The Journal of Technology Transfer (2019) 44:1505–1528
https://doi.org/10.1007/s10961-019-09730-3

The effects of technology transfers and institutional factors on economic growth: evidence from Europe and Oceania

Joao J. M. Ferreira[1] · Cristina Fernandes[1] · Vanessa Ratten[2]

Published online: 8 April 2019

Abstract
Most of the literature on technology transfers (TTs) has tended to focus on a country or regional level without looking at the cross-continent flows of knowledge that are becoming ever more important due to regional trading blocs. This study fills the gap on the role of cross-continent TTs and institutional factors by focusing on the impact of environment related patents on economic growth. The continents selected for comparison are Europe and Oceania, which differ in terms of economic climate, geography and sustainability policies. In this way, we contribute to the literature on cross-continent TT policies by examining how environmental patents influence the economic growth rate of continents. This will help provide government policy with better means of enhancing TT. We conclude with the implications for managers, theory and policy in conjunction with the limitations and suggestions for future research.

Keywords Climate change · Economic growth · Environmental patents · Europe · Institutional factors · Oceania · Technology transfer

JEL Classification L26 · M10 · O3

1 Introduction

The effectiveness of technology transfer (TT) policies arises out of the existing regional institutional structures that foster environmentally related initiatives (Aparicio et al. 2016). Environmental issues are an important part of the entrepreneurship process as they involve focusing on the ability of organizations and regions to be sustainable (Pinkse and Groot

✉ Joao J. M. Ferreira
jjmf@ubi.pt

Cristina Fernandes
cristina.isabel.fernandes@ubi.pt

Vanessa Ratten
v.ratten@latrobe.edu.au

1 Faculdade de Ciências Sociais e Humanas, Dep. Gestão e Economia, NECE-UBI Research Center in Business Sciences, Universidade da Beira Interior (UBI), Covilhã, Portugal

2 La Trobe University, Melbourne, Australia

2015). There is an increased emphasis on developing environmental technology due to the impacts of climate change on society (Greiner and Franza 2003). One way of doing this is through TTs, which represent important determinants of national efficiency and productivity growth (Danquah et al. 2018; Loko and Diouf 2009; Wooster and Diebel 2010). The efficiency of any country is susceptible to improvement whenever the technology transferred enables better production systems to emerge (Archarya and Keller 2009). Due to societal interest in environmental issues such as climate change and water usage, it has become increasingly important for governments to focus on TTs able to produce innovations in these areas.

Most prior research on TTs and innovation has focused on national settings without taking into account international comparisons (Audretsch and Belitski 2017). Innovation reflects a primary means for enhancing the efficiency of TTs and for triggering knowledge spillovers to surrounding industries (Danquah et al. 2018).

There is general agreement around measuring knowledge spillovers according to patent citation data in addition to the citations counting measurements commonly applied (Hall et al. 2005; Lerner 1994; Trajtenberg 1990). Patent documents provide a printed trail of knowledge flows as inventors need to reference prior patents of relevance to the development of the new knowledge described in their patents.

For example, Mohr (2002) concludes that the existence of knowledge spillovers hinders the replacement of old, polluting technology with newer, cleaner and more productive technology given that companies benefit from second-mover advantage whenever waiting for others to adopt first. The introduction of environmental regulations induces this switch to cleaner technologies and simultaneously triggering improvements to environmental quality and, eventually, increased productivity levels (Aghion et al. 2016).

With many clean technologies depending on political backing in one form or another, the expansion of clean technologies and their spillovers thus to a greater or lesser extent derives from public investment policies.

Countries that have a reputation for being innovative are considered better places to conduct TTs (Soto-Acosta et al. 2018). To improve a country's position in the global marketplace, it needs an image of being innovative and willing to adapt its market resources to respond to societal needs (Rosenzweig 2017). Therefore, technologies that contain a high level of new knowledge (radical innovations) tend to present higher spillover effects than technologies containing only low levels of new knowledge (incremental innovations). Clean technologies are new and in early phases of their development. In contrast, dirty technologies are much more mature and developed. Hence, environmental research and innovation rank as cornerstones to the Europe 2020 Strategy, which identifies intelligent, sustainable and inclusive technologies for growth as the means to aid the EU develop a more economic and competitive resource base, generating high levels of employment, productivity and social cohesion. Sustainable development also constitutes a priority set by European Union member states that are progressively adopting market and non-market regulations within the framework of environmental policies (Fabrizi et al. 2018). In general, on the one hand, innovation and on the other hand, regulation make up the core pillars of the EU policy for sustainable development (Arimura et al. 2007; Johnstone and Labonne 2006; Lanoie et al. 2011).

Studies that focus on the innovation and entrepreneurship resulting from TTs amongst continents are lacking in the empirical and theoretical literature, especially in terms of geographically distant continents such as Europe and Oceania.

Although the European Union lies far distant geographically, there are strong ties to Oceania particularly in terms of facilitating TTs between the two continents. TTs provide a key facet to any country's innovation strategy (Villani et al. 2017) and estimates point to the European Union allocating more than €800 million in formal aid to Oceania each year in addition to the sums spent on informal policy initiatives such as education and training. Oceania is important to the European Union due to cultural reasons with many European Union citizens living and doing business there. In addition, there are historical linkages in terms of language and culture as many countries in the region were colonised by European countries. Whilst there are many developing countries in the region, there are also developed countries such as Australia and New Zealand that contribute to regional economic development.

This gap in the literature means we have yet to ascertain to what extent cross-continent TTs are able to promote innovative developments and ensure better government policy. Hence, the research questions of this study are: "do Europe and Oceania display different behaviours in terms of TTs)?" and "do the institutional differences and TTs generate a positive impact on the economic growth of both continents?

The aim of this paper therefore involves analysis of the institutional differences and TTs in terms of the environmental patents of both continents while also verifying the impact of these differences to the economic growth of both continents.

In Oceania, there is a large amount of green tourism and sustainable businesses but also alongside a heavy reliance on mining, which needs to be managed through green policy initiatives. Green patents are particularly important for Oceania as coal accounts for 60% of its total primary energy supply compared to the average of 20% for the developed countries of Europe (Australian Government 2015). In addition, Oceania has a large resource industry and the policy towards sustainability has driven more firms to focus on 'green' patents. The European Union, due to its strong emphasis on sustainability, is also facilitating more environmental initiatives in Oceania through policy initiatives.

This paper then compares the effectiveness of TT policies by using data based on country-level aggregated information about patents from the Organization for Economic Co-operation and Development (OECD). This shall enable a better understanding of how institutional differences shape and fashion the effectiveness of TT policies as regards the economic growth of these specific continents.

This article contributes to the literature in three important ways. Firstly, despite the proliferation of research into TTs and economic growth models, there is a lack of consensus around the nature of these transfers and their actual economic impacts. This article complements the existing literature through considering a set of auxiliary variables that span the institutional factors prevailing on each continent and gauges their differences in terms of their impacts on economic growth.

Secondly, we reach beyond the neoclassical growth model in considering TTs as another feasible explanation for economic growth. The studies in the literature on both areas are only fragmented and modelled separately. The majority of studies evaluating TT policies concentrate primarily on qualitative research and are broadly, even if not exclusively, oriented towards the United States (Bozeman et al. 2015; Chen et al. 2018; Jaffe et al. 1998; Jaffe and Lerner 2001; Link et al. 2011; Stevens et al. 2011), while the literature on economic growth essentially spans endogenous factors, the factors of production, capital and labour (Romer 1986; Solow 1956, 2007; Swan 1956). To this end, we made recourse to a model similar to that of Aparicio et al. (2016), which emphasises the impact of entrepreneurship on economic growth taking into account institutional factors. We carried out the calculations according to dynamic panels based on econometric methodologies with the objective of capturing the differences emerging over the course of time (Bond 2002) given that patents may impact on economic growth over the following years (Romer 1986).

