is shown in equation 2.

(2) $$GDP_{it} = f\left(TPA_{it}\right),$$

where i = 1 is for Asian countries, i = 2 is for European countries, and t is for the time period. The patent application is the independent variable, and GDP is the dependent variable.

4. Econometric Analysis

4.1. Step-wise econometric analysis for Asian countries

For Asian countries, Table 2 shows descriptive statistics analysis for 112 observations for ATPA and 115 observations for the remaining variables AHTI, AGDP, and AASEI. Notably, descriptive statistical analysis of ATPA reflects a big gap between the minimum (30.00) and maximum (1381594) values with a much higher mean (67891.42) and standard deviation (240417.9).

Table 2.

Descriptive statistical analysis

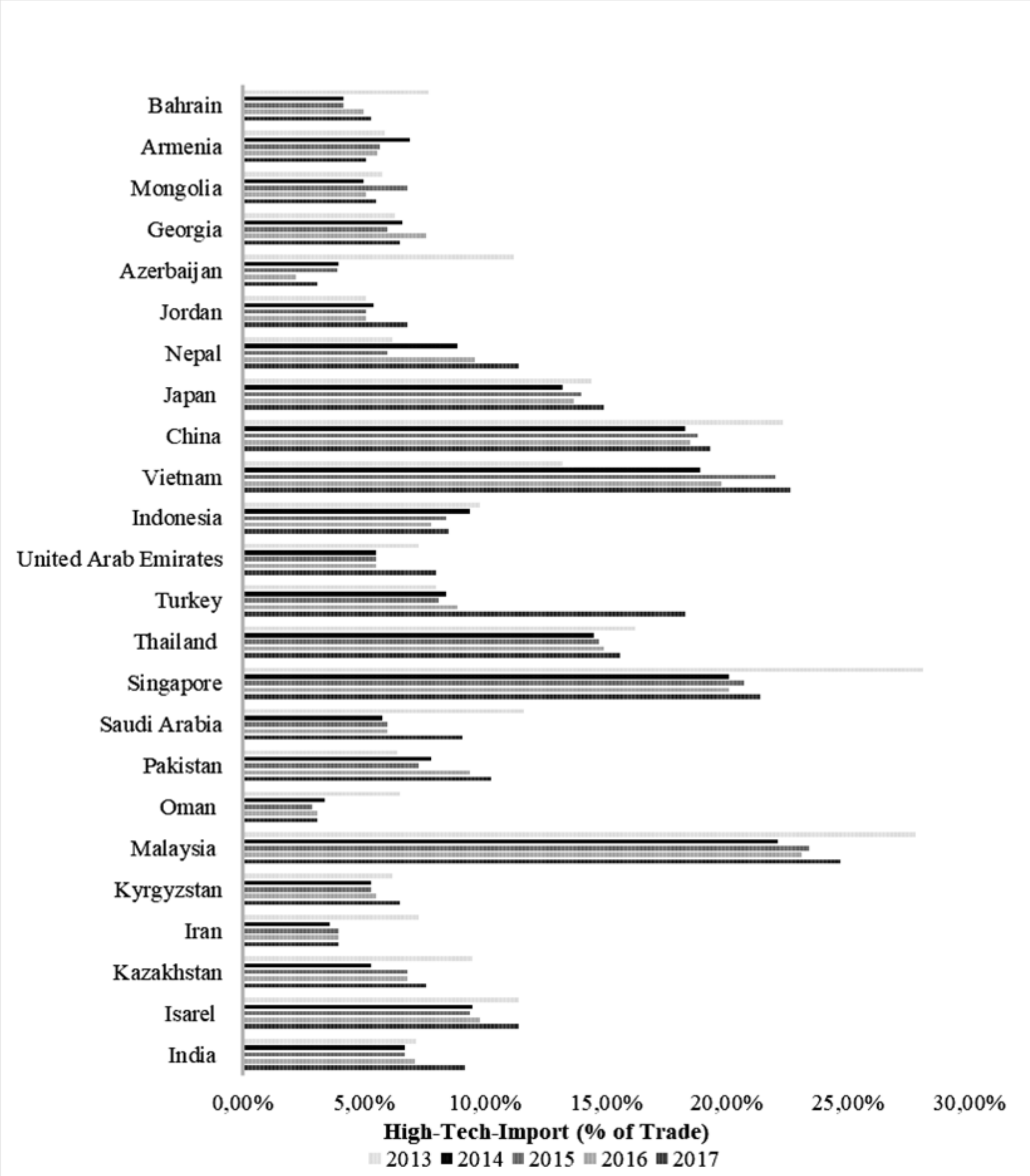
Variable name	Observations	Mean	Standard deviation	Maximum	Minimum
ATPA	112	67891.42	240417.9	1381594	30.00
AHTI	115	0.100991	0.061269	0.281000	0.0220
AASEI	115	4.3666	0.66134	5.570000	2.80000
AGDP	115	1006.348	2371.684	12310.00	6.6800

Source: Computed by authors.

Similarly, for AGDP, a wide gap between the minimum (6.6800) and maximum (12310.00) value with a greater mean value (1006.348) and higher standard deviation (2371.684). This result shows that few Asian countries, such as China, Japan, and India, are muchly advanced in science and technological innovation activities and have much bigger economies than the rest of their peers in the group. However, the data of the other two variables AHTI and AASEI are more uniformly distributed.

