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Research Article

Governance content, financial risk and innovation: A panel data analysis

Yönetişim içeriği, finansal risk ve inovasyon: Bir panel veri analizi

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Abstract

The effects of governance content characteristics, financial risk, financial development, and innovation infrastructure variables on the size of patent applications in advanced nations during the post-crisis period are examined in this research. For the 2010-2015 period, a panel dataset of 29 advanced economies was employed. The paper uses a Poisson and a Negative Binomial framework to accommodate national heterogeneity and dispersion concerns. According to the estimation results, financial development and financial risk index benefit patent applications, research and development expenditure, intellectual property rights, and gross fixed capital creation. In addition, according to this study, controlling corruption and upholding the rule of law boost innovation, whereas regulatory quality inhibits innovation in advanced economies.

Keywords: Financial Development, Financial Risk Ratings, Governance Content, Poisson Regression, Negative Binomial Regression, Patent, R&D Expenditure, Foreign Direct Investment, Intellectual Property Rights

Jel Codes: C4, G32, O32

Öz

Bu araştırmada, kriz sonrası dönemde gelişmiş ülkelerdeki patent başvurularının boyutuna yönetişim içerik özellikleri, finansal risk, finansal gelişme ve inovasyon altyapısı değişkenlerinin etkileri incelenmiştir. 2010-2015 dönemi için 29 gelişmiş ekonomiden oluşan bir panel veri seti kullanılmıştır. Ulusal heterojenlik ve dağılım endişelerini karşılamak için, kağıt hem Poisson hem de Negatif Binom çerçevesini kullanır. Tahmin sonuçlarına göre, finansal gelişme ve finansal risk endeksi, patent başvurularının yanı sıra araştırma ve geliştirme harcamaları, fikri mülkiyet hakları ve gayri safi sabit sermaye yaratımı üzerinde olumlu etkiye sahiptir. Bu çalışmaya göre, yolsuzluğu kontrol etmek ve hukukun üstünlüğünü desteklemek yeniliği artırırken, düzenleyici kalite gelişmiş ekonomilerde yeniliği engelliyor.

Anahtar Kelimeler: Finansal Gelişme, Finansal Risk Derecelendirmeleri, Yönetişim İçeriği, Poisson Regresyonu, Negatif Binomial Regresyonu, Patent, Ar-Ge Harcamaları, Doğrudan Yabancı Yatırım, Fikri Mülkiyet Hakları

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Introduction

As a well-known fact, innovation is a crucial issue driving countries' economic growth. Therefore, the extensive literature on innovation exists due to its importance. Innovation literature consists of two sections firm-based and country-based studies. However, country-based literature is considerably narrower than industry-based literature.

As an inevitable fact, research and development activity is a core essential for innovation. Research and development activities lead to the production of new ideas, technologies, and techniques. With upgraded technology, productivity will increase along with economic growth. Previous studies employing standard variables such as R&D activities and other innovation infrastructure variables such as GDP, trade openness, human capital in the labour force, intellectual property protection, gross fixed capital formation, foreign direct investment, and so on (see Porter and Stern, 2000; Meliciani, 2000; Furman, Porter, and Stern, 2002; Schneider, 2005; and among many others). On the other hand, the existing literature studies investigate the relationship between infrastructure variables and innovation activities. Besides, neither the nexus of financial risk indices and innovation nor the relationship between governance indicators and innovation took much attention. This paper examines, for the first time, the relationship between innovation activity with innovation infrastructure variables and financial development along with financial risk index and governance indicators. Under this concept, the financial risk index and governance indicators will be employed as control variables of the model.

A country's ability to meet its foreign debt obligations is determined by its economic, financial, and political performance. The cross-country risk index, which comprises economic, financial, and economic risk indices, is used to calculate it. Innovation and country risk indices are likely to interact with each other. High levels of innovation, according to Hoti and McAller (2006), "reflect a country's higher technological skills and growth potential, which results in higher country risk ratings or creditworthiness." On the other hand, "higher country risk ratings lead to more foreign investment and capital pouring into a country, which leads to more growth and technological advancement, thus more innovation”. As a result, high-risk countries are more likely to attract excellent international investment and capital inflow to foster innovation and long-term economic prosperity. This research aims to determine how successful advanced economies are at increasing patent applications despite having a high financial risk index.

According to Almeida and Teixeria (2007), the governance content of a country's creative activity is a critical problem. “The innovation process is significantly dependent on the country's governance setting, particularly in terms of the involvement of the government, law enforcement, and regulatory framework in general”. In their study, five dimensions of governance employed by Kaufmann, Kraay, and Mastruzzi (2010), as “ 1) Political Stability and Absence of Violence - evaluating public perceptions of the government's chances of being destabilized or overthrown through unconstitutional or violent tactics, such as domestic violence and terrorism; 2) Government Efficiency - evaluating the quality of government services, the civil service's quality and independence from political restrictions, policymaking and execution quality, and the government's compliance with such policies; 3) Regulatory Quality- evaluating the government's capacity to develop and enforce good rules and regulations that promote and permit private sector growth. 4) Rule of Law- analyzing the number of public powers used for private gains, such as petty and grand corruption, as well as state capture by elites and private interests, and the likelihood of crime and violence; and 5) Corruption Control- assessing the amount of public power used for private gains, such as petty and grand corruption, as well as state capture by elites and private interests, and the likelihood of crime and violence.” This research aims to see how successful advanced economies are in increasing patent applications while maintaining high governance standards.

The literature on innovation and financial development has been investigated in two sections: equity market and credit market developments. Furthermore, the effects of stock market development and credit market development on innovation have been investigated both and/or separately. The general argument is that equity market development is more likely to affect innovation than the credit market positively. Consequently, the relationship between innovation and financial sector development will be investigated in this paper from a credit market point of view.

In the next section, a brief literature review will be presented. Data and methodology will follow this; estimation results and discussion will present the conclusion.