Hence, there has been neither any explicit nor joint approach either to this problematic framework or to both the economies of Oceania and Europe. The recent empirical literature, in concentrating on TTs as the motor behind convergence, argues that poor countries facing major technological shortcomings might be able to experience more rapid growth depending on their capacity to absorb and adopt technology (Ahmed and Suardi 2007; Aminullah et al. 2013; Bozeman 2000; Coe and Helpman 1995; Fagerberg 1994; Hoekman et al. 2004; Schmid 2012; UNCTAD 2014). When combined with endogenous growth models, international TT theory forecasts that there is a short term boost to the rates of growth susceptible to explanation through recourse to catch-up technologies (Dowrick and Nguyen 1989; Howitt 2000). Finally, the empirical model applied in this article provides the means of testing whether the institutional factors and TT (in terms of environmental patents) contribute towards explaining economic growth. In turn, this aligns with a trend in the literature that maintains institutions and TT foster economic growth (Barbosa and Faria 2011; Constantini and Liberati 2014; Tang and Coveos 2008; Shih and Chang 2009).

This article is structured as follows. Firstly, we have above detailed the theoretical framework underpinning this study, which combines institutional factors and the development of environmental related patents. Next, we review the literature on institutional factors and TTs by focusing on their importance for development and the economic growth of a region's innovation strategy. We then present the methodology and data analysis for the study, which is based on OECD patent data focusing on the differences in institutional factors and TT policies between Europe and Oceania. Finally, we state the theoretical, managerial and policy implications of our study. This is followed by out conclusions, the limitations of this study alongside suggestions for future research.

2 Literature review

2.1 Institutional factors and their importance to economic growth

Institutional theory in its modern form began development after 1990 following foundational works by Soto (1989) and North (1991). Throughout economic history, institutions have established rules for society that have shaped human interactions (North 1990). According to North, there are two types of institution: formal (political, norms, etcetera) and informal (culture, behaviour, etcetera). Meanwhile, Pattit et al. (2012) report how formal and informal institutions performed a dominant role in preparing the ground for technological change in the United States over a long period of time. Wang et al. (2015) mention how laws, regulations and policies shape the innovative activities engaged in by companies. Institutions act to influence the input costs of innovation while also protecting the results and outputs and thus shape and mould the innovation activities ongoing as well as those of other companies.

Institutional theory posits that the respective institutional configurations of a country facilitate investment through providing incentives and supports while simultaneously nurturing a stable environment, mitigating transactional costs and reducing risks and uncertainties. North (1990) and Daude and Stein (2007) point to how investment decisions may depend on different dimensions of the surrounding environment. R&D activities, as a form of investment, are also sensitive to institutional qualities (Waarden 2001). Investments in education, strong legal protection, and stable political and economic frameworks all positively interrelate with technological performance

(Varsakelis 2006). Hence, institutional factors constitute those particular conditions embedded in the predominantly prevailing institutional and economic environments for business and capable of influencing access to, the acquisition of and payment for technologies in different manners (Yousafzai et al. 2015). Specifically, we may state that the equilibrium between the acquisition of national and international technologies and the collaborations ongoing among companies and R&D institutions plays a determining role in these factors. For example, when a company accesses technological knowledge of the type produced by R&D institutions, they may increase their participation as regards the purchase of collaborative technology. Furthermore, institutional factors may also influence the performance of technology development processes and, correspondingly, improve on the cooperation ongoing among research institutions (Hemmert 2004; Niosi 1999; Sigmund et al. 2015; Von Hippel 1988). According to Lundvall (1992) and Nelson (1993), national innovation systems incorporate an economic perspective, which also conveys potential for identifying the relevant factors for the performance of companies acquiring technology. Lundvall (1992) details how the internal organisation of companies, inter-firm relationships, the role of the public sector, the institutional structure of the financial sector and R&D organisation rank amongst the factors shaping the national innovation profile.

Choi et al. (2014) identify how efficient institutions may encourage R&D related investment through minimising the agency problems of decision makers. Better institutions foster and enable the liberalisation of financial markets so that there are real incentives for R&D investments and thereby freeing companies from some of their financial limitations (Laeven 2003). Therefore, it is highly probable that strengthening institutional configurations serves to foster investment in R&D and improve on the accumulation of knowledge and the spillovers of knowledge in a country (Priem and Butler 2001; Yi et al. 2013).

Thus, institutional theory has served to provide new contributions to the problematic of economic growth based on that termed institutional rules of behaviour (that is, factors), such as the legal structure or even the prevailing religion. Economic theory had hitherto tended to ignore such factors; however, these same factors may be the drivers behind unequal economic growth, variations in the intensities of convergence and inequalities among countries and peoples as measured by GDP per capita. GDP is therefore the measurement applied to make comparisons among the performances attained among richer and poorer countries. Even while economists have attempted to ascertain the causes of growth, the factors that hold influence alongside issues around their sustainability over long periods of time have still not yet received satisfactory responses. Such factors partially arise from concentrations in that identified as the hard factors of growth (for example, investments and technologies) or the omission of just how factors of growth do not reflect actions but are rather variables in a constant state of flux. Such conditions, by which the economy grows and therefore changes, encompass the existence of smooth factors of growth that include institutions that hold great importance to explanations both of their growth and their convergence as well as the inequalities prevailing among countries and their peoples (DiMaggio and Powell 1983; Meyer and Rowan 1977; Sucker 1987; Teo et al. 2003).

Hence, we may define our first research hypothesis as follows:

Hypothesis 1 Institutional factors generate positive impacts on economic growth.

2.2 Technology transfers and economic growth

TTs represent a fundamental principle of the 1992 United Nations Framework Convention on Climate Change (UNFCCC). Article 4 of the UNFCCC requires its signatory parties to “promote and cooperate in the development, application and diffusion, including transfer, of technologies, practices and processes that control, reduce or prevent anthropogenic emissions of greenhouse gases not controlled by the Montreal Protocol in all relevant sectors”.

TTs involve the movement of technology from the site of origin to the site of usage (Kirchherr and Matthews 2018). The main dimensions of TTs are hardware and software. Most of the literature on TTs adopts hardware as this refers to the physical facilities and services emerging from the transfer of technology even while this context has changed with the advance of the knowledge economy. Software refers to the skills required once the physical facilities have emerged from the TTs. Thus, the software transfer includes the ability to locally operate and maintain technology. This is important in further innovating a technology and providing knowledge about potential future business ventures. When technology is transferred across continents, there normally needs to be a degree of expertise in the knowledge capabilities of the recipient country (Kirchherr et al. 2017). This means that the recipient country should be able to learn skills about how to utilize the technology (Hensengerth 2015).

The main TT channels are foreign direct investment (FDI) and trade. FDI involves investments made by foreign entities in local projects (Kirchherr and Matthews 2018). The role of FDI and TTs in bringing about the growth of developing economies has received widespread debate in the economic development literature over a long period of time (Keller 2004; Saggi 2002).

The scope for the FDI allowed in any country is determined by trade regulations and restrictions. The business reason for TTs involves recipients needing technology that is otherwise unavailable to them (Kirchherr et al. 2017). Whenever the technology is more complex, it becomes likelier that the transfer results in more novel innovations. Developing countries usually require the transfer of more tangible goods from a particular technology whilst developed countries tend to focus more on transferring services (Gandenberger et al. 2016).

Bozeman (2000) propose a contingent effectiveness model for understanding TTs that focuses on transfer agents, transfer objects, transfer recipients, transfer media and demand environments. Within this contingent effectiveness model, the level of TTs in a country depends on the industry, the technology and the country’s economic stage of development, which occurs through convergence.

Ever since the earlier study by Bozeman, the broader scope of the TT literature has expanded swiftly in various key directions. Firstly, many studies have approached government laboratories and research centres, especially those located in European countries (Bozeman et al. 2015).

Lee et al. (2018: 524) define convergence as “combining different knowledge from interdisciplinary fields or different types of sources to develop new innovation”. This convergence is a trend in science and technology as the boundaries between industries, knowledge and markets combine particularly in terms of types of TT policy.

To facilitate the TT process, there needs to be both social capital and processes (Van Horne and Dutor 2017). Social capital enables the utilization of knowledge from an individual’s organizational network of relationships (Inkpen and Tsang 2005). This can include the people known to an individual who may then assist in facilitating the exchange of knowledge for value creation. Social capital is a facilitator for TTs as it enables individuals to share information for beneficial purposes. This may be conducted via relational trust based on a mutual understanding between individuals. To utilize social capital there needs to be shared cultural goals between individuals about how to utilize the technology. Networks configured in certain ways are better able to make usage of TTs. When there are stable relationships ongoing in a network, it becomes easier to transfer knowledge through repeated interactions.

The processes needed for TTs involve relational networks for the exchange of knowledge. The formal components of the transfer processes are patents and licensing agreements susceptible to codification and measurement (OECD 2009; Van Horne and Dutot 2017).

