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RESEARCH ARTICLE

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Green growth versus economic growth: Do sustainable technology transfer and innovations lead to an imperfect choice?

Cristina I. Fernandes[1,2] | Pedro Mota Veiga[3,4] | João J.M. Ferreira[1] | Mathew Hughes[5]

[1]Department of Management and Economics and NECE Research Unit in Business Sciences, University of Beira Interior, Covilhã, Portugal

[2]Centre for Corporate Entrepreneurship and Innovation, Loughborough University, Loughborough, UK

[3]Higher School of Education, Polytechnic Institute of Viseu, Viseu, Portugal

[4]NECE Research Unit in Business Sciences, University of Beira Interior, Covilhã, Portugal

[5]School of Business and Economics and Centre for Corporate Entrepreneurship and Innovation, Loughborough University, Loughborough, UK

Correspondence
Mathew Hughes, School of Business and Economics and Centre for Corporate Entrepreneurship and Innovation, Loughborough University, Loughborough, Leicestershire LE11 3TU, UK.
Email: m.hughes2@lboro.ac.uk

Abstract

A concern with the mitigation of climate change cuts a transversal line across economic agents, epitomized by two contradictory viewpoints. Some defend that green growth can be achieved without harming economic growth; others argue that it is not possible to respect sustainability if intensive consumption of goods continues to foster economic growth. Our research aims to analyze the role that sustainable technology transfer and sustainable innovations play in green growth and ascertain the impact of green growth on economic growth. We use aggregated country-level data provided by the OECD, including national accounts, population, and environment statistics (including patents) between 1990 and 2013 for 32 countries, corresponding to an unbalanced panel of 591 observations. We estimate econometric models based on dynamic panel methodologies to capture differences that exist over time. The results show that sustainable technology transfer and sustainable innovation promote green growth, which in turn positively impacts economic growth. We contribute new insight to the green growth versus economic growth debate and provide several political and management implications.

KEYWORDS

climate change, economic growth, environmental policy, green growth, sustainable innovation, sustainable technology transfer

1 | INTRODUCTION

Contemporary business is characterized by one overwhelming fault line: the *contest* between green growth and economic growth. Green growth refers to the production and search for low emission green technologies to manufacture and supply cleaner and more environmentally friendly goods (Wiebe & Yamano, 2016). Green growth is a plausible strategy for saving energy and reducing carbon emissions (Guo, Qu, & Tseng, 2017) and is a widely accepted solution to control the environment's deterioration (Sandberg, Klockars, & Wil, 2019). Historically, economic growth has relied on a substantial consumption of natural resources in ways increasingly recognized to be unsustainable. For example, Beckerman (1992) questioned whether the concept of sustainable growth is either morally indefensible or totally non-operational. Roca, Padilla, Farré, and Galletto (2001) argue that the relationship between income level and diverse types of emissions depends on many factors. Tabrizian (2019) posits that understanding the reasons for the slow diffusion of renewable energy technologies in developing countries requires an examination through the lens of the innovation (eco)system. The innovation ecosystem accounts for the socioeconomic factors that shape the capability for innovation in each specific country. Tabrizian (2019) identifies a meaningful link between innovation systems and the problem of poverty and inequality through a well-researched and planned innovation system. Therefore, it cannot be thought that economic growth, by itself, will solve environmental problems, and the pursuit of green growth is depicted as being at odds with optimizing economic growth.

This fault line raises a theoretical and empirical paradox that requires urgent attention. As the United Nations Environment Program (UNEP) argues, green growth depends on technological and market innovations, in particular, to improve production efficiency and, therefore, distinguishes the consumption of natural resources and the environmental impacts of unlimited economic growth (UNEP, 2011). Ecological technology holds the potential to become an effective method to encourage green *and* economic growth by implementing cleaner technologies capable of significantly reducing carbon emissions (Khan & Ulucak, 2020; Sohag, Taşkın, & Nasir, 2019; Yin, Zheng, & Chen, 2015). Consequently, *scholars must understand whether and under what conditions green growth can drive economic growth*.

Most prior research on technology transfer and innovation has focused on national settings without accounting for international comparisons (Audretsch & Belitski, 2017). Innovation is a primary means for enhancing technology transfer efficiency and bringing knowledge spillovers to surrounding industries (Danquah, Ouattara, & Quartey, 2018). Countries with a reputation for being innovative are considered better places to conduct technology transfer (Soto-Acosta, Popa, & Palacios-Marques, 2018).

To improve a country's position, in the global marketplace then, it needs to be seen as innovative *and* willing to adapt its market resources to respond to societal needs (Rosenzweig, 2017). The concept of green growth is not a new phenomenon since it was outlined in the early 1970s, but it has gained far greater attention since 2009. On this date, international organizations raised an alert and appealed to all international donors to make their economies sustainable through policies, reduce carbon investment, and look for new ways to mix renewable energy in their portfolios (IDS, 2013). After Europe and North America, the BRICS countries (Brazil, Russia, India, China, and South Africa), especially India and China, have taken a step toward green growth and the reduction of greenhouse gas emissions (IDS, 2014). Indeed, research into sustainable innovation is a cornerstone of the Europe 2020 Strategy, which identifies smart, sustainable, and inclusive growth solutions to help the European Union develop a more efficient, greener and more competitive economy. Doing so can support high levels of employment, productivity, and social cohesion. Sustainable development is also a priority for Member States of the European Union (http://ec.europa.eu/programmes/horizon2020/en/area/environment-climate-action), each of whom are progressively adopting market and non-market regulations for environmental policy (Fabrizi, Guarini, & Meliciani, 2018). Global economic growth has increased the scarcity of resources, forcing countries to shift their focus to sustainable development. Accordingly, our research question is: *is it possible to achieve economic growth through sustainable technological transfers and sustainable innovations?*

Growing green awareness has encouraged many countries to establish a green economic growth infrastructure for resources and environmental protection, especially in energy transformation (Acemoglu, Akcigit, Hanley, & Kerr, 2016; Khan & Ulucak, 2020; Song, Zhou, & Jia, 2019). Therefore, green technological innovation, the use of renewable and non-renewable energy, for example, is essential to realize pathways to green growth. These actions rely on the assumption that environmental technologies drive green *and* economic growth *consistently* at the *county* level. While firms bear the brunt of innovating and forming innovations that feed customers and markets (Gali et al., 2020; Rahman, Aziz, & Hughes, 2020), coordination at the country level is necessary to bring about more substantial economic effects. However, we know little about the role of environmental technologies in green growth in a broad spectrum to enable governments to specify policies and make decisions in line with this global imperative (see Song et al., 2019). This literature gap means we have yet to ascertain what changes are necessary to achieve green growth in ways that enable economic growth. In this context, our research objective is to theorize and analyze the role that sustainable technology transfer and sustainable innovations play in green growth and ascertain the impact of green growth on economic growth.

We contribute to the literature in three crucial and urgent ways. First, despite several kinds of research on models of technology transfer, sustainable innovation, and green growth, few studies have focused on the nature and role of sustainable technology transfer and sustainable innovation in green growth *and* economic growth. This article complements and takes a step to fill this gap in the literature and provide a comprehensive body of evidence about the relationship between sustainable technology transfer and innovations on economic growth and whether green growth matters to this nomological network.

