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Abstract

The relationship between innovation and corporate sustainability constitutes a long-lasting debate among policymakers and researchers. Despite the significant contributions to this field, extant literature does not provide clear answers. This can be attributed to the fact that prior studies do not incorporate the various aspects of innovation to measure their impact on sustainability performance. This study aims to cover this gap in the emerging literature by using a unique micro-level panel dataset consisting of many firms scattered across the US states over the period 2007-2016. Our findings reveal that the basic mechanism for achieving corporate sustainability is through the innovation channel. We also argue that the quantity and value of innovation enhance the sustainability level, whereas these effects are strengthened in times of recession. The empirical results survive robustness checks under alternative innovation measures and different econometric techniques dealing with endogeneity and reverse causality.

JEL classification: 031; 034; L2

Keywords: Innovation; Sustainability; Patents; Trademarks; SMEs

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1. Introduction

The study of corporate sustainability is rather new in the field of economics and management science. It is noteworthy that most of the existing studies investigate some contingencies and additional factors that push the firm to innovate more to become more sustainable (see for example Pedersen et al., 2018; Eccles et al., 2014; Batista and Francisco, 2018; and Staub et al., 2016). Nearly all the studies in the field argue that the innovation-sustainability nexus is more '*complicated'* than a simple direct effect. In this direction, Berrone et al., (2013) investigate the innovation concerning the institutional pressure – on how firms must adjust themselves (and therefore invest in innovation) to comply with an institutional context to deal with external requisites.

Existing literature deals with the environmental, social, and governance (ESG) dimensions of companies, as these are important factors for the economic value, competitiveness, and resilience of the company in the modern globalized environment. The researchers argue that companies, by incorporating sustainable policies into their strategy, enhance transparency by reducing asymmetric information, thus increasing trust between different stakeholders (DiVito and Ingen-Housz, 2021; Eccles et al., 2014). Companies with a strong environmental and social reputation, contribute more to social well-being than others (McWilliams and Siegel, 2001; Godfrey, 2005; Jacobs et al., 2010; and Hsu, 2012).

Wang and Lin (2007) address the topic of corporate sustainability in terms of the collective effort needed to incorporate economic, environmental, and social considerations into a business strategy. Other articles consider further aspects of corporate sustainability like the rise of business costs resulting from companies' non-compliance with governmental rules and regulations that meet sustainability goals. Since the non-compliance cost is usually burdensome for both small and large companies, it is argued that companies that implement sustainable policies not only outweigh the cost of regulations but also build positive customer relationships

(Sen and Bhattacharya, 2001), enhance their brand name, and establish reputation (Fombrun and Shanley, 1990).

The increasing importance of sustainable practices is further reflected in a series of studies covering a wider range of concerns. To give some typical examples, Ziegler and Schröder (2010) explore the impact of sustainability on the firm's size. Other studies (Margolis and Walsh, 2003; Wagner, 2010) examine possible interactions between sustainability and corporate performance whereas several researchers investigate the impact of sustainability on financial performance (Eccles et al., 2014; Dimson et al., 2015; Fatemi et al., 2015, Edmans, 2011; and Krüger, 2015).

Nowadays, it is evident that the corporate dimension of sustainability is a complex issue, as it involves various aspects of management, including cost savings, reputation maintenance, hiring talented people, risk management performance, and achieving resource efficiency. All types of companies and businesses of all sizes have now recognized that achieving sustainability through innovation plays a catalytic role in their development. Yet, despite the growing concern about the impact of innovation on corporate sustainability, the subject remains an open challenge for researchers and policy makers who demand to better understand it. Part of the reason for these unmet expectations is that different businesses have different dynamics depending on their unique characteristics, such as the degree of innovation implemented, the level of market recognition, and the way they compete. The argument that different aspects of innovation create a unique and superior business combination, goes back to Schumpeter (1942). Recent research has shown that innovation can be expressed through various knowledge assets such as R&D investments and patents (Cockburn and Griliches, 1988; Hall et al., 2005). Further, Allegrezza and Guarda-Rauchs (1999) see trademarks as a soft-intensive form of product innovation that adds value to a company. This idea that companies use trademarks to strengthen their strategic position has also been extensively explored by scholars such as Sandner and Block (2011), Block et al. (2014), and Bernstein (2015).

While patents are specific to R&D, trademarks are highly correlated to both R&D and marketing investments (see Castaldi, 2018 and 2020; Fosfuri & Giarratana, 2007; Gao & Hitt, 2012). In this respect, they have been employed as a measure of the innovative output produced by companies (Mendonça et al., 2004, Fosfuri et al., 2008; Block et al., 2015), of strategic downstream assets (Ceccagnoli & Jiang, 2013). Moreover, trademarked brands are strategic tools of communication embedding both cultural features (Barroso, Giarratana & Pasquini, 2019; Mendonça et al., 2004) and symbolic facets (Block et al., 2014). Thus, trademarks can represent a measure of strategic branding targeted to establish a premium price position with an increasing perceived differentiation (Gao & Hitt, 2012).

This paper follows closely the steps of various seminal studies in the field (Corrado and Hulten, 2010; Eisfeldt and Papanikolaou, 2013, 2014; and Peters and Taylor, 2016). Our purpose is to investigate whether firms that are engaged in innovation investments become more sustainable. In doing so, we develop four testable hypotheses regarding the impact of various aspects of innovation on sustainability (ESG).

This study contributes to the literature on many fronts. First, we use a newly developed dataset to measure Socially Responsible Investment (SRI).[1] In contrast to the CSR perspective which has a self-regulation form and provides information about the company's efforts to have a positive impact on employees, consumers, the environment, community, and the Triple Bottom Line approach, which focuses on future strategies, ESG quantifies the company's

[1] SRI includes any strategy which seeks to achieve both financial return and social/environmental goals. Under SRI, firms are encouraged to reduce environmental degradation by promoting consumer protection, human rights, and racial or gender diversity. Corporate social responsibility (CSR) integrates the economic, legal, ethical, and philanthropic responsibilities of a company towards its stakeholders (Carrol, 1991; Hill et al., 2007), the Triple Bottom Line (TBL) approach (Elkington, 1998) that considers the economic, environmental, and social dimensions into a firm's strategy and (ESG) index quantifies company's exposure to environmental, social and governance matters.

sustainability performance to arrive at a more precise assessment of a company's actions. By using ESG, our study takes advantage of this new sophisticated metric that can quantify in detail a firm's sustainable performance and examines the sustainability-innovation nexus more comprehensively. Second, previous literature has focused only on the research and development (R&D) measure of innovation input (Brown et al., 2009; Wagner, 2010) and relates this measure to sub-quantitative corporate sustainability measures. Instead, we examine the impact of research and development expenses (innovation inputs), patents, trademarks, and organizational and knowledge capital (innovation outputs) on the viability of a firm. To our knowledge, this is the first study to perform such a comprehensive analysis.

The rest of this paper proceeds as follows. Section 2 refers to the existing theory and presents a testable hypothesis for our empirical part. Section 3 describes the data, discusses the sample selection, and reports the descriptive statistics evidence. Section 4 introduces our estimation strategy whereas Section 5 presents the analytical framework and discusses the main results. Section 6 discusses the robustness analysis. Section 7 concludes the paper.

2. Related literature and Hypotheses Development

There are mainly two approaches in the innovation-sustainability nexus. The first approach considers social investments as value preserving (Surroca, Tribó, & Waddock, 2010; Barnett, 2007; Van der Have and Rubalcaba, 2016). This is based on the stakeholder's theory suggesting that social investments are a way to respond to institutional pressures and signal commitment, however, they entail monitoring and coordination costs (see among others Berrone, Fosfuri, Gelabert, & Gomez-Mejia, 2013; Godfrey, 2005; Wang & Qian, 2011). The second perspective regards social investments as a firm's or shared value creation. The latter draws upon the social identity theory (Porter & Kramer, 2011; Bode & Singh, 2018; Burbano, 2016; Carnahan, Kryscynski, & Olson, 2017; Flammer & Luo, 2017; Fosfuri, Giarratana, & Roca, 2015).