Patents involve know-why skills that are defined as "the ability to understand the principles of how the physical facilities at question work" (Kirchherr and Matthews 2018: 548). Patents are a form of know-why skills as they detail the information about how to use a technology. Thus, explanatory instruction about a novel technology is one important way of advancing and completing projects. To transfer know-why skills, there needs to be partner participation in the technology in order to enable innovation to occur (Urban et al. 2015). The informal components involve the non-codified knowledge that occurs in a more flexible manner. The exchange of informal knowledge increasingly accounts for an important part of social interactions. This enables networks to develop based on technology problem solving that increases the stock of knowledge exchanged. Often that which gains most value from knowledge transfers involves the creation of innovative technologies (Salter and Martin 2001). The next section discusses the role environmental patent TTs play by stating the hypotheses incorporated into this study.

In general terms, TTs may involve both marketplace transactions and externalities. While information on the former case is easily accessible through the payments made for patent and license utilisation as well as for copyrights, there is a broad understanding that the most effective TT channel derives from externalities. However, externalities may arrive in different ways depending on whether dealing with developed or developing economies. In the former case, FDI represents the main channel, ranging from face-to-face contacts or procedural norms that may encounter transfer problems interrelated with the tacit nature of technology (Coe et al. 1997; Constantini and Liberati 2014; Gholami et al. 2006; Markusen and Venables 1999).

Many governments provide significant incentives to attract internal investment, motivated by the expectations of indirect benefits. FDI generally emerges as the best channel for the transfer of technology not only across national borders but also among companies—in particular, among national and international companies (Samet 2014).

Research by Nelson and Phelps (1966), for example, highlights how human capital constitutes one of the main factors for explaining the capacity to transform imported technology into productivity gains (Engelbrecht 1997; Keller 2004). They also report that the long term benefits of economic integration are more probable whenever the formation of human capital progressively adapts to the changes in the technologies incorporated into the imported goods (Coe et al. 1997; Keller 2004; Mayer 2001). Madsen (2007) suggests that certain conditions require meeting in order to favour international knowledge. Franco et al. (2012) identify how the indirect spillovers from R&D may also leverage strong impacts on economic growth. Up to a certain point, the indirect effects may prevail over the direct effects such as, for example, in OECD member states when analysing the impact of the externally available resources. Hence, in a broader sense, the positive influence of TTs on economic performance may strictly interlink with the presence of a national innovation system that provides a good environment for the dissemination and adoption of new processes (Fagerberg et al. 2007; Malerba 2006) and alongside the capacity of absorption of this same country or region (Cohen and Levinthal 1990).

Thus, we may define our second respective hypothesis:

Hypothesis 2 TTs generate a positive effect on economic growth.

3 Conceptualization section: policies and contexts

There is a broad consensus that the differences in national histories, cultures, political contexts and the moment when the country entered into an industrialisation process reflect in the diversity prevailing among countries in terms of their objectives, priorities, limitations, directions, instrument and as well as in the overall performance of their science and technology policies (Björkman et al. 2007; Lemola 2002).

Science and technology policies stem from ideas around the deliberate integration of scientific knowledge and technological activities into the mesh of ongoing political, economic, military and social decisions. According to the traditional definition deployed broadly by the OECD (1963, 1971), scientific and technology policies constitute the collective measures taken by a government that, on the one hand, provide incentives for the development of scientific and technological research (a policy for science and technology) and, on the other hand, exploits the results of general political objectives (a policy through science and technology). The establishing of science and technology as national patrimony and the consequent direct intervention of government in the targets and scope of R&D activities represents a new and irreversible turning point in the relations between science and technology and the state (Salomon 1977).

There are various mechanisms through which the institutional convergence of national science and technology models may come about (DiMaggio and Powell 1983). The models may spread in either an explicit or unintentional fashion through the interactions of the persons engaged in the science and technology policy. The founding and growth of professional networks spanning organisations in the field in different countries may drive the formation of elites that, through means of interactions and cooperation, then define the appropriate models for their organisational and political structures. Convergence also results from the formal and informal pressures of supranational entities such as the OECD and the EU. Such pressures are not necessarily direct and explicit but rather more subtle and less explicit and derive from political influences and problems of legitimacy.

Government policies in support of innovation generally vary across the different technological fields. One important example is climate change policies that normally attempt both to support what get termed as clean energies, those that avoid greenhouse emissions, and to restrict those dirty technologies associated with polluting emissions (Dechezleprêtre et al. 2017).

In 2012, OECD member states spent over three billion euros in support of developing new clean technologies, such as renewable or hydrogen powered vehicles within the scope of mitigating climate change over the long term. However, many policy makers—very often in efforts to make climate change policies attractive to the public—suggest that this may also have a beneficial impact on economic results, such as short term growth and employment. Theoretically, this may only occur whenever the case that the clean technology innovation leads to a higher level of spillovers than the dirty technology undergoing substitution (Dechezleprêtre et al. 2017).

TTs from the government sector to industry have emerged as an important activity in both developed and developing countries to the extent that governments boost their financing for national innovation systems with the objective of developing technologies that improve and raise the prevailing level of national competitiveness (Tran et al. 2011). However, such efforts require best practices for the transfer of technology from state R&D installations to industry. The developed countries that embarked on this process over the last 2 decades did obtain some successes but other improvements remain necessary.

Lemola (2002) examines the development processes deployed by the Finnish science and technology policy to conclude that, rather than divergence, there is a surprising level of convergence between organisational forms and practices. In turn, Tran et al. (2011) discuss and compare the TT systems of the governments of the United States and of Vietnam in order to conclude that countries in different stages of development display different levels of institutional and legislative development as regards their TT policies.

According to Lemola (2002), the fundamental driver of a national science and technology policy is the search for competitive advantages for the respective country. The leading organisations implementing the science and technology policy compete with each other and seek to imitate the performance successes of others by replicating their organisational structures and practices in the struggle for resources, political power and institutional legitimacy and to adapt to the prevailing social and economic environment (DiMaggio and Powell 1983).

Lee and Tan (2006) approach the intensity of international TTs in selected ASEAN member economies through the importing of machinery and FDI. They correspondingly report that such transfer intensities vary substantially among these economies with Singapore leading among the four economies selected for study. The intensity of the FDI flows in the region intimately relate with the levels of TTs ongoing to the region. This also observes how the Asian financial crisis shifted the concentration of FDI flows in these countries. Walz and Marscheider-Weidemann (2011) also analyse the technological capacities across six fields of sustainable technology with indicators for innovation including publications, patents and trade in newly industrialising countries. They conclude by pointing to different patterns in the absorption capacity for environmental (green) technologies in these countries and identify a strong need for the strategic positioning of such countries and the coordination of the various participant political actors.

Puig et al. (2018) report evidence that there is a disconnection existing between the governments of developing countries and their understanding of the main drivers and barriers to TTs and how multilateral TT programs may provide, due to the budgetary restrictions prevailing and the logic of expenditure, a means of assistance for development. Their study conveys the well-established notion that rendering climate change mitigation actions an integral part of solid development plans holds particular relevance for TTs. These authors furthermore set out indicators for just how this might be done in practice, within the context of technological action development plans within the framework of processes for evaluating the technology needs now taking place under the auspices of the United Nations.

4 Methodology

4.1 Data

The data analysed encapsulates aggregate data at the national level collected from various different sources for the period between 1995 and 2015. Table 1 presents the 27 member states included in the study, corresponding to balanced panel data. The final sample consists of a set of balanced panel data containing 567 observations and 27 countries.

4.2 Measures

4.2.1 Dependent variable

As its dependent variable, this study deploys labor productivity (dividing Gross Domestic Product by the number of employees), a proxy variable for economic growth (Y).

4.2.2 Predictor variables

Institutional variables The institutional variables applied in this analysis were: exports of goods and services (EXP); Foreign direct investment (FDI), General government final consumption expenditure (GC); Gross fixed capital formation (K); Life expectancy at birth (LE); Government budget allocations for R&D (RD).

Patent variables/technology transfer In relation to the patents, we applied the following variables: total patents (PAT); ICT patents; environment-related technological patents.

In Table 2, we set out the variables, their respective bibliographic references and the hypotheses.