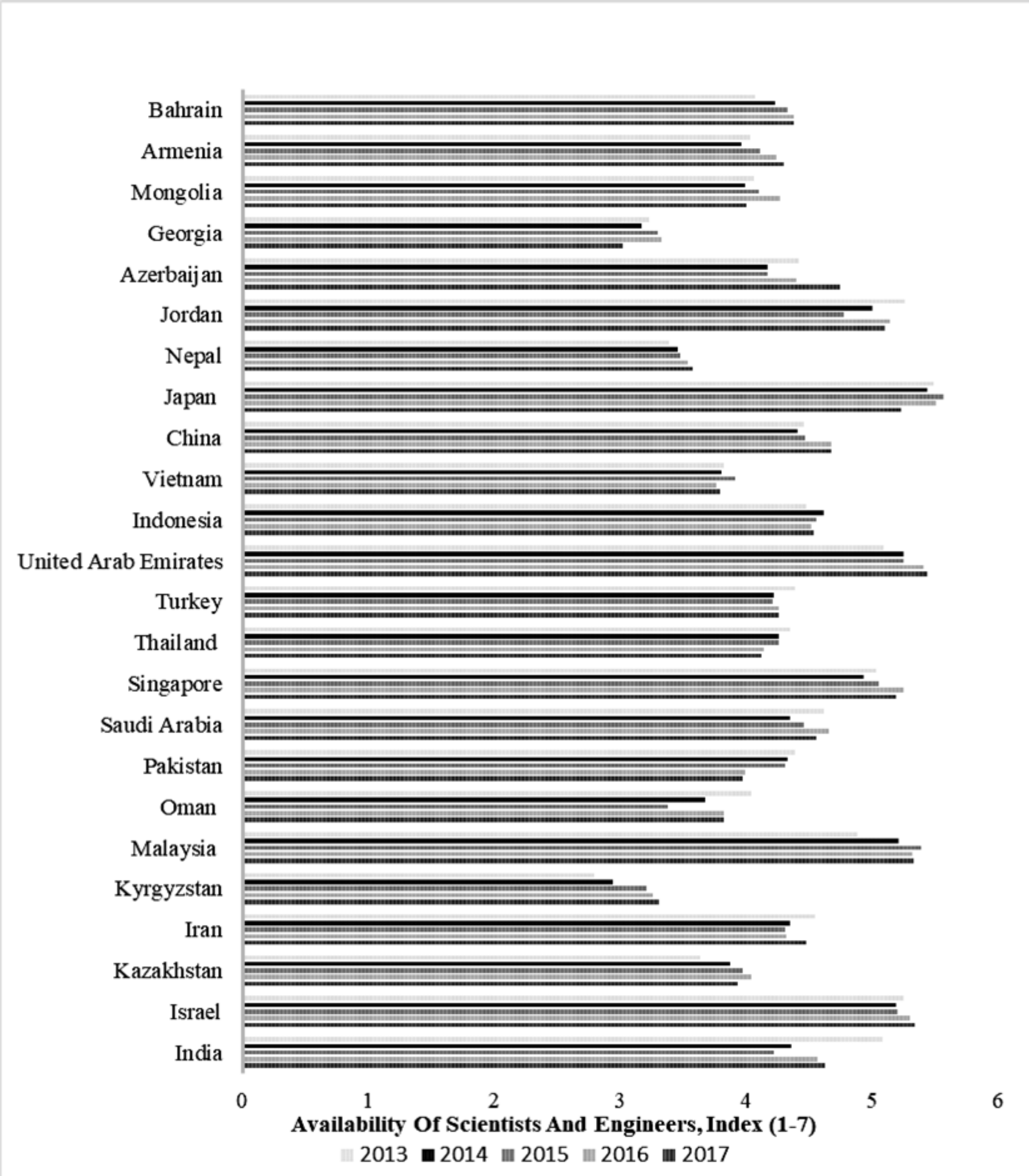
Figure 2 shows the contribution of high-tech imports to the total trade for selected Asian countries in 2013–2015. The figure shows that most selected countries have consistently focused on high-tech imports in 2013–2017 as part of the total trade. However, their high-tech imports remained within the range of 10% to 15% of total trade volumes. The latter fact points to a robust market for indigenous high-tech products for countries such as India, Israel, and Indonesia, supporting their innovation framework. On the other hand, countries such as Malaysia, Singapore, Vietnam, and China registered their High-Tech imports between 25% to 30% of total trade, which shows that these countries are focusing more on off-the-shelf High-Tech to expedite their innovation process.

Figure 3 shows the availability of scientists and engineers for selected Asian countries in 2013–2017. It is an important illustration that links the potential of human capital to innovation throughput. It confirms that higher-ranking countries such as Israel, Malaysia, UAE, and Japan register an increase in education, youth employment, and globalization performance better than their PEER-country group and produce human resources contributing significantly to the innovation landscape. Indeed the graph shows that where better-performing countries in Asia have more than 5 points out of the 7 points during the mentioned time frame.



Source: Constructed by authors.

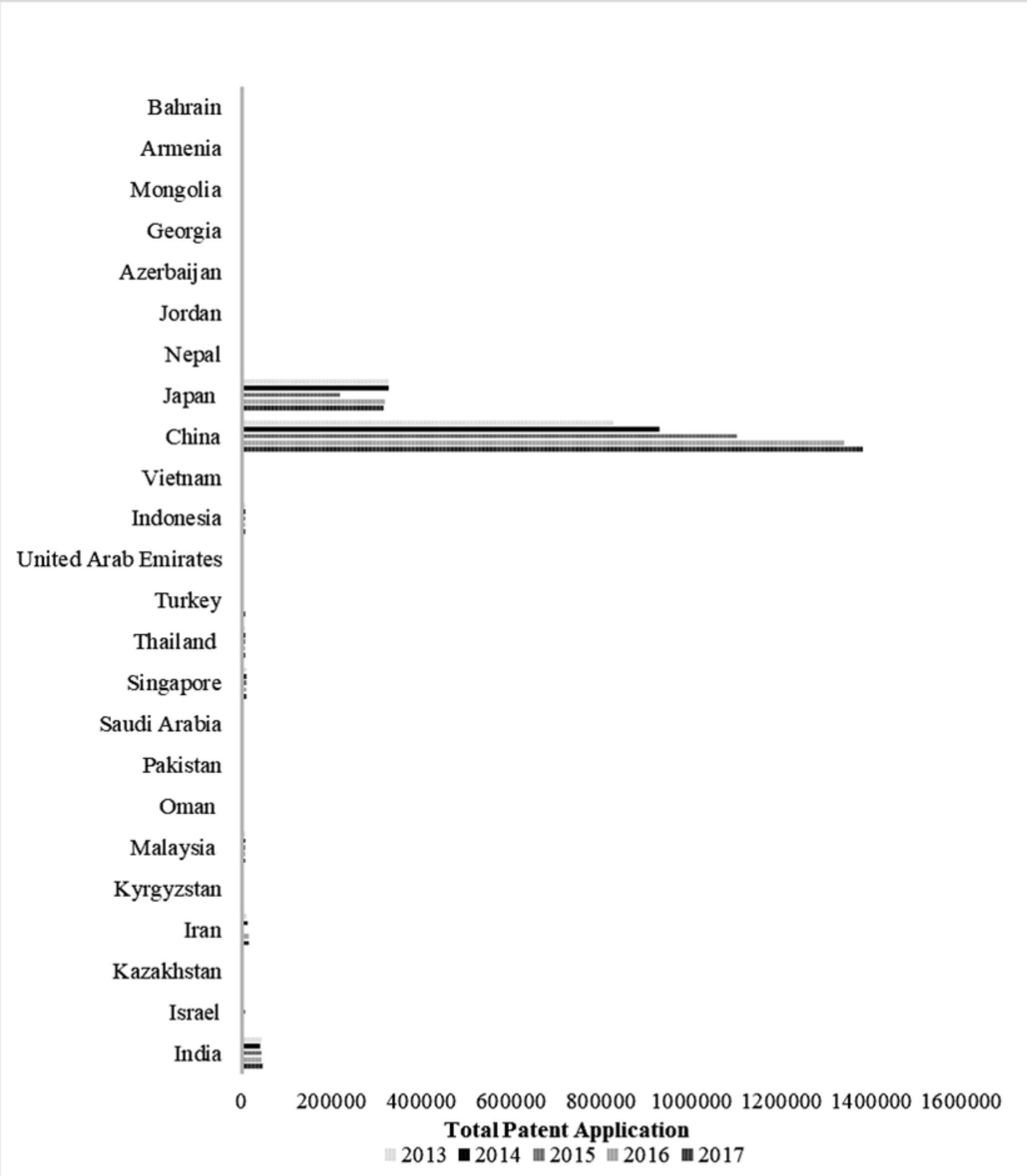
Fig. 2. High-tech-imports (% of trade) of Asian countries



Source: Constructed by authors.