Literature review

Innovation

Several definitions exist for innovation. It can be defined as new ideas, devices, or methods. At the same time, it is also observed as the application of an enhanced clarification to meet new or existing market requirements that are succeeded by more effective products, processes, services, technologies, or business methods that are already accessible. However, innovation cannot be precisely measured. As suggested by Hu and Mathews (2005), patenting activity can be used as a proxy for the extent of innovation activity where they use to extend and modify the Furman, Porter and Stern (FP&S) approach by applying it to five "latecomer" countries from East Asia. Patent applications have been considered a well-grounded indicator of innovation (see Jaffe, 1989; Trajtenberg, 1990; Eaton and Kortum, 1996; Porter and Stern, 2000; Popp, 2002; Furman et al., 2002; Schneider, 2005; Ghazal and Zulkhibri, 2015; Hong, Feng, Wu and Wong, 2016; Lee, 2016; Wu, 2017; and among many others). On the other hand, some studies used different proxies for innovation. For example, Kanwar and Everson (2003) used R&D expenditure as a percentage share of GNP as a sign of improvement and technological change.

The patent and R&D relationship is the primary stone of the innovation literature. The influence of R&D expenditure on patents, which is the usual direction of patent-R&D relationship investigations, shows a positive correlation between both, with more significant R&D investments/expenditures resulting in more patents. In this case, patenting is a natural intermediate output of R&D, or it is a result of a successful production of valuable knowledge, which, in return, is a direct function of R&D (see Jaffe, 1986; Porter and Stern, 2000; Beneito, 2006; and among many others). On the other hand, the impact of patents on R&D has been investigated as a reverse causality relationship between patents and R&D and concluded as a cross-correlation (Kitch, 1997; Sakakibara and Branstetter, 2001; among many others). Nevertheless, R&D expenditure/investment is expected to affect patenting as a determinant positively. The right to intellectual property is thought to be a motivator for innovation. In a sense, it encourages the development of technology by giving an inventor a temporary monopoly and ensuring a steady income stream that keeps R&D funding sources consistent. In addition, strengthening patent protection increases the owners' market share for new goods and eliminates the threat of imitators entering the market (Ramzi and Salah, 2015). Many experts, such as Chu, Leung, and Tang (2012). and Eicher and Newiak (2013) contend that intellectual property rights stimulate innovation. Foreign investment is attracted to the country because of its highly skilled workforce. According to Ramzi and Salah (2015), the increased petition for engineers and scientists in the host country encourages multinational corporations to conduct research in other countries. According to Ernst (2006), many scientific and engineering students and workers drew foreign research investments, particularly in India and China.

Some studies investigate the determinants of innovation for only developed countries. Hence some investigate to compare determinants of innovation in emerging and developing countries. The innovation performance of countries and firms has been extensively investigated for the last two decades. One of the first studies that consider innovation in a country-based is by Porter and Stern (2000) for the period from 1973-1993. The study considers patents as innovation indicators for 17 OECD countries. They also considered imports, exports, GDP, population, the full-time labour force, non-residential capital stock, and the growth in total factor productivity. Additionally, they also considered full-time equivalent scientists and engineers in all sectors, world patent stock, the rest of the world's patent stock, regional patent stock, and patents of countries that spoke similar languages. They used a direct approach and an inversion approach for model estimations. Porter and Stern (2000) stated that innovation positively relates to human capital in the R&D sector and national knowledge stock. A parallel study to the variable selection of Porter and Stern (2000) and Furman et al. (2002) used the same innovation indicators as patent and patent per capita for 17 OECD countries from 1973-1996. A novel framework based on the concept of 'innovative national capacity' has been introduced in this study. In their study, international trade openness, R&D expenditure, strength of protection of intellectual property, higher education spending, strength of national antitrust policies, R&D that was founded by private industries, patent concentration index of chemical, electrical and mechanical to total patent size, R&D performed by universities, the strength of venture capitals, publication in academic journals, and market share added to the variable selection as the quality of innovation structure. They emphasized the critical role of a set of additional factors in innovation. R&D workforce and R&D spending are essential determinants of country-level of innovation. Innovation varies with intellectual property protection, international trade openness, R&D performed by the academic sector, R&D funded by the private sector, degree of specialization by specialized area, and country's knowledge stock also have explanatory power on country's innovation.

The study of Hu and Mathews (2005) has extended and modified the study approach of the Furman, Porter and Stern (FP&S) approach by applying it to five "latecomer" countries in East Asia. The core findings are common between latecomer and OECD countries. The positive contribution of innovative infrastructure variable found, while interestingly, results suggested that intellectual property rights harm innovation. They emphasized that latecomer countries can catch up and close the gap with more developed countries by using the resources to increase their innovative capacity.

Schneider (2005) investigated the effect of the level of human capital stock, absolute import level of high-technology goods, R&D expenditure, GDP, patent protection index, foreign direct investment, and country's infrastructure on innovation rate as a patent application of country for 19 developed and 28 developing countries. This study's panel data set of 47 developed and developing countries from 1970 to 1990 has been considered for estimations. In addition to Ordinary Least Square (OLS) estimation, panel regression using country-fixed effects has been employed. The findings of the study suggest that the high-technology import and patent protection index affects the innovation rate; however, results regarding FDI are inconclusive.

On the other hand, Hanley et al. (2011) used panel data analysis on 30 Chinese provinces to evaluate the role of financial development and FDI on innovation from 2000 to 2008. They used utility, design, and invention patents as their dependent variables. In contrast, their study's repressor variables included government intervention, financial depth, and the amount of total investment that foreigners funded (as a proxy for FDI), as well as science and technology personnel, spending on science and technology, and exports as a percentage of GDP and GDP per capita. In addition, this study applied Ordinary Least Square (OLS) estimation and two-way error components estimations. They found a significant positive role of the financial depth of the regional financial system on patenting, while FDI was nonsignificant.