Table 1 Countries

European countries	
Austria	Lithuania
Belgium	Luxembourg
Czech Republic	Netherlands
Denmark	Norway
Estonia	Poland
Finland	Portugal
France	Slovak Republic
Germany	Slovenia
Greece	Spain
Hungary	Sweden
Ireland	Switzerland
Italy	United Kingdom
Latvia	
Oceania countries	
Australia	New Zealand

Table 2 Study variables

Variable	Authors	Hypotheses
Dependent		
Economic growth	Quinn (1997), GGDC (2009), Ouardighi (2011) and Chen and Quang (2014)	
Predictor variables		
Institutional		
Exports of goods and services (EXP)	Hensengerth (2015), Kirchherr and Matthews (2018), Saggi (2002) and Keller (2004)	H1
Foreign direct investment (FDI)		
General government final consumption expenditure (GC)		
Gross fixed capital formation (K)		
Life expectancy at birth (LE)		
Government budget allocations for R&D (RD)		
Technology transfer		
Total patents (PAT)	OECD (2009, 2018), Van Horne and Dutot (2017) and Karanikić et al. (2017)	H2
ICT patents; environment-related technological patents		

4.3 Description of the variables

In order to analyse the impact of the variables on economic growth, we applied the following Cobb–Douglas function:

$$Y_{it} = \alpha EXP_{it}^{\beta_1} FDI_{it}^{\beta_2} GC_{it}^{\beta_3} K_{it}^{\beta_4} LE_{it}^{\beta_5} RD_{it}^{\beta_6} PAT_{it}^{\beta_1}$$

The equation above is similar to that applied by Aparicio et al. (2016), which seeks to emphasise the impact of entrepreneurship on economic growth through taking into consideration the institutional factors. In order to linearize the production function, we deployed the natural logarithm for the variables depicting the institutional factors, as well as patents, interpreting the coefficients, such as their impacts, in terms of the percentile variations of the independent variables and the dependent variable. We also tested the scope for the existence of moderation effects (interactions) of the countries belonging to Oceania on the impact of the predictive variables on the dependent variable.

We carried out the estimates based on dynamic panel econometric methodologies with the objective of capturing the differences arising over the course of time (Bond 2002) in keeping with how patents might impact on economic growth in subsequent years (Romer 1986). We employed the two-step GMM estimators deploying moment conditions (Arellano and Bond 1991) in which one lagged the level of the dependent and two lagged the Patent variable levels.

Furthermore, we processed the data through STATA software version 14.0 (StataCorp LP, Texas, USA).

5 Results and discussion

5.1 Descriptive statistics

Table 3 presents the measures, standard deviations and correlation coefficients for the variables applied in this study. We may also observe that labor productivity, the proxy for economic growth, correlates significantly with the other variables.

Table 4 sets out the results returned by the different models estimated. The Arellano–Bond test specifies no problems relating to serial correlation ($p \geq 0.05$) and the Sargan test also accepts the validity of the instruments ($p \geq 0.05$).

As regards the results of these estimates, we may report that the institutional variables, Exports of goods and services, FDI, Gross fixed capital formation and Life expectancy at birth, hold a statistically significant positive effect on GDP per labor population, hence, on economic growth across all of the models. According to various authors, these variables serve for measuring the impact of institutional factors on economic growth (Alvarez and Urbano 2011; Aparicio et al. 2016; Audretsch and Keilbach 2004a, b, 2008; Bleaney and Nishiyama (2002, 2005). In addition, Karanikic´ et al. (. 2017) deploy GDP as an indicator for economic growth in arguing how this is an essential ingredient for a healthy economy following analysis of the influence of the number of patents granted in Europe on economic growth per field of technology.

Government budget allocations for R&D equally returns a statistically significant positive effect on GDP per labor population, thus on economic growth but only for the

Table 3 Descriptive statistics and correlation matrix

Variable	European countries			Oceania countries		
	N	Mean	SD	N	Mean	SD
Ln labor productivity	525	11.014	0.678	42	11.224	0.227
Ln exports of goods and services	525	25.505	1.314	42	25.171	0.838
Ln FDI, net inflows	525	21.483	5.415	42	19.436	8.149
Ln general government final consumption expenditure	525	24.739	1.465	42	24.900	1.021
Ln gross fixed capital formation	525	7.416	1.569	42	7.364	0.982
Ln life expectancy at birth, total	525	24.774	1.455	42	25.101	1.135
Ln government budget allocations for R&D	525	4.352	0.044	42	4.382	0.020
Ln total patents	525	5.820	2.179	42	6.438	0.908
Ln ICT patents	525	3.678	2.497	42	4.346	1.192
Ln environment-related technologies Patents	525	3.232	2.096	42	3.858	1.085

Variable	1	2	3	4	5	6
1. Ln labor productivity	1					
2. Ln exports of goods and services	0.6449*	1				
3. Ln FDI, net inflows	0.1016*	0.2367*	1			
4. Ln general government final consumption expenditure	0.4934*	0.9216*	0.2411*	1		
5. Ln gross fixed capital formation	0.6432*	0.9256*	0.2345*	0.9047*	1	
6. Ln life expectancy at birth, total	0.5128*	0.9308*	0.2446*	0.9837*	0.9089*	1
7. Ln government budget allocations for R&D	0.7990*	0.7272*	0.0661	0.6402*	0.6984*	0.6673*
8. Ln total patents	0.7385*	0.9040*	0.1778*	0.8474*	0.8762*	0.8562*
9. Ln ICT patents	0.7162*	0.8396*	0.1635*	0.7794*	0.8085*	0.7742*
10. Ln environment-related technologies patents	0.6998*	0.8933*	0.1481*	0.8480*	0.8675*	0.8428*

	7	8	9	10
7. Ln government budget allocations for R&D	1			
8. Ln total patents	0.7745*	1		
9. Ln ICT patents	0.7352*	0.9583*	1	
10. Ln environment-related technologies patents	0.7682*	0.9628*	0.9338*	1

*$p < 0.05$

countries of Oceania. This continental effect stems from how the variable "Government budget allocations for R&D (t) × Oceania" represents a statistically significant coefficient in the ICT patents and Environmental Patents models. We may also observe how the impact of the Gross fixed capital formation and Life expectancy at birth variables generates a positive impact on both continents while nevertheless reaching higher levels of labor productivity, therefore economic growth, in the countries of Oceania. Falk (2006) also concludes that the fiscal incentives for R&D return significant and positive impacts on the R&D expenditure of OECD member states irrespective of specification and estimation techniques. Falk (2006) further argues that governments may stimulate business R&D through

Table 4 Regression coefficients (SE)

	Total patents	Total patents	ICT patents	ICT patents	Environmental patents	Environmental patents
Ln labor productivity (t − 1)	0.36 (0.1)*	0.5 (0.09)*	0.23 (0.08)*	0.1 (0.13)	0.37 (0.09)*	0.15 (0.17)
Ln total patents (t)	0.00 (0.01)	− 0.02 (0.03)				
Ln total patents (t − 1)	0.01 (0.01)	0.01 (0.02)				
Ln total patents (t − 2)	0.02 (0.01)*	0.04 (0.02)*				
Ln total patents (t)		0.12 (0.26)				
Ln total patents (t − 1)		− 0.29 (0.27)				
Ln total patents (t − 2)		0.25 (0.36)				
Ln ICT patents (t)			0.01 (0.01)	0.00 (0.02)		
Ln ICT patents (t − 1)			0.01 (0.00)*	0.01 (0.01)		
Ln ICT patents (t − 2)			0.01 (0.00)*	0.01 (0.01)		
Ln ICT patents (t) × Oceania				− 0.04 (0.14)		
Ln ICT patents (t − 1) × Oceania				0.09 (0.08)		
Ln ICT patents (t − 2) × Oceania				0.01 (0.07)		
Ln environment-related technologies patents (t)					− 0.01 (0.01)	0.03 (0.02)
Ln environment-related technologies patents (t − 1)					0.00 (0.00)	0.01 (0.02)
Ln environment-related technologies patents (t − 2)					0.01 (0.01)	0.03 (0.01)*
Ln environment-related technologies patents (t) × Oceania						0.11 (0.10)
Ln Environment-related technologies Patents (t − 1) × Oceania						0.26 (0.19)
Ln Environment-related technologies Patents (t − 2) × Oceania						0.56 (0.23)*
Ln exports of goods and services (t)	0.17 (0.03)*	0.27 (0.06)*	0.19 (0.03)*	0.2 (0.04)*	0.17 (0.02)*	0.11 (0.04)*
Ln exports of goods and services (t) × Oceania		− 0.73 (0.60)		− 0.54 (0.55)		− 0.7 (0.56)
Ln FDI (t)	0.01 (0.00)*	0.00 (0.00)	0.01 (0.00)*	0.00 (0.00)	0.01 (0.00)*	0.01 (0.00)*
Ln FDI (t) × Oceania		0.00 (0.00)		0.00 (0.00)		0.00 (0.00)
Ln general government final consumption expenditure (t)	− 0.12 (0.09)	− 0.26 (0.16)	− 0.05 (0.07)	0.05 (0.16)	0.07 (0.08)	0.18 (0.27)