2.1 Environmental, social, and governance framework

The model of the ESG aspects of corporate sustainability was first introduced back in the 1950s (Carrol, 2009) and since then has gained significant attention within the business strategy analytical framework.[2] Within the last few years, many researchers cast light on various issues related to this framework of reference. In particular, Ghoul *et al.* (2011) report that a strategy based on the ESG model creates firms' value. Ng and Rezaee (2015) propose that firms that achieve simultaneous social, environmental, and financial performance increase their corporate sustainability and, in this way, create value for all stakeholders (Schuler et al., 2017). In other words, when a firm embraces a strategy in the context of the ESG model and conducts business with ethical consideration (Hoepner et al., 2016), it incorporates the organizational capital that matters for the stakeholders and succeeds in becoming economically effective (Sharfman and Fernando, 2008; Schuler et al., 2017).

Firms that implement strategies concerning social responsibility to protect the surrounding community have also many advantages. According to many scholars, firms invest more and more in green practices, therefore managing to reduce their carbon emissions (Hart and Ahuja, 1996). As a side effect, environmentally friendly firms accomplish higher returns than others which disregards society's welfare (King and Lenox, 2002). Eccles and Serafeim

[2] The ESG describes the environmental, social and corporate governance issues. The environmental vector includes climate change, GHG emissions, global pollution, waste issues, and animal mistreatment. The social vector is divided into two parts; the community relations that include human rights abuses, corporate complicity, impacts on communities and social discrimination and the employee relations that include forced labor, discrimination in employment, poor employment conditions. The governance vector that includes corruption, bribery, extortion, money laundering, executive compensation issues, misleading communication, fraud, tax evasion, tax optimization and anti-competitive practices to ensure transparency and accountability.

(2013) argue that the firms, through these types of strategies, can contribute to social prosperity and create a more sustainable society. Others, such as Stern (2008) claim that firms adopt green strategies only to overcome regulations and avoid legal penalties imposed by disobedience to the law such as carbon tax. Whatever their intentions, companies benefit from the introduction of these socially responsible behavioral motivations and, thus, often succeed in producing profitable results. Furthermore, firms with strong environmental awareness, have lower loan spreads and lower average capital costs (Sharfman and Fernando, 2008; Ambec and Lanoie, 2008).

McGuire et al. (1988) demonstrate that a firm can be exposed to risks from lawsuits and fines, as an aftermath of an absence of a strategy related to social responsibility. Furthermore, if a firm fails to commit to the community, consumers may boycott its brand (Sen et al., 2001). Margolis and Walsh (2003) showed that as firms become more socially responsible and concentrate on environmental, social, and ethical cases, they establish a strong brand name and outperform their competitors. Employees' relations (Edmans, 2011) and social giving (Brammer and Millington, 2008) can be further identified as corporate social dimensions, that a firm should address to improve its reputation and social image (Fombrun and Shanley, 1990; Hsu, 2012). Consumers prefer to buy a product or a service from firms with ethical awareness (Godfrey, 2005). Consequently, firms incorporate strategies sensitized to socially sustainable practices to reinforce customer loyalty (McWilliams and Siegel, 2001; Sen and Bhattacharya, 2001). Corporate governance can be quantified and its consequences may have positive effects on the profits of a firm (Godfrey, 2009). A firm's ultimate social responsibility goal is to increase profits. Shareholders observe that the financial performance is better as the corporate governance increases and invest in firms with higher ESG performance (Cremers and Ferrell, 2014; Jo and Harjoto, 2011), which in turn leads to lower cost of equity financing (Cremers and Nair, 2005).

It is worth noting that according to several surveys, institutional ownership (shareholder governance mechanism) and the percentage of external directors on corporate boards have a negative effect on bond yields and a positive effect on bond valuations. Creditors consider that the firms with ESG concerns may damage their reputation and financial position while lenders consider the firms with ESG strategy as profitable investments that can lead to better lending conditions, through transparency and accountability.

2.2 The multi-dimensional nature of innovation

Innovation is the way to companies' growth and evolution. Porter and van der Linde (1995) report that firms in modern competitive economies innovate with the purpose of raising productivity, lowering the total cost, and improving their value. Nidumolu et al. (2009) consider innovation as the key to progress whereas other scholars (Brown and Eisenhardt, 1995; Maskus and Penubarti, 1995; Wadhwa and Kotha, 2006; Miller *et al,* 2007) claim that firms anticipate competitors more on a technology and quality basis rather than price competition. Hall (1992) argues that firms with innovation and intangible assets create a competitive advantage and value for a longer period.

To understand the conceptual differences of innovation as well as their relationship to corporate sustainability, we need to study further the different aspects of innovation such as R&D, patents, trademarks, organization capital, and knowledge capital. R&D activities, patents, and trademarks were often used as individual variables for measuring companies' innovation activities (Kleinknecht *et al*., 2002). Using a set of key variables that construct the concept of corporate innovation, this research is the first of its kind which studies the overall impact of innovation across all dimensions of firms' sustainability.

In particular, we distinguish between the input and output factors of the innovation process. Due to their differences in many ways, especially considering the high uncertainty surrounding R&D investments, their effects on firms' sustainability may differ. Firstly, we use as an input factor to the innovation process, the knowledge capital, which is valued as the replacement cost of unsuccessful expenditures on R&D (Sandner and Block, 2011; Peters and Taylor, 2016). Knowledge-based capital consists of all the knowledge that a company possesses, such as information, experience, and learning skills of its employees and it's a key factor for efficiency and innovation. Chen, (2008) and Boiral (2002) report that the knowledge capital of a firm is part of the intangible capital that is created by R&D and gives a significant competitive advantage to a firm.

Secondly, we take a step forward and separate the output factors of the innovation process to record the difference between an innovation with a patent and a non-patented one. We use several innovation-outputs, such as patents, trademarks, and organizational and knowledge capital, to explore their impact on corporate sustainability.

Organizational capital is another important corporate asset that contains diversified risk characteristics for a firm's internal and external environment. Many scholars in the field studied organizational capital and have analyzed its important contribution to the production processes and systems (Prescott and Visscher, 1980; Atkeson and Kehoe, 2005; Eisfeldt and Papanikolaou, 2013; Lustig *et al*, 2011). Organizational capital can include knowledge that has been registered, captured, exchanged, or even codified, through several tools, such as databases, manuals, routines, and patents. It constitutes human and social capital interactions. It is a value-contributing asset that differentiates the firm from its competitors and, thus, creates a competitive advantage. Moreover, it enables tangible and intangible assets, such as machinery, buildings, land, patents, brands, and human capital, to be productive. To capture the aggregate effect of innovation on corporate sustainability, we use the intangible capital construct which is the sum of the knowledge capital and the organizational capital (Peters and Taylor, 2016). As far as we know there is no previous research that studies in such detail the impact of innovation aspects on sustainability so we expect to make a significant contribution.