Second, we reach beyond the neoclassical growth model in considering sustainable technology transfer and sustainable innovation as feasible explanations for economic growth. Extant studies in both areas are fragmented and model the two separately, a problem further exacerbated by single-country studies. Moreover, the majority of studies evaluating sustainable technology transfer policies rely on qualitative research and are broadly, even if not exclusively, oriented towards the United States (Bozeman, Rimes, & Youtie, 2015; Chen, Link, & Oliver, 2018; Jaffe, Fogarty, & Banks, 1988; Jaffe & Lerner, 2001; Link, Siegel, & Van Fleet, 2011; Stevens et al., 2011). The literature on economic growth by comparison spans endogenous factors, the factors of production, capital, and labor (Romer, 1986; Solow, 1956, 2007; Swan, 1956). To this end, we employed the two-step GMM estimators deploying moment conditions (Arellano & Bond, 1991) in which one model lagged the level of the dependent and one lagged the Sustainable Technology Transfer and Sustainable Patents variables. The methods applied to empirically test the different direct and mediating relationships between the variables studied are innovative in that, among previous studies, these variables were studied in a fragmented way and modelled separately. Our estimation is based on a dynamic panel econometric methodologies to capture differences existing over time (Bond, 2002; Ferreira, Fernandes, & Ratten, 2019).

For our third contribution, we use country-level aggregated data provided by the OECD (https://stats.oecd.org/), in the form of national accounts, population, and environment statistics (including patents) between 1990 and 2013 for 32 countries, corresponding to an unbalanced panel of 591 observations, to enrich knowledge on green and economic growth. Our results allow us to conclude that economic growth can be achieved with more sustainable use of resources. Also, green growth has a mediating effect on the relationship between sustainable technology transfer and sustainable innovation on economic growth. We conclude that it is *through* green growth that both sustainable technology transfer and sustainable innovation positively influence economic growth. Sustainable innovations and using sustainable technologies contribute to countries' green growth. Thus they do not harm the environment and instead enable the economy to grow sustainably.

2 | LITERATURE REVIEW AND HYPOTHESES

We begin with a brief approach to economic growth theories. Thereafter, we discuss sustainable technology transfer and green growth, then sustainable innovation and green growth, and finally green growth and economic growth.

2.1 | Economic growth theories

Schumpeter (1934) presented the cornerstone concept, known in the economic literature as "creative destruction." The emergence of new inventions is a common event in an economy; however, the development of this creatively destructive process is rarely harmonious. For Schumpeter, the new is not born from the old, but appears next to it and eliminates it through competition (Schumpeter, 1934).

Later, Solow's (1956) work became a reference point in the literature on economic growth. Solow concludes that the growth rate of the product per capita of an economy, once the long-term equilibrium (steady-state) is reached, will only be sustainable if technical progress occurs in the economy. Labelled as an exogenous growth model, the Solow model is open to criticism for not explaining the technological transformation process's intrinsic nature. In this way, there is room for effective State actions through the formulation of public policies. These, combined with the actions of private economic agents, can decisively influence the long-term growth of an economy.

However, this neoclassical approach to absolute convergence has not explained the increasing asymmetry between economies, except for the case of a group of economies with a similar structure. The unsatisfactory results of absolute convergence gave rise to a new concept of convergence, known as conditional convergence, developed by theories of endogenous growth (Barro, 1991; Sala-i-Martin, 1994).

In this way, human capital emerges as a theoretical basis for developing endogenous growth models, making the role of human capital the central assumption of endogenous growth models (Lucas, 1988; Romer, 1990). Based on Schumpeter's considerations, Aghion and Howitt (1998) defended a model in which there is the perfect competition for innovations, which can yield to the successful innovator the monopoly of the intermediate good of the economy and destroy the monopoly of the previous innovator.

The interval between two innovations is stochastically given by a function of the work employed in the innovation sector. In this model, it is possible to sustain a sustainable growth rate, as in the endogenous growth models. In 2007, Audretsch (2007) showed how and why Solow's growth accounting framework is useful for linking entrepreneurship capital to economic growth. The knowledge filter prevents the spread of knowledge for commercialization, thus weakening the impact of investments in knowledge on economic growth.

In serving as a channel for knowledge spillovers then, entrepreneurship is the missing link between investments in new knowledge and economic growth. Entrepreneurship is an important mechanism that permeates the knowledge filter to facilitate knowledge spillovers and, ultimately, generate economic growth. Thus, the emergence of an entrepreneurship policy to promote economic growth is interpreted as an attempt to promote capital for entrepreneurship, or the ability of an economy to generate the start-up and growth of new companies.

Concurrently, then, the introduction of entrepreneurship as a crucial rent-generating mechanism underpins a considerable amount of economic growth. To this point, the incentive has consistently been profit, reinvested into driving yet more economic growth. The contemporary world has gained and suffered because of these effects, as the push for economic growth has led to evermore, increasingly unsustainable resource consumption and environmental damage. At this juncture, the question becomes whether the shift to sustainable technologies, green innovations and green growth priority is incompatible with economic growth ambitions (e.g., Beckerman, 1992; Tabrizian, 2019).

2.2 | Sustainable technology transfer and green growth

Recently, green growth has received significant attention from several researchers and international organizations (Geddes, Schmidt, & Steffen, 2018; Guo et al., 2020; Mazzucato & Penna, 2016; WIPO, 2019) as the global search for economic success often leads to (and historically has led to) environmental degradation. To reduce the potential risk of climate change for humans, growth in environmental requirements must be associated with an investment in green technologies (Lin & Zhu, 2019).

For Guo et al. (2020), sustainable technology transfer, initially referred to in the literature as "environmentally sound technology," must play a crucial role in conquering sustainable development goals at the global and local market levels. These goals should mitigate the negative consequences of the traditional economic development model and improve living standards (Ishak, Jamaludin, & Abu, 2017; UNCTAD, 2018). Understanding sustainable technology transfer has shifted the focus onto pollution control and resource conservation (Hansen, Li, & Svarverud, 2018) towards integrated sustainable solutions that consider the environment, the economy, and society together (UNCTAD, 2018). This has led countries to invest in infrastructure supporting sustainable technology development and its transfer, such as the Clean Energy Finance Corporation (Austria), Green Investment Bank (United Kingdom), National Bank for Economic and Social Development (Brazil), and Green Technology Bank (China) (Geddes, Schmidt, & Steffen, 2018; Guo et al., 2020; Mazzucato & Penna, 2016), in addition to the 12 green investment banks announced by the OECD (2017a, 2017b). However, the development and adoption of sustainable technology transfer still face political (Yoshino, Taghizadeh-Hesary, & Nakahigashi, 2019), market (Agyemang, Zhu, Adzanyo, Antarciuc, & Zhao, 2018), knowledge and awareness (Liao & Shi, 2018), and financial barriers (Bhandari, Singh, & Garg, 2019). The crux of this is a lack of evidence about whether the investment pays dividends in green growth that is itself economically rewarding.

Divergent opinions exist on whether green growth is a panacea for the challenges humanity faces because of climate change and environmental and natural resource vulnerabilities (Pullanikkatil, Mubako, & Munthali, 2014). First, broad international consensus views the green economy as a route to poverty reduction and sustainable development (Burkolter & Perch, 2014; Faccer, Nahman, & Audouin, 2014; UNEP, 2011), and multilateral institutions such as UNEP and the International Labour Organisation (ILO) have been credited with universalizing the concept (Faccer, Nahman, & Audouin, 2014). Theoretically, those countries investing in sustainable technology transfer should witness a general rise in the standard of green technologies across its economy. For example, the greater diffusion of patented environment-related technologies and greater co-invention of environment-related technology with foreign inventors are indicative of environmentally productive entrepreneurship. Diffusion of these new technologies through transfer practices then creates the opportunity to cascade these technologies into business practices while encouraging further development and transfer of sustainable technologies. In sum, green growth by way of greater productive use of natural resources with fewer undesirable by-products should then be achieved.