Table 4 (continued)

	Total patents	Total patents	ICT patents	ICT patents	Environmental patents	Environmental patents
Ln general government final consumption expenditure (t) × Oceania		1.78 (1.36)		1.48 (1.28)		4.13 (2.24)
Ln gross fixed capital formation (t)	0.19 (0.04)*	0.17 (0.05)*	0.18 (0.03)*	0.19 (0.06)*	0.14 (0.03)*	0.32 (0.08)*
Ln gross fixed capital formation (t) × Oceania		0.81 (0.62)		0.37 (0.5)		2.01 (0.73)*
Ln life expectancy at birth (t)	0.66 (0.23)*	0.66 (0.66)	1.00 (0.21)*	0.37 (0.42)	1.08 (0.25)*	2.11 (0.63)*
Ln life expectancy at birth (t) × Oceania		−0.16 (0.12)		−0.12 (0.14)		0.20 (0.43)*
Ln government budget allocations for R&D (t)	0.01 (0.03)	0.09 (0.13)	0.07 (0.05)	0.03 (0.35)	−0.05 (0.04)	0.02 (0.14)
Ln government budget allocations for R&D (t) × Oceania		0.99 (0.55)		0.15 (0.08)*		0.95 (0.46)*
Constant	3.81 (1.43)*	8.37 (3.34)*	5.13 (1.43)*	4.35 (2.35)	2.44 (1.28)	19.83 (10.01)*
Sagan test	16.46	15.64	12.65	7.97	18.20	4.09
Arellano–Bond tests[1]	0.080	0.227	0.610	0.325	0.071	0.425

*$p < 0.05$

[1]Lowest p value to zero autocorrelation in first-differenced errors AR(2)

direct measures, whether providing fiscal incentives or through means of direct financial support. This also refers to the role that the public sector might also play in acting as a complement to the private sector through cutting the research costs for industry. Carrying out research and publicly releasing the results represents one means of achieving this goal.

R&D investment ranks as one of the essential factors for fostering economic growth (Alam et al. 2018). Wang (2010) observed that countries with sufficient levels of R&D investment may attain growth, boosting productivity and deepening their knowledge base. According to Barge-Gil and López (2014), analysing the determinants of R&D holds particular importance. In addition to the Schumpeterian hypotheses and the inter-sectoral effects (Barge-Gil and López 2014) of the Resource Based View (Lai et al. 2015), Wang (2010) also affirms the role institutional factors may play in helping to explain R&D focused investments. Better institutional environments may stimulate R&D activities by endowing capacities on companies (Wu et al. 2016). In the same fashion, Srholec (2011) maintains that company attributes as well as institutional factors and the configurations within which companies operate account for important facets to their innovation performances (Alam et al. 2017; Wang et al. 2015).

Hence, we may confirm the first hypothesis (H1): *institutional factors generate positive impacts on economic growth*.

In terms of patents, this observes how the number of patents in a particular year returns statistically significant positive effects on labor productivity after a period of 2 years ($\beta = 0.02$; $p < 0.05$; $\beta = 0.04$; $p < 0.05$). In the model without any interactive effects, the number of ICT patents in 1 year returns a statistically significant positive effect on labor productivity in the following year ($\beta = 0.01$; $p < 0.05$) and after 2 years ($\beta = 0.01$; $p < 0.05$). In terms of environmental related patents, the model with interactive variables reports that they hold a statistically significant positive effect on labor productivity after a 2-year period ($\beta = 0.03$; $p < 0.05$) and that this impact is significantly higher in the countries of Oceania ($\beta = 0.56$; $p < 0.05$). Thus, innovation does generate a positive impact on economic growth. According to Varsakelis (2001), patent protection and other measures in defence of intellectual property rights creating temporary technological rights may therefore tend to raise the benefits accruing from R&D results. There would also seem to be a relationship between patent protection and innovation activities (Falk 2006).

The main objective of TTs involves building bridges between countries undergoing processes of obtaining technological competences according to long term plans for developing technologies and skills (Hoekman et al. 2004). Brey (2018) defines TTs as the flows of technology necessary to economic development from where they currently exist to where needs them. TTs may take place both vertically and horizontally; vertical transfers occur within companies while horizontal transfers take place from one industry or country to another industry or country (Appiah-Adu et al. 2016). Knowledge transfers may also be passive or active depending on the capacities and the willingness of the human resources of countries to incur the costs of TTs and innovation. Thus, countries may advance in their development more rapidly in keeping with their respective capacities, institutional barriers, and incentives in effect for TTs and in the field of technology through means of foreign direct investment, trade, licensing and joint ventures (UNCTAD 1999, 2014).

We may therefore confirm the second research hypothesis (H2): *TTs generate positive impacts on economic growth*.

6 Policy, theoretical and managerial implications

Our results encapsulate two important policy implications. Firstly, the fact that we prove how environmental patent TTs contribute towards economic growth serves to justify the need for greater subsidies for green innovations and specific R&D programs for clean technologies in addition to the implicit support for clean R&D through climate policies such as higher rates of carbon dioxide taxation. Radical and new clean technologies deserve greater state support than research activities designed to improve the existing dirty technologies.

However, justifications for such specific supports may equally stem from a series of other emerging areas, such as nanotechnologies and IT (Acemoglu et al. 2012; Hart 2008). While a first political scenario would suggest a combination of emissions pricing and R&D subsidies specifically targeting clean technologies, in terms of the tight budgets facing government, raising the level of subsidy necessary might prove challenging. There may also be concerns over the capacity of government to channel funding into those R&D projects with the greatest potential, whether due to asymmetries of information or due to political interference (Gerlagh et al. 2009; Hart 2008; Kverndokk and Rosendahl 2007). Secondly, our results support the idea that institutional factors contribute towards economic growth, induced by the Exports of goods and services, FDI, Gross fixed capital formation and Life expectancy at birth and Government budget allocations for R&D variables. Hence, institutional quality generates an absolute, stable and robust impact on economic growth, independently of the specific structure and weighting of the TTs and the means of measuring the stock of knowledge thereby conveyed.

This also makes another two important contributions to the literature on cross-continent TTs in terms of environmental patents. First, it contributes to the literature on institutional factors by indicating that the regional trading bloc of the European Union provides benefits in terms of promoting sustainable policies. We demonstrate in our analysis that climate change mitigation patents have an effect on the economic growth of both continents and this can be viewed as the result of entrepreneurial contexts emphasizing the importance of climate change. This enhances our knowledge of the interrelationships with government policy regarding such an important societal issue as climate change. This finding supports Vonortas (2018) who views the policy mix for TTs as involving both the R&D and the innovation domains. The R&D domain includes the generic and sectoral policy influenced by financial and industry linkages. The innovation domain encompasses competition, environmental, energy, defence, trade and consumer protection policies. This is important as both continents have policies designed around being innovative in the development of natural resources.

There are different managerial challenges associated with TTs that depend on the knowledge type and context involved as conveyed by the results of this study in demonstrating how, overall, the European-based environmental policy has been more successful in impacting on the level of patents and innovation. Van Horne and Dutot (2017) suggest there are four main difficulties with knowledge and TTs: the characteristics of the knowledge, the transfer source, the transfer recipient and the environmental context. Some knowledge becomes hard to transfer due to its unproven nature that makes it hard to understand. This means that managers need to focus on how environmental related knowledge that has an uncertain outcome but still amounts to innovation might be harnessed through TTs. The transfer source may also hinder the transfer whenever not having any need to exchange the knowledge.

