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Too good to be true: The inverted U-shaped relationship between home-country digitalisation and environmental performance.

ABSTRACT

The current pandemic era has increased the need for a better understanding of the pros and cons of digital transformation. Digitalisation has been seen in the past as a *panacea*, as it was argued that higher digitalisation would translate into better environmental performance. As the process of digitalisation advances, however, we realise that it may have some environmental drawbacks that need addressing. We thus explore the inverted U-shaped relationship between home country digitalisation and environmental performance. More particularly, we hypothesise that, in the first stage, home country digitalisation has a positive impact on environmental performance (e.g., enhanced energy efficiency and resource management), but then it reaches a tipping point where an *excessive* level of digitalisation causes a "rebound effect", hence increasing the use of resources and resulting in higher pollution. Our panel data of 5,015 firms from 47 countries in 10 sectors for the period 2014-2019 confirms our predictions. The panel smooth transition regression model (PSTR) confirms the moderating effect of a country's institutional framework level on this relationship between digital transformation and environmental performance. More particularly, our results show that countries with stronger institutional frameworks flatten the inverted U-shaped curve.

KEYWORDS: digitalisation; environmental performance; inverted U-shaped relationship; institutional framework; longitudinal analysis; home country; innovation; resource use; emissions.

1. INTRODUCTION

While digital transformation has been in the political and organisational agendas for some years, the current pandemic situation has placed it on the frontline (Muzio & Doh, 2021), and a better understanding is thus now more urgent than ever. The Institute for Management Development (IMD, 2020) has noted the importance of this topic at governmental level, and at the same time a recent study made by the Boston Consulting Group (BCG) revealed that over 80% of high-level executives believe digital transformation to be a top priority (BCG, 2020). A digital strategy is thus no longer an option, nor something that is "nice-to-have" for firms: it is a must (Forbes, 2020). Digital transformation is not only a synonym of technology, however, but also involves new ways of working, innovating, decision-making and the transformation of organisational strategies and cultures (PwC & Microsoft, 2017). Advocators of digital transformation go beyond the benefits it provides for operational and financial performance and establish a positive link with a firm's environmental results (Ford & Despeisse, 2016; Ghobakhloo, 2020).

In order to test this alleged relationship, an incipient number of works have begun analysing the effect of digital transformation on emissions, energy consumption, and resource and energy efficiency (GeSI & Deloitte, 2019; Lange, Pohl, & Santarius, 2020; Lange & Santarius, 2020; World Bank, 2020). Such interest has yielded important, but mixed, findings. The mainstream line largely supports the positive effect of digitalisation on a firm's environmental performance (Rajput & Singh, 2019; Queiroz & Wamba, 2019). These studies indicate that digitalisation brings benefits such as lower emissions, higher resource efficiency, improvements in supply chain management, flexibility of production, lifecycle management, and reduction of waste (Ford & Despeisse, 2016; Rajput & Singh, 2019; Queiroz & Wamba, 2019; GeSI & Deloitte, 2019). For instance, the use of *recyclebots*, an open-source hardware device for converting waste plastic into 3-D printing filament, resulted in a decrease of recycling-related energy consumption of up to 70% (Kreiger, Mulder, Glover, & Pearce, 2014). The positive benefits can thus be explained by the fact that technologies include energy management systems, advanced analytics, optimisation, and smart grids (Bengtsson & Ågerfalk, 2011; Watson, Boudreau, Chen, & Sepúlveda, 2011).

Nevertheless, digital economy may be a double-edged sword that has been overlooked in the literature (Verbeke & Hutzschenreuter, 2021). While the positive effect of digitalisation for a firm's environmental performance is relatively well known, digital transformation poses some drawbacks that need to be addressed. For example, Lange and Santarius (2020) point out that, although the energy intensity of processing units (CPUs) halves every 1.5 years, Moore's Law predicts that the capacity of CPUs also doubles every 1.5 years, thus outbalancing the energy savings. This is due to the fact that digitalisation is "energy-hungry" and resource-intensive (Coroamă & Mattern, 2019; Lange et al., 2020; Lange & Santarius, 2020). Findings show that digitalisation can increase energy consumption, exhaust scarce resources, and increase environmental pollution resulting from waste output and recycling challenges (Kunkel & Matthess, 2020). For instance, Honée, Hedin, St-Laurent, & Fröling's (2012) analysis of Swedish insurance administration showed that more than half its carbon footprint is due to the PC equipment, given the "relative short economic lifetime of the IT hardware" (p. 1).

In the energy economics literature, these undesirable counter effects are known as *rebound effects* (Belaïd, Youssef, & Lazaric, 2020; Khazzoom, 1980; Lange et al., 2020). A central argument is that rebound effects occur when initial positive effects make a product or service more attractive, which in turn, increases its use (Galvin, 2015; Lange et al., 2020). The positive effect of the technology can be "eaten up" by the increased demand for energy (Santarius, Pohl, & Lange, 2020). For instance, digitalisation has fostered video conference systems such as Zoom and Microsoft Teams, but this technology has replaced many traditional calls, which are less energy intensive. Another example is the appearance of online platforms such as Netflix as a replacement for DVD rentals. While this initially reduced energy consumption, the greater (and unlimited) access to this platform has meant that users have significantly increased their hours of video consumption (Cisco, 2019), resulting again in a rebound effect. More digitalisation therefore stimulates more energy and resources, consequently leading to more pollution, and decreasing the initial positive effect or, in the worst cases, even outweighing it (Coroamă & Mattern, 2019).

These mixed results challenge our understanding of digital transformation and its implications for a firm's environmental performance, and suggest that the relationship between the two variables is more complex than a linear nature. We consider a curvilinear model where the positive or negative effects of digital transformation on environmental performance are not unlimited. The use of nonlinear models for analysing complex phenomena is somewhat present in the context of energy economics (Liu, Hu, Song, & Zhang, 2020; Grossman & Krueger, 1991; Merlevede, Verbeke & De Clercq, 2006; Solarin & Lean, 2016). In particular, the Environmental Kuznets Curve (EKC) hypothesis introduced by Grossman and Krueger (1991) represents a remarkable advance in explaining complex relationships like this one. This EKC examines the interaction between economic growth and environmental degradation, and how pollution levels increase up to a certain point as economic development goes up; and after that decrease (Blampied, 2021).

Studies have also established a link between digitalisation and environmental results at both the firm(micro)-level or country(macro)-level (Benzidia, Makaoui, & Bentahar, 2021; Chiarini, 2021; ElMassah & Mohieldin, 2020; Lange, Pohl, & Santarius, 2020). Less is known about the country (macro) – firm (micro) level relationship, as country level factors affect the technological paths taken by firms (Casper & Whitley, 2004; Leyva de la Hiz, 2019), suggesting that country-level inclination towards digitalisation spurs corporate behaviour in that direction. Indeed, the literature shows that firm-level factors alone do not fully explain firm behaviour relative to corporate environmental performance (Hartmann & Uhlenbruck, 2015). From this perspective, we study the effect of home country digitalisation on firm environmental performance, since country level factors allow us to analyse a more complex picture of "how institutions affect firms and how this plays out in different countries" (Hartmann & Uhlenbruck, 2015, p. 729).