2.3. Sustainability: A risk mitigation tool

Being innovative and sustainable requires more than just having good ideas. By investing in R&D, companies generate new knowledge and increase their knowledge capital. But companies need to keep in mind that innovation activity is a long and continuous process, idiosyncratic and without guaranteed results (Holmstrom, 1989). To gain a competitive advantage through innovation (Brown and Eisenhardt, 1995; Wadhwa and Kotha, 2006; Miller et al, 2007), firms must undertake risks and invest significantly in intangible capital (Helfat, 1994). They should use trademarks (Cardozo et al., 1995; Cockburn and Griliches, 1988) and patents (Hall et al., 2005; Sandner and Block, 2011) to promote and secure new products. The implementation of such strategies increases investment in intangible assets and the uncertainty of the company. Eisfeldt and Papanikolaou (2013) report that firms with higher organization capital are considered riskier by shareholders than those with physical capital. This leads shareholders who invest in those companies to seek higher risk premiums. Huberman and Regev (2001) report that intangible assets due to the increased asymmetric information they enclose are difficult to assess, especially by investors with limited attention. From all of the above, we end up that firms with increased intangible assets such as R&D, patents, trademarks, knowledge, and organizational capital involve significant non-systemic risks and are hard to evaluate. However, over the years firms tend to hold more and more intangible assets (Syverson 2011; Kogan et al., 2017) to become more competitive and increase their performance (Grant, 1996). Hence, there is a strong need to implement risk control and limitation policies through monitoring and the development of appropriate innovation strategies.

The development of a framework with appropriate sustainability strategies and the disclosure of information about this implementation can help investors evaluate long-term risk factors and identify investment opportunities based on these risks. Innovation is a long-term investment, so investors and shareholders want to minimize the risk of investing in firms that are likely to be out of business shortly. A sustainability scoring framework is a tool that enables investors to formulate strategies in this direction by making quantitative-driven investing. One of the many advantages of this quantitative analysis is that mirrors the value of the firm's intangible capital (Peters and Taylor, 2016). Investors, through the implementation of the ESG analytical framework, are motivated to invest responsibly to create value (McGuire et al., 1998). The ESG is a risk mitigation tool that can reduce asymmetric information around innovation and create transparency. It consists of an important tool, especially for risk-averted investors who shape strategies with the belief that the benefits may lie more in reducing risk versus adding value. Following the discussion above, we came to the conclusion that is very useful for highly intensive innovation companies to be sustainable.

2.4. Innovation and sustainability nexus

Given that the concept of sustainability covers a large range of aspects, someone would expect to see these differences depicted in much of the earlier research related to the subject. The literature shows, however, that most of the studies undertaken up to now focus just on the effects of individual innovation aspects rather than on a more holistic approach. A large number of studies found a positive relationship between innovative environmental strategies and firms' performance (Hart, 1995; Nehrt, 1998, Dean and Brown, 1995; Porter and van der Linde, 1995; Klassen and McLaughlin, 1996; Judge and Douglas, 1998; Sharma and Vredenburg, 1998; Klassen and Whybark, 1999). Firms use proactive environmental strategies to overcome regulatory issues, and entry barriers and increase their capabilities as well as social acceptance (Dean and Brown, 1995; Hart, 1995; Russo and Fouts, 1997; Sharma and Vredenburg, 1998; Aragón-Correa and Sharma, 2003). Other studies report that highly innovative firms respond more to rapid and abrupt environmental changes (Schumpeter, 1942; Grossman and Helpman, 1994). Sustainable innovation is not only limited to overcoming regulation costs associated with environmental outcomes (Carrion-Flores and Innes 2010) but also has the potential to radically change the structures of corporate innovation (Aghion et al., 2015). This is mainly because innovation generates positive externalities and accelerates the diffusion and adoption of new, more sensitive, sustainable standards.

Another strand of literature reports a positive association between corporate governance and various aspects of innovation (R&D, patents, and trademarks). Sandner and Block (2011) argue that R&D, patent, and trademark activity increases market value by protecting firms' knowledge and marketing assets. Firms through innovation transmit information and signal their value, increase transparency, and untimely increase their financial performance (Landes and Posner, 1987; Cockburn and Griliches, 1988; Besen and Raskind, 1991). This paper follows the work of Heeley et al. (2007), Krasnikov et al. (2009), Sandner and Block (2011), Useche (2014), Bernstein (2015), and Block *et al.* (2014) who empirically examined the relationship between innovation and corporate sustainability. All the above yields substantial first-mover advantages that help firms to adapt and face regulators as allies by leading the way toward innovative corporate sustainability.

2.5 Hypothesis Development

Based on the above discussion, we end up making testable predictions. Innovation is a significant factor that creates value and helps firms to turn the compliance arising from the regulations into opportunity, but it is also idiosyncratic and has an economic cost and risk. Investment in innovation, however, improves monitoring, raises awareness, develops risk prevention strategies, and formulates tools for responding to different levels of market and technological challenges. In addition, innovation is an essential factor that enhances competitiveness, and technological improvements, and helps firms to comply with the rules before they are legally enforced.

2.2.1. R&D activity has a positive impact on sustainability (H1)

The literature justifies that R&D is linked positively with innovation. We hypothesize that R&D empowers companies to generate innovation, increase their competitiveness and formulate the tools to be more sustainable.

2.2.2. Patent activity has a positive impact on sustainability (H2)

The literature provides evidence that patents promote and secure new products and the firm's market position. Also, they enable companies to increase their standards and turn regulators into allies by leading the way. Firms' patent activity enhances and protects ESG's possible outcomes. We hypothesize that patents have a positive impact on sustainability.

2.2.3 Trademarks activity has a positive impact on sustainability (H3).

The literature documents that trademarks express the firm's soft-intensive innovation about the product and enable companies to establish and secure a strong market position and customer loyalty. Firms create trademarks at the early stage of sustainable development as a tool to capitalize on and protect its possible outcomes. Therefore, we assume that trademarks of a protective and informative role have a positive impact on sustainability.

2.2.3 Firms' knowledge and organizational capital have a positive impact on sustainability (H4).

We proxy the quality of innovation by using the firm’s replacement cost of organization and knowledge capital. The former, that is the organizational capital, is an important corporate asset that contains diversified risk characteristics and comprises the value of a firm's capabilities such as organizational learning, infrastructure, organization processes, and knowledge to create products and services as well as the organization’s philosophy. It provides information on internal knowledge (Atkeson and Kehoe,2005), strategies, technology, and human capital (Eisfeldt and Papanikolaou,2013). The latter, that is the knowledge capital, comprises the value of the firm's knowledge and internal procedures. It represents the full body of knowledge and innovation that the firm possesses. It also contains human, relational, and structural capital such as experience, learning, and skills of employees. Chen (2008) and Boiral (2002) with their empirical results propose that it enhances a firm's efficiency and improves its competitive advantage Additional, knowledge capital is a catalyst that through knowledge transfer plays a significant role in the formation of better strategies that help the integration of tangible and intangible assets. From all the above, we expect that firms who invest in organizational and knowledge capital will face a higher probability of complying with regulations, reducing risk, increasing revenue streams, and creating sustainability. So, we expect a positive relationship between knowledge capital, organizational capital, and sustainability.