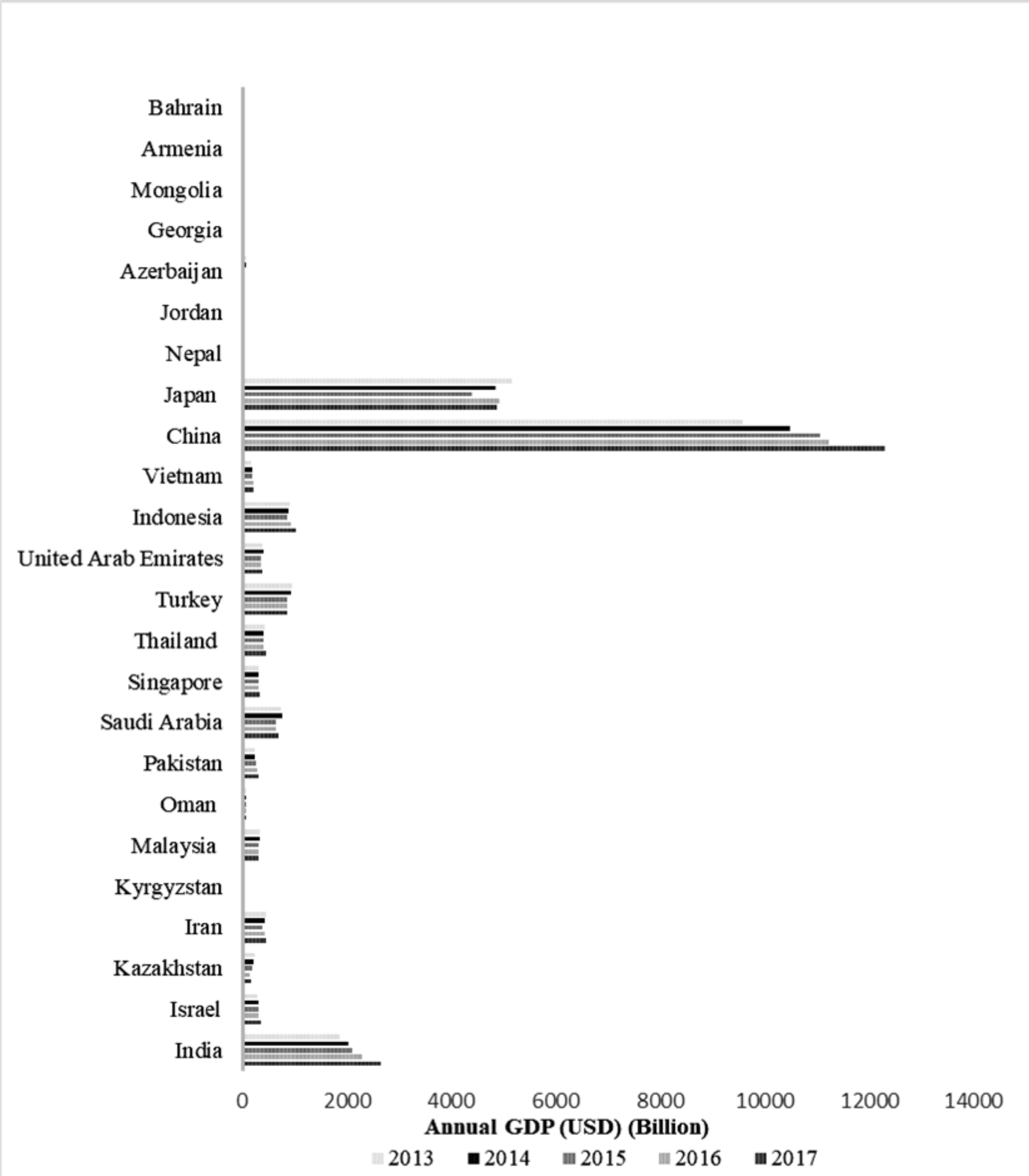
Fig. 3. Availability of scientists and engineers, index (1–7) of Asian countries

Figure 4 shows the number of patent applications filed from selected Asian countries in 2013–2015. It is an important variable that points to the throughput and the level of scientific activities. The figure depicts that only a few countries, such as China, Japan, and India leading the innovation process. Asia accounts for over two-thirds of all patents, trademarks, and industrial design applications. In Asia, as evident, China is driving overall growth in demand for intellectual property (IP) rights.



Source: Constructed by authors.

Fig. 4. Total patent applications of Asian countries



Source: Constructed by authors.

Fig. 5. Annual gross domestic product (GDP) of Asian countries

Figure 5 shows the GDP of selected Asian countries in 2013–2017. One can see that Asian economies are beginning to find their footing as they slowly emerge from the worst of geopolitical uncertainties and natural disasters. China, Japan, India, Singapore, Indonesia, Thailand,

and Vietnam are the key players in Asia. For example, between 2013 to 2017, when analyzing GDP, China emerged as a top performer with its GDP growth from 9570 billion USD in 2013 to 12310 billion USD in 2017. Despite a slight decline in GDP growth from 5160 billion USD in 2013 to 4920 billion USD in 2017, Japan has emerged as the second-largest economy in Asia. Other Asian countries such as India, Israel, Turkey, Indonesia, and Saudi Arabia also make a significant contribution to the total volume of the Asian market, with a continued upward trajectory of their GDP growth while factoring in a few intermittent dips.

Correlation analysis and unit root test for Asian countries. As a result of the preliminary analysis for variables representing Asian countries, one can see that the AHTI, AASEI, and AGDP are significantly and positively correlated with ATPA. Similarly, ATPA, AHTI, and AASEI have a significant and positive correlation with AGDP. Nevertheless, to safeguard our panel model from potential multicollinearity, we apply a VIF test for explanatory variables. The results show that the mean VIF value is 1.14, and the individual VIF values for AHTI and AASEI are 1.14 and 1.15, respectively, which are well below the critical value (Table 3, Appendix[1]). Moreover, to check the presence of unit roots in the considered variables, the Levin, Lin & Chu, ADF – Fisher Chi-square, and PP – Fisher Chi-square methods have been applied. The univariate analysis result of Levin, Lin & Chu, ADF, and PP unit root test for chosen variables are not stationary on the level I (0). On the other hand, all the variables are stationary at the first difference I (1) (Table 4, Appendix).

Innovation model estimation. The innovation model (Asian Countries) was estimated by generalized method of moments (GMM). AASEI and AHTI are the two independent variables and AHTI is the dependent variable.

Table 5.

Dynamic GMM estimation; dependent variable: ATPA of Asian countries

Dependent Variable: ATPA (Total Patent Applications of Asian Countries)
Method: Panel Generalized Method of Moments (P-GMM)
Transformations: First Differences

Variable	Coefficient	Standard Error	t-Statistics	Probability
ATPA (–1)	0.697181	0.001510	461.7242	0.0000**
AASEI	151409.8	1306.261	115.9108	0.0000**
AHTI	198734.2	50686.76	3.920830	0.0007**

Effects Specifications
Cross-Section Fixed (First Differences)
Mean Dependent Variable – 6986.646
S E of Regression – 42301.70
J-Statistics – 7.156390
Probability (J-Statistic) – 0.209267
S D Dependent Variable – 40746.30
Instrument Rank – 8

Source: Computed by authors. ** – indicates significance at 1% level of significance.

[1] See here and further Appendix on the website: https://ej.hse.ru/data/2023/02/20/2033333983/

Table 5 shows the results of the dynamic GMM estimation in the context of the effect of independent variables high technology import (AHTI) and availability of scientists and engineers (AASEI) on innovation (ATPA) in Asian countries. Both independent variables (AHTI) and (AASEI) give positive coefficient values (198734.2) and (151409.8) accordingly, with a probability value of (0.0000<0.05).

One can see that high technology import and availability of scientists and engineers exhibit a significant positive effect on innovative development in Asian countries. This result substantiates the findings of [Federico et al., 2013; Salmon, Shaver, 2006; Schneider, 2005], underscored the importance of high technology import to enhance innovation activities and the development of innovative products and processes. Moreover, in the context of the linkage between the availability of scientists and engineers (human capital) and innovation, this result also supported the findings of [Dakhli, Clercq, 2004; Oluwatobi et al., 2016], who advocated the development of human capital and their availability is always a good sign for the development of innovation.