Several papers also investigate the nexus mentioned above. Ramzi and Salah (2015) attempted to investigate the driving forces of innovation in 11 Euro-Mediterranean countries from 2000 to 2012. While patent per capita was used as a dependent variable, other variables included intellectual property rights, FDI inflows, R&D spillovers, public R&D funding, private R&D funding, foreign R&D funding, R&D personnel remuneration as a per cent of R&D expenditure, imports of high technology, and GDP per capita. Their study employed a one-step generalized method of moments (GMM) for estimation. They discovered that economic growth, FDI, and R&D employment have a beneficial impact on innovation. On the other hand, financial advances, technological infrastructure, tertiary-educated labour force, wages, and private R&D financing have a detrimental impact on innovation. Tüylüğolu and Saraç (2012) examined how innovation occurs and which factors have an impact on the mechanism of innovation emergence in 26 industrialized and 18 developing countries from 1998 to 2007. Their study employed the number of domestic patents as a dependent variable, with GDP per capita, human capital, R&D spending, trade openness, FDI as net inflows, and intellectual property rights as regressors. In this study, Dynamic Ordinary Least Square (DOLS) estimation technique has been used to investigate the case. Except for FDI, all regressors exhibit statistically significant contributions to the patenting rate. Meliciani (2000) looked into the impact of patent per capita research and investment in 12 countries from 1973 to 1993. In this study, the Poisson model has been employed for estimations. Since the evidence of over-dispersion was investigated in Poisson estimations, Negative-Binomial models were estimated. R&D expenditure and gross fixed capital creation, which stands for investment intensity, have statistically significant effects on patenting.

Financial development and innovation

Financial development is also a vital component of innovation. Financial restrictions significantly impact a company's ability to spend on R&D and innovation. On the other hand, a well-functioning financial market can lower financial costs and obtain additional funding. Rajan and Zingales (1998) pointed out financial sector provides reallocating capital to the highest value use without risk of loss through moral hazard, adverse selection, and transaction cost that is necessary cause to economic growth. They found evidence that financial development speeds up economic growth by reducing the cost of external financing. Well-functioning financial markets play an essential role in reducing financial costs. Therefore, equity and credit markets may play an essential role in reducing financing costs, eventually influencing innovation (see Hsu et al., 2014). Ang (2014) stated that financial sector reforms might encourage economic growth by increasing innovative activities. Hanley, Liu, and Vaona, 2011 pointed out financial depth positively affect innovation (patenting) activity. On the other hand, financial liberalization retarding technology deepens by reallocating talent from the innovative sector to the financial system (see Ang, 2011). Ramzi and Salah (2015) pointed out that development in finance hinders innovation in less developed countries. The literature on innovation and financial development has been investigated in two sections: equity market and credit market developments. Both and/or individually, the effects of the stock market and credit market development on innovation have been studied.

Overall, it has been suggested that the development of equity markets is more likely to favour innovation in businesses that rely on external capital. Equity financing has advantages over debt, such as no collateral requirements, no exaggeration of financial distress caused by additional equity, and no adverse selection concerns (see Carpenter and Petersen 2002; Brown et al., 2009). Additionally, Carpenter and Petersen (2002) pointed out that another advantage of equity financing is that it does not restrict investors' upside returns.

Hsu et al. (2014) studied the effects of financial development on technological innovations in 32 developed and emerging markets from 1976 to 2006 by distinguishing the effect of credit market and equity market developments on innovation. A large data set has been used with fixed effects identification strategy for empirical estimation. However, industries more dependent on external finance exhibit a higher innovation in countries with better-developed equity markets. On the other hand, credit market development discourages innovation in industries with the same characteristics. Furthermore, increasing venture capital activity is associated with higher patent rates (Kortum and Lerner, 2000). Popev and Roosenboom (2012) examined venture capital investment in innovation for ten cross-industry and 21 cross-countries from 1991 to 2005. They pointed out the positive impact of venture capital on patenting in high-venture capital countries. Besides, by using a survey, Bravo-Biosca (2007) has examined the effect of financial intuitions on the innovation incentive in both banks- and market-based institutions. The equity and credit markets have been established, considerably promoting innovation, i.e., patenting activity. It was discovered that industries more reliant on outside capital innovate more in countries with higher financial development. It was discovered, however, that the stock market is linked to higher-quality patents, although bank financing has no influence.

In contrast, there is a lack of consensus on the impact of credit market development on innovation. Nanda and Nicholas (2014) showed that during the Great Depression, bank distress reduced the quality and quantity of firm patenting, suggesting the credit market's positive role in innovation by employing Ordinary Least Square (OLS) estimation. Bernstein (2015) used OLS and included firm fixed effects and year fixed effects to find an answer to “does going to public affect innovation?”. Empirical findings suggested that going public reduces a firm's innovation quality. Benfratello et al. (2008) found significant and essential evidence that banking development affects innovation. They stated that innovative activity might be embodied in new machinery that could be used as collateral, although this depends upon the firm's inherence by using logit model estimation. On the other hand, Beck and Levine (2002) stated that a bank-based financial system stymies innovation by humper external financing based on Ordinary Least squares (OLS) and two-stage least squares (TSLS) estimations. Weinstein and Yafeh (1998) examine the effects of bank-firm relationships on firm performance in Japan by using Ordinary Least Square (OLS) estimation. They pointed out that banks discourage firms from risky and highly profitable projects. Finally, Brown et al. (2009) explore whether supply shifts in finance can explain a significant portion of the 1990s R&D boom and subsequent decline. This paper examines firm-level panel data for 1,347 publicly traded, high-tech firms from 1990 to 2004 by employing one-step GMM in the first difference and system-GMM procedures. They stated that limited collateral value of the intangible asset would restrict to use of debt. Later on, Brown et al. (2013) examined the causal connections between a country's legal system and the access firms have to stock market financing and innovative investment at the firm level using the Ordinary Least Square (OLS) estimation procedure for the period 1990-2007. They emphasized that R&D investments of innovative firms have little or no collateral value, limiting firms' ability to use debt financing.