3. Data and sample variables

Our empirical analysis is based on a micro-level dataset of 1,048 US small and medium-sized firms covering the period 2007- 2016. We solely focus on firms that report R&D spending for the whole period of our analysis. Our variables come from different databases. Specifically, the dependent variable is firm sustainable performance (*ESG*) and is constructed based on a firm's risk index (Rep Risk Index, RRI). We define ESG=100-RRI, where RRI is a proprietary risk metric that quantifies a company's exposure to environmental, social, and governance matters. The RRI score is calculated based on several factors. It includes possible information source influences, the frequency of criticisms, and the novelty and severity of the criticism. The RRI score ranges from zero (lowest) to 100 (highest) and the higher the value of the score, the higher the risk exposure. Accordingly, our dependent variable (*ESG*) ranges from zero (lowest level of sustainability) to 100 (highest level of sustainability). Information on RRI is derived from the: RepRisk, *Global Business Intelligence* database. We also consider three major components of (ESG), namely the environmental (*Environmental*), social (*Social*), and corporate (*Corporate*).[3] We obtain information for the firm's sales (*Sales*) in millions of dollars from the Compustat database. To increase the sensitivity of our analysis we capture the firm's innovation using the following variables: (i) R&D spending (millions of dollars) shared to total sales (*R&D/ Total Assets*) which is the major asset of the innovation activity and represents the input of innovation; (ii) The number of patents of a firm share to total sales (*Pat/Total Assets*) as an output of innovation activity; iii) In addition to the innovation of the product, we use (Trademarks/Sales) to capture the firm's soft intensive innovation around the product. Therefore, we study the impact of innovation on firms' sustainable performance through the market establishment channel. Data on the former's measures come from the Compustat database, while for the latter from the Orbis Intellectual Property, a global company database, produced by the Bureau Van Dijk. Finally, following Peters and Taylor (2016) to study a firm's innovation activity we use the replacement cost of a firm's organizational capital, knowledge capital, and intangible capital as a proxy of a firm's innovation. These measures come from the WRDS database Peters and Taylor (2016). To capture firms' market establishment, we use trademarks as a share of sales (*TM/Sales*) and data that come from the Orbis database. Finally, we add a dummy for the 2008 financial crisis (*Crisis*) which takes the value of 1 for the years 2007, and 2008, and zero otherwise. Table 1 provides the summary statistics of our sample variables over the examined period.

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[3] Environmental sustainability relates to environmental policy and environmental management performance; Social sustainability concerns citizenship and socially responsible stakeholders' engagement, labor practice indicators, human capital development, knowledge management, and organizational learning, social reporting, talent attainment, and retention. Corporate governance sustainability as defined by Letza et al. (2004), is about the understanding and institutional arrangements for relationships among various economic actors and corporate participants who may have direct or indirect interest in a corporation, such as shareholders, directors/ managers, employees, creditors, suppliers, customers, local communities, government, and the general public.

Table 1: Descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
ESG	6,802	91.33	11.65	28.5	100
Sales/Total assets	6,802	1.12	.81	0	8.60
(Sales/Total assets)2	6,802	1.93	3.83	0	74.07
Sales growth (%)	6,802	.24	6.10	0	474.81
Advertising	6,802	111.86	503.56	0	9729
Firm Age	6,802	36.47	29.85	2	159
R&D/Total assets (%)	6,802	.08	1.43	0	93.08
Patents/Total assets (%)	6,802	.03	1.00	0	61.32
Knowledge Capital/Total assets (%)	6,802	.42	7.20	0	469.65
Organization Capital/Total assets (%)	6,802	.34	1.26	0	81.13
TM/Sales (%)	6,802	.03	1.04	0	53.57
Crisis	6,802	.11	.31	0	1

This table reports descriptive statistics for a sample of 1,048 US firms. It provides the mean, standard deviation, minimum and maximum statistics for the sample as well as the total number of observations.

Table 1 documents descriptive statistics for our sample. Firms' sustainable performance (*ESG*) is on average quite high about 91.33 (out of 100), and on average, firms grow by 0.24%. When it comes to their innovation performance, firms spend, on average, 8% of their economic value on R&D investment. Respectively, the share of patents to total assets and trademarks to sales is 3%. Last but not least, a firm's organization and knowledge capital replacement cost weighted by total assets is 34% and 42% respectively.

Figure 1 provides a visualization of the spatial distribution of sustainability across the US states over the sample period, 2007 - 2016. As we have the location of the firms and their sustainability performance, we were able to provide a spatial presentation of the firms in our sample.

Figure 1: Spatial distribution of average sustainability performance for US firms, 2007-2016

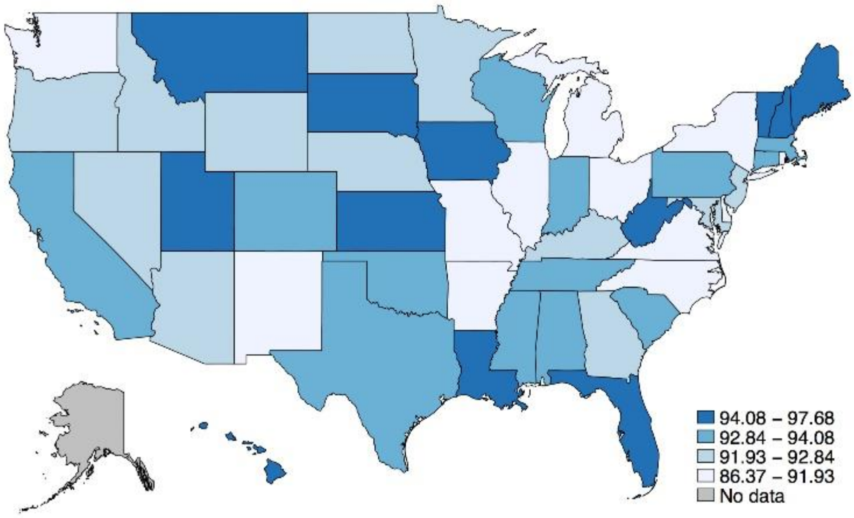

Figure 1, documents a high concentration of sustainable firms with deep blue in the Northeast, Southeast, and central states, whereas a very light blue (almost white) are states with the least sustainable performance. Comparing Figure 1 with Figure A.1, A.2, and A.3 in Appendix one can derive a positive relationship between sustainability, innovation, and firms' market establishment.

4. Estimation strategy and methodology

To support the basic research hypotheses (i.e., H1, H2, and H3) as expressed in a previous section of this paper, our model follows closely Wagner (2010) description which is given in brief as follows:

$$SUS_{it} = \beta_i + \beta_1 (Sales/Total\ assets)_{t-1} + \beta_2 (Sales/Total\ assets)^2_{t-1} + \beta_3 (Sales\ growth)_{t-1} + \beta_4 (FirmAge)_{t-1} + \beta_5 (Patents/Total\ assets)_{t-1} + \beta_6 (Trademarks/Total\ assets)_{t-1} + \beta_7 (Sales\ growth)_{t-1} + \beta_8 (R\&D/Total\ assets)_{t-1} + \beta_9 (Advertising)_{t-1} + \beta_{10} (Crisis\_dummy)_{t-1} + \varepsilon_{it} \quad (1)$$

The following equation tries to explore the validity of hypothesis (H4):

$$SUS_{it} = \beta_i + \beta_1 (Sales/Total\ assets)_{t-1} + \beta_2 (Sales/Total\ assets)^2_{t-1} + \beta_3 (Sales\ growth)_{t-1} + \beta_4 (FirmAge)_{t-1} + \beta_5 (Knowledge\ Capital/Total\ assets)_{t-1} + \beta_6 (Organization\ Capital/Total\ Assets)_{t-1} + \beta_7 (Advertising)_{t-1} + \beta_8 (Crisis\_dummy)_{t-1} + \varepsilon_{it} \quad (2)$$

We use the following variation to study the effect of innovation efficiency on sustainability

$$SUS_{it} = \beta_i + \beta_1\,(\mathit{Sales/Total\ assets})_{t-1} + \beta_2\,(\mathit{Sales/Total\ assets})^2_{t-1} + \beta_3\,(\mathit{Sales\ growth})_{t-1} + \beta_4\,(\mathit{FirmAge})_{t-1} + \beta_5\,(\mathit{Crisis})_{t-1} + \beta_6(\mathit{Advertising})_{t-1} + \beta_7(\mathit{Patents/Total\ assets})_{t-1} + \beta_8(\mathit{Trademarks/Sales})_{t-1} + \beta_9(\mathit{Patents/R\&D})_{t-1} + \beta_{10}(\mathit{TM/R\&D})_{t-1} + \varepsilon_{it} \quad (3)$$

where *t* and *i* are year and firm, respectively and ε_{it} is i.i.d. error term.