Conversely, critics contend that: (i) the concept is merely a re-emerging issue in the policy debate that does not account for political, economic and cultural constraints in trying to meet environmental and poverty reduction goals; (ii) the valuation of ecosystem services in monetary terms will result in the control and privatization of natural resources by a handful of powerful actors with financial capital, who will unduly influence governments to the detriment of the rest of society's poor and vulnerable groups (IPACC et al., 2011; Lorek & Spangenberg, 2014). Theoretically then, control over protected sustainable technologies may result in unequal or little green growth. In addition, a strong push for sustainable technology transfer may generate entrepreneurship for its own sake without a nationally coordinated or coherent strategy to tackle the specific (rather than board) needs of various groups. In such case, green growth may under impress despite efforts to increase sustainable technology transfer nationally.

Balancing these theoretical discussions, we predict that sustainable technology transfer will legitimate and increase both investment and use of sustainable technologies in a nation, leading to increases in green growth as more efficient and clean use of natural resources occur and negative by-products recede. Therefore, we offer our first hypothesis:

H1. Sustainable technology transfer has a positive impact on green growth.

Several studies report a general positive effect from sustainable technology transfer on economic growth (Ferreira, Fernandes, & Ferreira, 2020; Ferreira, Fernandes, & Ratten, 2019). However, the relationship between sustainable technology transfer and economic growth is long-linked, increasingly the likelihood that a complete causal explanation relies on intermediate factors. The causal mechanism behind why and how sustainable technology transfer may increase economic growth, or not, is largely missing.

Green growth focuses on the production and consumption of green goods and services (Gotschol, De Giovanni, Esposit, & Vinzi, 2014; Luukkanen et al., 2019) through the invention of green technologies and the use of clean energy. Therefore, sustainable technology transfer deals with emissions based on production and demand, seen as the main driving force of industrial evolution (Yao, Di, Zheng, & Xu, 2018). Designing, developing, and executing clean technologies can improve companies' sustainability (Bhupendra & Sangle, 2015; Mensah et al., 2019). Based on the natural-resource-based view of the firm (Hart, 1995), competitive advantage accrues to those firms that best manage their relationship to the natural environment, providing an economic incentive to seek, develop and support the transfer of sustainable technologies within a country.

In this sense, Bagatin, Kleme, Reverberi, and Huisingh (2014) argue that not all types of innovations are desirable as some technologies can have disastrous impacts on the environment. Sustainable technologies as something that companies and entrepreneurs can collectively develop and build capacities to encourage environmental improvements (Koops, Oosterlaken, Romijn, Swierstra, & van den Hoven, 2015; Owen, Bessant, & Heintz, 2013) and socially desirable results (Voegtlin & Scherer, 2017). The accumulation of technological capabilities increases countries' ability to mitigate climate change, not only as users of low-carbon technology but also as innovative producers (Bell, 2012; Ockwell, Mallet, & Urban, 2013). The alternative option to import and install sustainable technology is quick solution that adds little to the learning of countries in creating sustainable innovations.

Creatively starting the underlying technology helps a country to master and adapt to the processes involved in sustainable development and consequently, boost economic growth *through* the green growth that occurs in-between. Thus, the technology transfer begins with the development of technologies and progresses through its dissemination and implementation (Global Mobility Report, 2017). Thus, the effective transfer of sustainable technologies requires an understanding of the knowledge, projects and production systems that enable modifications and greater innovations (Ockwell, Watson, MacKerron, Pal, & Yamin, 2008). The ultimate use of sustainable technologies is by business and organizations, for whom the incentive to do so is an economic advantage (natural-resource-based view) and returns to firm performance (Rahman, Aziz, & Hughes, 2020) but indirectly through improved environmental and social performance too, for example (Gali et al., 2020). Therefore, we predict the effectiveness of a country in achieving green growth by enabling the superior transfer of sustainable technologies to be the gateway to economic growth.

We hypothesize that green growth acts as an intermediate mechanism through which the transfer of sustainable technologies enhances economic growth:

H2. Green growth mediates the effect of sustainable technology transfer on economic growth.

2.3 | Sustainable innovation and green growth

It was with Solow (1956) that the study of the innovation-growth linkage began. Solow explained the long-term relationship between economic growth and innovation and the vital role that innovation plays in economic growth. Since then, several authors have supported this view with empirical evidence (e.g., Bayarçelik & Taşel, 2012; Ferreira, Fernandes, & Ratten, 2019; Ferreira, Fernandes, & Ferreira, 2020; Freeman, 2002; Grossman & Helpman, 1993; Hasan & Tucci, 2010; Segerstrom, 1991; Wong, Ho, & Autio, 2005). Teece (1986) defended the approach of profiting from innovation (PFI). For Teece, this ability stems from the characteristics of the appropriability regime: environmental factors, excluding the company and the market structure, which govern the ability to capture the profits generated by a given innovation.

Among environmental factors, Teece emphasized the legal mechanisms that protect an invention, particularly patents that address problems arising from knowledge externalities. Considering that the inventor bears the costs of developing new technology, the knowledge generated is freely available to all competitors once the new technology is revealed. Legal mechanisms protect innovation and reward the innovator but introduce a degree of jeopardy insofar as new inventors can innovate around patents.

According to PFI theory, the more legal mechanisms protect inventions from being copied, the more inventors profit from their inventions (Teece, 1986). However, although the externalities of knowledge are indisputable, Malen and Marcus (2017) call our attention to environmental externalities. When companies pollute, the resulting environmental damage is usually borne by society at large rather than the company itself. That is, pollution is a negative externality. In this sense, technologies that reduce pollution are differentiated from other technologies. In mitigating negative effects on the environment, green innovations explicitly create benefits for society for which companies pay the development costs. Theoretically then, the presence of environmental externalities means that at least part of the value created through the PFI reverts to society, thus limiting the incentives that companies have to invest and develop the PFI (Jaffe, Newell, & Stavins, 2005). Just as governments can, by implementing effective legal mechanisms, mitigate the deterrent effect of positive knowledge externalities in the development of new technologies, governments can create actions that mitigate the deterrent effect of negative environmental externalities on efforts to reduce pollution (Marcus, 1980; Sharfman, Shaft, & Tihanyi, 2004). The larger the quantity of patented sustainable innovations related to the environment (e.g., environmental management and water-related adaptation) and proportion of environmental patents related to climate change mitigation, the greater the countermeasures available to reward an innovator for their sustainable innovations (e.g., see countermeasures agreed in the United Nations Framework Convention on Climate Change, UNFCCC, 2015). We expect this will directly encourage green growth.

We also expect a growing quantity of sustainable innovations will attract new innovators keen to accrue rents, further supporting green growth. For instance, new market opportunities and jobs are created due to increased demand for low-carbon and other environmental technologies.

Sustainable innovations are a means by which firms develop new capabilities at pollution prevention, product stewardship, and sustainable development in ways that minimize or substantially reduce the environmental burden of firm growth (Hart, 1995). Aggregated to a country level then, those countries with a more considerable stock of sustainable innovations are more likely to generate green growth. Thus:

H3. Sustainable innovation has a positive impact on green growth.