It thus becomes more meaningful to go beyond the traditional views that primarily focus on either the positive or negative effects of digital transformation on a firm's environmental performance, and explore the dynamic performance resulting from the changing combination of the benefits and drawbacks of digital transformation that arise in practice. This paper extends previous work (Lange et al., 2020) that has emphasised the double-edged sword of digitalisation, as its rebound effects may lead it to backfire. We also examine the effect that the home-country institutional framework has on the nonlinear relationship between home-country digital transformation and environmental performance. Home-country institutions are a relevant setting because a number of studies have shown that firms in to different institutional environments differ in their resource profiles and willingness to make strategic decisions (Hitt, Holmes, & Arregle, 2021; Hitt, Sirmon, Li, Ghobadian, Arregle & Xu, 2021). For instance, disparities in information-processing-related policies between a firm's home country and foreign partners may present a critical challenge in digital innovation projects (Luo, 2021). In other words, a firm's performance and strategic decision-making vary depending on their home country, because of the particular set of national institutions (Cuervo-Cazurra, 2011; Donbesuur, Ampong, Owusu-Yirenkyi, & Chu, 2020; Kolk & Fortanier, 2013; Levänen, Lyytinen & Gatica, 2018; North, 1990). In the context of digital transformation, we believe that supporting institutions will extend the advantages of digitalisation over environmental performance and reduce its negative effects, but the latter will not completely disappear.

Our work makes the following contributions to the existing literature. Previous literature reporting on the relationship between digitalisation and environmental performance has proposed a linear nature (Benzidia et al., 2021; Rajput & Singh, 2019). In our paper, we enrich these prior research works with a novel attempt to examine the relationship between digitalisation and environmental sustainability in inverted-U shaped form. We provide an integrative and empirical view by showing that digitalisation can be a double-edged sword. Our study also offers an international and multi-industrial perspective. We also contribute to institutional theory, finding that institutional framework has an effect on this relationship. In our methodological contribution, using panel smooth transition regression (PSTR), we find that the effect of the home country digital transformation on a firm's environmental performance changes between the low and the high regime of institutional framework.

The remainder of the article is organised as follows. The next section reviews the theoretical background, and extends previous findings of institutional theory, to develop our research hypotheses regarding an inverted U-shaped relationship between a home country's digital transformation and a firm's environmental performance, and the transition effect of the institutional framework. In the third section, we explain the research methodology, including details from our sample, variable measures, and statistical methods. We performed the estimation of the PSTR models in order to check our hypotheses, which provides a complementary vision to previous studies. We discuss the results in the fourth section. Finally, we conclude the paper with a discussion of our findings, along with future research lines and limitations.

2. BACKGROUND LITERATURE AND HYPOTHESES

Sustainability is a global issue, and, in the same way that firms are increasingly globalising, the effect of institutions on a firm's environmental approach is increasing (Aragón-Correa, Marcus & Vogel, 2020; Hartmann & Uhlenbruck, 2015). Despite this, there are notable differences in the level of institutional development among countries. Scholars have taken a keen interest in studying how institutions affect a firm's environmental outcomes (Hartmann & Uhlenbruck, 2015; Iannou & Serafeim, 2012). For example, strong legal and general institutional frameworks improve a firm's engagement in generating environmental innovations (Aragon-Correa et al., 2020). Some authors (Haxhi & Van Ees, 2010; Ho, Wang, Vitell, 2012) have found that a firm's environmental behaviour is driven by cultural context. Graafland and Noorderhaven (2020) argued that the cultural trait of long-term orientation in combination with economic freedom improve a firm's engagement in CSR practices.

2.1 HOME COUNTRY DIGITALISATION AND ENVIRONMENTAL PERFORMANCE

Despite the existing institutional differences among countries, concerns about both the environment and digitalisation appear at the top of the political and business agenda worldwide

(Council of the EU, 2020; DigitalES, 2020; IMD, 2020; BCG, 2020). Digitalisation and environmental sustainability have largely been addressed separately, so that studying their relationship is becoming a cutting-edge research topic (Coroamă & Mattern, 2019; Ghobakhloo, & Fathi, 2021; Lange, et al., Santarius, 2020; Rajput & Singh, 2019; Queiroz & Wamba, 2019). The findings of these studies have resulted in two seemingly competing perspectives (positive and negative) that co-exist to explain how digitalisation shapes environmental performance (Lange et al., 2020). In other words, digitalisation is a double-edged sword capable of both improving and damaging environmental quality.

On the one hand, digitalisation offers great benefits for addressing environmental issues such as energy consumption (Ghobakhloo & Fathi, 2021), CO2 emissions (Schulte, Welsch, Rexhäuser, 2016), waste reduction (Kiel, Müller, Arnold, & Voigt, 2020), and others (GeSI & Deloitte, 2019; Mickoleit, 2010). A first interesting research line argues that digitalisation is a potential tool for reducing energy consumption. For instance, Ghobakhloo and Fathi (2021) found that digital industrial transformation contributes to energy efficiency through more intelligent energy production and distribution equipment. Similarly, the digitalisation of manufacturing enables the advanced tracking of resource and energy utilisation (Bai, Dallasega, Orzes, & Sarkis, 2020).

Schulte et al. (2016) found evidence that digitalisation can be a potential solution for reducing CO2 emissions. This might be because digital technologies enable the tracking of air pollution and facilitate the capture and storage of carbon emissions (IEA, 2017a, 2017b).

The literature has supported the idea that technological intensity drives firms to be engaged in environmental innovation (Doran & Ryan, 2012; Horbach, 2008; Leyva-de la Hiz, Hurtado-Torres, & Bermúdez-Edo, 2019; Rehfeld, Rennings, & Ziegler, 2007). Leyva et al.'s (2019) analysis of 80 international firms showed that higher levels of technological intensity led firms to generate green innovations. Similar findings were reported by Doran and Ryan (2012) in the context of European firms.

Nascent technologies such as big data analytics and artificial intelligence (BDA-AI) drive the green supply chain (Kshetri, 2018; Queiroz & Wamba, 2019). The literature reports that such technological infrastructure improves the coordination and standardisation of supply chain processes, since it allows complex information from diverse sources to be interpreted and combined (Benzidia et al., 2021; Wang, Gunasekaran, Ngai, & Papadopoulos, 2016). In a sample of 168 French hospitals, Benzidia et al. (2021) found that the use of BDA-AI technologies has a significant effect on environmental process integration and green supply chain collaboration. Similarly, the World Bank's report (2021) on the port and maritime sector shows that the use of smart technology-based methods improves environmental performance.

Despite these studies showing a positive impact of digitalisation over sustainability, a number of scholars have also found a negative relationship between these phenomena (Collard, Fève, & Portier, 2005; Chiarini, 2021; Kamble, Gunasekaran, & Gawankar, 2018; Zhou, Zhou, & Wang, 2018). Studies reveal that digitalisation may lead to higher energy demand (Faucheux & Nicolaï, 2011; Wang, Thorngren, & Onori, 2015), resource use (Waibel, Steenkamp, Moloko, & Oosthuizen, 2017), CO_2 emissions (Honée et al., 2012), and other severe environmental impacts. For instance, a report by the Öko-Institut for the European Commission (2019) noted that the use of digital technologies has a negative effect on resource consumption (abiotic and biotic), water consumption, land use and biodiversity. Similarly, Jungmichel, Schampel, and Weiss' (2017) analysis of the German electronics industry showed that, for each EUR of turnover obtained, companies used three litres of water during their production system. This research shows that some 15% of water consumption is attributed to regions with high water stress, such as Asia and Africa, where raw materials are extracted to produce the hardware that will enable digital technologies.