Some transferees may have reputations for their unwillingness to share sensitive data due to business reasons, which managers need to try to mitigate with an emphasis on the environmental benefits of such TTs. The transfer recipient might not be able to understand how to utilize the knowledge because of a lack of resources, thus requiring the training and education of managers in both Europe and Oceania. Often organizations in geographically distant countries lack the capabilities for harnessing the potential of knowledge but a factor susceptible to mitigation through greater communication among managers. The environmental context may make it unstable in terms of the political conditions for transferring knowledge although managers may also mitigate this risk by emphasizing the increased economic growth rates resulting from environmental related patents.

7 Conclusions

The aim of this paper was to analyse the influences of the different institutions and environmental patent TTs on both continents while also verifying the impact of the differences on economic growth again on both continents. We may therefore conclude that, irrespective of the institutional and TT differences, they generate a positive impact on the economic growth of both continents.

Leveraging the economic growth theoretical frameworks, this study has added to the literature on institutional factors and TTs by examining the role of content based environmental patents. The successful exploitation of environmental patents is made possible by the innovative capabilities of countries in how they disseminate technological innovations. As an increased societal focus has stressed the need to develop innovations to alleviate climate change, this study has shown that policy initiatives, on both continents, have been successful in terms of TTs. Thus, this study has provided additional information on the importance of comparing the economic impact of environmental related TTs. In conclusion, a cross-continental perspective of environmental patents moves us closer to a deeper understanding of emerging TT trends.

There are some limitations to this study that pave the way for future research. First, we utilized OECD data to focus on two continents: Europe and Oceania. This means there is a unique focus on two different geographical regions in terms of environmental related patents but we do not evaluate other continents. This is not a limitation stemming only from this study as other cross-cultural studies display similar such limitations in terms of their geographical scope of inquiry. However, future studies might examine other parts of the world to see whether there is the same emphasis on environmental related TT. To the best of our knowledge, no other studies have focused on comparing Europe and Oceania environmental related TT, which means our study helps to bridge the gap in our understanding of cultural contexts.

Second, our study focused on environmental related patents using OECD panel data. Organizations that have higher levels of patents are better able to learn about how they can satisfy market needs using their internal capabilities (Teece 2010). Another interesting area for future research would be to utilize qualitative data in the form of in-depth interviews to provide some more information about the reasons why water related patents impact on economic growth.

Third, future research could examine the role of universities in facilitating environmental related TTs. There are interactions ongoing between universities, industry and business that affect the ability of countries to focus on environmental patents. Thus, future research might approach the application of multi-country comparative studies on the different policy factors influencing environmental related patents. Due to time and cost considerations in collecting data from multiple countries, our approach of comparing Europe and Oceania returns a holistic understanding of the major geographical areas but still requiring further research in order to continue to evaluate changing societal trends towards environmental issues.

Acknowledgements The authors would like to thank to NECE-Research Unit in Business Sciences funded by the Multiannual Funding Programme of R&D Centres of FCT-*Fundação para a Ciência e a Tecnologia,* under the Project UID/GES/04630/2019.

References

Acemoglu, D., Aghion, P., Bursztyn, L., & Hemous, D. (2012). The environment and directed technical change. *American Economic Review, 102*(1), 131–166.
Aghion, P., Dechezlepretre, A., Hemous, D., Martin, R., & Van Reenen, J. (2016). Carbon taxes, path dependency and directed technical change: Evidence from the auto industry. *Journal of Political Economy, 124*(1), 1–51.
Ahmed, A., & Suardi, S. (2007). Sources of economic growth and technology transfer in sub-saharan Africa. *South African Journal of Economics, 75*(82), 159–178.
Alam, A., Uddin, M., & Yazdifar, H. (2017). Financing behaviour of R&D investment in the emerging markets: The role of alliance and financial system. *R&D in Management*. https://doi.org/10.1111/radm.12303.
Alam, A., Uddin, M., & Yazdifar, H. (2018). Institutional determinants of R&D investment: Evidence from emerging markets. *Technological Forecasting and Social Change*. https://doi.org/10.1016/j.techfore.2018.08.007.
Alvarez, C., & Urbano, D. (2011). Environmental factors and entrepreneurial activity in Latin America. *Academia Revista Latinoamericana de Adminstración, 48,* 31–45.
Aminullah, A., Fizzanty, T., Kusnandar, K., & Wijayanti, R. (2013). Technology transfer through OFDI: The case of Indonesian natural resource-based MNEs. *Asian Journal of Technology Innovation, 21,* 104–118.
Aparicio, S., Urbano, D., & Audretsch, D. (2016). Institutional factors, opportunity entrepreneurship and economic growth: Panel data evidence. *Technological Forecasting and Social Change, 102,* 45–61.
Appiah-Adu, K., Okpattah, B., & Djokoto, J. (2016). Technology transfer, outsourcing, capability and performance: A comparison of foreign and local firms in Ghana. *Technology in Society, 47,* 31–39.
Archarya, R. C., & Keller, W. (2009). Technology transfer through imports. *Canadian Journal of Economics, 42*(4), 1411–1448.
Arellano, M., & Bond, S. (1991). Some tests of specification for panel data: Monte carlo evidence and an application to employment equations. *The Review of Economic Studies, 58*(2), 277.
Arimura, T., Hibiki, A., & Johnstone, N. (2007). An empirical study of environmental R&D: What encourages facilities to be environmentally-Innovative? In N. Johnstone (Ed.), *Corporate behaviour and environmental policy* (pp. 142–173). Cheltenham: Edward Elgar.
Audretsch, D., & Belitski, M. (2017). Entrepreneurial ecosystems in cities: Establishing the framework conditions. *Journal of Technology Transfer, 42,* 1030–1051.
Audretsch, D., & Keilbach, M. (2004a). Entrepreneurship capital and economic performance. *Regional Studies, 38*(8), 949–959.
Audretsch, D., & Keilbach, M. (2004b). Does entrepreneurship capital matter? *Entrepreneurship Theory and Practice, 28*(5), 419–429.
Audretsch, D., & Keilbach, M. (2008). Resolving the knowledge paradox: Knowledge-spillover entrepreneurship and economic growth. *Research Policy, 37*(10), 1697–1705.
Australian Government. (2015). Setting Australia's post-2020 target for greenhouse gas emissions. Issue paper, March 2015. https://www.dpmc.gov.au/sites/default/files/publications/Issues_Paper_greenhouse_gas_1.pdf. Accessed 12 Nov 2018.
Barbosa, N., & Faria, A. P. (2011). Innovation across Europe: How important are institutional differences? *Research Policy, 40,* 1157–1169.