It is essential that entrepreneurs are aware of environmental dilemmas and integrate sustainable, green innovations to respond to current ecological concerns (Amara & Chen, 2020). In the same vein, the extent to which a country profits economically from sustainable innovation relies on whether its government sufficiently implement environmental regulations, instruments and policies to protect and increase sustainable innovations to minimize the degradation of natural resources.

According to Guoyou, Saixing, Chiming, Haitao, and Hailiang (2013), the management of sustainable innovations becomes an essential tool for entrepreneurs and the government to achieve significant results in protecting the environment and improving environmental sustainability. The lack of awareness among entrepreneurs on how to protect the environment is associated with the government's attempts to increase economic benefits first and foremost as a route to poverty reduction. The irony is a concurrent ecological degradation because the wrong mechanism is emphasized. So far, it has been difficult to achieve a win-win solution for poverty alleviation and protection of the environment, as policymakers have not been able to implement appropriate instruments and regulations to coordinate the interests of various stakeholders (Amara & Chen, 2020). We argue that the countries that best increase economic growth from sustained innovations are the ones that can first channel and optimize green growth as an intervening, intermediate mechanism, Fankhaeser, Sehlleier, and Stern (2008) found that some positive impacts of efforts to alleviate climate change are job creation, innovation, and economic growth. However, Horbach, Oltra, and Belin (2013) show that product green oriented innovations do not generate jobs (with a direct impact on economic growth), but process green innovations do, especially for green process innovations that lead to material and energy savings. By contrast, Rennings, Ziegler, and Zwick (2004) found that green product innovations do positively affect the likelihood of increased employment and consequently economic growth. Thus, a link exists between sustainable innovations and employment, which is stronger for companies that voluntarily introduce these innovations (Kunapatarawong & Martínez-Ros, 2016). But the inconsistent evidence among studies to date clearly denote that intermediate factors are at play. We predict the efficacy of the country at achieving green growth to represent this intervening mechanism.

The relationships between the three constructs of sustainable innovation, economic growth, and green growth are complex (Dritsaki & Dritsaki, 2014; Soytas & Sari, 2009; Su & Moaniba, 2017). However, customers and consumers are responding to a narrative that channels collective pressures from stakeholders onto firms to invest in environmental policies and innovations, and markets are adjusting to reward those firms that do so as a result (Rahman, Aziz, & Hughes, 2020). Higher levels of sustainable innovation suggest that a country experiences a closer relationship between its economic agents (e.g., firms) and their various stakeholders. Sustainable innovations intended for green growth would then be expected to increase economic growth as the signals sent by green growth and growing environmental concern amplifies among customers and consumers, channeling responses among firms. Greater amounts of green innovation should increase green growth and generate a cascade of changes in demand, employment, and natural resource efficiencies that ultimate support economic growth. Therefore, we hypothesize the following:

H4. Green growth mediates the effect of sustainable innovation on economic growth.

2.4 | Green growth and economic growth

Green growth is suggested as a key element in sustainable development: on the one hand, it protects the environment, while on the other hand, it allows for economic growth. This is undoubtedly a feature that makes the concept more and more attractive to politicians and other decision-makers, as traditional approaches to environmental protection argued that this protection would lead to an economic slowdown.

In countries around the world, governments have increasingly adopted the green growth discourse to underline and promote their ambition for clean(er) economies. The central principle of this narrative is that of economic opportunities rather than challenges arising from the search for environmental sustainability (Capasso, Hansen, Heiberg, Klitkou, & Steen, 2019). Indeed, the OECD (2011) defines green growth as promoting growth and economic development while ensuring that natural assets continue to provide the environmental resources and services on which it depends our well-being, a notion consistent with the natural-resource-based view.

Several investigations evidence the idea that non-green growth driven by most human activity, and particularly the consumption levels of the higher income classes, degrades the environment (IPCC, 2014; Ripple et al., 2017; Steffen et al., 2015; WWF, 2016). The most widely accepted solution to prevent environmental degradation is green growth (Sandberg, Klockars, & Wil, 2019). Green growth decouples the use of natural resources and environmental impacts from the continuation of economic growth (Ward et al., 2016; Wiedmann et al., 2015). Ironically though, initiatives such as the Paris Agreement and the United Nations Sustainable Development Goals *presuppose* the existence of continuous economic growth (Alexander, 2015; Hickel, 2017). It is readily apparent that continuous economic growth will not contribute to the sustainable use of natural resources. Causally then, economic growth cannot drive green growth, but the converse can. Green growth brings about structural changes in the organization and behavior of business and society, including substantial reductions in the levels of unsustainable production and consumption in developed countries (D'Alisa, Demaria, & Kallis, 2015; Jackson, 2016; Ripple et al., 2017).

When little room to slow down private demand exists, government efforts to channel technological progress and investment towards green growth and avoid investments funds being channeled to brown technologies for short-term returns become essential (Capasso, Hansen, Heiberg, Klitkou, & Steen, 2019). An emphasis on and commensurate set of policies for green growth can then rectify for areas of the economy where markets do not function automatically with concern for the environment (Capasso, Hansen, Heiberg, Klitkou, & Steen, 2019). Green growth can help economies to overcome these and other needs sustainably, respecting the environment and achieving economic growth by renewing fading industries or transitioning to new areas of (green) industrial growth (e.g., Perez, 2015). Thus, policies for green growth are the basis of a new technological revolution and industrial leadership in emerging green industries that, in theory at least, should enable new forms of long-term growth (Stern, 2011) and new paid jobs (Bowen & Fankhauser, 2011; Jacobs, 2013; Jänicke, 2012).

Therefore, we predict that green growth promotes economic growth by catalyzing investments and innovations that will maintain sustainable development and give rise to new opportunities for economic growth (Jakob & Edenhofer, 2014):

H5. Green growth has a positive direct impact on economic growth.

Figure 1 presents our conceptual research model.

3 | METHODOLOGY

3.1 | Data

This research used country-level aggregated data provided by the OECD (https://stats.oecd.org/), specifically, national accounts and population and environment statistics (including patents) between 1990 and 2013 for 32 countries, corresponding to an unbalanced panel of 591 observations. We used the data available at the beginning of the year 2020. Appendix A shows the countries and years used in the present study.

3.2 | Measures

3.2.1 | Dependent variables

This study included Environmentally Adjusted Multifactor Productivity (EAMFP) and the real growth in gross domestic product (GDP_GR) as dependent variables. The EAMFP measures a country's ability to produce more income than in the past from a given set of inputs (including domestic natural resources), also counting undesirable by-products, such as pollution). The EAMFP makes the connection between "growth" and "green" and produce a measure of economic and environmental performance (Cárdenas Rodríguez, Haščič, & Souchier, 2018). The growth in GDP measured economic growth.

3.2.2 | Independent variables

Sustainable technology transfer

We use the Technology Diffusion (TD) variable, corresponding to an invention count indicator, per million inhabitants, for whom patent protection of environment-related technologies was requested in a given jurisdiction, the enforcement authority (national or regional), and the year of application (OECD, 2011). Another variable used alluding to technology transfer was International Collaboration in Technology Development (ICTD), referring to the percentage of co-invention technology, related to the environment, developed within the country in cooperation with foreign inventors.

Sustainable innovation

Variables referring to sustainable innovation used in this investigation were the number of patents related to the environment (PAT), including environmental management, water-related adaptation, and climate change mitigation technologies, including only higher value inventions (with patent family = 2). We also included the proportion of environmental patents related to climate change mitigation (CLI_CHA).