In the same vein, Collard et al.'s (2005) analysis of the tertiary sector in France showed that the consumption of ICT commodities led to a loss of energy use efficiency. Kamble et al. (2018) also showed that the extensive use of sensors and smart equipment resulted in higher energy use. Recently, Chiarini (2021), in a study of Italian manufacturing firms, found that some smart technologies, such as automated mobile robots, additive manufacturing, collaborative robots, traditional robots and autonomous guided vehicles had a negative effect on a firm's environmental performance. An analysis of the Swedish insurance administration showed that more than half its carbon footprint is due to the relatively short economic lifetime of the IT hardware (Honée et al., 2012). Other studies (Waibel et al., 2017; Wang, Thorngren, & Onori, 2015; Wang, Wan, & Zhang, 2016) have argued that smart factories employing massive electronic equipment will consume more energy and resources than traditional ones. These undesirable adverse effects are known as the "rebound effect" (Belaïd et al., 2020; Khazzoom, 1980; Lange et al., 2020). In other words, technological progress not only brings improvements in resource use, but it also decreases the cost of use, what may result in a disproportionate increase in consumption (Li & Wang, 2017; Herring & Roy, 2007).

From this review, it is clear that the relationship between digital transformation and environmental performance is more complex than a simple, linear one. Since both views have support from the empirical evidence to some extent, we have taken both views into consideration by proposing a curvilinear relationship, where the positive or negative effects of digital transformation on environmental performance are not unlimited: digitalisation in a business context can become a double-edged sword. We propose that the initial developments of digitalisation bring considerable benefits in improving a firm's environmental performance until it reaches a tipping point where an *excess* of digitalisation becomes disadvantageous for environmental performance. Consequently, we propose the following:

H1. There is an inverted U shape relationship between home country digitalisation and environmental performance.

2.2 THE EFFECT OF INSTITUTIONAL FRAMEWORK ON THE RELATIONSHIP BETWEEN DIGITALISATION AND ENVIRONMENTAL PERFORMANCE

Once we have established our baseline hypothesis, the U shape relationship between digitalisation and environmental importance, we consider whether the relationship between these elements is even more complex than "just" a nonlinear one. In order to gain a better understanding of the relationship between digitalisation and environmental performance we also have to bring the institutional context into the equation. Although we are witnessing a worldwide increase in digitalisation, notable differences remain at the institutional level (Godil, Sharif, Ali, Ozturk, & Usman, 2021; Hoffman, 1999; Leyva-de la His, 2019). Institutions are generally defined as the rules of the game in a country (North, 1990). These rules provide structure and order in a country, and guide the behaviour and actions of individuals, groups, and firms (North, 1990). The previous literature argues that national-level institutions affect the technological path taken by firms (Casper & Whitley, 2004; Leyva de la His, 2019). This is because firms follow institutional pressures and behave similarly within a given institutional context (Hoffman, 1999). Institutional theory thus explains why a firm's decisions to implement certain practices does not have rational or economic reasons, but are instead due to its adaptations to the rules and norms of institutional context (Glover, Champion, Daniels, & Dainty, 2014; Vasudeva, Spencer, & Teegen, 2013). Firms therefore tend to imitate practices implemented by other firms, which subsequently leads to isomorphism and towards earning legitimacy.

This leads us to suggest that the effects of digitalisation on environmental performance, both positive and negative, are not homogeneous among countries (Lange et al., 2020). For instance, a World Bank report (2020) states that "while the technology forms the backbone of a digital platform, the institutional framework and available human capital are crucial to ensuring its success" (p.108). Similarly, the EU Council (2020) noted that digitalisation is an excellent tool to accelerate the transition towards decarbonisation, however, at the same time, an appropriate policy framework is stressed as essential to avoid the adverse effects of digitalisation on the natural environment. Scholars have argued that governments need to act in order to foster an efficient transition toward a digital economy (Weber, Gudowsky, & Aichholzer, 2019). These researchers found that institutional quality has a positive effect on environmental performance (Ali, Bakhsh, & Yasin, 2019; Majeed, 2018; Sun, Edziah, Sun, Kporsu, 2019). For instance, Ali et al. (2019) and Panayotou (1997) show that CO_2 emissions can be potentially reduced by higher institutional quality at national level. Salman, Long, Dauda and Mensah (2019) found that well-organised and unbiased national institutions play a very significant part in decreasing C02 emissions. Jones and Manuelli (2001) argue that strong policies and regulation flatten the EKC and reduce environmental degradation, along with achieving higher economic growth.

Al-Mulali, Ozturk and Lean's (2015) analysis of institutions in developed vs developing countries, showed that internet use decreases carbon emissions in developed countries, but they did not find any significant relationship in developing countries. In a similar vein, Majeed (2018) empirically showed that digitalisation has a positive impact on CO_2 emissions in developed countries; but this effect was the opposite in emerging countries. Since developed countries tend to possess stronger institutions (e.g., Vasudeva, Spencer, & Teegen, 2013), we believe that such a stronger institutional framework will favour the advantages of digitalisation, and help reduce their disadvantages.

Put differently, we argue that in countries with a weak institutional framework, home country digitalisation worsens a firm's environmental results at an earlier stage compared to countries with stronger institutional frameworks, and vice versa. In other words, although the overall relationship between digitalisation and environmental performance has a U inverted shape (as argued in H1), this shape is different for home countries with higher and lower institutional levels. More specifically, high institutional frameworks *flatten* the curve between digitalisation and environmental performance. Consequently, we propose the following:

> *H2. The national institutional framework provides a transition effect to an inverted U shape relationship between home country digitalisation and environmental performance, such that stronger institutions broaden the positive effects of digitalisation on environmental performance, whereas weaker institutions curtail these positive effects.*

3. DATA AND METHOD

3.1 Sample and data collection

We selected a sample of firms from Thomson Reuters Eikon, from different countries around the world (the USA, UK, Australia, Canada, Japan, China, Taiwan, European countries, etc.) and diverse sectors of activity (energy, basic materials, technology, telecommunications, and industrials, among others). The Thomson Reuters database offers a comprehensive platform for establishing customisable benchmarks for the assessment of a firm's operating behaviour, environmental management and financial performance (Ellimäki, Gómez-Bolaños, Hurtado-Torres, & Aragón-Correa, 2021).

Our analysis uses an unbalanced panel dataset including 16,893 observations from 5015 different firms for the period between 2014 and 2019. Following previous environmental studies (e.g. Leyva-de la His, Hurtado-Torres, & Bermúdez-Edo, 2019), our sample included firms with a minimum net sales revenue of US$ 1 million.

Table 1 shows the variety of 47 different countries in the analysis, the higher percentages being from the United States of America, China, the United Kingdom, Japan and Australia.