The dependent variable is the firm's sustainability performance (ESG) index. To increase the sensitivity of our analysis we capture the firm's innovation using the following variables: (i) R&D spending (millions of dollars) shared to total sales (*R&D/ Total Assets*) which is the major asset of the innovation activity and represents the input of innovation; (ii) The number of patents of a firm to total assets (*Pat/Total Assets*) as an output of innovation activity; iii) In addition to the innovation of the product, we use the share of trademarks over sales (*Trademarks/Sales*) to capture the firm's soft intensive innovation on the product. Therefore, we study for the first time in the literature the impact of innovation on sustainability through the channel of the firm's market establishment iv) Finally, following Peters and Taylor (2016) our study is also the first that uses the replacement cost of intangible capital, knowledge capital, and organizational capital, to capture the aggregate effect of the quality of innovation on sustainability.

In line with Johnstone and Labonne (2009), we control for firms' sales over total assets (Sales/Total Assets); we use the quadratic term of the former variable *(Sales/Total assets)*^{2} to control for diminishing returns and the sales growth (*Sales Growth)* to control for profitability trend. Finally, we control for firm extroversion using advertising expenses (*Advertising*), firm age (*FirmAge*), and cold periods (Crisis Dummy) as in Gompers (1995) and Li (2008). In our analysis, we use both industry and year-fixed effects.

Although we use a rich set of control variables there may be still unobserved variables that are missing from our model as well as problems that may arise from the heterogeneity between the firms in the sample. For this reason, we re-estimate our model by applying propensity matching score techniques (Rosenbaum and Rubin, 1983) to alleviate possible endogeneity issues[4]. Specifically, we use a propensity to match firms that have innovation below the average of our sample with those above. In this way, we compare firms in matching samples that differ only in the level of innovation.

To secure our findings and check for robustness, we re-estimate our model with the two-stage least square method (2SLS). For this reason, we employ exogenous instruments to firm-specific characteristics (e.g. state R&D weighted by firm size, yearly total Utility patents issued to state residents[5], and Higher Education R&D performance[6]). In all the regressions, we keep the number of observations constant for a better comparison of the estimates and include industry and year-fixed effects. Overall, our estimation strategy by using 2SLS with a rich set of instruments and propensity matching score techniques, secures that our results are not driven by endogeneity and reverse causality.

5. Results and discussion

Our first hypothesis argues that there is a positive relationship between sustainability and innovation. Table 2 presents the estimates of equation (1). Columns (1) and (2) refer to innovation investment and *R&D*, and columns (3) to (7) to the output of innovation in various

[4] Based on the propensity score matching method, we much firms that have sustainability above the sector average (i.e. treated firms) with those they do not (i.e. control firms) based on the control variables of our model specification. To further account that our results are not driven by different matching methods we use the three most common methods (Zhao 2004) which are based on the nearest neighbor, kernel, and stratification matching.

[5] Yearly totals for patents granted is determined by the residence of the first-named inventor

[6] The Higher Education Research and Development performance is a source of information for R&D expenditures at U.S. colleges and universities

specifications expressed by patents and trademarks. Finally, column (8) tests for the extroversion of innovation through advertising. Robust standards are included in parentheses.

Table 2: Effect of Innovation on Sustainability (Dep. Var.: *ESG*)

VARIABLES	(1) ESG	(2) ESG	(3) ESG	(4)	(5) ESG	(6) ESG	(7) ESG	(8) ESG	(9) ESG
(Sales/Total assets) $_{t-1}$	0.871***	0.885***	0.869***	0.870***	0.883***	0.807**	0.820**	0.755**	0.882***
	(0.330)	(0.330)	(0.329)	(0.330)	(0.330)	(0.328)	(0.329)	(0.326)	(0.330)
(Sales/Total assets) $^{2}_{t-1}$	-0.052	-0.054	-0.052	-0.052	-0.054	-0.041	-0.043	-0.037	-0.052
	(0.059)	(0.059)	(0.059)	(0.059)	(0.059)	(0.059)	(0.059)	(0.059)	(0.059)
(Sales growth) $_{t-1}$	0.026*	0.026*	0.026*	0.026*	0.026*	0.026*	0.026*	0.025*	0.027*
	(0.015)	(0.015)	(0.015)	(0.015)	(0.015)	(0.015)	(0.015)	(0.015)	(0.015)
(FirmAge) $_{t-1}$	-0.067***	-0.067***	-0.067***	-0.067***	-0.067***	-0.063***	-0.063***	-0.065***	-0.067***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Crisis	6.919***	6.915***	6.920***	6.916***	6.916***	7.199***	7.196***	7.334***	6.909***
	(0.504)	(0.504)	(0.504)	(0.504)	(0.504)	(0.501)	(0.501)	(0.498)	(0.505)
(Advertising) $_{t-1}$	-0.008***	-0.008***	-0.008***	-0.008***	-0.008***	-0.008***	-0.008***	-0.010***	-0.008***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
(Patents/Total assets) $_{t-1}$			0.128*** (0.033)		0.128*** (0.033)	0.134*** (0.036)	0.133*** (0.036)	0.127*** (0.034)	0.127*** (0.032)
(R&D/Total assets) $_{t-1}$	0.088**	0.087**							
	(0.038)	(0.038)							
(TM/Sales) $_{t-1}$		0.077***		0.078***	0.078***		0.072***	0.067***	0.076***
		(0.019)		(0.019)	(0.019)		(0.019)	(0.019)	(0.019)
(Patents/Total assets) $_{t-1}$ *x(Advertising)* $_{t-1}$								0.302***	
								(0.061)	
(TM/ R&D) $_{t-1}$									0.271***
									(0.097)
(Patents/ R&D) $_{t-1}$									0.045
									(0.080)
Observations	6,802	6,802	6,802	6,802	6,802	6,802	6,802	6,802	6,802
R-squared	0.288	0.288	0.288	0.288	0.288	0.300	0.300	0.314	0.289
Year FE	YES	YES	YES	YES	YES	YES	YES	YES	YES
Sector FE	YES	YES	YES	YES	YES	YES	YES	YES	YES
ROBUST	YES	YES	YES	YES	YES	YES	YES	YES	YES

The table reports coefficient estimates and standard errors of regressions based on equations (1) and (3). The dependent variable is the firm's sustainability (ESG). All variables are defined in Table A1. The estimation method is OLS with robust standard errors. All models include year and industry-fixed effects. An asterisk indicates significance at the 10% level; two indicate significance at the 5% level; three indicate significance at the 1% level.

The key explanatory variables are (*R&D/ Total Assets*), *(Patents/Total assets), and (TM/Sales).* In line with Johnstone and Labonne (2009), we control for firms' sales over total assets (Sales/Total Assets); we use the quadratic term of the former variable *(Sales/Total assets)*^{2} to control for diminishing returns and the sales growth (*Salesgrowth)* to control for profitability trend. Finally, we control for firm extroversion using advertising expenses (*Advertising*), firm age (*FirmAge*), and cold periods (*Crisis_dummy*) as in Gompers (1995) and Li (2008). The response variable is the firm's sustainability performance, (*ESG).* In our analysis, we use both industry and year-fixed effects.