Control variables

The control variables used in the analysis include GDP per capita (in thousands of dollars and constant 2010 prices) (GDP_PC), the total population (POP), and the Gross fixed capital formation (GFCF). We also used a dummy variable associated with the financial crisis between 2008 and 2013 (CRI).

3.3 | Data analysis and empirical strategy

To analyze the impact of variables on green growth and economic growth, we estimate the models based on dynamic panel econometric methodologies to capture the differences that exist over time (Bond, 2002), namely, the impact of patents on economic growth in subsequent years (Ferreira, Fernandes, & Ratten, 2019; Romer, 1986). Following Barro (1991), we adopt major macroeconomic environment variables as the control variables. These comprise the gross fixed capital formation (GFCF), population (POP), real GDP per capita, and the years of economic crisis. The estimated models for green growth were

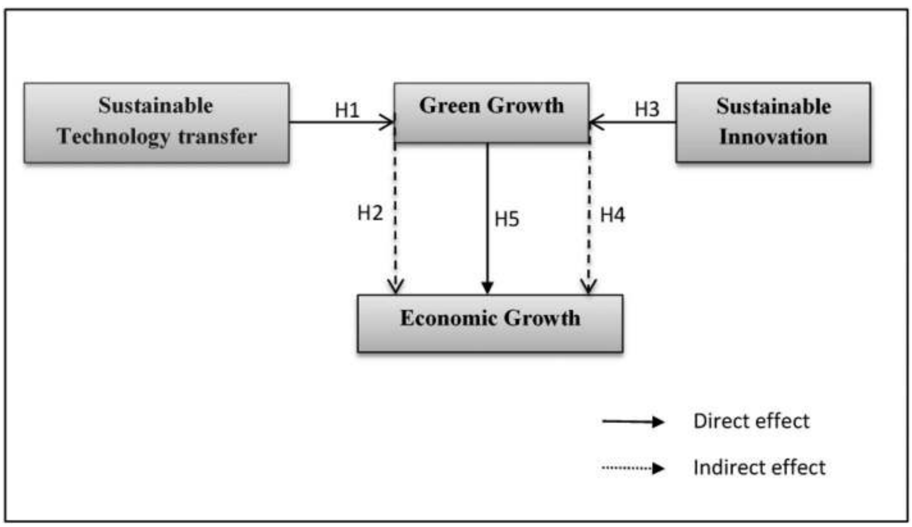

FIGURE 1 Conceptual model

$EAMFP_t = \beta_0 + \beta_1 EAMFP_{t-1} + \beta_2 GDP\_PC_t + \beta_3 POP_t + \beta_4 GFCF_t + \beta_5 CRI_t$ (I)

$EAMFP_t = \beta_0 + \beta_1 EAMFP_{t-1} + \beta_2 GDP\_PC_t + \beta_3 POP_t + \beta_4 GFCF_t + \beta_5 CRI_t + \beta_6 TD_t + \beta_7 TD_{t-1} + \beta_8 ICTD_t + \beta_9 ICTD_{t-1}$ (II)

$EAMFP_t = \beta_0 + \beta_1 EAMFP_{t-1} + \beta_2 GDP\_PC_t + \beta_3 POP_t + \beta_4 GFCF_t + \beta_5 CRI_t + \beta_6 PAT_t + \beta_7 PAT_{t-1} + \beta_8 CLI\_CHA_t + \beta_9 CLI\_CHA_{t-1}$ (III)

$EAMFP_t = \beta_0 + \beta_1 EAMFP_{t-1} + \beta_2 GDP\_PC_t + \beta_3 POP_t + \beta_4 GFCF_t + \beta_5 CRI_t + \beta_5 CRI_t + \beta_6 TD_t + \beta_7 TD_{t-1} + \beta_8 ICTD_t + \beta_9 ICTD_{t-1} + \beta_{10} PAT_t + \beta_{11} PAT_{t-1} + \beta_{12} CLI\_CHA_t + \beta_{13} CLI\_CHA_{t-1}$ (IV)

Regarding economic growth, the following models were estimated:

$GDP\_GR_t = \beta_0 + \beta_1 GDP\_GR_{t-1} + \beta_2 EAMFP_t + \beta_3 EAMFP_{t-1} + \beta_4 GDP\_PC_t + \beta_5 POP_t + \beta_6 GFCF_t + \beta_7 CRI_t$ (I)

$GDP\_GR_t = \beta_0 + \beta_1 GDP\_GR_{t-1} + \beta_2 EAMFP_t + \beta_3 EAMFP_{t-1} + \beta_4 GDP\_PC_t + \beta_5 POP_t + \beta_6 GFCF_t + \beta_7 CRI_t + \beta_8 TD_t + \beta_9 TD_{t-1} + \beta_{10} ICTD_t + \beta_{11} ICTD_{t-1}$ (II)

$GDP\_GR_t = \beta_0 + \beta_1 GDP\_GR_{t-1} + \beta_2 EAMFP_t + \beta_3 EAMFP_{t-1} + \beta_4 GDP\_PC_t + \beta_5 POP_t + \beta_6 GFCF_t + \beta_7 CRI_t + \beta_8 PAT_t + \beta_9 PAT_{t-1} + \beta_{10} CLI\_CHA_t + \beta_{11} CLI\_CHA_{t-1}$ (IIII)

$GD\_GR_t = \beta_0 + \beta_1 GDP\_GR_{t-1} + \beta_2 EAMFP_t + \beta_3 EAMFP_{t-1} + \beta_4 GDP\_PC_t + \beta_5 POP_t + \beta_6 GFCF_t + \beta_7 CRI_t + \beta_8 TD_t + \beta_9 TD_{t-1} + \beta_{10} ICTD_t + \beta_{11} ICTD_{t-1} + \beta_{12} PAT_t + \beta_{13} PAT_{t-1} + \beta_{14} CLI\_CHA_t + \beta_{15} CLI\_CHA_{t-1}$ (IV)

Equations of green and economic growth are a group of related equations. The residuals of these two regressions are likely to be highly correlated. The Seemingly Unrelated Regressions (SUR) models are an efficient method for dealing with situations where the proper description involves an econometric model with multiple equations.

The SUR method estimates the entire system of equations—instead of estimating each equation in the model separately—results in substantial gains in the efficiency of the coefficient estimators. The second set of equations take into consideration estimated results from the first set of equations. Thus, using Seemingly Unrelated Regressions (SUR) can reduce heterogeneity and the contemporaneous correlation of residuals. Also, the parameters obtained from the SUR model are unbiased and efficient. Therefore, the multiple-equation panel data procedure that combines the SUR and the panel data regression model is adopted for the estimation.

We employed the two-step GMM estimators deploying moment conditions (Arellano & Bond, 1991). One lagged the level of the dependent and one lagged the Sustainable Technology Transfer and Sustainable Patents variable levels. All systems of equations were estimated using the statistical analysis software STATA version 13.0 (StataCorp LP, Texas, USA).

4 | RESULTS AND DISCUSSION

Table 1 presents the results of descriptive statistics and the correlation coefficients of the variables used in econometric modelling.