Barge-Gil, A., & López, A. (2014). R&D determinants: Accounting for the differences between research and development. *Research Policy, 43*(9), 1634–1648.
Björkman, I., Stahl, G., & Vaara, E. (2007). Cultural differences and capability transfer in cross-border acquisitions: The mediating roles of capability complementarity, absorptive capacity, and social integration. *Journal of International Business Studies, 38,* 658–672.
Bleaney, M., & Nishiyama, A. (2002). Explaining growth: A contest between models. *Journal of Economic Growth, 7*(1), 43–56.
Bond, S. R. (2002). Dynamic panel data models: A guide to micro data methods and practice. *Portuguese Economic Journal, 1*(2), 141–162.
Bozeman, B. (2000). Technology transfer and public policy: A review of research and theory. *Research Policy, 29*(4), 627–655.
Bozeman, B., Rimes, H., & Youtie, J. (2015). The evolving state-of-the-art in technology transfer research: Revisiting the contingent effectiveness model. *Research Policy, 44,* 34–49.
Brey, P. (2018). The strategic role of technology in a good society. *Technology in Society, 52,* 39–45.
Chen, C., Link, A., & Oliver, Z. (2018). U.S. Federal laboratories and their research partners: A quantitative case study. *Scientometrics, 115*(1), 501–517.
Chen, J., & Quang, T. (2014). The impact of international financial integration on economic growth: New evidence on threshold effects. *Economic Modelling, 42,* 475–489.
Choi, Y. R., Yoshikawa, T., Zahra, S. A., & Han, B. H. (2014). Market-oriented institutional change and R&D investments: Do business groups enhance advantage? *Journal of World Business, 49,* 466–475.
Coe, D., & Helpman, E. (1995). International R&D Spillovers. *European Economic Review, 39,* 859–887.
Coe, D. T., Helpman, E., & Hoffmaister, A. W. (1997). North–south R&D spillovers. *Economic Journal, 107,* 134–149.
Cohen, W. M., & Levinthal, D. A. (1990). Absorptive capacity: A new perspective on learning and innovation. *Administrative Science Quarterly, 35,* 128–152.
Constantini, V., & Liberati, P. (2014). Technology transfer, institutions and development. *Technological Forecasting and Social Change, 88,* 26–48.
Danquah, M., Outtara, B., & Quartey, P. (2018). Technology transfer and national efficiency: Does absorptive capacity matter? *African Development Review, 30*(2), 162–174.
Daude, C., & Stein, E. (2007). The quality of institutions and foreign direct investment. *Economics and Politics, 19,* 317–344.
Dechezleprêtre, A., Martin, R., & Mohnen, M. (2017). Knowledge spillovers from clean and dirty technologies. Grantham Research Institute working series, paper no. 135.
DiMaggio, P., & Powell, W. (1983). The iron cage revisited: Institutional isomorphism and collective rationality in organizational fields. *American Sociological Review, 48,* 147–160.
Dowrick, S., & Nguyen, D. (1989). OECD comparative economic growth 1950–1985: Catch up and convergence. *American Economic Review, 79,* 1010–1030.
Engelbrecht, H. J. (1997). International R&D spillovers, human capital and productivity in OECD economies: An empirical investigation. *European Economic Review, 41,* 1479–1488.
Fabrizi, A., Guarini, G., & Meliciani, V. (2018). Green patents, regulatory policies and research network policies. *Research Policy, 47,* 1018–1031.
Fagerberg, J. (1994). Technology and international differences in growth rates. *Journal of Economic Literature, 32,* 1147–1175.
Fagerberg, J., Srholec, M., & Knell, M. (2007). The competitiveness of nations: Why some countries prosper while others fall behind. *World Development, 35,* 1595–1620.
Falk, M. (2006). What drives business Research and Development (R&D) intensity across Organisation for Economic Co-operation and Development (OECD) countries? *Applied Economics, 38*(5), 533–547.
Franco, C., Montresor, S., & Vittucci Marzetti, G. (2012). On indirect trade-related R&D spillovers: The "average propagation length" of foreign R&D. *Structural Change and Economic Dynamics, 22,* 227–237.
Gandenberger, C., Bodenheimer, M., Schleich, J., Orzanna, R., & Macht, L. (2016). Factors driving international technology transfer: Empirical insights from a CDM project survey. *Climate Policy, 16,* 1065–1084.
Gerlagh, R., Kverndokk, S., & Rosendahl, K. E. (2009). Optimal timing of climate change policy: Interaction between carbon taxes and innovation externalities. *Environmental and Resource Economics, 43*(3), 369–390.
GGDC. (2009). *The conference board total economy database, Groningen growth and development centre*. http://www.conference-board.org/economics. Accessed 12 Nov 2018.
Gholami, R., Lee, S. Y. T., & Heshmati, A. (2006). The causal relationship between information and communication technology and foreign direct investment. UNU-WIDER working paper, Helsinki.

Greiner, M. A., & Franza, R. M. (2003). Barriers and bridges for successful environmental technology transfer. *Journal of Technology Transfer, 43,* 522–544.
Hall, B. H., Jaffe, A. B., & Trajtenberg, M. (2005). Market value and patent citations. *The Rand Journal of Economics, 36*(1), 16–38.
Hart, R. (2008). The timing and balance of policies for CO_2 abatement when technological change is endogenous. *Journal of Environmental Economics and Management, 55,* 194–212.
Hemmert, M. (2004). The influence of institutional factors on the technology acquisition performance of high-tech firms: Survey results from Germany and Japan. *Research Policy, 33,* 1019–1039.
Hensengerth, O. (2015). Where is the power? Transnational networks, authority and the dispute over the Xayaburi dam on the Lower Mekong Mainstream. *Water International, 40,* 911–928.
Hoekman, B., Maskus, K., & Saggi, K. (2004). Transfer of technology to developing countries: Unilateral and multilateral policy options. University of Colorado, PEC2004-0003.
Howitt, P. (2000). Endogenous growth and cross-country income differences. *American Economic Review, 90,* 829–846.
Inkpen, A. C., & Tsang, E. (2005). Social capital, networks and knowledge transfer. *Academy of Management Review, 30,* 146–166.
Jaffe, A. B., Fogarty, M. S., & Banks, B. A. (1998). Evidence from patents and from patent citations on the impact of NASA and other federal labs on commercial innovation. *Journal of Industrial Economics, 46*(2), 183–205.
Jaffe, A. B., & Lerner, J. (2001). Reinventing public R&D: Patent policy and the commercialization of national laboratory technologies. *RAND Journal of Economics, 32*(1), 167–198.
Johnstone, N., & Labonne, J. (2006). Environmental policy, management and R&D. *OECD Economic Study, 42*(1), 169–203.
Karanikic´, P., Mladenovic´, I., Sokolov-Mladenovic´, S., & Alizamir, M. (2017). Prediction of economic growth by extreme learning approach based on science and technology transfer. *Quality & Quantity, 51,* 1395–1401.
Keller, W. (2004). International technology diffusion. *Journal of Economic Literature, 42*(3), 752–782.
Kirchherr, J., & Matthews, N. (2018). Technology transfer in the hydropower industry: An analysis of Chinese dam developers' undertakings in Europe and Latin America. *Energy Policy, 113,* 546–558.
Kirchherr, J., Matthews, N., Charles, J. J., & Walton, M. J. (2017). Learning it the hard way: Social safeguards norms in Chinese-led dam projects in Myanmar, Laos and Cambodia. *Energy Policy, 102,* 529–539.
Kverndokk, S., & Rosendahl, K. E. (2007). Climate policies and learning by doing: Impacts and timing of technology subsidies. *Resource and Energy Economics, 29*(1), 58–82.
Laeven, L. (2003). Does financial liberalization reduce financing constraints? *Financial Management, 32,* 5–34.
Lai, Y.-L., Lin, F.-J., & Lin, Y.-H. (2015). Factors affecting firms R&D investment decisions. *Journal of Business Research, 68,* 840–844.
Lanoie, P., Laurent Lucchetti, J., Johnstone, N., & Ambec, S. (2011). Environmental policy, innovation and performance: New insights on the porter hypothesis. *Journal of Economy and Management Strategy, 20*(3), 803–842.
Lee, C., Park, G., & Kang, J. (2018). The impact of convergence between science and technology on innovation. *Journal of Technology Transfer, 43,* 522–544.
Lee, H., & Tan, H. (2006). Technology transfer, FDI and economic growth in the ASEAN region. *Journal of the Asia Pacific Economy, 11*(4), 394–410.
Lemola, T. (2002). Convergence of national science and technology policies: The case of Finland. *Research Policy, 31*(8–9), 1481–1490.
Lerner, J. (1994). The importance of patent scope: An empirical analysis. *The Rand Journal of Economics, 25*(2), 319–333.
Link, A. N., Siegel, D. S., & Van Fleet, D. (2011). Public science and public innovation: Assessing the relationship between patenting at U.S. National Laboratories and the Bayh–Dole Act. *Research Policy, 40*(8), 1094–1099.
Loko, B., & Diouf, M. A. (2009). *Revisiting the determinants of productivity growth: What's new?*. Geneva: International Monetary Fund.
Lundvall, B. A. (1992). *National system of innovation: Towards a theory of innovation and interactive learning*. London: Pinter.
Madsen, J. (2007). Technology spillovers through trade and TFP convergence: 135 years of evidence for OECD countries. *Journal of International Economics, 72,* 464–480.
Malerba, F. (2006). Innovation and the evolution of industries. *Journal of Evolutionary Economy, 16,* 3–23.

Markusen, J. R., & Venables, A. (1999). Foreign direct investment as a catalyst for industrial development. *European Economic Review, 43,* 335–356.

Mayer, J. (2001). Technology diffusion, human capital and economic growth in developing countries. UNCTAD discussion papers no. 154, United Nations Conference on Trade and Development, Geneva, Switzerland.

Meyer, J. W., & Rowan, B. (1977). Institutionalized organizations: Formal structure as myth and ceremony. *American Journal of Sociology, 83,* 340–363.

Mohr, R. D. (2002). Technical change, external economies, and the porter hypothesis. *Journal of Environmental Economics and Management, 43*(1), 158–168.

Nelson, R. R. (1993). *National innovation systems: A comparative analysis*. Oxford: Oxford University Press.

Nelson, R., & Phelps, E. (1966). Investment in humans, technological diffusion, and economic growth. *American Economic Review, 56,* 65–75.