Economic growth model estimation. The Economic Growth model (Asian Countries) was estimated by generalized method of moments (GMM). ATPA is the independent variable and AGDP is the dependent variable.

Table 6.

Dynamic GMM estimation; dependent variable: AGDP of Asian countries

Dependent Variable: AGDP (Gross Domestic Product of Asian Countries)
Method: Panel Generalized Method of Moments (P-GMM)
Transformations: First Differences

Variable	Coefficient	Standard Error	t-Statistics	Probability
ATPA (–1)	–0.168705	0.015777	–10.69312	0.0000**
ATPA	0.003738	5.73E-05	65.20635	0.0000**

Effects Specifications

Cross-Section Fixed (First Differences)

Mean Dependent Variable – 38.78985
S E of Regression – 157.1758
J-Statistics – 6.470626
Probability (J-Statistic) – 0.263078
S D Dependent Variable – 183.1001
Instrument Rank – 7

Source: Computed by authors. ** – indicates significance at 1% level of significance.

Table 6, gives the results of the economic growth model for Asian countries obtained by employing GMM shows a positive elasticity value (0.003) of ATPA, significant at 1 percent. This indicates that development of innovation in Asian countries stimulates economic growth.

4.2. Step-wise econometric analysis for European countries

Table 7 shows a descriptive statistical analysis of 140 observations for variables ETPA, EGDP, and EASEI for European countries, and 139 observations describe EHTI. Here similar outcomes have been found. However, the gap between the maximum and minimum values of ETPA and EGDP is much narrower relative to the upper and lower values of ATPA and AGDP of Asian countries. Hence, mean value and standard deviation also reflect fewer sharp results. This result shows that though a few western European countries, such as Germany, France, Sweden, Belgium, etc., have better innovation activities and better economies, many central and eastern European countries, such as Romania, Latvia, Finland, Poland, etc., are also trying to perform better on the front of innovation activities and economic growth.

Table 7.

Descriptive statistical analysis summary of European countries

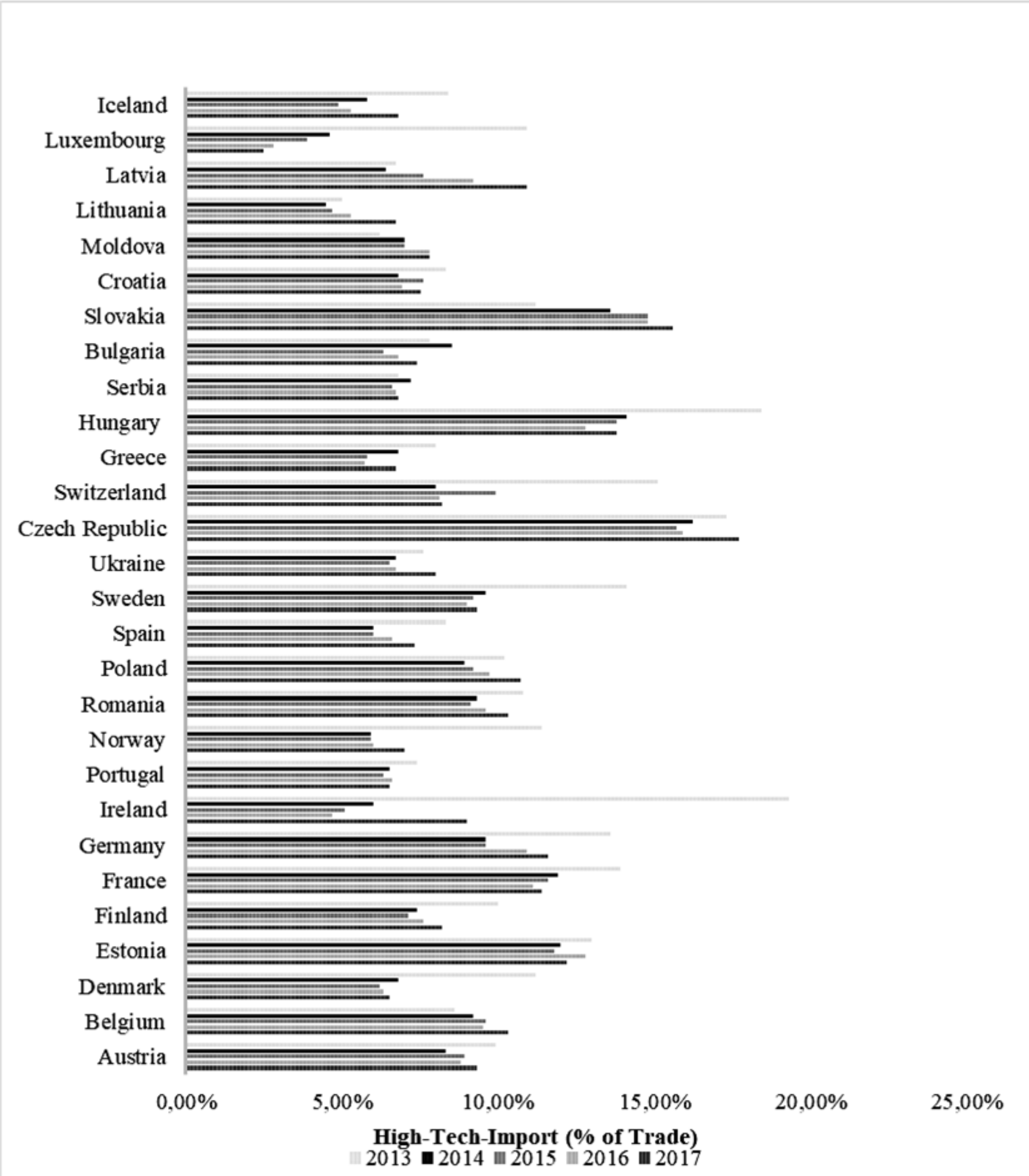
Variable Name	Observations	Mean	Standard Deviation	Maximum	Minimum
ETPA	140	4043.800	12371.91	67900.00	30.00000
EHTI	139	0.089504	0.032916	0.193000	0.025000
EASEI	140	4.421786	0.661266	6.300000	2.870000
EGDP	140	466.0643	801.6524	3880.000	7.750000

Figure 6 shows the contribution of high-tech imports to the total trade for selected European countries in 2013–2017. The figure shows that most of the countries had their high-tech import growth below 20% of the total trade volume, which reflects that these countries are less inclined to import High-Tech products. It also translates to a decline in this growth. Only a few countries, such as Austria, Belgium, Ireland, Latvia, etc., showed an increase in high-tech imports in 2017.

Figure 7 shows the availability of scientists and engineers for selected European countries in 2013–2017. The best-performing country was Finland having 6.3 points out of 7 in 2013, whereas Moldova registered the worst performance with 3.1 out of 7 in the same year. A trend that one can see from this figure is that from 2013 to 2017, there was no significant increase in the availability of the scientists and engineers index. Instead, most of the countries reported a slight decline in this index.