Tables 2 and 3 present the results for the different models estimated for green growth and economic growth, respectively. Regarding green growth (Table 2), it is observed that the variables referring to contemporary values of GDP per capita (GDP_PC) and Gross Fixed Capital Formation (GFCF) have a statistically significant positive impact on green growth (EAMFP), and in the crisis (CRI) the green growth was statistically lower than in the other years. The previous year's green growth value has a statistically significant positive impact on contemporary green growth. With regard to variables referring to the transfer of sustainable technology, the Technology Diffusion (TD) (Model II: $\beta = 0.02$, $p < 0.05$) and the contemporary International Collaboration In Technology Development (ICTD) (Model IV: $\beta = 0.07$, $p < 0.05$) and the previous year (Model II: $\beta = 0.01$, $p < 0.01$; Model IV: $\beta = 0.01$, $p < 0.05$ and $\beta = 0.06$,

TABLE 1 Descriptive statistics and correlation matrix for variables used in empirical analyses

	EAMFP	GDP_GR	GDP_PC	POP	GFCF	CRI	TD	ICTD	PAT	CLI_CHA
Mean	1.55	2.35	30.46	38.80	233.13	0.239	40.42	8.60	14.30	60.20
Median	1.69	2.57	30.67	10.71	70.86	0.00	41.56	8.03	9.08	59.46
Minimum	−13.06	−9.13	8.94	0.25	0.53	0.00	15.71	0.00	0.00	0.00
Maximum	16.17	21.83	84.05	311.58	2682.90	1.00	68.75	28.85	88.54	100.00
SD	2.23	2.99	9.95	57.53	407.95	0.427	8.63	3.68	15.23	13.23
EAMFP	1.00									
GDP_GR	0.81	1.00								
GDP_PC	−0.11	−0.17	1.00							
POP	−0.03	−0.05	0.16	1.00						
GFCF	−0.03	−0.06	0.26	0.95	1.00					
CRI	−0.29	−0.32	0.15	0.01	0.02	1.00				
TD	0.16	0.14	−0.28	−0.01	−0.06	0.41	1.00			
ICTD	0.21	0.26	0.09	−0.07	−0.04	0.21	0.22	1.00		
PAT	0.10	0.18	0.53	0.12	0.22	0.33	0.30	0.32	1.00	
CLI_CHA	0.10	0.07	0.10	−0.04	0.01	0.39	0.48	0.06	0.20	1.00

TABLE 2 Econometric models—regression coefficients (standard error)

	Model I	Model II	Model III	Model IV
EAMFP (t − 1)	0.28* (0.04)	0.09* (0.04)	0.25** (0.04)	0.25** (0.04)
GDP_PC (t)	34.78* (4.13)	48.86 (26.2)	6.3 (0.01)	7.4 (8.96)
POP (t)	0.01 (0.01)	0.01 (0.01)	0.01 (0.01)	0.00 (0.01)
GFCF (t)	0.05** (0.01)	0.02 (0.01)	0.02* (0.01)	0.00 (0.01)
CRI (t)	−1.08** (0.2)	−1.30** (0.22)	−1.51** (0.22)	−1.57** (0.22)
TD (t)		0.02* (0.01)		0.00 (0.01)
TD (t − 1)		0.01** (0.00)		0.01* (0.00)
ICTD (t)		0.04 (0.03)		0.07* (0.04)
ICTD (t − 1)		0.04 (0.03)		0.06* (0.03)
PAT (t)			0.09** (0.03)	0.11** (0.03)
PAT (t − 1)			0.12** (0.03)	0.12** (0.03)
CLI_CHA (t)			0.03** (0.01)	0.02* (0.01)
CLI_CHA (t − 1)			0.02* (0.01)	0.03** (0.01)
N	541	541	541	541
Wald χ^2	358.60**	369.60**	408.21**	409.72**
R^2	39.9%	40.6%	43.0%	43.1%

Note: Dependent variable: Green Growth (EAMFP).
*p < 0.05. **p < 0.01.

$p < 0.05$) have a positive impact on green growth. In this way, we support our *H1: Sustainable technology transfer has a positive impact on green growth.*

We thus find the same empirical evidence from other authors who point out that sustainable technology transfer is something that companies and entrepreneurs can collectively develop and build capacities to encourage these sustainable innovations (Koops, Oosterlaken, Romijn, Swierstra, & van den Hoven, 2015; Owen, Bessant, & Heintz, 2013). Thus, sustainable technology transfer is one that leads to socially desirable results (Stahl, Eden, & Jirotka, 2013;

TABLE 3 Econometric models—regression coefficients (standard error)

	Model I	Model II	Model III	Model IV
GDP_GR (t − 1)	0.29** (0.03)	0.28** (0.04)	0.29** (0.04)	0.12** (0.04)
EAMFP (t)	0.88** (0.04)	0.89** (0.04)	0.88** (0.04)	0.96** (0.03)
EAMFP (t − 1)	−0.04 (0.06)	−0.04 (0.06)	−0.05 (0.06)	0.42** (0.05)
GDP_PC (t)	−13.77 (7.94)	−14.61 (8.16)	−10.43 (8.79)	11.78 (14.56)
POP (t)	−0.01 (0.01)	−0.01** (0.00)	−0.03** (0.01)	−0.01 (0.01)
GFCF (t)	0.01** (0.00)	0.01** (0.00)	0.01** (0.00)	0.01 (0.01)
CRI (t)	−0.53** (0.17)	−0.40** (0.17)	−0.44** (0.19)	−0.48** (0.18)
TD (t)		0.01 (0.05)		0.01 (0.05)
TD (t − 1)		0.01 (0.01)		0.01 (0.01)
ICTD (t)		0.05 (0.03)		0.04 (0.02)
ICTD (t − 1)		0.10 (0.15)		0.01 (0.02)
PAT (t)			0.01 (0.02)	0.02 (0.02)
PAT (t − 1)			−0.02 (0.02)	0.01 (0.02)
CLI_CHA (t)			−0.02 (0.01)	0.09 (0.08)
CLI_CHA (t − 1)			0.01 (0.01)	0.01 (0.01)
N	541	541	541	541
Wald χ^2	1069.18**	1084.10**	1072.10**	1086.21**
R^2	66.4%	66.7%	66.5%	66.8%

Note: Dependent variable: Economic Growth (GDP_GR).
*p < 0.05. **p < 0.01.

Voegtlin & Scherer, 2017; Von Schomberg, 2011). The accumulation of technological capabilities and relevant innovations thus increases countries' ability to engage in mitigating climate change, not only as users of low-carbon technology but also as innovative producers (Bell, 2012; Ockwell, Mallet, & Urban, 2013).

Table 3 shows that the effect of sustainable technology transfer on economic growth is mediated by green growth. In this way, we support our *H2: Green growth has a mediating effect on the impact of sustainable technology transfer on economic growth*. In this way, we were able to verify the positive relationship between the three variables so far by studying in the literature. Existing research findings are in conflict. While some studies argue that sustainable technology transfer has a positive effect on green growth (Geddes, Schmidt, & Steffen, 2018; Guo et al., 2020; Mazzucato & Penna, 2016), others argue that technology transfer has a positive effect on economic growth (Ferreira, Fernandes, & Ferreira, 2020; Ferreira, Fernandes, & Ratten, 2019). We can prove that the insertion of green growth into the equation continues to maintain the positive effect of sustainable technology transfer on economic growth.