--- Insert table 1 about here ---

The economic activity of most of the firms in Table 2 pertains to the industrial, consumer cyclical, financial and basic materials sectors.

--- Insert table 2 about here ---

3.2 Variables

Dependent variables

This study uses the environmental performance scores of ESG criteria retrieved from Thomson Reuters' Asset4 database as dependent variables. Measuring environmental performance is multi-dimension in character, and some scholars have used emissions reduction (Hartmann & Vachon, 2018), or levels of consumption and resource efficiency (Kock, Santaló, & Diestre, 2012) as proxies for the firm's environmental performance. Following previous studies (e.g. Qureshi, Kirkerud, Theresa, Ahsan, 2019), we opted for the Thomson Reuters Eikon's environmental performance score, defined as "a company's impact on living and non-living natural systems, including the air, land and water, as well as complete ecosystems". This index is generated from the weighted score of a company's strengths and weaknesses on indicators related to: (1) environmental innovation, (2) emissions, and (3) resource use. We employed this index since it includes deeper metrics that record different environmental aspects and determines how well a company uses best management practices to avoid environmental risks and capitalise on environmental opportunities in order to generate long term shareholder value. The values range between 0 and 100, where higher values represent better environmental performance. This paper also separately analyses the three components of environmental performance.

i) Environmental Innovation. This category score reflects a company's capacity to reduce the environmental costs and burdens for its customers, thereby creating new market opportunities through new environmental technologies and processes or eco-designed products.

ii) Emissions. This category measures a company's commitment and effectiveness in reducing environmental emissions in the production and operating processes.

iii) Resource Use. This category reflects a company's performance and capacity to reduce the use of materials, energy or water, and to find more eco-efficient solutions by improving supply chain management.

INDEPENDENT VARIABLE

The IMD World Digital Competitiveness (WDC) database was used to determine home country digitalisation. The WDC analyses and ranks the extent to which countries adopt and explore digital technologies leading to transformation in government practices, business models and society in general. Home country digitalisation takes a value on a continuous scale from "low" to "high" (0 to 100). The methodology of WDC ranking defines three main dimensions of country digitalisation: knowledge, technology and future readiness..The knowledge dimension captures the intangible infrastructure necessary to discover, understand, and build new technologies. The technology dimension quantifies the overall context that enables the development of digital technologies. The dimension of future readiness examines the level of an economy's preparedness to assume and exploit its digital transformation.

TRANSITION VARIABLE

The institutional framework of home country was selected as a transition variable. This variable was extracted from the IMD World Competitiveness (WCC) database. The institutional framework is elaborated by aggregating several country-specific items such as legal and regulatory framework, adaptability of government policy, government decisions, cost of capital, central bank policy, and country credit ranking. This variable also ranges between 0 and 100, where higher values represent the strong institutional framework of the specific country.

CONTROL VARIABLES

We include some firm-level control variables that take into account different factors that can affect a firm's environmental performance. In line with previous studies (Aragón-Correa, 1998; Chen, Ong, & Hsu, 2016; Christmann, 2004) about the environmental behaviour of firms, we included firm size as a control variable. This variable was assessed as the natural logarithm of the total revenue. Following previous studies (e.g. García-Martín & Herrero, 2019), we considered firm indebtedness as having an impact on environmental performance. This variable was measured as firm total debt by total assets. Finally, we control for *firm industry* with economic sectors from Thomson Reuters Eikon, as used in previous environmental studies (e.g., Purcheta-Martínez & Gallego-Álvarez, 2018), which categorises different industries: industrial, communication services, consumer discretionary, consumer staples, financial, energy, health care, information technology, materials, real estate, and utilities.

At the country level, GDP was considered in the analysis to measure the economic development of the home country (Alam, Atif, Chien-Chi, & Soytaş, 2019). In order to measure the home country's environmental culture, we selected the Environmental Performance Index (EPI), as used in other studies (e.g., Leyva-de la His et al., 2019). The EPI is produced by Yale University (e.g., Wendling, Emerson, Esty, Levy, & Sherbinin, 2018) by aggregating several environmental items, such as water waste, energy, and other factors. It can be assumed that countries which rank highly on the EPI tend to invest more in environmental protection (Singh, Ma, & Yang, 2016). This index ranges between 0 for the worst-environmental value and 100 for the maximum environmental performance for a country.

3.3 METHODS

BASE MODELS

Inverted U-shaped relationships can be found in a growing body of business management literature, in different themes, such as corporate innovation (Delgado-Márquez, Hurtado-Torres, Pedauga, & Cordón-Pozo, 2017; Ma, Zhang, & Yin, 2021), green investment (Huang, & Lei, 2021), a firm's financial performance (Boakye, Tingbani, Ahinful, & Nsor-Ambala, 2021) and so on. In this study, we propose four potential inverse-U shaped relationships as base models according to the following expression:

$$FEP_{i,t} = \mu_i + \beta_1 HCD_{i,t} + \beta_2 HCD^2{}_{i,t} + \lambda' Z_{it} + \nu_i + \tau_t + \varepsilon_{i,t} \quad (1)$$

where *i* = 1, . . ., *N*, and *t* = 1, . . ., *T*. *N* is the number of firms, and *T* is the number of years. $FEP_{i,t}$ represents a firm's environmental performance and the three components of the index (environmental innovation, emissions and resource use). $HCD_{i,t}$ represents home country digitalisation, and we add the square term ($HCD_{i,t}^2$) to verify the possible nonlinear relationship between environmental performance and home country digitalisation. $Z_{i,t}$ contains control variables that may affect FEP, including home country environmental performance (EPI), home country economic profile (GDP), firm's revenue (REV), and firm's indebtedness ($INDEB$). Parameters ν_i and τ_t are dummy variables to account for a firm's potential industry effect and year effect, respectively and ε_{it} is the error term.

PANEL SMOOTH TRANSITION REGRESSION (PSTR)

In line with previous environmental studies (Aydin, Esen, & Aydin, 2019; He, & Lin, 2019; Lahouel, Bruna, Zaied, 2020; Wang, Yan, Komonpipat, 2019), we adopt a panel smooth transition regression (PSTR) model: an extension of panel threshold regressions (Hansen, 1999). This model was first applied by González, Teräsvirta, van Dijk, and Yang (2005) to examine the effect of capital market imperfections on investment. A PSTR framework has two main advantages (Cheikh, Zaied, & Chevallier, 2021). First, as Lahouel et al. (2019) note, "the threshold value of the transition variable in not given a priori but is generated by the PSTR model" (p. 4). Second, the transition across the identified regimes is relatively smooth and gradual (Cheikh et al., 2021).