Financial risk ratings, governance, and innovation

Country risk refers to a country's financial and economic status, as well as its political stability. It is a creditworthiness indicator that emphasizes a country's ability to meet its financial obligations based on its economic, financial, and political performance. Higher country risk ratings result in more cash inflow into a country, resulting in more growth, technical advancement, and hence increased innovation (Hoti and McAleer, 2006). However, the link between country risk index and innovation does not receive much attention in the literature. For the first time in literature, the link between country risk components - that are economical, financial, and political risk indices- and innovation has been studied by Hoti and McAleer (2006). Using the least square estimation for January 1984 to December 1997, they attempted to examine the effects of economic, financial, and political risk ratings, which are various measures of cross-country risk indices, on innovation activities for 12 major foreign patenting countries in the United States. Hoti and McAleer (2006) emphasized that all of the country's risk decompositions significantly impacted innovation. On the other hand, this research focuses solely on the influence of a financial risk index on innovation.

Corruption is another critical factor that may harm product innovation. The importance is that in the case of corrupt practices would yield lower innovation activities that would result in lower growth in the entire economy. Veracierto (2008) illustrated how corruption could lower the rate of product innovation in industry and showed a slight increase in corruption penalties would result in a considerable increase in the level of product innovation by using their data calculations from the University of Pennsylvania. DiRienzo and Das (2014) investigated the corruption and cultural diversity in innovation in cross-country analyses and found evidence of significant harm of corruption on innovation activities across countries.

On the other hand, the governance environment is likely to influence innovation activity. Almeida and Teixeria (2007) look at the governance environment and patenting productivity, claiming that innovation depends on the country's governance context. They studied R&D and patent relationships for 88 countries along with high tech exports, FDI, and five governance dimensions: political stability and absence of violence; government effectiveness; regulatory quality; the rule of law; and finally, control of corruption for the period 1996-2003. This paper uses the fixed effects model, random effects model, and pooled OLS estimation procedures in addition to the traditional (R&D to Patents) or the reverse causality (Patents to R&D). The positive influence of regulatory quality on patenting propensity was found for intermediate developed countries.

Data and methodology

Annual data covering the period from 2010 to 2015 are utilized in this paper for 29 advanced economy countries. A list of advanced economies has been obtained from World Economic Outlook as 34 countries. However, this study considers 29 countries to construct a panel set. The countries employed in this paper are illustrated in Table 1. In addition, this paper examines the relationship between innovation and financial development, innovation infrastructure, and control variables.

Table 1. List of Countries

Code	Country Codes	Country	Code	Country Codes	Country
1	AU	Australia	16	JP	Japan
2	AT	Austria	17	KR	Korea Republic
3	BE	Belgium	18	LU	Luxemburg
4	CA	Canada	19	MT	Malta
5	CN	China	20	NL	Netherlands
6	CY	Cyprus	21	NZ	New Zealand
7	CZ	Czech Republic	22	NO	Norway
8	EE	Estonia	23	PT	Portugal
9	FI	Finland	24	SG	Singapore
10	FR	France	25	SK	Slovakia
11	DE	Germany	26	SI	Slovenia
12	GR	Greece	27	SE	Sweden
13	IE	Ireland	28	GB	United Kingdom
14	IL	Israel	29	US	United States of America
15	IT	Italy			

This research simulates the number of patent applications filed on a national part throughout the year. Count data models will be utilized to investigate the hypothesized link because the number of patent applications is discrete and has non-negative integer values. STATA statistical software will carry out model estimations due to its advantage over other statistical software programs. Moreover, it provides partial effects of the coefficient with the estimation results.

Data

Total patent applications, including resident and non-resident patent applications, are the study's variables (TOTPAT). In addition, research and development (RD), foreign direct investment (FDI), intellectual property rights (IPR), gross fixed capital formation (GFCF), and high-skill employment, which includes managers, professionals, technicians, and associated professionals (HSE), high technology export (HTEX) are the variables of interest in this study. Moreover, the composite financial development index (CFDI), financial risk index (FRISK), and governance indicators as a proxy for financial sector development are all examples of indicators that can be used to gauge the progress of the financial sector (FD). Therefore they also considered in this study. The World Data Bank provided us with FD, CC, GE, PSAV, RL, and RQ, and the variables of RD, FDI, IPR, GFCF, and HTEX, which were retrieved from the World Bank. In addition, FRISK has been obtained from the Political Risk Service (PRS) Group, TOTPAT has been obtained from the World Intellectual Property Organization Database, and ILO has been obtained from the International Labor Organization. The list of the variables employed in this study is illustrated in Table 2.

Table 2. List of Variables

VARIABLE	SYMBOL IMAGE	DEFINITION	SOURCE
Total Patent Application	Totpat	Resident patent applications and non-resident patent applications	World Intellectual Property Organization
Research and Development Expenditure	R&D	Research and development expenditure (% of GDP)	World Development Indicators
Foreign Direct Investment	FDI	Foreign direct investment, net inflows (BoP, current US $)	World Development Indicators
Intellectual Property Rights	IPR	Charges for the use of intellectual property, payments (BoP, current US $)	World Development Indicators
Gross Fixed Capital Formation	GFCF	Gross fixed capital formation (constant 2010 US$)	World Development Indicators
High Skilled Employment	HSE	Skill levels 3 and 4; 1-Managers; 2-Professionals; 3- Technicians and associated professionals	International Labour Organization
High Technology Export	HTEXP	High-technology exports (% of manufactured exports)	World Development Indicators
Financial Development Index	FD	Broad Money (%GDP)	World Development Indicators
		Domestic credit to the private sector by banks (% of GDP)	
		Domestic credit to the private sector (% of GDP)	
Financial Risk Index	FR	Financial risk rating	Political Risk Service (PRS) Group
Control of Corruption	CC	Control of corruption estimate	World Bank
Government Effectiveness	GE	Government effectiveness estimate	World Bank
Political Stability and Absence of Violence	PSAV	Political stability and absence of violence estimate	World Bank
Rule of Law	RL	Rule of law estimate	World Bank
Regulatory Quality	RQ	Regulatory quality estimate	World Bank

In the literature, various proxies for financial sector development have been employed to measure various qualities used to measure financial system development. In this research, three variety proxies will be run to create a compound monetary expansion index, similar to the mutable selection used by Beck et al. (1999) and Levine et al. (2000). The following are the factors that influence financial development: (1) comprehensive money supply (M2), (2) domestic banking sector credits (DC), and (3) domestic private sector credits (DCP), The financial development index is calculated using SPSS statistical software's primary component factor analysis (Chen 2010). To introduce the creation of composite financial development in this study, the following functional relationship can be used:

$$FD = f\,(M2, DC, DCP) \quad (1)$$

The variables of M2, DC, and DCP have been obtained from World Development Indicators. Domestic credits by the banking sector (DC) have been used to incorporate the overall credit extension as a pointer to economic enlargement, as in Jenkins and Katircioglu (2010). As argued by Levine et al. (2000) and Ang (2009), domestic credits provided to the private sector (DCP) have been used as an important proxy for financial intermediation. They are vital to financial development because the private sector can use reserves more effectively and efficiently than the public sector. Broad money supply (M2) has been utilized in this study as an indicator of financial depth.