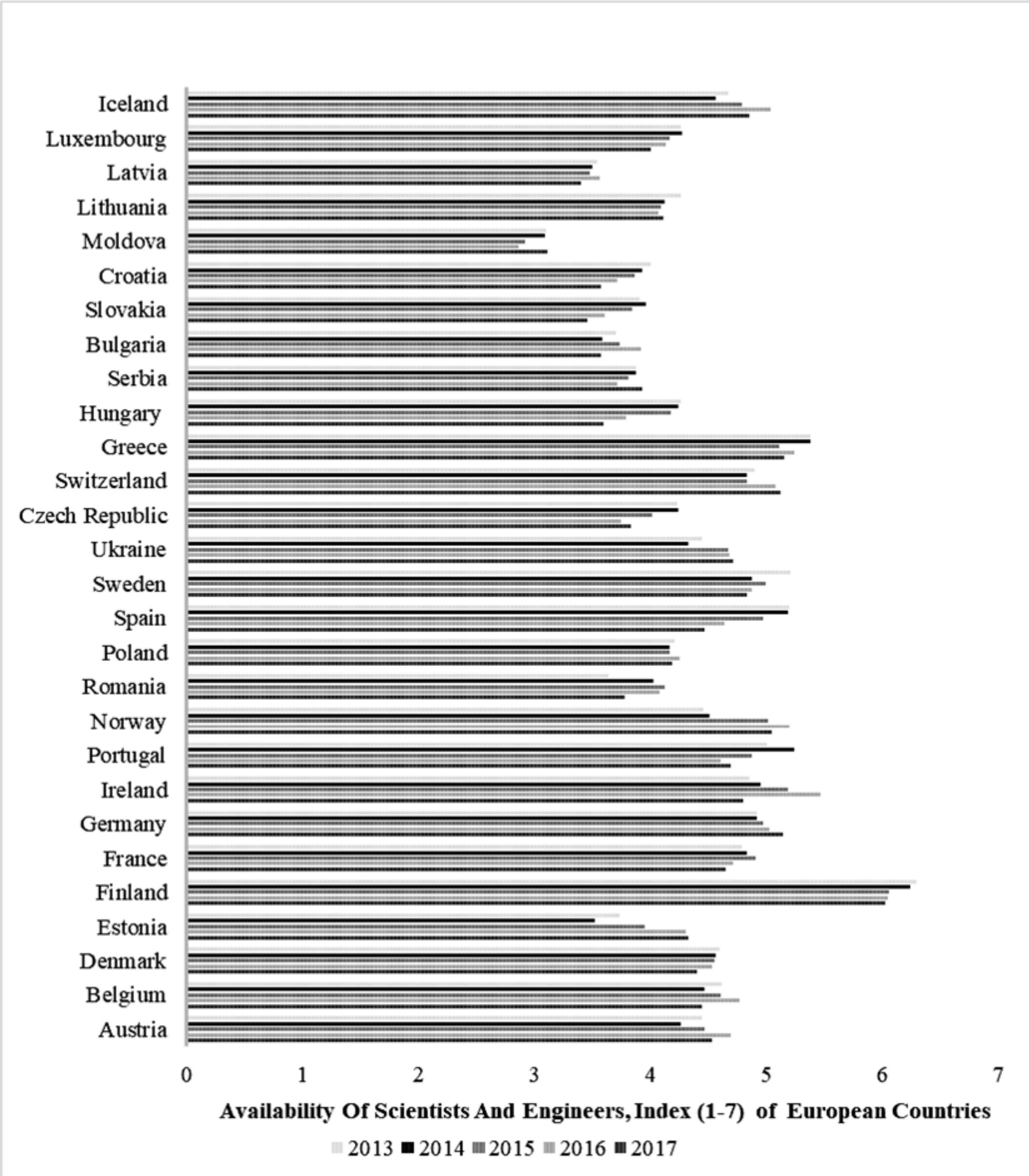
Figure 8 shows the number of patent applications filed from selected European countries in 2013–2015. It is a critical parameter that illustrates the throughput of scientific activities. Germany and France are the frontrunners of innovation initiatives in the EU market. Key reasons behind this are world-class educational/research infrastructure, the presence of highly matured industrial sectors, and access to best-in-class resources.

Figure 9 shows GDP numbers from selected European countries in 2013–2017, where Germany, France, Spain, and Switzerland were the main contributors to the economic growth of Europe. The main factors of this growth are political stability, positioning in the EU, access to a large resource pool, supportive policies for fostering innovation, and strong trade relationships with major markets in the world.



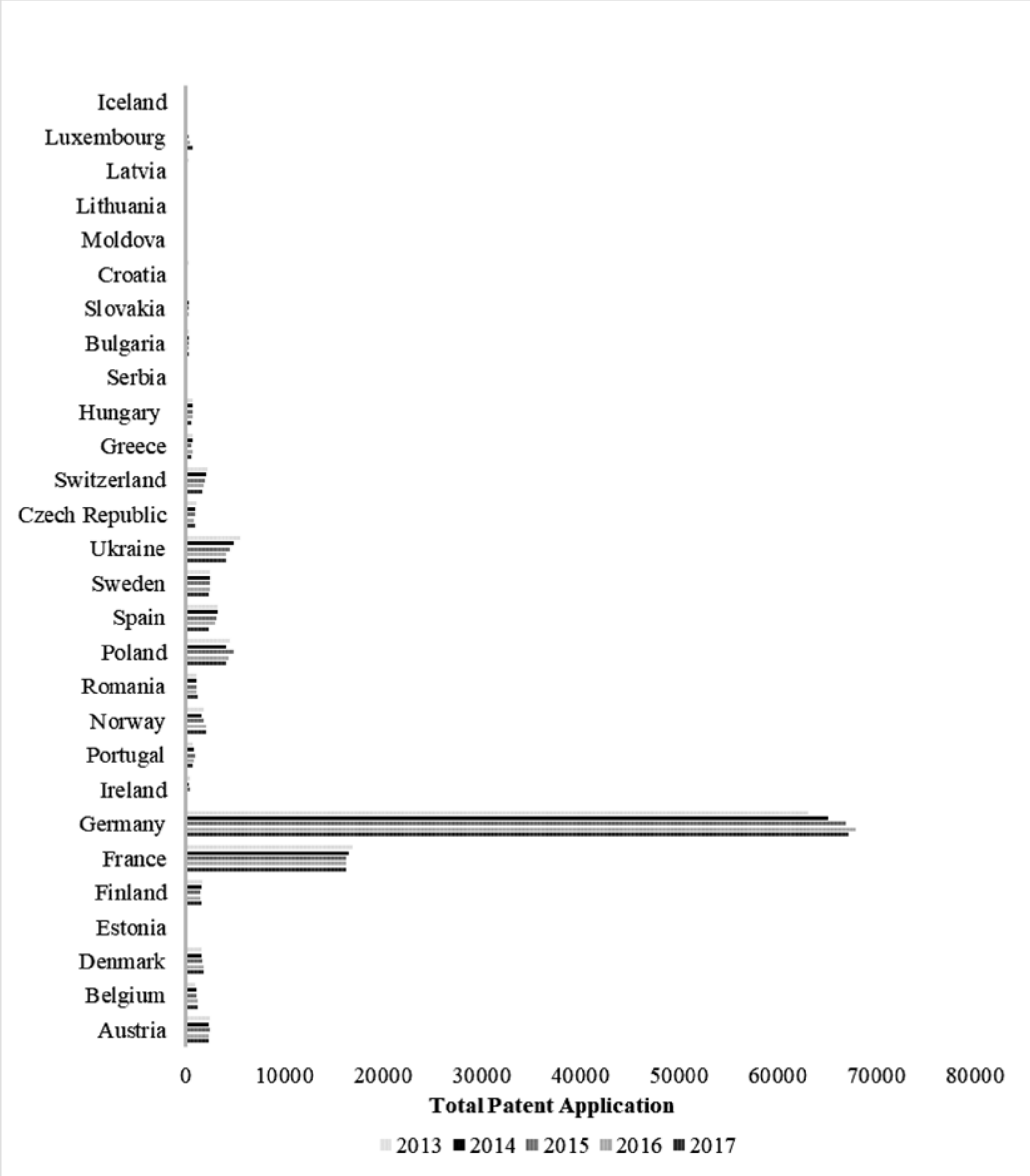
Source: Constructed by authors.