In a PSTR model, the effect of the threshold variable on the dependent variable may change depending on the regimes below and above the threshold (Inglesi-Lotz, Hakimi, Karmani, Boussaada, 2020). The coefficient that shows the effect of the threshold variable on the dependent variable is thus different depending on the regimes (Lahouel et al., 2020; Wang, Hao, & Yao, 2017). Theoretically, the PSTR is given by Equation (2):

$$y_{i,t} = \mu_i + \beta_0' x_{i,t} + \beta_1' x_{i,t} \mathrm{g}(q_{i,t,}\ y, c) + \varepsilon_{i,t,} \quad (2)$$

In this model, the dependent variable is $y_{i,t}$. μ_i indicates the vector of the individual fixed effects. The PSTR model is based on a continuous function of transition $\mathrm{g}(q_{i,t,}\ y, c)$, usually bounded between 0 and 1. $x_{i,t}$= ($x_{i,t}^1, .., x_{i,t}^k$) is a vector of *k* explanatory variables. β_0 and β_1 indicate the parameter vector of the linear model and the nonlinear model, respectively. ε_{it} is an independent and identically distributed (i.i.d.) error term.

The given logistic transition function $\mathrm{g}(q_{i,t,}\ y, c)$ is formulated as follows:

$$\mathrm{g}(q_{it}; \gamma, c) = \left\{1 + exp\left[-\gamma(q_{it} - c)/\hat{\sigma}_q\right]\right\}^{-1}, \quad \gamma > 0 \quad (3)$$

where parameter c indicates the threshold parameter (location) between one regime and another and γ denotes the smoothness of transition (Duarte, Pinilla, & Serrano, 2013). On one hand, when γ tends to infinity, the transition function g is sharp and PSTR is transformed to a panel threshold model developed by Hansen (1999). On the other hand, when γ tends to 0, the transition function g is constant, and the model degenerates to the standard linear model with fixed effects.

The basic idea is that when some threshold is exceeded, the relationship between home country digitalisation and a firm's environmental performance becomes different between low and high regime. In our study, we examine the transition effect of the institutional framework on the relationship between home country digitalisation and a firm's environmental performance. We use the following econometric model, and the transition function is given in Equation (4):

$$FEP_{i,t} = \mu_{i,t} + \beta_1 HCD_{i,t} + \beta_2 HCD^2{}_{i,t} + \left[\beta_3 HCD_{i,t} + \beta_4 HCD^2_{i,t}\right] g\left(IF_{i,t}; y, c\right) + \lambda' Z_{it} + \nu_i + \tau_t + \varepsilon_{i,t} \qquad (4)$$

In this model, the institutional framework ($IF_{i,t}$) acts as transition variable in the transition function g(·). As before, a firm's environmental performance (FEP) is the dependent variable, HCD is home country digitalisation, and HCD^2 is the quadratic term of home country digitalisation. $Z_{i,t}$ contains control variables, parameter ν_i and τ_t control by industry-year effects, and ε_{it} is the error term.

TEST OF LINEARITY

Before estimating the PSTR, it is essential to test whether the regime-switching effect is statistically significant using linearity. The linearity versus non-linearity test is the first step prior to the specification and estimation of the non-linear model. H_0 is the linear model and is suitable, while H_1 is PSTR with two regime or one transition is suitable. First, following Fracasso and Marzetti (2014), the Fisher LM test (LMF)[1] was conducted, which can be represented as follows:

$$\text{Fischer LM test: } LM_f = \left(\frac{\mathrm{SSR_0 - SSR_1}}{\mathrm{K}}\right) / \left(\frac{\mathrm{SSR_0}}{\mathrm{N\Gamma - N - K}}\right) \qquad (5)$$

Although, in the null hypothesis (H_0), the addition of squared residuals is illustrated by $\mathrm{SSR_0}$,in alternative hypothesis (H_1), the addition of squared residual is illustrated by $\mathrm{SSR_1}$. In *F*(*K, NT*

1 Likelihood ratio tests (LRT) and Wald LM test (LMw) were also checked but are not reported here. They are available upon request.

$- N - K$) distribution, K is the number of explanatory variables, the time length of the panel and the number of cross sectional units are denoted by T and N, respectively. As in previous studies (Fracasso & Marzetti, 2014), a third-order Taylor approximation was applied. If the null hypothesis of linear relationship is rejected, it thus means that the connection between the variables is non-linear and can be apprehended by the PSTR with at least two regimes.

Second, we employ the approach suggested by Hansen (1999, 2000) for threshold regression models. The null hypothesis of this model suggests that there is no threshold effect and it is defined by the linear constraint: $H_0: \beta_1 = \beta_2$. Following Hansen (1999, 2000), this null hypothesis is tested using likelihood ratio test (LR) having a non-standard distribution, that is defined as follows:

$$LR_F = (SSR_0 - SSR_1(\gamma, c))/\hat{\sigma}^2 \tag{6}$$

As indicated by Hansen (1996), a bootstrap is implemented to obtain first-order asymptotic distribution. The p-values of this test are thus constructed from the bootstrap procedure that is asymptotically valid.

ESTIMATION OF THE PSTR SPECIFICATION

Once linearity is checked, the final stage of the PSTR analysis is the estimation stage (Aydin, Esen, & Aydin, 2019). The PSTR model's parameters γ and c are estimated using nonlinear least squares (NLS) (González et al., 2005). Following previous studies (Duarte et al. 2013), the minimum residual sum of squares is used to estimate the corresponding β' coefficient vector of Equation (4):

$$SSR = \underset{\gamma>0,\ c\in\Gamma_n}{argmin}\, S_1(\gamma, c) \tag{7}$$

where $S_1(\gamma, c)$ is the sum of squared residuals for a fixed value γ and c and such that $\Gamma_n = \Gamma \cap \{q_1, \dots, q_n\}$. To obtain the slope coefficient γ and the threshold parameter c values, a grid search was applied. Given this, the values of γ and c that allow $S_1(\gamma, c)$ to be minimised could be selected as good starting values.

4. EMPIRICAL RESULTS

Table 3 shows the Pearson correlation coefficients for all variables included in the models. The mean, standard deviation, and minimum and maximum values for all variables are also reported.

--- INSERT TABLE 3 ABOUT HERE ---

Our starting point is to test our base models with random effect regression. Table 4 shows the results of this analysis for a firm's overall environmental performance and each of its components. Model 1 takes overall environmental performance as a dependent variable and tests the existence of an inverted U-shaped relationship between home country digitalisation and a firm's environmental performance. A firm's environmental performance is based on three dimensions: environmental innovation, emissions and resource use. Each dimension represents the different characteristics of environmental outcomes. For this reason, it is important to examine the relationship between digitalisation and the environmental performance dimensions. For model 1A, Model 1B, and Model 1C, we thus used a firm's environmental innovation, emissions and resources, respectively, as dependent variables.

--- INSERT TABLE 4 ABOUT HERE ---

We introduced the linear variable for home country digitalisation and also the squared term for this variable, for each model. Respectively, in each model, we see a positive and significant coefficient for the linear term of home country digitalisation, and a negative and significant coefficient for the squared home country digitalisation term. These results provide a clear strong support for our hypotheses, confirming the existence of an inverted U-shaped relationship between proposed relationships. Figure 1 depicts this effect graphically for better understanding. In the first steps of home country digitalisation, firms thus obtain high environmental results, both in overall performance, and in each category (innovation, emissions, and resource use), however, at a certain level, the positive contribution of home country digitalisation becomes negative, consequently leading to the deterioration of the firm's environmental results. It is worth mentioning that the inverted U-shaped relationship is more pronounced for a firm's emissions. To ensure the correct interpretation of our findings, we ran a U-test developed by Lind and Mehlum (2010). This test allows the statistical verification of the existence of hump-shaped relationships. The results of this test are shown in Table 5. This test was applied for the four potential inverse U-shaped relationships proposed in this study. The findings of this test collaborate our hypotheses. The test also indicates the extremum point of each hump-shaped relationship, which coincides with the turning point shown in Figure 1.