Regarding Sustainable Innovation, patents per capita (PAT) have a statistically significant positive impact on green growth, both in contemporary values (Model III: $\beta = 0.09$, $p < 0.01$; Model IV: $\beta = 0.11$, $p < 0.01$) and the values of the previous year (Model III: $\beta = 0.12$, $p < 0.01$; Model IV: $\beta = 0.12$, $p < 0.01$), as well as the proportion of environmental patents related to the mitigation of climate change (CLI_CHA), also in contemporary values (Model III: $\beta = 0.03$, $p < 0.01$; Model IV: $\beta = 0.02$, $p < 0.01$) and in the values of the previous year (Model III: $\beta = 0.02$, $p < 0.01$; Model IV: $\beta = 0.03$, $p < 0.01$). In this way, we support our *H3: Sustainable innovation has a positive impact on green growth*. We thus support the empirical evidence from several authors, who argue that sustainable innovation is a way to achieve green growth (Bayarçelik & Taşel, 2012; Bektas et al., 2015; Ferreira, Fernandes, & Ratten, 2019; Ferreira, Fernandes, & Ferreira, 2020).

Sustainable innovations mean, among others, the adoption of transportation facilities with low levels of polluting gases, promoting clean purchasing activities and companies' supply chain (Mensah et al., 2019). This implies that sustainable innovations combined with strategic policies are crucial for sustainable growth and green growth (Bekhet & Latif, 2018).

Table 3 shows that the effect of sustainable innovation on economic growth is mediated by green growth, supporting our *H4: Green growth has a mediating effect on the impact of sustainable innovation on economic growth*. We thus find empirical evidence similar to that found by other authors (Geddes, Schmidt, & Steffen, 2018; Guo et al., 2020; Mazzucato & Penna, 2016). In this way, innovation should be considered as holding the keys to the sustainable development of our societies (Matos & Silvestre, 2013).

A technological breakdown or the deployment of technologies that capture carbon would be crucial in controlling climate change (Wennersten, Sun, & Li, 2015). Several researchers thus point to technology transfer and sustainable innovation as something that companies and entrepreneurs can collectively develop and build capacities to encourage these sustainable innovations (Koops, Oosterlaken, Romijn, Swierstra, & van den Hoven, 2015; Owen, Bessant, & Heintz, 2013). Sustainable innovation leads to socially desirable results (Stahl, Eden, & Jirotka, 2013; Voegtlin & Scherer, 2017; Von Schomberg, 2011).

Regarding economic growth (Table 3), it is observed that the variable referring to contemporary values of GDP per capita (GDP_PC) and green growth (EAMFP) has a statistically significant positive impact on economic growth (GDP_GR). In contrast, the population has a statistically significant negative impact. As with green growth, in the crisis (CRI), economic growth was statistically lower than in the other years. The previous year's economic growth value has a statistically significant positive impact on contemporary economic growth. The value of contemporary green growth (Model I: $\beta = 0.88$, $p < 0.01$; Model II: $\beta = 0.89$, $p < 0.01$; Model III: $\beta = 0.88$, $p < 0.01$; Model IV: $\beta = 0.96$, $p < 0.01$) has a statistically significant positive impact on contemporary economic growth. Regarding variables referring to the transfer of sustainable technology and sustainable innovation, there was no direct effect on GDP.

We find partial support for our *H5: Green growth has a positive impact on economic growth*. As advocated by several authors, green growth does not impede economic growth; on the contrary, green growth positively affects economic growth (Capasso, Hansen, Heiberg, Klitkou, & Steen, 2019;Ward et al., 2016 ; Wiedmann et al., 2015). In this way, it is possible to have growth and economic development while ensuring that natural assets continue to provide the environmental resources and services on which our well-being depends (OECD, 2011).

5 | THEORY, POLICY, AND MANAGEMENT IMPLICATIONS

5.1 | Implications for theory

Our research highlights several important contributions and implications for the theoretical, political, and managerial fields of sustainable technology transfer and innovation at the level of all OECD countries.

For theory, the first contribution is related to the results of the influence of the transfer of sustainable technology and innovation to green growth. In our research, we have shown that sustainable innovation (climate change mitigation patents) affects green growth, and this can be seen as a result of business contexts that emphasize the importance of climate change. This improves our knowledge of the interrelationship between government policies concerning an essential social issue regarding climate change. Wiesenthal, Leduc, Haegeman, and Schwarz (2012) found that aggregate research and development (R&D) investments devoted to low-carbon energy technologies amounted to €3.3 billion in the EU. This amount came mainly from public funding from EU member states and the industrial research activities of companies registered in the EU. However, gaining access to public climate change mitigation funds is not always easy. Lettice, Smart, Baruch, and Johnson (2012) found evidence of this challenge when analyzing the factors associated with fund allocation decisions. These researchers confirmed that, despite funding agencies' clear intentions and expectations, the allocation of funds is not always linear. Even though carbon reduction is a priority, this is not a significant factor when organizations allocate funds to candidate projects.

The second contribution is the relationship between green growth and economic growth. We prove that both can exist simultaneously and that one does not exclude the other. Therefore, we contradict the considerations of several authors who argue that it is very difficult for countries to maintain economic growth while respecting the sustainability of resources (Ward et al., 2016; Wiedmann et al., 2015). With our findings, we ascertain that it is possible to continue to have economic growth without compromising the sustainability of existing resources. Thus, the most appropriate solution to prevent environmental degradation is green growth. UNEP (2011) stated that green growth depends mainly on technological and market innovations to improve production efficiency and, therefore, decouple the use of natural resources and the respective environmental impacts of this use on economic growth. Although there are arguments that indicate that green growth is highly unlikely to succeed without affecting the evolution of economic growth (Ward et al., 2016; Wiedmann et al., 2015), others suggest that the solution is at the level of economic degrowth (Weiss & Cattaneo, 2017). We find that both are possible and reveal a set of reasons why this is so. We thereby follow the line of other authors who argue that despite the arguments in favor of economic degrowth, green growth remains the dominant solution for environmental sustainability, while degrowth remains a marginal task (Alexander, 2015; Hickel, 2017; Jackson, 2016).

The third theoretical contribution was to support the relationship between green growth mediates between sustainable technological transfer, sustainable innovation, and economic growth. Extensive scientific research shows that household consumption is a significant contributor to environmental degradation (IPCC, 2014; WWF, 2016). Thus, there is unanimity in thinking about the need to introduce changes that mitigate this effect and that at the same time do not affect economic growth (Ripple et al., 2017; UNEP, 2011). Here lies the great challenge, as authors argue that it is doubtful to mitigate climate change without causing a decrease in economic growth (Ward et al., 2016; Wiedmann et al., 2015). Are we then faced with an imperfect choice, or can both co-exist? Our empirical evidence shows that economic growth *is* possible with the inclusion of sustainable technologies and innovations and that both can co-exist and are complementary in that respect.

5.2 | Implications for policy

At the political level, some implications of our investigation are also revealed. The fact that we prove that International Collaboration in Technology Development has a positive effect on green growth and then, mediated by it, on economic growth highlight the need to create new policies. Policies are urgently needed to promote cooperation between companies in different countries regarding technology development, which will then transfer between the different actors. Several mechanisms through which the institutional convergence of a national science and technology policy can occur exist (DiMaggio & Powell, 1983). Models are disseminated either explicitly or unintentionally through the interaction of people involved in science and technology policy. Our multi-country, longitudinal analysis provides evidence for conditions needed to generate green growth and the constructive relationship green growth has with economic growth and its intermediate and direct influence.

The growth and development of professional networks covering field organizations in different countries have led to elites who, through interaction and cooperation, define appropriate models of organizational and political structure. According to Dechezleprêtre, Martin, and Mohnen (2017), these policies to support sustainable technologies and innovations vary between different technology areas. For example, climate change mitigation policies generally try to support so-called clean technologies preventing pollution by greenhouse gases and hamper dirty technologies associated with polluting emissions.