Niosi, J. (1999). Limited by design: R&D laboratories in the U.S. national innovation system. *Journal of Policy Analysis of Management, 18*(4), 717–719.

North, D. C. (1990). *Institutions, institutional change and economic performance*. Cambridge: Cambridge University Press.

North, D. C. (1991). Institutions. *Journal of Economic Perspectives, 5*(1), 97–112.

OECD. (1963). *Science and policies of the governments*. Paris: OECD.

OECD. (1971). *Science, growth and society, a new perspective*. Paris: OECD.

OECD. (2009). *OECD patent statistics manual*. Paris: OECD Publishing. https://doi.org/10.1787/9789264056442-en.

OECD. (2018). *The measurement of scientific, technological and innovation activities Oslo manual 2018 guidelines for collecting, reporting and using data on innovation*. Paris: OECD Publishing.

Ouardighi, J. (2011). Pro-development economic growth and international income mobility: Evidence worldwide. *International Economics, 128,* 77–96.

Pattit, J. M., Raj, S. P., & Wilemon, D. (2012). An institutional theory investigation of US technology development trends since the mid-19th century. *Research Policy, 41*(2), 306–318.

Pinkse, J., & Groot, K. (2015). Sustainable entrepreneurship and corporate political activity: Overcoming market barriers in the clean Energy sector. *Entrepreneurship Theory and Practice, 39*(3), 633–654.

Priem, R. L., & Butler, J. E. (2001). Is the resource-based theory a useful perspective for strategic management research? *Academy of Management Review, 26*(1), 22–40.

Puig, D., Haselip, J., & Bakhtiari, F. (2018). The mismatch between the in-country determinants of technology transfer, and the scope of technology transfer initiatives under the United Nations Framework Convention on Climate Change. *International Environment Agreements, 18,* 659–669.

Quinn, D. (1997). The correlates of change in international financial regulation. *American Political Science Review, 91,* 531–551.

Romer, P. M. (1986). Increasing returns and long-run growth. *Journal of Political Economy, 94*(5), 1002–1037.

Rosenzweig, S. (2017). The effects of diversified technology and country knowledge on the impact of technological innovation. *Journal of Technology Transfer, 42*(3), 564–584.

Saggi, K. (2002). Trade foreign direct investment, and international technology transfer: A survey. *The World Bank Research Observer, 17*(2), 191–235.

Salomon, J.-J. (1977). Science policy studies and the development of science policy. In I. Spiegel-Rösing & D. de Solla Price (Eds.), *Science, technology and society. a cross-disciplinary perspective* (pp. 43–70). London: Sage.

Salter, A. J., & Martin, B. R. (2001). The economic benefits of publicly funded basic research: A critical review. *Research Policy, 30*(3), 509–532.

Samet, K. (2014). Brain gain, technology transfer and economic growth: Case of Tunisia. *International Journal of Economic and Finance, 6*(9), 57–72.

Schmid, G. (2012). Technology transfer in the CDM: The role of host-country characteristics. *Climate Policy, 12*(6), 722–740.

Shih, H.-Y., & Chang, T.-L. S. (2009). International diffusion of embodied and disembodied technology: A network analysis approach. *Technological Forecasting and Social Change, 76,* 821–834.

Sigmund, S., Semrau, T., & Wegner, D. (2015). Networking ability and the financial performance of new ventures: Moderating effects of venture size, institutional environment, and their interaction. *Journal of Small Business Management, 53*(1), 266–283.

Solow, R. M. (1956). A contribution to the theory of economic growth. *Quarterly Journal of Economics, 70*(1), 65–94.

Solow, R. M. (2007). The last 50 years in growth theory and the next 10. *Oxford Review Economic Policy, 23*(1), 3–14.
Soto, H. D. (1989). *The other path: The invisible revolution in the Third World*. New York: Harper & Row.
Soto-Acosta, P., Popa, S., & Palacios-Marques, D. (2018). Social web knowledge sharing and innovation performance in knowledge-intensive manufacturing SMEs. *Journal of Technology Transfer, 42,* 425–440.
Srholec, M. (2011). A multilevel analysis of innovation in developing countries. *Industrial and Corporate Change, 20*(6), 1539–1569.
Stevens, A. J., Jensen, J. J., Wyller, K., Kilgore, P. C., Chatterjee, S., & Rohrbaugh, M. (2011). The role of public sector research in the discovery of drugs and vaccines. *The New England Journal of Medicine, 364*(6), 535–541.
Sucker, L. G. (1987). Institutional theories of organization. *Annual Reviews in Sociology, 13,* 443–464.
Swan, T. W. (1956). Economic growth and capital accumulation. *Economic Record, 32*(2), 334–361.
Tang, L., & Coveos, P. E. (2008). Embodied and disembodied R&D spillovers to developed and developing countries. *International Business Review, 17,* 546–558.
Teece, D. J. (2010). Business models, business strategy and innovation. *Long Range Planning, 43*(2), 172–194.
Teo, H. H., Wei, K. K., & Benbasat, I. (2003). Predicting intention to adopt interorganizational linkages: An institutional perspective. *MIS Quarterly, 27,* 19–49.
Trajtenberg, M. (1990). A penny for your quotes: Patent citations and the value of innovations. *The Rand Journal of Economics, 22*(1), 172–187.
Tran, T., Daim, T., & Kocaoglu, D. (2011). Comparison of technology transfer from government labs in the US and Vietnam. *Technology in Society, 33,* 84–93.
UNCTAD. (1999). Trade and development trade and development. In *United Nations conference on trade development*.
UNCTAD. (2014). Transfer of technology and knowledge sharing for development science, technology and innovation issues for developing countries. In *United Nations conference on trade development* (Vol. 71).
Urban, F., Nordensvard, J., Siciliano, G., & Li, B. (2015). Chinese overseas hydropower dams and social sustainability: The Bui dam in Ghana and the Kamchay dam in Cambodia. *Asia Pacific Policy Studies, 2,* 573–589.
Van Horne, C., & Dutot, V. (2017). Challenges in technology transfer: An actor perspective in a quadruple helix environment. *Journal of Technology Transfer, 42,* 285–301.
Varsakelis, N. C. (2001). The impact of patent protection, economic openness and national culture on R&D investment: A cross-country empirical investigation. *Research Policy, 30*(7), 1059–1068.
Varsakelis, N. C. (2006). Education, political institutions and innovation activity: A crosscountry empirical investigation. *Research Policy, 35,* 1083–1090.
Villani, E., Rasmussen, E., & Grimaldi, K. (2017). How intermediary organizations facilitate university-industry technology transfer: A proximity approach. *Technological Forecasting and Social Change, 114,* 86–102.
von Hippel, E. (1988). *The sources of innovation*. New York: Oxford University Press.
Vonortas, N. S. (2018). International perspectives on innovation: Introduction. *Journal of Technology Transfer, 43,* 259–262.
Waarden, F. V. (2001). Institutions and innovation: The legal environment of innovating firm. *Organization Studies, 22*(5), 765–795.
Walz, R., & Marscheider-Weidemann, F. (2011). Technology-specific absorptive capacities for green technologies in Newly Industrialising Countries. *International Journal of Technology and Globalisation, 5*(3/4), 212–229.
Wang, E. C. (2010). Determinants of R&D investment: The extreme-bounds analysis approach applied to 26 OECD countries. *Research Policy, 39,* 103–116.
Wang, C., Yi, J., Kafouros, M., & Yan, Y. (2015). Under what institutional conditions do business groups enhance innovation performance? *Journal of Business Research, 68,* 694–702.
Wooster, R. B., & Diebel, D. S. (2010). Productivity spillovers from foreign direct investment in developing countries: A meta-regression analysis. *Review of Development Economics, 14*(3), 640–655.
Wu, J., Wang, C., Hong, J., Piperopoulos, P., & Zhuo, S. (2016). Internationalization and innovation performance of emerging market enterprises: The role of host-country institutional development. *Journal of World Business, 51*(2), 251–263.
Yi, J., Wang, C., & Kafouros, M. (2013). The effects of innovative capabilities on exporting: Do institutional forces matter? *International Business Review, 22,* 392–406.

Yousafzai, S., Saeed, S., & Muffatto, M. (2015). Institutional theory and contextual embeddedness of women's entrepreneurial leadership: Evidence from 92 countries. *Journal of Small Business Management, 53*(3), 587–604.

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.