Fig. 6. High-tech-import (% of trade) of European countries



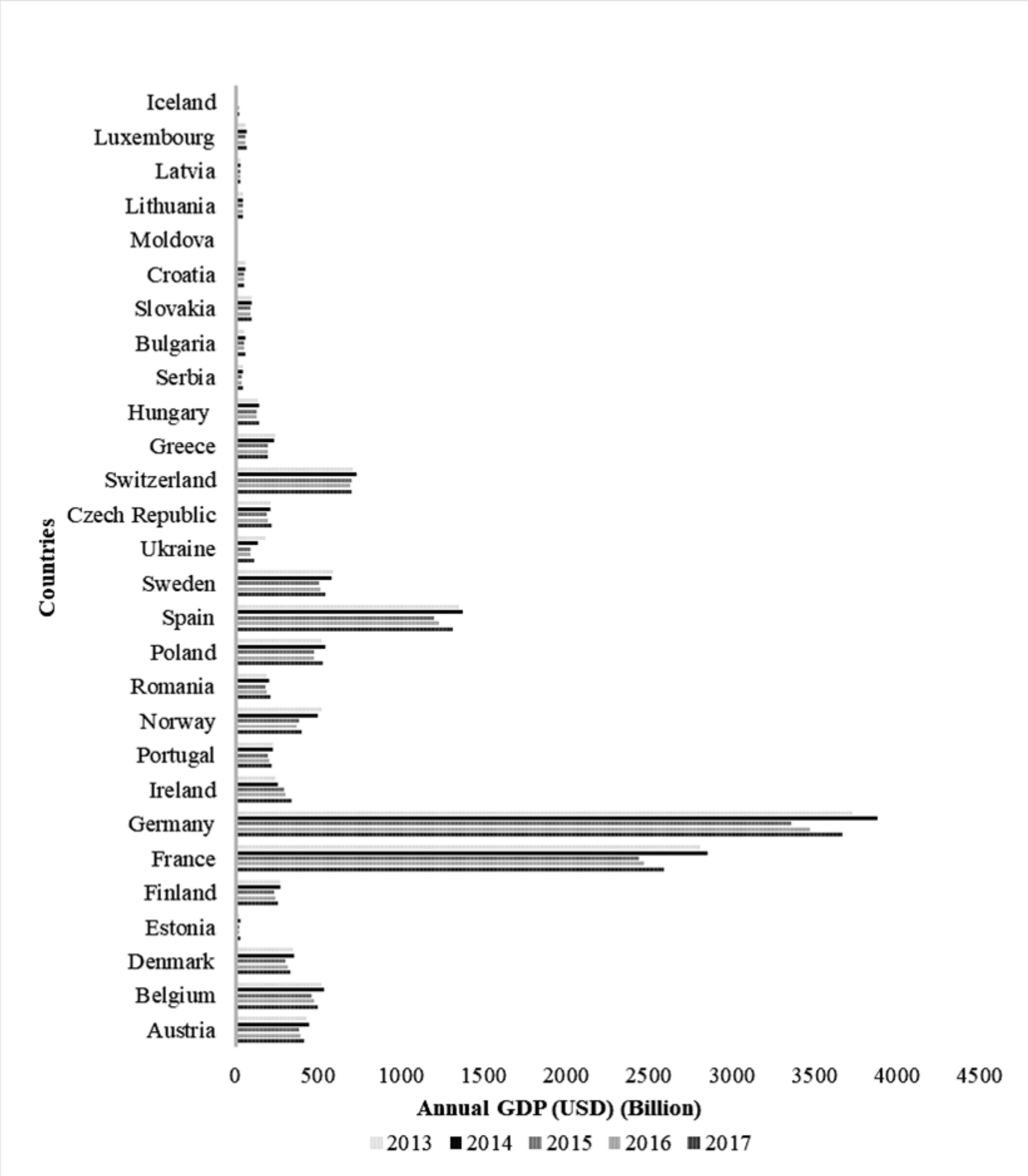
Source: Constructed by authors.

Fig. 7. Availability of scientists and engineers, Index (1–7) of European countries



Source: Constructed by authors.

Fig. 8. Total patent applications of European countries



Source: Constructed by authors.

Fig. 9. Annual gross domestic product (GDP) USD (Billion) of European countries

Correlation analysis and unit root test for European countries. Similar to the preliminary analysis done on variables for Asian countries, the results for European countries look essentially the same. One can see that EHTI, EASEI, and EGDP have a strong positive correlation with ETPA. Similarly, ETPA, EHTI, and EASEI have a strong positive correlation with EGDP. However, the results indicate a negative correlation between EASEI and EHTI. While adhering to our panel model from the potential multicollinearity, we apply a VIF test for explanatory variables (Table 8, Appendix). The results are similar to those for Asian countries. For European countries, the presence of unit root has also been checked in the studied variables using Levin, Lin & Chu, ADF – Fisher Chi-square, and PP – Fisher Chi-square methods. The results are consistently similar to those obtained in the case of Asian countries (Table 9, Appendix)

Innovation model estimation. The innovation model (European Countries) is estimated by generalized method of moments (GMM). EASEI and EHTI are the two independent variables and ETPA is the dependent variable.

Table 10.

Dynamic GMM estimation; dependent variable: ETPA of European countries

Dependent Variable: ETPA (Total Patent Applications of European Countries)
Method: Panel Generalized Method of Moments (P-GMM)
Transformations: First Differences

Variable	Coefficient	Standard Error	t-Statistics	Probability
ETPA (–1)	0.441222	0.075656	5.831920	0.0000**
EASEI	637.2821	521.4790	1.222067	0.2322
EHTI	–3938.279	11792.58	–0.333962	0.7410

Effects Specifications
Cross-Section Fixed (First Differences)
Mean Dependent Variable – –0.036585
S E of Regression – 280.8517
J-Statistics – 5.720680
Probability (J-Statistic) – 0.334353
S D Dependent Variable – 290.0703
Instrument Rank – 8

Source: Computed by authors. ** – indicates significance at 1% level of significance.

Table 10 shows the results of the dynamic GMM estimation concerning the effect of independent variables high technology import (EHTI) and availability of scientists and engineers (EASEI) on innovation (ETPA) in European countries. Since both independent variables EHTI and EASEI have a probability value of (0.0000>0.05), one can deduce that high technology import and availability of scientists and engineers have no significant effect on innovation development in European countries. In the context of European countries, this result completely rejects the findings of [Federico et al., 2013; Salmon, Shaver, 2006; Schneider, 2005] who underscored the importance of high technology import in the enhancement of innovation activities and development of innovative products and processes. The results look similar in the case of the linkage between the availability of scientists and engineers (human capital) and innovation. This result does not support the findings of [Dakhli, Clercq, 2004; Oluwatobi et al., 2016] who advocated the development of human capital and their availability is always a good sign for the development of innovation.