--- INSERT TABLE 5 ABOUT HERE ---

Second, we adopt a PSTR model to examine the threshold effect of institutional framework on the relationship between home country digitalisation and a firm's environmental results. As we said earlier, before estimating the PSTR model, we conducted a Fischer LM test. The results of this test are presented in Table 6. As shown, the results reject the null hypothesis and accept the existence of non-linearity by taking institutional framework as the transition variable for environmental performance, emissions, and resource use. However, it can be seen that the linear model is suitable for environmental innovation. We checked the existence of a threshold effect using LR_F. The results of this test, shown in Table 6, suggest that the null hypothesis is rejected for the proposed variables, with the exception of environmental innovation. Consequently, the threshold effect is confirmed for environmental performance, emissions, and resource use.

--- INSERT TABLE 6 ABOUT HERE ---

As we stated earlier, the lower and higher levels of a home country's institutional framework can have different effects on the relationship between home country digitalisation and a firm's environmental results. To check these hypotheses, we performed an estimation of the PSTR models. The results of the models are reported in Table 7. Figure 2 illustrates the transition function of the institutional framework for all four proposed relationships. Two regimes were found regarding the variable of institutional framework, namely low and high regimes. The results of Table 7 show that the variable of home country digitalisation also has two regimes. In regard to Model 1, where environmental performance is a dependent variable, the results suggest that the effect of home country digitalisation varies from a low regime to a high regime. In the low-level regime, the positive effect of home country digitalisation on a firm's environmental performance becomes exhausted earlier (with an extremum point of 73.331), while it seems to be prolonged in the high-level regime (with an extremum point of 87.103).
Regarding the variable of a firm's environmental innovation in Model 1a as a dependent variable, we observe from Table 7 that a home country's digitalisation does not vary from a low regime to a high regime, with an extremum point of 74.176 and 76.704, respectively. We also consider a firm's emission and resource use in Models 1b and 1c as dependent variables, respectively. We obtain a similar transition effect of institutional framework for these models, which is significantly different between the low and high regimes. In the low regime, the home country digitalisation worsens a firm's environmental results at an earlier stage, while its positive contribution does not become exhausted in the high regime. In Model 1c, it is worth mentioning that the extremum point of the curve is 98.702. This implies that home country digitalisation allows firms to decrease the use of resources in countries with a strong institutional framework. In summary, these results suggest that institutional framework plays an important role in shaping the impact of home country digitalisation on a firm's environmental results. , The effect of digitalisation on a firm's environmental results is thus

harmful for countries with weak institutions. Conversely, a country's strong institutions can affect a firm's environmental results through high digitalisation.

5. Discussion

This research makes several contributions to the literature. First, we bring the non-linear relationship into debate, as we argue (and empirically show) that further digitalisation can be a double-edged sword: digitalisation is no longer an activity that needs to be maximised by any means (Verbeke & Hutzschenreuter, 2021). Our evidence shows that in the first stage, home country digitalisation has a positive effect on environmental results through enhanced energy efficiency and better resource management, but later, an excess of digitalisation has negative consequences on the environment via high electricity consumption, resource use, and emissions. Second, our results show that institutional framework has an effect on this relationship. The PSTR model empirically confirms that in a high regime of institutional framework, the negative effect of home country digitalisation takes a long time. Conversely, in a low regime, the positive effect of home country digitalisation depletes earlier. Specifically, our findings contribute to the existing body of knowledge in various ways. First, it is a pioneering study of the relationship between home country digitalisation and a firm's environmental performance along its three dimensions (environmental innovation, emissions, and resource use). The findings of our study also provide an international and multi-industrial perspective. Our results can therefore be generalised to other geographic areas and across multiple industries. Second, the importance of our work lies in its contribution to the environmental proactivity literature. We challenge articles that treat digitalisation in a naive way as regards the subject of the natural environment. Our paper demonstrates that digitalisation is not a panacea for the environment. Finally, this research contributes to institutional theory, by showing that institutional framework can flatten the suggested U-shaped curved in the countries with strong institutions.

Our work has some limitations that present new research lines for future study. We analysed home country digitalisation since there was no data available at the firm level regarding the degree of digitalisation. Future works can thus explore whether these findings are confirmed with firm level data. Second, we obtain environmental scores from secondary data that is provided by Thomson Reuters Eikon. It would be useful for future research to propose additional proxies of environmental performance that can be obtained through surveys. Third, we focused on the home-country's institutional framework in the relationship between digitalisation and firm's environmental performance. It would be important to explore other home country dimensions that can alter this relationship. Future research can also provide more empirical evidence, for example, conducting a comparison study between levels of economic development of countries.

Our research has implications for practitioners and policy makers. From a managerial perspective, our research is relevant for managers because our results suggest that they should consider the possibility of encountering challenges in environmental performance at high levels of digitalisation. For instance, Chiarini's work (2021) with Italian manufacturers found that managers remain unsure about the final results of 3D addictive printing. As anecdotal evidence, one of the managers interviewed stated that "[o]ver the years, we gradually introduced first AGVs2 and now the new AMR3. However, we have not saved consumption significantly; on the contrary, we have increased our environmental problems because we now have to cope with batteries and their end-of-life disposal." Our longitudinal, multi-country analysis provides more robust evidence regarding this salient concern about the rebound effects of high levels of digitalisation. Such awareness can allow managers to develop better knowledge, politics and practices to prevent such negative outcomes.

Our study serves as empirical evidence for global discussion on the link between digitalisation and the environment. We confirm that digitalisation itself is not a panacea for the natural environment. Developing an appropriate institutional framework from long-term perspective can avoid the negative environmental impacts of digitalisation. Our analysis of the different home country institutional levels has clear policy implications. Our work shows that government should not take a *laissez faire* policy regarding the digitalisation of companies because, although digital transformation is a global trend, governments still play a key role in fostering (or hindering) the advantages of this technological change. This remaining importance of policymakers has been recently echoed by the European Commission (2020), as an appropriate policy framework allows the adverse effects of digitalisation on the environment to be avoided. For instance, Sanna Marin, Prime Minister of Finland (World Economic Forum, 2021) has indicated that technology alone cannot solve climate change issues, suggesting that national states need to create policy frameworks that enable the transition toward a green economy.

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2 AGV: autonomous guided vehicle.
3 AMR: autonomous mobile robot.