In this study, a wide range of control variables are used as follows: foreign direct investment is a significant source of knowledge transfer, increasing the critical mass for knowledge creation in a country while also encouraging increased R&D and patenting; a high degree of technology in exports indicates that a country is more technologically advanced and therefore more skilled at developing and patenting; gross fixed capital formation is the process of acquiring the physical plant, equipment, and infrastructure required to support innovation and the positive impact of R&D expenditure on innovation is an inevitable fact. Thus, intellectual property rights protect intellectual property creators, encouraging innovation activities. In addition, high-skilled employment is essential for a country's potential for innovation; for example, senior management's role in encouraging entrepreneurial behaviour by supporting new ideas and tolerating associated risks. Finally, financial development is required to facilitate further access to R&D investment funding that will result in innovation.

The financial risk index, the composite country risk rating component, will also be employed in this study. Financial risk is that a national government miscarries to meet its debt obligations. It is significant in appraising the worth of a nation's currency since a nation that cannot pay its debt has a higher risk, eventually affecting the inflow of foreign currency. Higher nation danger grades are expected to attract more overseas ventures and wealth inflow, thereby increasing innovation activity. An increase in risk ratings indicates related country becomes less risky, and a decrease in risk rating indicates related country becomes riskier to attract capital inflow. Therefore, it is expected to have a positive correlation between risk indices and innovation. Financial risk appraisal scores are based upon analysis of a mix of quantitative and qualitative information.

According to Kaufmann et al. (2010), *control of corruption* includes the degree to which community authority is used for private gain, including both petty and grand types of corruption, as well as "capture" of the state by bests and corporate benefits; views of the excellence of public services, the civil service's independence from political constraints, the quality of policy formulation and implementation, and the government's credibility. *Political stability* and *the lack of violence/terrorism* reflect public perceptions of the government's vulnerability to destabilization or overthrow using illegal or violent measures such as politically motivated violence and terrorism. The majority's opinion of the administration's ability to enact legislation and norms that support and promote the development of the private sector is summed up by the concept of regulatory quality. The term "the rule of law" refers to how much a population trusts and upholds current societal rules, such as the effectiveness of enforcing contracts, property ownership, the authorities, and courts, as well as the possibility of criminal activity.

All World Bank World Governance indicators have zero mean and one standard deviation, ranging from -2.5 to 2.5. A higher rank is associated with better governance outcomes, such as controlling corruption -2.5 indicates very high corruption, while 2.5 indicates very low corruption. Easterly and Levine (2003) defines *government effectiveness* as 'the superiority of community facility distribution, competence of civil servants, and the degree of politicization of the civil provision'; *political stability and absence of violence* as a low likelihood that the government will be overthrown by illegal or intense means'; the *rule of law* as 'defence of persons and property against violence or theft. Thus, administration measures are expected to correlate positively with innovative activity, fair and efficient court systems, and adherence to agreements. The descriptive statistics of variables and the expected sign of the variables of interest have been summarized in Tables 3 and 4, respectively.

Table 3. Expected Signs

Variables	Expected Signs
Research & Development Expenditure ratio to GDP	+
Intellectual Property Rights	+
Gross Fixed Capital Formation	+
Foreign Direct Investment	+
High Tech Export	+
High Skilled Employment	+
Financial Development	+
Financial Risk Index	+
Control of Corruption	+
Government Effectiveness	+
Political Stability and Absence of Violence	+
Regulatory Quality	+
Rule of Law	+

Table 4. Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
TOTPAT	162	76007.17	183800.5	37	1101864
RD	162	2.153973	1.034702	0.381291	4.890868
IPR	162	7.90013	1.866401	3.756497	11.22676
GFCF	162	11.43687	1.902906	7.36283	15.21953
FDI	146	23.33715	1.928406	17.32849	26.95012
HTEXP	162	2.682758	0.57963	1.255884	3.910194
HSE	162	14.62633	1.730532	10.96989	18.33144
FD	162	112.1854	62.83354	22.49428	641.543
FRISK	162	37.15279	5.279236	22.083	48
CC	162	1.156071	0.791212	-0.595	2.320842
GE	162	1.354005	0.505756	0.004753	2.259651
PSAV	162	0.719273	0.578631	-1.32003	1.437269
RL	162	1.323404	0.586226	-0.48189	2.120458
RQ	162	1.278826	0.502551	-0.283	2.262884

Notes: TOTPAT, FD, FRISK, CC, GE, PSAV, RL, and RQ have been used as raw data, whereas IPR, GFCF, FDI HTEXP, and HSE have been used in logarithmic form; and finally, RD has been used as a per cent of GDP.