Economic growth model estimation. The Economic Growth model (European Countries) is estimated by generalized method of moments (GMM). Here, ETPA is the independent variable and EGDP is the dependent variable.

Table 11.

Results of dynamic GMM estimation; dependent variable: EGDP of European countries s

Dependent Variable: EGDP (Gross Domestic Product of European Countries)
Method: Panel Generalized Method of Moments (P-GMM)
Transformations: First Differences

Variable	Coefficient	Standard Error	t-Statistics	Probability
EGDP (–1)	–0.13005	0.071126	–1.827815	0.0786***
ETPA	–0.216601	0.025724	–0.420047	0.0000**

Effects Specifications
Cross-Section Fixed (First Differences)
Mean Dependent Variable – –9.343571
S E of Regression – 74.40004
J-Statistics – 3.803141
Probability (J-Statistic) – 0.578093
S D Dependent Variable – 84.289709
Instrument Rank – 7

Source: Computed by authors. ** and *** indicates significance at 1% and 10% level of significance respectively.

Table 11 presents the results derived from the functional and GMM model. The results of the economic growth model for European countries obtained by employing GMM show a negative elasticity value (–0.216) of ETPA, significant at 1 percent. It indicates that the development of innovation in Asian countries retards economic growth in European countries. This finding is also supported by [Hollanders et al., 2019], who also concluded that despite the European Union having a performance lead (measured by SII) over China, this lead decreased strongly from 2008 to 2018. This result, also supported by the World Economic Forum report [Heimburg, 2021], underscored that Europe's tech ecosystem is lagging far behind the US and China, and Europe needs to start learning from Asia, where one of the key lessons is how to adapt and innovate quickly.

5. Conclusion and Policy Recommendation

This study provides an analysis of the dynamic growth of technological innovation in the Asian and European economies for the period 2013 to 2017. The study investigated the impact of High-Tech-Import (HTI) (as a percentage of trade), Availability of Scientists and Engineers Index (ASEI), and Total Patent Application (TPA)on the Gross Domestic Product (GDP) in selected Asian and European countries. The findings have shown that rapid innovation in Asian countries fuelled by R&D investment growth and industrial policy landscape attracts more growth opportunities offered by first mover advantages when new markets emerge. It inadvertently slows growth in European countries when juxtaposed with that of key Asian markets. The findings resonate with [Cincera, Veugelers, 2013] showing that most of the EU R&D investment gaps stem from a different sectoral composition with a shortage of young leading innovators and a uniform innovation support framework across the member economies. In contrast to the popular notion that high technology import and availability of scientists and engineers always fuels innovation, we observed that it has no significant effect on the development of innovation in European countries unless they are tightly coupled with a holistic policy framework and work in tandem, as demonstrated by Asian economies.

This study abounds with examples of selected countries from Asia and Europe along with main parameters covering various industry sectors, investment landscape, innovation potential and scientific resources to the extent that further incremental progress along these well-established trajectories to showcase the system of innovation and its direct impact on the overall growth while indicating pathways for European economies to claw back lost grounds and generate economic welfare amidst competitive pressure to develop the innovative capabilities in the areas of product innovation, design, marketing, and distribution.

5.1. Policy implications

Governments can amplify the ability of institutions to innovate through policy changes designed to reduce governance barriers and reap maximum benefit from their resources for innovation. Poor governance quality may discourage firms at the margins, grappling with the taxation procedure, R&D funding, and implications for the legal and institutional framework. There is a need for the government to introduce a policy and regulatory framework that encourages firms to take up initiatives that they usually consider risky by providing appropriate funding for their R&D [Dutz, 2007]. According to the «grease the wheel» theory, corruption may be a link between firms and government-related formalities that can lead to Pareto improving outcomes [Huntington, 2006].The main implications for research and innovation policies which are integral to setting a more conducive environment, especially for EU economies, are outlined below.

1. Government policies need to focus on new and potentially riskier R&D-intensive sectors, favoring entrepreneurship and scaling up knowledge-intensive start-ups with innovation potential in various industry sectors and strategic technologies.

2. Supporting an innovative approach characterized both by the import and diffusion of new technologies from other sectors and by seeking innovative solutions for business transformation to underpin the response to address future challenges.

3. Development and integration of innovative technologies, and supporting industrial frameworks are crucial to drive and sustain a techno-economic revolution to represent an opportunity for Europe to maintain a leadership position in strategic industries.

4. Overall, the structural shift towards innovation-backed sector growth should not be pushed with the singular focus on increasing the R & D budget. There must be a policy-driven initiative where the competitiveness of firms whose R&D investment growth strategies, together with their capacity to turn innovation into value-added, comes to the fore with a sustainable growth model in the long run.

Policymakers need a better understanding of the relevant factors that influence firm-level innovation so that they can direct policy and resources to promote innovation culture and improve the Information and Communication Technology (ICT) exports, infrastructure, and R&D expenditure in the field of Science and Technology. Overall, the interplay of Technology input, Research Activity, Innovation, and Economic Growth of Countries is essential to provide a deeper and more nuanced understanding of innovation.

6. Limitations of the Study

The reason behind choosing data from 2013 to 2017 is that data for one important variable (Availability of Scientists and Engineers Index – ASEI) is available for 2007–2017, whereas data for another variable (High-Tech Imports, % Of Total Trade – HTI) is available from 2013 to 2019 in the World Bank data repository. Hence, to incorporate the data for all the concerned variables with the same period for each member country and to perform a better econometric analysis, the period from 2013 to 2017 has been chosen. In this work, we do not account for geopolitical undercurrents, and we are also unable to assess how country differences could impact the findings and future outlook. Further research might consider those nuances and unfold the linkages between a country's political framework, its relative standing in the international community, and its capacity to generate companies leading new waves of innovation-led technological changes.

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References

Aghion P., Howitt P. (1992) A Model of Growth Through Creative Destruction. *Econometrica*, 60, 2, pp. 323–351.

Aghion P., Howitt P. (1998) *Endogenous Growth Theory*. Cambridge, MA: MIT Press.

Allen M. (2017) *The SAGE Encyclopedia of Communication Research Methods* (Vols. 1–4) Thousand Oaks, CA: SAGE Publications, Inc Doi: 10.4135/9781483381411

Arellano M., Bond S. (1991) Some Tests of Specification for Panel Data: Monte CarloEvidence and an Application to Employment Equations. *Review of Economic Studies*, 58, pp. 277–297.

Broughel J., Thierer A. (2019) *Technological Innovation and Economic Growth: A Brief Report on the Evidence*. Mercatus Research, MercatusCenter at George MasonUniversity, Arlington, VA, February.

Cincera M., Veugelers R. (2013) Young Leading Innovators and the EU's R&D Intensity Gap. *Economics of Innovation and New Technology*, 22, 2, pp. 177–198.

Coe D.T., Helpman E. (1995) International R&D Spillovers. *European Economic Review*, 39, pp. 859–887.

Crescenzi R., Rodríguez-Pose A. (2017) The Geography of Innovation in China and India. *International Journal of Urban and Regional Research*, 41, 6, pp. 1010–1027.

Dahlman C.J. (2009) Different Innovation Strategies, Different Results: Brazil, Russia, India, China and Korea (the BRICKs). Chandra V., Erocal D., Padoan P., Brage C.A. *Innovation and Growth: Chasing a Moving Frontier*. OECD/World Bank, pp. 131–168.