As Table 2 shows, estimates are quite stable and statistically robust across all the specifications. Sales *(Sales/Total assets)* have a positive impact on sustainability as a one percent increase in sales results in 0.75 (column 8) to 0.88 (column 2) units of increase in the firm's sustainability performance[7]. This finding is in alignment with prior literature (see for example Hirsch, 1990; Wagner, 2010). Further, we examine the presence of no linear effects of sales on sustainability by using the quadratic term of sales *(Sales/Total assets)* ^{2}. We expect to find a negative association with sustainability, as the marginal effect is negative at the data means but we take no statistically significant effect. In other words, we argue that non-linear effects are not present and monotonicity prevails. Growth in sales (*Sales growth*) is generally found to be positively correlated with a firm's value (Hirsch, 1990). Specifically, we argue that when a firm's sales growth is relatively high, corporate sustainability is positively related to firm value. In contrast, when a firm's sales growth is relatively low, the magnitude of the positive relationship is reduced. The higher the sales growth, the stronger the relationship will be between corporate sustainability and firm value. The possible managerial implication for this result is that some investors may be hesitant about a firm's sustainable strategies which, in

[7] In level-log specifications, as it is ours, estimates of log regressors are interpreted as follows: If regressor x increases by one percent, one expects regressant y to increase by (β1/100) units of y [Δy=(β1/100) %Δx].

their beliefs, will increase a firm's production and operation costs and thus reduce sales. Therefore, good news on sales growth for a sustainable firm will stimulate investors to give a higher valuation. Investing in R&D activity is associated with an increase of 0.08 in the firm's sustainability, as the coefficient (*R&D/Total assets*) in columns (1) and (2) indicate. Investing in patents also increases the sustainability performance of a firm. An increase in patent activity (*PAT/ Total assets*) relates to an increase in a firm's performance from 0.127 to 0.134 percent as shown in columns (3) and (5) to (8) respectively. A firm's reconcilability and penetration in the market -both proxied by trademarks (*TM/Sales*) in columns (2) to (4) and (7) to (8) are important factors for a firm's sustainability. Even when we include hard intensive innovation measures such as R&D and patents together results do not alter and the trademarks effect plays a significant role in firms' sustainability that ranges from 0.67 to 0.77. The financial crisis of 2008, as expected, had a positive impact on firms' sustainability. [8] Last but not least, as column (8) presents the effect of advertising on innovation increases sustainability. Consumers are making adjustments in their preferences and strongly support companies that are more sustainable conscious.

In column (9) we use an alternative model specification to study the impact of innovation efficiency on sustainability. [9] Therefore, we construct the variables (*Patents/R&D and (TM/R&D) as* the shares of patents and trademarks to R&D to capture hard and soft-intensive innovation efficiency respectively (see Hirshleifer, 2013). These measures are not in general highly correlated with the innovation predictors (Chan, 2001; Gu, 2005) that we have already used therefore their usage may reveal useful incremental information.

[8] Firms use sustainability as a risk mitigation tool.

[9] Is the maximization of the output produced from the invested R&D improving innovation performance and enhancing competitiveness?

Based on the above considerations, we estimate equation (3). The results document that soft-intensive innovation efficiency matters (see Table A2). The intuition behind this finding is that the ultimate competitive advantage in terms of sustainability is capitalized from policies and methods that companies develop. This finding is in line with the existing literature (McWilliams and Siegel, 2001; Sen and Bhattacharya, 2001; Godfrey, 2005).

Next, we split the response variable (ESG) into its three major components namely environmental (EP), social (SP), and governance (GP). As Table 3 shows, columns (1) to (4) and columns (5) to (7) present the effect of innovation expressed by R&D patents and trademarks respectively on the major components of sustainability.

Table 3: Effect of Innovation on the three major sustainability (*ESG*) components namely environmental (*EP*), social (*SP*), and governance (*GP*)

VARIABLES	(1) ESG	(2) EP	(3) SP	(4) GP	(5) EP	(6) SP	(7) GP
(Sales/Total assets) $_{t-1}$	0.871***	0.035***	-0.004	0.048***	0.035***	-0.004	0.048***
	(0.330)	(0.009)	(0.008)	(0.009)	(0.009)	(0.008)	(0.009)
(Sales/Total assets) $^{2}_{t-1}$	-0.052	-0.006***	0.004***	-0.005***	-0.006***	0.004***	-0.005***
	(0.059)	(0.002)	(0.001)	(0.002)	(0.002)	(0.001)	(0.002)
(Sales growth) $_{t-1}$	0.026*	0.000	0.000	0.001**	0.000	0.000	0.001**
	(0.015)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)
(Advertising) $_{t-1}$	-0.008***	-0.000***	-0.000***	-0.000***	-0.000***	-0.000***	-0.000***
	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
(FirmAge) $_{t-1}$	-0.067***	-0.001***	-0.001***	-0.000***	-0.001***	-0.001***	-0.000***
	(0.005)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Crisis	6.919***	0.007	0.130***	0.208***	0.007	0.130***	0.208***
	(0.504)	(0.009)	(0.014)	(0.013)	(0.009)	(0.014)	(0.013)
(Patents/Total assets) $_{t-1}$					0.001***	0.001**	0.005***
					(0.000)	(0.001)	(0.001)
(TM/Sales) $_{t-1}$					0.001***	0.001	0.003***
					(0.000)	(0.001)	(0.001)
(R&D/Total assets) $_{t-1}$	0.088**	0.001**	0.001	0.003***			
	(0.038)	(0.000)	(0.001)	(0.001)			
Observations	6,802	6,802	6,802	6,802	6,802	6,802	6,802
R-squared	0.288	0.134	0.108	0.129	0.134	0.108	0.129
Year FE	YES	YES	YES	YES	YES	YES	YES
Sector FE	YES	YES	YES	YES	YES	YES	YES
ROBUST	YES	YES	YES	YES	YES	YES	YES

The table reports coefficient estimates and standard errors of regressions based on equations (1). The dependent variable is the firm's sustainability (ESG) and its components namely environmental (*EP*), social (*SP*), and governance (*GP*). All variables are defined in Table A1. The estimation method is OLS with robust standard errors. All models include year and industry-fixed effects. An asterisk indicates significance at the 10% level; two indicate significance at the 5% level; three indicate significance at the 1% level.

As sales become larger, a firm's sustainability increases at a decreasing rate until it reaches a maximum level; this finding also aligns with existing literature (Wagner, 2010). In the next stage, we check for non-linear effects of sales on sustainability by using the quadratic term of sales *(Sales/Total assets)* ^{2}, we find a negative and statistically significant correlation with all components of sustainability. The dynamics of the market, proxied by the growth of sales (*Salesgrowth*), do not play an important role in environmental (EP) and social (SP) components but governance (GP) is statistically significant. We find a positive relationship between innovation proxy by R&D, patents, and trademarks and firms' sustainable performance (ESG). One can note that although the coefficients are different in size compared to those reported in Table 2, their relative significance remained unaltered. One reason for this might be attributed to the fact that firms are less motivated to work on social aspects of sustainability as regulation or taxation are more relevant to the other two aspects of the ESG.

In the next stage, we study the impact of innovation quality on a firm's corporate sustainability which is a direct test that corresponds to our hypothesis (H4). The structure of Table 4 resembles that of Table 2, but we shed light on the quality aspect of innovation proxy by its value. We use knowledge capital, organization capital, and the aggregate sum of intangible capital to measure the value of innovation.