Methodology

The empirical study uses a Poisson or negative binomial distribution model because the total number of patent applications is non-negative count data (see Hsiao, 2003; Chen, 2010). The Poisson model is a broader variant of the negative binomial model (Chen, 2010). The negative binomial model is distinguished by adding a discrete parameter to explain data heterogeneity, making it more relevant (Kareem, 2018). When the number approaches infinity, it indicates that occurrences are not occurring at random but rather in clusters. As the number approaches zero, the event becomes random, and the negative binomial distribution reverts to the Poisson spreading. As a result, the Poisson distribution is a subset of the negative binomial circulation. The massive prospect function of the destructive binomial model is assumed by Equation.

$$F(y_i) = P(Y_i = y_i) = \frac{\Gamma(y_i+\theta^{-1})}{\Gamma(y_i+1)\Gamma(\theta^{-1})}\left(\frac{\theta^{-1}}{\theta^{-1}+\lambda_i}\right)^{\theta^{-1}}\left(\frac{\lambda_i}{\theta^{-1}+\lambda_i}\right)^{y_i} \quad (1)$$

$$\lambda_i = Exp(X_i\beta + e_i) = Exp(X_i\beta)Exp(e_i)$$

Where e_i is the variance heterogeneity, θ is the discrete parameter, and Γ is the gamma function.

The negative binomial distribution's log-likelihood function is:

$$L = \sum_{i=1}^{n} \left\{ \ln \left[\frac{\Gamma(y_i+\theta^{-1})}{\Gamma(y_i+1)\Gamma(\theta^{-1})} \right] - (y_i + \theta^{-1}) ln(1 + \theta\lambda_i) + y_i \ln(\theta\lambda_i) \right\} \quad (2)$$

As a result, a negative binomial model is used since the expected variance values of total patents differ from the actual ones, which contradicts the Poisson distribution model's assumptions. Finally, the researchers used negative binomial regression of random effects (rather than fixed effects) for the analysis, based on the results of a Hausmann test.

Estimation results and discussion

Poisson appraisal outcomes of seven different technique options are mentioned in Tables 5 and 6, random-effects and fixed-effects, respectively. Additionally, the Hausman test was conducted to select between Poisson fixed-effects and Poisson random-effects estimations, as illustrated in Table 9. The null hypothesis of the Hausman test is that the preferred model is the fixed effects alternative random effects. In all model options, it is noteworthy that the dispersion parameter, alpha, is statistically significant. This demonstrates that the Negative Binomial model is further suitable than the Poisson model.

Table 5: Poisson Random-Effects Estimation

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
RD	0.112***	0.095***	0.095***	0.150***	0.141***	0.065***	0.067***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
IPR	0.373***	0.355***	0.352***	0.350***	0.339***	0.276***	0.272***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
GFCF	1.010***	1.126***	1.097***	1.152***	1.221***	1.003***	1.024***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
FDI	-0.001*	-0.001	-0.001**	-0.003***	-0.003***	-0.009***	-0.010***
	(0.060)	(0.403)	(0.028)	(0.000)	(0.000)	(0.000)	(0.000)
HTEXP	-0.299***	-0.378***	-0.367***	-0.124***	-0.137***	0.018	0.014
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.243)	(0.360)
HSE	1.879***	1.774***	1.744***	1.416***	1.434***	1.124***	1.081***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
FD	0.005***	0.004***	0.004***	0.003***	0.003***	0.003***	0.003***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
FRISK	-	0.010***	0.009***	0.004***	0.003***	0.011***	0.014***
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
CC	-	-	0.048***	-0.066***	-0.053***	0.298***	0.273***
			(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
GE	-	-	-	0.186***	0.183***	0.358***	0.345***
				(0.000)	(0.000)	(0.000)	(0.000)
PSAV	-	-	-	-	-0.093***	-0.046***	-0.066***
					(0.000)	(0.000)	(0.000)
RL	-	-	-	-	-	-0.750***	-0.680***
						(0.000)	(0.000)
RQ	-	-	-	-	-	-	-0.106***
							(0.000)
ALPHA	5.635***	5.750***	5.505***	4.376***	4.738***	2.520***	2.475***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Log Likelihood	-15308.32	-15094.711	-15077.89	-14312.774	-14209.779	-12750.635	-12655.205

Notes: Beta coefficients are reported with p-values in parentheses. *** and ** and * indicate rejection of the null hypothesis at 1% and 5%, and 10% significance levels. All panel regressions include year dummies. Time dummies are not shown here to save space. TOTPAT, FD, FRISK, CC, GE, PSAV, RL, and RQ have been used as raw data, whereas IPR, GFCF, FDI, HTEXP, and HSE have been used in logarithmic form; and finally, RD has been used as a per cent of GDP.

Table 6: Poisson Fixed-Effects Estimation

	(8)	(9)	(10)	(11)	(12)	(13)	(14)
RD	0.112***	0.095***	0.095***	0.149***	0.141***	0.065***	0.066***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
IPR	0.373***	0.354***	0.352***	0.350***	0.339***	0.276***	0.272***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
GFCF	1.010***	1.125***	1.097***	1.152***	1.222***	1.004***	1.026***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
FDI	-0.001*	-0.001	-0.001**	-0.003***	-0.003***	-0.009***	-0.010***
	(0.057)	(0.393)	(0.029)	(0.000)	(0.000)	(0.000)	(0.000)
HTEXP	-0.300***	-0.380***	-0.369***	-0.126***	-0.139***	0.015	0.011
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.343)	(0.488)
HSE	1.887***	1.781***	1.752***	1.427***	1.445***	1.142***	1.100***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
FD	0.005***	0.004***	0.004***	0.003***	0.003***	0.003***	0.003***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
FRISK	-	0.010***	0.009***	0.004***	0.004***	0.011***	0.015***
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
CC	-	-	0.046***	-0.067***	-0.054***	0.294***	0.270***
			(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
GE	-	-	-	0.186***	0.181***	0.356***	0.343***
				(0.000)	(0.000)	(0.000)	(0.000)
PSAV	-	-	-	-	-0.094***	-0.047***	-0.068***
					(0.000)	(0.000)	(0.000)
RL	-	-	-	-	-	-0.746***	-0.676***
						(0.000)	(0.000)
RQ	-	-	-	-	-	-	-0.106***
							(0.000)
Log Likelihood	-14956.489	-14742.411	-14726.582	-13966.688	-13861.893	-12416.306	-12321.242

Notes: Beta coefficients are reported with p-values in parentheses. *** and ** and * indicate rejection of the null hypothesis at 1% and 5%, and 10% significance levels. All panel regressions include year dummies. Time dummies are not shown here to save space. TOTPAT, FD, FRISK, CC, GE, PSAV, RL, and RQ have been used as raw data, whereas IPR, GFCF, FDI, HTEXP, and HSE have been used in logarithmic form; and finally, RD has been used as a per cent of GDP.