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TABLE 1. NUMBER OF FIRMS BY COUNTRY

COUNTRY	FIRMS	SHARE (%)	COUNTRY	FIRMS	SHARE (%)
ARGENTINA	10	0.20	MALAYSIA	51	1.02
AUSTRALIA	248	4.95	MEXICO	39	0.78
AUSTRIA	28	0.56	NETHERLANDS	57	1.14
BELGIUM	44	0.88	NEW ZEALAND	41	0.82
BRAZIL	87	1.73	NORWAY	46	0.92
CANADA	235	4.69	PERU	13	0.26
CHILE	27	0.54	PHILIPPINES	21	0.42
CHINA	473	9.43	POLAND	30	0.60
COLOMBIA	16	0.32	PORTUGAL	13	0.26
CZECH REPUBLIC	3	0.06	QATAR	2	0.04
DENMARK	39	0.78	RUSSIA	40	0.80
FINLAND	34	0.68	SINGAPORE	39	0.78
FRANCE	138	2.75	SOUTH AFRICA	78	1.56
GERMANY	158	3.15	SPAIN	65	1.30
GREECE	17	0.34	SWEDEN	118	2.35
HUNGARY	4	0.08	SWITZERLAND	107	2.13
INDIA	90	1.79	TAIWAN	122	2.43
INDONESIA	31	0.62	THAILAND	37	0.74
IRELAND	31	0.62	TURKEY	24	0.48
ISRAEL	12	0.24	UKRAINE	1	0.02
ITALY	77	1.54	UNITED ARAB EMIRATES	5	0.10
JAPAN	357	7.12	UNITED KINGDOM	362	7.22
KAZAKHSTAN	2	0.04	UNITED STATES OF AMERICA	1517	30.25
LUXEMBOURG	26	0.52			
			TOTAL	5015	100.00

TABLE 2. NUMBER OF FIRMS BY INDUSTRY

COUNTRY	FIRMS	SHARE (%)
BASIC MATERIALS	577	11.51
CONSUMER CYCLICAL	781	15.57
CONSUMER NON-CYCLICAL	387	7.72
ENERGY	374	7.46
FINANCIAL	793	15.81
HEALTH CARE	341	6.80
INDUSTRIAL	946	18.86
TECHNOLOGY	462	9.21
TELECOMMUNICATION SERVICES	118	2.35
UTILITIES	236	4.71
TOTAL	**5015**	**100.00**

TABLE 3. DESCRIPTIVE STATISTICS AND PEARSON CORRELATIONS

	VARIABLE	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(1)	ENVIRONMENTAL PERFORMANCE	1.000									
(2)	ENVIRONMENTAL INNOVATION	0.647*** (0.000)	1.000								
(3)	EMISSIONS	0.847*** (0.000)	0.289*** (0.000)	1.000							
(4)	RESOURCE USE	0.848*** (0.000)	0.307*** (0.000)	0.721*** (0.000)	1.000						
(5)	HOME COUNTRY DIGITALISATION	-0.082*** (0.000)	-0.010 (0.279)	-0.095*** (0.000)	-0.017** 0.024)	1.000					
(6)	INSTITUTIONAL FRAMEWORK	0.013* (0.056)	0.012 (0.209)	-0.009 (0.243)	0.021*** 0.005)	0.661*** (0.000)	1.000				
(7)	EPI	0.090*** (0.000)	0.083*** (0.000)	0.094*** (0.000)	0.122*** (0.000)	0.629*** (0.000)	0.313*** (0.000)	1.000			
(8)	FIRM SIZE (LOG)	0.474*** (0.000)	0.208*** (0.000)	0.429*** (0.000)	0.425*** (0.000)	0.082*** (0.000)	0.055*** (0.000)	0.066*** (0.000)	1.000		
(9)	FIRM INDEBTEDNESS (LOG)	0.053*** (0.000)	0.052*** (0.000)	0.023*** (0.002)	0.029*** (0.000)	-0.011*** (0.000)	-0.036*** (0.000)	-0.027*** (0.000)	0.060*** (0.000)	1.000	
(10)	GDP (LOG)	-0.098*** (0.000)	-0.069*** (0.000)	-0.102*** (0.000)	-0.090*** (0.000)	-0.465*** (0.000)	-0.331*** (0.000)	-0.631*** (0.000)	-0.056*** (0.000)	0.021*** (0.000)	1.000
	MEAN	39.56	50.17	49.52	49.90	75.89	49.98	66.36	18.60	2.68	0.77
	STANDARD DEVIATION	26.62	25.27	28.94	29.08	18.56	9.48	15.41	2.20	1.54	0.88
	MIN	0.02	0.18	0.13	0.14	23.46	10.94	29.09	13.82	-15.67	-4.34
	MAX	98.53	99.82	99.88	99.86	100	80.38	90.68	26.97	9.43	3.17

Specific p-values are in parenthesis.

*p < 0.10; **p < 0.05; ***p < 0.01

TABLE 4. RANDOM EFFECT MODEL RESULTS

INDEPENDENT VARIABLES:	DEPENDENT VARIABLES: ENVIRONMENTAL PERFORMANCE			
	TOTAL	ENVIRONMENTAL INNOVATION	EMISSIONS	RESOURCE USE
	MODEL 1	MODEL 1A	MODEL 1B	MODEL 1C
HOME COUNTRY DIGITALISATION	1.112*** (0.000)	1.060*** (0.000)	1.206*** (0.000)	0.718*** (0.000)
HOME COUNTRY DIGITALISATION (SQUARED)	-0.008*** (0.000)	-0.007*** (0.000)	-0.009*** (0.000)	-0.005*** (0.000)
EPI	0.132*** (0.000)	0.047 (0.163)	0.196*** (0.000)	0.241 (0.000)
FIRM SIZE (LOG)	6.940*** (0.000)	3.149*** (0.000)	7.759*** (0.000)	7.595 (0.000)
FIRM INDEBTEDNESS (LOG)	0.157 (0.193)	0.371 (0.084)	-0.051 (0.752)	-0.044 (0.782)
GDP (LOG)	-0.192 (0.197)	-0.288 (0.229)	-0.464** (0.019)	0.020 (0.918)
SECTOR EFFECT	Yes	Yes	Yes	Yes
YEAR EFFECT	Yes	Yes	Yes	Yes
CONSTANT	-163.261*** (0.000)	-65.842 (0.000)	-176.816 (0.000)	-163.655 (0.000)
R^2	0.249	0.049	0.225	0.205
NUMBER OF FIRMS	5,015	2,747	4,594	4,516
NUMBER OF OBSERVATIONS	16,893	8,930	15,219	15,068

Standard errors are in parenthesis.

*p < 0.10; **p < 0.05; ***p < 0.01

TABLE 5. TEST FOR HUMP-SHAPED RELATIONSHIPS

	Dependent variables: Environmental performance							
	Total		**Environmental Innovation**		**Emissions**		**Resource Use**	
	Model 1		Model 1a		Model 1b		Model 1c	
Bounds	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
Interval	23.463	100	23.463	100	23.463	100	23.463	100
Slope	0.758	-0.399	0.725	-0.369	0.792	-0.559	0.489	-0.256
t-value	12.499	-10.463	6.742	-5.940	9.835	-11.550	6.157	-5.221
P>t	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Extremum point:	73.593		74.164		68.316		73.712	
Overall test of:	U-shape		U-shape		U-shape		U-shape	
T value	10.46		5.94		9.83		5.22	
P>t	0.000		0.000		0.000		0.000	

TABLE 6. TEST RESULTS FOR MODEL'S NON-LINEARITY

	Dependent variables: Environmental performance			
	Total	Environmental Innovation	Emissions	Resource use
	Model 2	Model 2a	Model 2b	Model 2c
Threshold variable:	Institutional framework			
Fisher Tests (LMF)	7.902 (0.000)	0.574 (0.933)	6.563 (0.000)	6.141 (0.000)
LR_F	9.216 (0.010)	0.282 (0.868)	12.971 (0.002)	6.656 (0.036)

Specific p-values are in parenthesis.