Table 4: Effect of the value of Innovation on Sustainability (Dep. Var.: *ESG*)

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	ESG	ESG	ESG	ESG	ESG	ESG
(Sales/Total assets) $_{t-1}$	0.870***	0.871***	0.799**	0.891***	0.902***	0.741**
	(0.329)	(0.330)	(0.331)	(0.329)	(0.331)	(0.334)
(Sales/Total assets) $^{2}_{t-1}$	-0.052	-0.052	-0.045	-0.055	-0.056	-0.038
	(0.059)	(0.059)	(0.059)	(0.059)	(0.059)	(0.059)
(Sales growth) $_{t-1}$	0.026*	0.026*	0.026*	0.024*	0.025*	0.027*
	(0.015)	(0.015)	(0.015)	(0.014)	(0.014)	(0.015)
(FirmAge) $_{t-1}$	-0.067***	-0.067***	-0.067***	-0.067***	-0.067***	-0.067***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Crisis	6.920***	6.919***	6.929***	5.777***	6.710***	6.339***
	(0.504)	(0.504)	(0.504)	(0.652)	(0.529)	(0.614)
(Advertising) $_{t-1}$	-0.008***	-0.008***	-0.008***	-0.008***	-0.008***	-0.008***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
(Intangible Capital/Total assets) $_{t-1}$	0.019**			0.019**		
	(0.009)			(0.009)		
(Organization Capital/Total assets) $_{t-1}$			0.272*			0.264*
			(0.154)			(0.150)
(Knowledge Capital/Total assets) $_{t-1}$		0.018**			0.017**	
		(0.008)			(0.008)	
(Intangible Capital/Total assets) $_{t-1}$				1.588***		
x Crisis				(0.435)		
(Knowledge Capital/Total assets) $_{t-1}$					0.912***	
x Crisis					(0.297)	
(Organization Capital/Total assets) $_{t-1}$						2.075**
x Crisis						(1.009)
Observations	6,802	6,802	6,802	6,802	6,802	6,802
R-squared	0.288	0.288	0.289	0.289	0.288	0.289
Year FE	YES	YES	YES	YES	YES	YES
Sector FE	YES	YES	YES	YES	YES	YES

ROBUST	YES	YES	YES	YES	YES	YES

The table reports coefficient estimates and standard errors of regressions based on equations (2). The dependent variable is the firm's sustainability (ESG). All variables are defined in Table A1. The estimation method is OLS with robust standard errors. All models include year and industry-fixed effects. An asterisk indicates significance at the 10% level; two indicate significance at the 5% level; three indicate significance at the 1% level.

In line with Johnstone and Labonne (2009), we control for firms' sales over total assets (Sales/Total Assets); we use the quadratic term of the former variable *(Sales/Total assets)*^{2} to control for diminishing returns and the sales growth (*Salesgrowth)* to control for profitability trend. Finally, we control for firm extroversion using advertising expenses (*Advertising*), firm age (*FirmAge*), and cold periods (*Crisis_dummy*) as in Gompers (1995) and Li (2008). The response variable is the firm's sustainability performance, (*ESG).* In our analysis, we use both industry and year-fixed effects. The results indicate that the value of innovation measured by organization, knowledge, and intangible capital has a positive impact on the firm's sustainability. We find that coefficients of (*Organization Capital/Total assets) and (Knowledge Capital/Total assets)* are positive and statistically significant as well as their aggregate effect expressed by the coefficient of (intangible capital/total assets). Besides, in crisis periods this impact becomes significantly stronger which probably happens because companies through target innovation activity invest in their resources and competencies resulting in higher sustainable performance and ultimately better resilience. The results are in line with the theoretical arguments of (section 5.1) and support the argument that asset accumulation is not only vital for the firm's growth and market establishment but and for its sustainable performance. The value generated by innovation, in particular, is highly beneficial for a firm's sustainability, as via ESG strategy differentiation a firm can penetrate the market. In sum, we document in this section that firms with higher innovation quality are associated with better (ESG) performance and this effect in cold periods becomes even stronger.

6. Robustness checks

This section presents the necessary robustness of our findings. One could argue that the results may be driven by endogeneity issues. To alleviate such concerns and address possible feedback effects between innovation and sustainability, we deploy two techniques: a) instrumental analysis and b) propensity matching score. These techniques are described below.

6.1. Instrumental Analysis

We first perform a two-stage least square (2SLS) estimation. We include the same control variables and industry year fixed effect as in our corresponding baseline regressions. We use as instruments the state R&D weighted by firm size; the yearly total utility patents issued to state residents and the Higher education R&D performance. The intuition in using these variables comes from the fact that our sample includes firms from states with different innovation activities, institutional characteristics, and regulations. These characteristics play a crucial role in shaping a firm's innovation activity. The former instruments are exogenous to the firm’s specific characteristics so we expect the results to be causal. Our equations will be exactly identified. We use the under-identification test by Kleibergen and Paap to check if the number of instruments is adequate compared with the number of endogenous variables. The null hypothesis is that there is under-identification and requires a value lower than 0.05 to reject the null hypothesis at the 5% level. We use the Hansen over-identification test to test for possible correlation between the instruments and the error term. If there is any correlation then the instruments are not treated as acceptable. Under the null hypothesis, over-identifying restrictions are valid and require a higher value than 0.05 to reject the null hypothesis at the 5% level. We check for the instrument’s explanatory powers by using a weak identification test. In this test, we compare the critical values with the Cragg-Donald Wald F statistic and if any of them is greater than that, then the instruments are weak and do not have explanatory power. Finally, we use Durbin and Wu-Housman tests to check if the variables are exogenous or endogenous. These statistics have a very low *p*-value we correctly performed 2sls. In Table 5, we report our instrumental variable results.

Table 5: Instrumental Variable Analysis of the Relationship Between Innovation and Sustainability

VARIABLES	(1) ESG	(2) ESG	(3) ESG	(4) ESG	(5) ESG
(Sales/Total assets) $_{t-1}$	0.352	0.293	0.031	0.345	0.308
	(0.365)	(0.363)	(0.361)	(0.365)	(0.363)
(Sales/Total assets)$^2_{t-1}$	0.017	0.025	0.053	0.018	0.022
	(0.069)	(0.069)	(0.068)	(0.069)	(0.069)
(Sales growth) $_{t-1}$	0.031	0.031	0.031	0.031	0.031
	(0.019)	(0.019)	(0.019)	(0.019)	(0.019)
(FirmAge) $_{t-1}$	-0.064***	-0.064***	-0.064***	-0.064***	-0.064***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Crisis	7.122***	7.124***	7.119***	7.119***	7.151***
	(0.494)	(0.494)	(0.494)	(0.494)	(0.520)
(Advertising) $_{t-1}$	-0.009***	-0.009***	-0.009***	-0.009***	-0.009***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
(Patents/Total assets) $_{t-1}$		0.903***	(0.519)	(0.520)	
		(0.248)			
(R&D/Total assets) $_{t-1}$	0.739***				
	(0.204)				
(Intangible Capital/Total assets) $_{t-1}$					0.122***
					(0.033)
(Knowledge Capital/Total assets) $_{t-1}$				0.144***	
				(0.040)	
(Organization Capital/Total assets) $_{t-}$			0.781***		
			(0.217)		
Observations	6,802	6,802	6,802	6,802	6,802
R-squared	0.275	0.276	0.279	0.275	0.276
Year FE	YES	YES	YES	YES	YES
Industry FE	YES	YES	YES	YES	YES
Under-Identification Test	0.000	0.000	0.000	0.000	0.000
Weak-Identification Test	46.879	68.095	53.388	49.545	50.733
	(13.91)	(13.91)	(13.91)	(13.91)	(13.91)
Over-Identification Test	0.229	0.237	0.194	0.238	0.242
Durbin (score)	0.000	0.000	0.00	0.000	0.000
Wu-Hausman	0.000	0.000	0.00	0.000	0.000

Notes: This table documents 2sls estimates and stander errors (in parentheses) based on equations (1) and (2). Column 1 focuses only on firms in R&D activity; Column 2 considers the firm's patent activity. Column 3 and column 4 document evidence for the value of innovation expressed by Knowledge *Capital* and *Organization Capital*. In all regressions, we keep the number of observations constant for a better comparison of the estimates and include industry and year-fixed effects. All models include year and industry-fixed effects. In all models, the instrumental variables are stated as higher education R&D performance, utility patents issued to the state, and state total industry R&D performance. The under-Identification Test reports the *p*-value of the LM test by Kleibergen and Paap, which requires a value lower than 0.05 to reject the null hypothesis at the 5% level. Weak-Identification Test reports the Wald *F*-statistic test by Kleibergen and Paap, which must be higher than its critical value included in parentheses to reject the null. Over-Identification Test reports the *p*-value of the over-identification test by Hansen, which requires a value higher than 0.05 to reject the null hypothesis at the 5% level. Durbin and Wu-Housman statistics have a very low *p*-value so correct performed 2sls. An asterisk indicates significance at the 10% level; two indicate significance at the 5% level; three indicate significance at the 1% level.