The negative binomial estimate results of seven different model options are mentioned in Tables 7 and 8, random and fixed effects, respectively. Additionally, the Hausman test was conducted to select between Negative Binomial fixed-effects and Negative Binomial random-effects estimations, as illustrated in Table 10. In all model estimations, the Chi-Square of the Hausman test confirms that Negative Binomial random-effects estimation should overall complete for analyzing the relation between the variables of interest, except for model (17) and model (24), which includes financial risk and control for corruption as control variables.

Table 7: Negative Binomial Random-Effects Estimation

	(15)	(16)	(17)	(18)	(19)	(20)	(21)
RD	0.268***	0.228***	0.143***	0.207***	0.207***	0.203***	0.228***
	(0.000)	(0.000)	(0.002)	(0.000)	(0.000)	(0.000)	(0.000)
IPR	0.200***	0.202***	0.174***	0.179***	0.181***	0.169***	0.200***
	(0.007)	(0.005)	(0.005)	(0.003)	(0.003)	(0.005)	(0.001)
GFCF	0.929***	0.921***	0.536***	0.564***	0.557***	0.503***	0.538***
	(0.000)	(0.000)	(0.005)	(0.003)	(0.004)	(0.009)	(0.005)
FDI	-0.002	0.001	-0.008	-0.010	-0.011	-0.009	-0.012
	(0.909)	(0.986)	(0.549)	(0.406)	(0.394)	(0.497)	(0.330)
HTEXP	0.098	0.010	0.066	0.108	0.113	0.027	0.095
	(0.464)	(0.944)	(0.609)	(0.430)	(0.413)	(0.851)	(0.506)
HSE	-0.413**	-0.465**	-0.035	0.049	0.059	0.045	0.030
	(0.033)	(0.015)	(0.848)	(0.790)	(0.750)	(0.807)	(0.876)
FD	0.002***	0.002***	0.002***	0.002***	0.002***	0.002***	0.002***
	(0.000)	(0.001)	(0.001)	(0.001)	(0.000)	(0.001)	(0.001)
FRISK	-	0.020**	0.018*	0.009	0.009	0.008	0.011
		(0.062)	(0.066)	(0.376)	(0.378)	(0.452)	(0.243)
CC	-	-	0.503***	0.293**	0.282**	0.234*	0.213*
			(0.000)	(0.012)	(0.020)	(0.060)	(0.088)
GE	-	-	-	0.307***	0.303***	0.142	0.183
				(0.003)	(0.004)	(0.387)	(0.209)
PSAV	-	-	-	-	0.037	0.016	0.024
					(0.738)	(0.887)	(0.825)
RL	-	-	-	-	-	0.386	0.519*
						(0.179)	(0.070)
RQ	-	-	-	-	-	-	-0.330**
							(0.015)
Log-Likelihood	-1286.5248	-1284.7212	-1270.8456	-1266.8813	-1266.8255	-1265.9916	-1263.2032

Notes: Beta coefficients are reported with p-values in parentheses. *** and ** and * indicate rejection of the null hypothesis at 1% and 5%, and 10% significance levels. All panel regressions include year dummies. Time dummies are not shown here to save space. TOTPAT, FD, FRISK, CC, GE, PSAV, RL, and RQ have been used as raw data where IPR, GFCF, FDI HTEXP, and HSE have been used in logarithmic form; and finally, RD has been used as a per cent of GDP.

Table 8: Negative Binomial Fixed-Effects Estimation

	(22)	(23)	(24)	(25)	(26)	(27)	(28)
RD	0.242***	0.172***	0.092**	0.115**	0.115**	0.128**	0.150***
	(0.000)	(0.001)	(0.076)	(0.032)	(0.032)	(0.019)	(0.007)
IPR	0.184**	0.172**	0.148**	0.150**	0.150**	0.141**	0.161***
	(0.017)	(0.014)	(0.012)	(0.012)	(0.012)	(0.013)	(0.006)
GFCF	0.628***	0.660***	0.365**	0.344**	0.344*	0.328*	0.359**
	(0.005)	(0.001)	(0.041)	(0.056)	(0.056)	(0.062)	(0.045)
FDI	-0.001	-0.001	-0.006	-0.007	-0.007	-0.005	-0.005
	(0.997)	(0.981)	(0.671)	(0.613)	(0.607)	(0.710)	(0.687)
HTEXP	0.175	0.035	0.076	0.067	0.070	-0.007	0.043
	(0.184)	(0.788)	(0.536)	(0.595)	(0.585)	(0.959)	(0.749)
HSE	-0.394**	-0.517***	-0.100	-0.051	-0.048	-0.031	-0.051
	(0.041)	(0.005)	(0.572)	(0.776)	(0.793)	(0.861)	(0.781)
FD	0.002***	0.002***	0.002**	0.002***	0.002***	0.002***	0.002***
	(0.000)	(0.002)	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)
FRISK	-	0.033***	0.027**	0.025**	0.025**	0.018*	0.019*
		(0.006)	(0.012)	(0.023)	(0.024)	(0.096)	(0.073)
CC	-	-	0.555***	0.444***	0.441***	0.302**	0.297**
			(0.000)	(0.000)	(0.000)	(0.015)	(0.018)
GE	-	-	-	0.211*	0.204*	0.001	0.010
				(0.072)	(0.100)	(0.997)	(0.946)
PSAV	-	-	-	-	0.020	0.005	0.024
					(0.883)	(0.969)	(0.847)
RL	-	-	-	-	-	0.602**	0.698***
						(0.017)	(0.009)
RQ	-	-	-	-	-	-	-0.209
							(0.191)
Log-Likelihood	-964.339	-960.611	-946.258	-944.676	-944.665	-942.085	-941.261

Notes: Beta coefficients are reported with p-values in parentheses. *** and ** and * indicate rejection of the null hypothesis at 1% and 5%, and 10% significance levels. All panel regressions include year dummies. Time dummies are not shown here to save space. TOTPAT, FD, FRISK, CC, GE, PSAV, RL, and RQ have been used as raw data where IPR, GFCF, FDI HTEXP, and HSE have been used in logarithmic form; and finally, RD has been used as a per cent of GDP.