TABLE 7. ESTIMATION RESULTS OF THE PSTR MODEL

INDEPENDENT VARIABLES:	DEPENDENT VARIABLES: ENVIRONMENTAL PERFORMANCE			
	TOTAL	ENVIRONMENTAL INNOVATION	EMISSIONS	RESOURCE USE
	MODEL 2	MODEL 2A	MODEL 2B	MODEL 2C
LOW REGIME:	LOW INSTITUTIONAL FRAMEWORK			
HOME COUNTRY DIGITALISATION	1.138*** (0.000)	1.070*** (0.000)	1.244*** (0.000)	0.735*** (0.000)
HOME COUNTRY DIGITALISATION (SQUARED)	-0.008*** (0.000)	-0.007*** (0.000)	-0.009*** (0.000)	-0.005*** (0.000)
EXTREMUM POINT	73.331	74.176	68.081	73.051
HIGH REGIME:	HIGH INSTITUTIONAL FRAMEWORK			
HOME COUNTRY DIGITALISATION	0.900*** (0.000)	1.022*** (0.000)	0.875*** (0.000)	0.498*** (0.000)
HOME COUNTRY DIGITALISATION (SQUARED)	-0.005*** (0.000)	-0.007*** (0.000)	-0.005*** (0.000)	-0.003* (0.053)
EXTREMUM POINT	87.103	76.704	84.798	98.702
CONTROLS:				
EPI	0.134**** (0.000)	0.046 (0.174)	0.200*** (0.000)	0.245*** (0.000)
FIRM SIZE (LOG)	6.942*** (0.000)	3.153*** (0.000)	7.757*** (0.000)	7.588*** (0.000)
FIRM INDEBTEDNESS (LOG)	0.152 (0.207)	0.371 (-0.283)	-0.057 (0.745)	-0.049 (0.760)
GDP (LOG)	-0.284* (0.071)	-0.283 (0.257)	-0.633** (0.002)	-0.129 (0.534)
SECTOR EFFECT	Yes	Yes	Yes	Yes
YEAR EFFECT	Yes	Yes	Yes	Yes
CONSTANT	-164.083*** (0.000)	-66.239*** (0.000)	-177.899 (0.000)***	-164.010*** (0.000)
THRESHOLD	62.756	62.756	62.756	62.756
NUMBER OF FIRMS	5,015	2,747	4,594	4,516
NUMBER OF OBSERVATIONS	16,893	8,930	15,219	15,068

Standard errors are in parenthesis.

*p < 0.10; **p < 0.05; ***p < 0.01

FIGURE 1. HOME COUNTRY DIGITALISATION AND A
FIRM'S ENVIRONMENTAL PERFORMANCE INVERSE U-SHAPED RELATIONSHIP

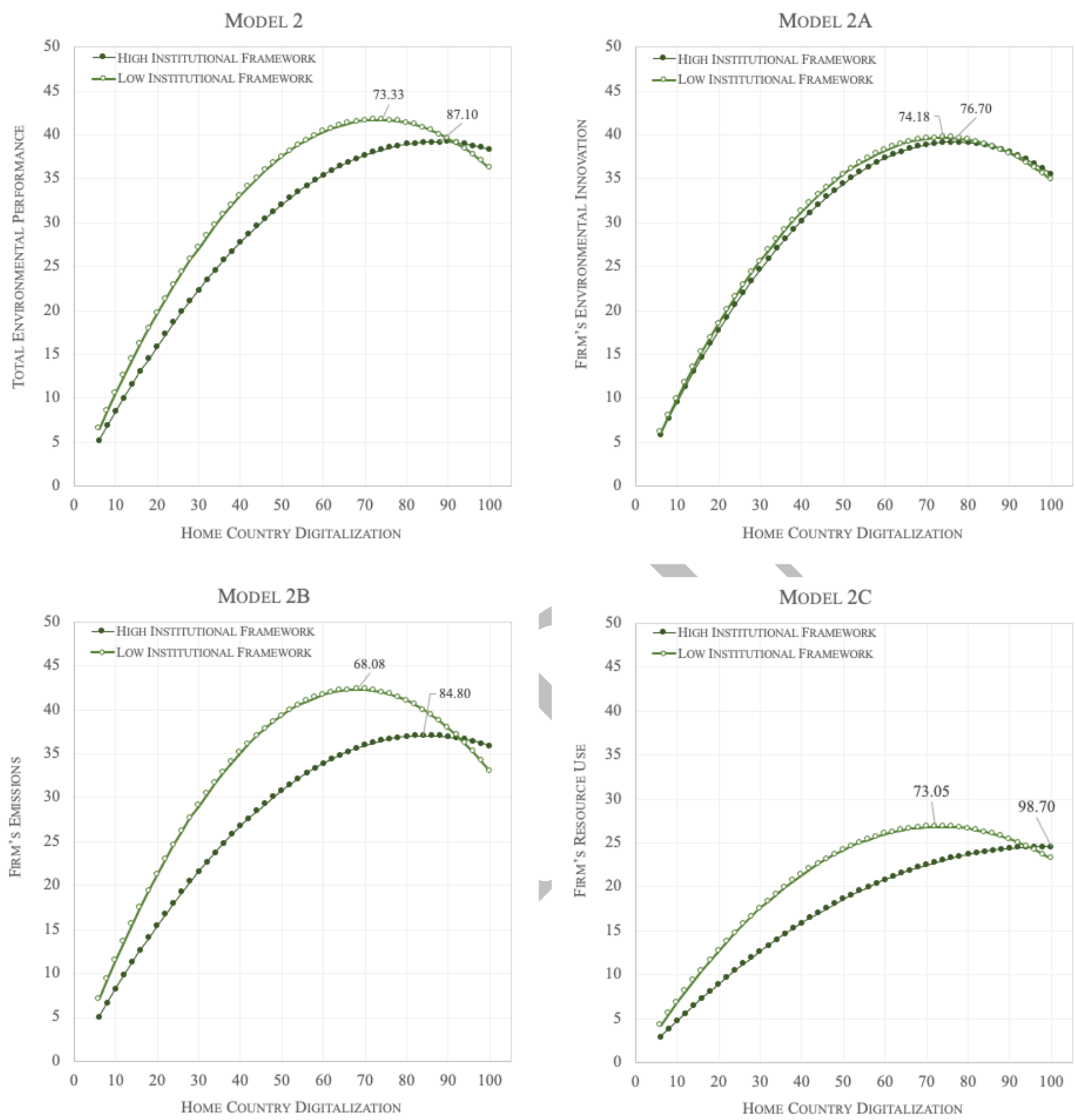

FIGURE 2. ESTIMATED TRANSITION FUNCTION OF THE PSTR MODEL:
TRANSITION VARIABLE: INSTITUTIONAL FRAMEWORK