The second political contribution has to do with the fact that environmental patents related to climate change mitigation have a positive effect on green growth and, consequently, through green growth. Although the call for attention to climate change dates to the 19th century, concerns only began to emerge in the 1980s (UNFCCC, 2015). Strategies and objectives to minimize its effects are since established globally, including many government policies at the country level. Among these were the different mechanisms imposed to induce clean and environmental innovations, but responses tend to be idiosyncratic rather than coordinated. For example, the growing interest in environmental protection has led to more pollution control technologies (Lanjouw & Mody, 1996; Su & Moaniba, 2017). Veugelers (2012) investigated the reasons for introducing environmental innovations in different sectors. Veugelers (2012) then found that public subsidies were not seen as important factors in most sectors. On the other hand, regulation and taxes were highly motivating factors in the food sectors, chemicals, and manufacturing sectors. However, previously Grubb (2004) drew our attention to the fact that there is no "silver bullet" that mitigates climate change. However, there are several portfolio options for the different sectors of activity. Therefore, economic and fiscal policies must be adapted to different contexts: sector of activity and country of origin.

5.3 | Implications for managerial practice

In terms of management implications, it is inevitable to observe the relationship between entrepreneurship and green growth. Without entrepreneurship, there will be no innovation, and this premise has been apparent since Schumpeter (1934). Without innovation, there will be no technology transfer and, consequently, economic growth

(Ferreira, Fernandes, & Ferreira, 2020). Thus, entrepreneurs face the challenge of creating and transferring sustainable innovations to mitigate climate change. As advocated by Earley (2016), sustainable entrepreneurship models have a higher value than what reality attributes to them. Traditional businesses with conventional products target revenues and profits at certain levels that, almost certainly, add additional challenges to sustainable entrepreneurship and to establish its legitimacy in entrepreneurial ecosystems (Neumeyer & Santos, 2018). A further implication for management is precisely to show that the focus on sustainability does not have to be seen as a liability for countries and companies but as a source of competitive advantage for countries and companies.

6 | CONCLUSIONS, LIMITATIONS, AND FUTURE RESEARCH

The objective of our research was to analyze the role that sustainable technology transfer and sustainable innovations play in green growth. At the same time, we intend to ascertain the impact of green growth on economic growth. The results confirm that sustainable technology transfer and sustainable innovation have an impact on green growth. On the other hand, we find that green growth has a positive impact on economic growth and mediates the positive effect between sustainable technology transfer and sustainable innovation and economic growth.

Thus, we find that we probably do have an "imperfect choice" between having green growth or economic growth, as evidenced by several authors (Ward et al., 2016; Wiedmann et al., 2015), because we can have "the best of both worlds." As for our research question, we asked, is it possible to achieve economic growth using sustainable technology transfers and sustainable innovations? Through the empirical evidence of this study, we can verify that it is possible to obtain not only economic growth but also green growth. To this end, it is essential to design sustainable business models capable of fostering and leveraging an increasingly green and clean society. Therefore, they are not an exception but a rule.

In the last decade, interest in the study and implementation of alternative economic systems that enable climate change mitigation has emerged (Neumeyer & Santos, 2018). As Daly and Farley (2011) argue, one of the main criticisms of the traditional economy is precisely the exclusive focus on the efficient allocation of resources, ignoring the social well-being and ecosystems' biological support capacity. As presented by several authors, ecological economists and environmental scientists have repeatedly pointed out that the increase in environmental degradation should trigger robust political decision-making (Grant et al., 2012; Hicks et al., 2016). Therefore, we can say that one way to deal with the intensive consumption of natural resources is to develop new systems with an emphasis on sustainable practices, processes, and technologies. However, these sustainable systems will only be possible if all stakeholders - government agencies, entrepreneurs, and consumers- actively build a greener and more sustainable society.

As all investigations have limitations, ours is also not the exception, and limitations underlying the development of our investigation can inform future investigations. First, our study focused on related patents with the environment using panel data from the OECD. Organizations with higher levels of patents will be more likely to learn how they can satisfy market needs using their internal capabilities. In future research, qualitative data in the form of detailed interviews can help explain why International Collaboration in Technology Development and environmental patents on climate change mitigation positively affect green growth.

Second, we do not examine for a breakdown of results at the country level. Instead, we aggregated data for all OECD countries. In future, country-level analyses may reveal how the level of economic development and even the inequality of countries impact green growth. The third limitation is that we have not studied the influence of the application of particular policies. Thus, in future studies, we propose the analysis of green growth within entrepreneurial ecosystems to have the notion of the systemic effect on green growth and economic growth.

Finally, we recommend that scholars evaluate our conceptual model and findings in the context of ecosystems. Specifically, the creation of sustainable entrepreneurial ecosystems is essential to achieve growth and economic development. But an ecosystem logic may help establish and embed commitments to sustainable practices, thus contributing to the positive impact of green growth. In sum, there is much to learn now about the chain of effects revealed in our study among sustainable technology transfer, sustainable innovation, promoting green growth, and the relationship through to economic growth. We contribute new insight to the green growth versus (or what now be *and*) economic growth debate and encourage scholars to continue understanding the crucial relationship between green growth and economic growth revealed in our study.

ORCID

Cristina I. Fernandes https://orcid.org/0000-0001-8560-0758
João J.M. Ferreira https://orcid.org/0000-0002-5928-2474
Mathew Hughes https://orcid.org/0000-0001-6859-558X

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APPENDIX A: COUNTRIES AND YEARS IN WHICH DATA WERE AVAILABLE

Country	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Austria	NA	NA	NA	NA	NA	NA	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Belgium	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	NA	✓	✓	✓	✓	✓	NA	✓	✓	✓	✓	✓	✓
Canada	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	NA	NA	NA
Chile	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	X	NA	✓	✓	✓	NA
Czech Republic	NA	NA	NA	NA	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	NA	✓	✓	✓	✓
Denmark	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	X	✓	✓	✓	✓
Estonia	NA	NA	NA	NA	NA	NA	✓	✓	✓	NA	X	NA	X	NA	NA	NA	NA	✓	NA	NA	✓	✓	NA	NA
Finland	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
France	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Germany	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Greece	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Hungary	NA	NA	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	NA
Iceland	X	NA	NA	NA	NA	NA	NA	NA	✓	✓	✓	✓	NA	✓	NA	✓	NA	✓	NA	NA	NA	✓	✓	✓
Israel	NA	NA	NA	NA	NA	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	NA	NA
Italy	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Japan	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	NA
Korea	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	NA
Luxembourg	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	X	NA	NA	NA
Mexico	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	✓	✓	✓	✓	✓	✓	✓	NA	NA
Netherlands	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
New Zealand	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	NA
Norway	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Poland	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	NA
Portugal	NA	NA	NA	NA	NA	NA	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	NA	NA
Slovak Republic	NA	NA	NA	NA	✓	✓	✓	✓	✓	✓	✓	NA	✓	NA	X	NA	NA	✓	✓	✓	✓	NA	✓	✓
Slovenia	NA	NA	NA	NA	NA	NA	✓	✓	✓	✓	NA	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Spain	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Sweden	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Switzerland	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	✓	✓	✓	✓	✓	✓	✓	✓	✓
Turkey	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	✓	✓	✓	✓	✓	✓	✓	NA
United Kingdom	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
United States	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	NA	NA

Abbreviation: NA, not available.