Table 9: Hausman Test for Poission Estimation

	vs (8)	vs (9)	vs (10)	vs (11)	vs (12)	vs (13)	vs (14)
Chi2	28.44	21.98	18.54	24.33	24.52	29.00	40.88
Prob>Chi2	(0.055)	(0.056)	(0.138)	(0.064)	(0.057)	(0.074)	(0.082)
Conclusion	RE	RE	RE	RE	RE	RE	RE

Table 10: Hausman Test for Negative Binomial estimation

	(15) vs (22)	(16)vs (23)	vs (24)	vs (25)	vs (26)	vs (27)	vs (28)
Chi2	16.54	9.42	43.39	28.12	87.41	3.99	4.11
Prob>Chi2	(0.168)	(0.741)	(0.021)	(0.061)	(0.126)	(0.099)	(0.097)
Conclusion	RE	RE	FE	RE	RE	RE	RE

Negative Binomial fixed-effects estimation, model (24), confirms the positive effect of all statistically significant variables on the total patent applications. The considerable favourable influence on a complete patent application is confirmed by inquiry and growth of spending, rational assets rights, and gross fixed capital creation. The positive sign of the financial development index indicates that an increase in financial development clues to advanced improvement (Hanley et al., 2011; Ang, 2014; among many others). The positive sign of the financial risk index indicates that an increase in financial risk ratings leads to higher growth and technological advancement via more excellent foreign investment and capital inflow into a country, leading to higher innovation than the total patent applications (Hoti and McAller, 2006). As expected, the positive sign of control of fraud specifies that an increase in control of corruption leads to an increase in the total patent application. An increase in corruption lowers the rate of product innovation (Veracierto, 2008; DiRienzo and Das, 2014).

As motioned previously, the dispersion parameter, alpha, is statistically significant. This result suggests that the Negative Binomial model is more suitable than the Poisson model. Model (21) is a Negative Binomial random-effects estimation, and Model (28) is a Negative Binomial fixed-effects estimation, the most comprehensive Negative Binomial model. Even though the best model seems the model (28) because its log-likelihood is the biggest among the others, model (21) will be the one chosen for further interpretations. The Hausman test results suggest that a Negative Binomial random-effects assessment should be favoured to examine the association. Based on the likelihood estimations of the Negative Binomial random-effects estimation, the model (21) estimation result is appropriate to investigate the overall association among the variables of interest. Research and development spending exerts a highly significant and positive effect on the total patent applications (β=0.228, $p< 0.01$); therefore, a 10% increase in research and development leads to approximately two units increase in total patent applications. Moreover, intellectual property rights exert a highly significant and positive effect on the total patent applications (β=0.200, $p< 0.01$), suggesting that a 10% increase in intellectual property rights increases total patent applications by two units. As another essential determinant, gross fixed capital formation has a significant positive effect on the total patent applications (β=0.538, $p< 0.01$), this result suggests that a 10% increase in gross fixed capital formation increases total patent applications by approximately five units. The bottom line, research and development spending, intellectual property rights, and gross fixed capital formation confirm statistically positive impacts on the complete patent application. Empirical estimation of the model (21) shows a minimal but positive influence of the financial development index (β=0.002, $p< 0.01$) on the complete patent application. This result suggests that a 1-unit increase in the financial development index will lead to a 0.002 increase in the complete patent application. The positive sign of the financial development index indicates that an increase in financial development leads to higher innovation (Hanley et al., 2011; Ang, 2014; among many others). The positive sign of control of corruption and the rule of law indicates that an increase in both controls of corruption (β=0.213, $p< 0.08$) and the rule of law (β=0.519, $p< 0.07$) leads to an upsurge in the complete patent application. One unit of increase in control of corruption will lead to 0.213 units of increase in the total patent applications. On the other hand, one unit of increase in the rule of law will lead to 0.519 units of increase in the total patent applications. Almeida and Teixeria (2007) state the innovation process is mainly dependent on the country's governance context; it is expected to influence overall innovation activity in a country positively. Empirical estimation of the model (21) shows a negatively significant impact of regulatory quality (β=-0.330, $p< 0.05$) on the total patent applications. One increase in regulatory quality will reduce total patent applications by 0.330 units. Interestingly, it negatively impacts a complete patent application that indicates the failure of the supervision to convey and implement sound policies and regulations that allow and endorse private segment expansion to incentivize innovation in advanced economies.

Conclusion

This paper investigated the impact of financial development on the size of total patent applications in advanced nations during the post-crisis period. In this regard, a total of 29 countries have been chosen. The impact of financial development on the complete patent application was investigated utilizing 28 different model options and other control variables specified in the literature. The findings of this study backed the evidence of a progressive influence of financial development on total patent applications in advanced economies (Hanley et al., 2011; Ang, 2014; among many others). An increase in financial risk rating leads to more significant growth and technology advancement through high foreign investment and capital inflow into a country. As a result, higher innovation will lead to higher total patent applications. The positive effect of the financial risk index is found in the complete patent application (Hoti and McAller, 2006). This study also finds the positive effect of some governance indicators, which are control of corruption and the rule of law on innovation. The significant harm of corruption is found in the country's innovation level (see Veracierto, 2008; DiRienzo and Das, 2014). Therefore, increased corruption control is expected to increase total patent applications. Regulatory quality, it turns out, harms overall obvious requests, implying that the government has failed to set and enforce strict rules and principles that permit and support private sector expansions in advanced economies to incentivize innovation. Authorities in advanced economies need to pay attention to regulatory quality to permit and promote private sector development to increase innovation activities. Further research can be undertaken in developing and/or transition countries for comparative purposes.

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