Dakhli M., Clercq D. De (2004) Human Capital, Social Capital, and Innovation: A Multi-Country Study. *Entrepreneurship & Regional Development. An International Journal*, 16, iss. 2, pp. 107–128. Available at: https://doi.org/10.1080/08985620410001677835

Damijan J.P., Kostevc C. (2010) *Learning from Trade Through Innovation: Causal Link between Imports, Exports and Innovation in Spanish Microdata (August 2010*). LICOS Discussion Paper no 264/2010, Available at: https://ssrn.com/abstract=1658389 or http://dx.doi.org/10.2139/ssrn.1658389

Danquaha M., Amankwah-Amoahb J. (2017) Assessing the Relationships between Human Capital, Innovation and Technology Adoption: Evidence from Sub-Saharan Africa. *Technological Forecasting and Social Change*, 122, September, pp. 24–33.

Dutz M. (2007) *Unleashing India's Innovation: Toward Sustainable and Inclusive Growth*. The World Bank.

European Bank for Reconstruction and Development (EBRD) (2014) *Transition Report 2014: Innovation in Transition*. London.

Federico B.A., Cantwell J., Spadavecchia A. (2013) Innovation and Foreign Technology. *The Oxford Handbook of the Italian Economy Since Unification*. Oxford University Press. DOI: 10.1093/oxfordhb/9780199936694.013.0014

Gallié E.P., Legros D. (2012) Firms' Human Capital, R&D and Innovation: A Study on French Firms. *Empir Econ*, 43, pp. 581–596. https://doi.org/10.1007/s00181-011-0506-8

Gimenez G., Sanau J. (2007) Interrelationship among Institutional Infrastructure, Technological Innovation and Growth. An Empirical Evidence. *Applied Economics*, 39, 10, pp. 1267–1282.

Gupta H., Barua M.K. (2016) Identifying Enablers of Technological Innovation for Indian MSMEs Using Best–Worst Multi Criteria Decision Making Method. *Technological Forecasting and Social Change*, 107, pp. 69–79.

Hansen L.P. (1982) Large Sample Properties of Generalized Method of Moments Estimators. *Econometrica*, 50, pp. 1029–1054.

Heimburg F. von (2021) *Europe Needs to Learn from Asia to Stop Falling Behind in Tech*. World Economic Forum. Available at: https://www.weforum.org/agenda/2021/03/europe-learn-from-asia-stop-falling-behind-tech/

Hoekman B., Javorcik B. (2006) *Global Integration and Technology Transfer*. Palgrave Macmillan, World Bank and CEPR.

Hollanders H., Es-Sadki N., Kanerva M. (2019) *European Innovation Scoreboard 2019*. Luxembourg: Office for Official Publications of the European Communities

Huntington S.P. (2006) *Political Order in Changing Societies*. Yale University Press.

Innovate Europe: Competing for Global Innovation Leadership (2019) World Economic Forum in collaboration with McKinsey & Company, January.

Jalles J.T. (2010) How to Measure Innovation? New Evidence of the Technology–Growth Linkage. *Research in Economics*, 64, 2, June, pp. 81–96.

Jones C. (1995) R&D-based Models of Economic Growth. *Journal of Political Economy*, 103, 4, pp. 759–784.

Kumar R.S., Subrahmanya M.B. (2010) Influence of Subcontracting on Innovation and Economic Performance of SMEs in Indian Automobile Industry. *Technovation*, 30(11–12), pp. 558–569.

Lee C.-C., Wang C.-W., Ho S.-J. (2020) Country Governance, Corruption, and the Likelihood of Firms' Innovation. *Economic Modelling*.

Li B., Piachaud D. (2019) Technological Innovations and Social Development in Asia. *Journal of Asian Public Policy*, 12, 1, pp. 1–14. DOI: 10.1080/17516234.2018.1546419

Lindley D.V. (1990) Regression and Correlation Analysis. Eatwell J., Milgate M., Newman P. (eds.) *Time Series and Statistics*. London: The New Palgrave, Palgrave Macmillan. https://doi.org/10.1007/978-1-349-20865-4_30

Mehmet Adak (2015) Technological Progress, Innovation and Economic Growth; the Case of Turkey, *World Conference on Technology, Innovation and Entrepreneurship, Procedia – Social and Behavioral Sciences 195*, pp. 776–782.

Ming Chen, Hongbo Wang (2021) Import Technology Sophistication and High-Quality Economic Development: Evidence from City-Level Data of China. *Economic Research-Ekonomska Istraživanja*. DOI: 10.1080/1331677X.2021.1956362

Moncada-Paternò-Castello P. (2022) Top R&D Investors, Structural Change and the R&D Growth Performance of Young and Old Firms. *Eurasian Bus Rev*, 12, pp. 1–33. https://doi.org/10.1007/s40821-022-00206-3

Moncada-Paternò-Castello P., Hernandez H. (2018) Ten-Year Evolution of EU Industrial R&D in the Global Context. *JRC Policy Insights*, Iritec Briefs Series issue no 6, European Commission, July.

Murthy S.N., Bhojanna U. (2009) *Business Research Methods*. 2nd ed. New Delhi, India: Excel Books India. Google Books.

Nicola F. de, Chen P. (2022) *The Returns to Innovation in East Asia – The Role of the Business Environment and Firms' Characteristics*. Policy Research Working Paper 9921, World Bank Group, East Asia and the Pacific Region Office of the Chief Economist February 2022.

Oluwatobi S., Oluyomi Ola-David, Isaiah Olurinola, Philip Alege, Adeyemi Ogundipe (2016) Human Capital, Institutions and Innovation in Sub-Saharan Africa. *International Journal of Economics and Financial Issues*, 6, 4, pp. 1507–1514.

Popescu C.C., Diaconu L.C. *Human Capital and Innovation*. AnaleleUniversitatii din Oradea, Forthcoming. Available at: https://ssrn.com/abstract=1099025

Romer P.M. (1990) Endogenous Technological Change. *Journal of Political Economy*, 98, 5, pp. S71–S102. Available at: http://www.jstor.org/stable/2937632

Salmon R., Shaver J. (2005) Learning by Exporting: New Insights from Examining Firm Innovation. *Journal of Economics & Management Strategy*, 14, pp. 431–460.

Shao J.C. (2017) A Comparative Empirical Research on the Economic Growth Effects of China's Import Technological Sophistication. *Science Research Management*, 3, pp. 128–134. https://doi.org/10.19571/j.cnki.1000-2995.2017.03.014

Scherer F.M. (1999) *New Perspectives on Economic Growth and Technological Innovation*. Washington, D.C: Brookings Institution Press.

Schneider P.H. (2005) International Trade, Economic Growth and Intellectual Property Rights: A Panel Data Study of Developed and Developing Countries. *Journal of Development Economics*, 78, pp. 529–547.

Sveikauskas L. (2007) *R&D and Productivity Growth: A Review of the Literature*. Bureau of Labor Statistics Working Paper 408.

Worz J. (2005) Skill Intensity in Foreign Trade and Economic Growth. *Empirica*, 32, 1, pp. 117–144.

Ze-Lei X., Xin-Ya D., Fei F. (2017) Convergence in China's High-Tech Industry Development Performance: A Spatial Panel Model. *Appl Econ*, 49, pp. 5296–5308.

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https://data.worldbank.org/indicator/IP.PAT.RESD?end=2020&start=1980

https://data.worldbank.org/indicator/IP.PAT.NRES

https://data.worldbank.org/indicator/NY.GDP.PCAP.CD