Focusing on the estimates of our interest, both quantity and quality measures of innovation continue to play an important role in firms' sustainable performance. We find that the coefficients of our instrumental analysis are positive and significant at a 1% level across all proxies of innovation and associated with an increase of 0,14 to 0,9 of the firm's sustainability depending on the innovation proxy we use. In sum, the output of IV analysis indicates that the results of our baseline are causal which supports our hypothesis H1 to H4.

6.2. Propensity Matching

A second approach to alleviating possible endogeneity concerns involves propensity score matching analysis. The idea behind this is to compare the ESG performance of similar firms along other dimensions with only differences in their innovation profile. We compare with propensity score matching method firms that have innovation over the average with those that do not. To do it, we construct dummy files (*DummyR&D, DummyPatents, DummyTrademarks, DummyKnowledgeCapital, DummyOrganization Capital)* that take the value 1 if the innovation aspect is over the average and zero otherwise. We match firms with similar characteristics across the control variables, so any observed difference across the firm is then attributed to their innovation behavior. Our results provide evidence that in matching samples, controlling for all the other factors and with only different levels of innovation, firms with innovation activity over the average have around 0.996 to 3.907 times more sustainable performance depending on the innovation aspect and the matching method (see Table 6).

Table 6: Robustness results with Propensity Score Matching

Panel A:

Dependent Variable: Sustainability									
Treatment Variable:	R&D			Patents			Trademarks		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Nearest neighbor	3.907***			2.650***			0.651		
	(0.299)			(0.922)			(1.041)		
Kernel		3.907***			2.829***			2.995***	
		(0.269)			(0.229)			(0.645)	
Stratification			3.907***			2.200***			1.691***
			(0.102)			(0.309)			(0.796)
				2.650***					
Observations	6,802	6,802	6,802	6,802	6,802	6,802	6,802	6,802	6,802

Panel B:

Dependent Variable: Sustainability						
Treatment Variable:	Knowledge Capital			Organization Capital		
	(1)	(2)	(3)	(4)	(5)	(6)
Nearest neighbor	1.522***			1.317**		
	(0.518)			(0.605)		
Kernel		1.908***			1.089***	
		(0.478)			(0.269)	
Stratification			1.479***			0.996***
			(0.302)			(0.187)
Observations	6,802	6,802	6,802	6,802	6,802	6,802

Notes: In this table, we present robustness for all the aspects of innovation by using Propensity Matching score techniques based on the control variables of Table 3. In Columns (1), (4), and (7) we employ the nearest neighbor method, additionally in columns (2), (5), (8),) (3), (6), and (9) the kernel and at the stratification method (Zhao 2004) respectively. An asterisk indicates significance at the 10% level; two indicate significance at the 5% level; three indicate significance at the 1% level. Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

7. Conclusions

In this paper, we analyze the impact of several aspects of innovation on a firm's sustainability. The results of the innovation effect on sustainability suggest that the theoretical arguments behind the positive forces of innovation are dominant in our sample. The effect of innovation quality and efficiency on sustainability is also in line with and generalizes these findings in our sample. This study is the first that relates all types of innovation with firms' sustainability performance, and, in this sense, we provide a policy implication for the possible formulation of sustainable strategies. Our study focuses on US firms, so takes place in an economically developed economy.

A firm's sustainability is promoted not only by its innovative activity but also by exposure to relatively higher or lower innovation environments. Our sample includes firms from states with different innovation activities, institutional characteristics, and regulations. This characteristic differs and cannot be sufficiently captured by state-year fixed effects but has an important effect on the firm's innovation. Thus, we don't argue that these specific characteristics are less important in shaping ESG than the firm's innovation activity. Precisely the opposite; due to these characteristics business innovation activity is shaping up.

Our results indicate that the quantity and value of innovation do enhance corporate sustainable performance. We also argue that these effects become even stronger during times of recession (e.g. global financial crisis). We supplement our analysis with the use of various techniques such as the propensity matching score and instrumental variable analysis to check for the robustness of our findings. The empirical results reveal that our analysis survives robustness checks.

The current framework will offer new insights and help firms to evolve and design business strategies according to the "new sustainable rules" of the modern economic environment. Indeed, the case of sustainability is already starting to transform the competitive business environment and forces companies to adapt their standards and turn regulators into allies by leading the way in sustainable products and services. Developing new strategies and addressing the needs of the current sustainable way requires learning to question existing knowledge mechanisms. While firms struggle to adapt, those who have already pursued sustainable innovation advance as leaders beyond the competition.

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APPENDIX

Table A.1. Description of sample variables

Variables	Definition
Dependent Variables:	
ESG	Sustainability index that quantifies a company's performance to environmental, social and governance matters
EP	Sustainability component that quantifies a company's performance to environmental
SP	Sustainability component that quantifies a company's performance to social
GP	Sustainability component that quantifies a company's performance to governance
Treatment Variables:	
DummyR&D	Dummy variable set to 1 if firms R&D expenses are is over the sample average, else 0.
DummyPatents	Dummy variable set to 1 if firms patent activity is over the sample average, else 0.
DummyTrademarks	Dummy variable set to 1 if firms trademark activity is over the sample average, else 0.
DummyKnowledgeCapital	Dummy variable set to 1 if firms knowledge capital is over the sample average, else 0.
DummyOrganization	Dummy variable set to 1 if firms organization capital is over the sample average, else 0.
Control Variables:	
Sales/Total assets	Firms' sales over total assets
(Sales/Total assets)2	A quadratic term that indicates firms' sales over total assets
Sales growth	The growth of firm's sales
Firm Age	The number of years from the firm's initial incorporation date.
Advertising	The natural log of Firms advertising expenses in millions of dollars
TM/Sales	The number of trademarks of a firm share to total sales
R&D/Total assets	Firms research and development expenses spending in millions of dollars share to total sales
Patents/Total assets	The number of patents of a firm share to total assets.
Intangible Capital/Total assets	Firm's intangible capital share to total assets; It is estimated as the total replacement cost of organization capital and knowledge capital and coming from WRDS database (Peters and Taylor, 2016).
Knowledge Capital/Total assets	The replacement cost of knowledge capital share to total assets; Coming from WRDS database (Peters and Taylor, 2016).
Organization Capital/Total assets	The replacement cost of knowledge capital share to total assets; Coming from WRDS database (Peters and Taylor, 2016).
(TM/ R&D)	The share of trademarks over research and development expenses, indicates TM efficiency
(Patents/ R&D)	The share of patents over research and development expenses, indicates patent efficiency
Crisis	Dummy variable that takes the value of 1 for financial crisis period, else 0.

Table A.2: Robustness checks

VARIABLES	(1) ESG	(2) ESG	(3) ESG
(Sales/Total assets) $_{t-1}$	0.889***	0.880***	0.882***
	(0.330)	(0.330)	(0.330)
(Sales/Total assets)$^{2}_{t-1}$	-0.054	-0.052	-0.052
	(0.059)	(0.059)	(0.059)
(Sales growth) $_{t-1}$	0.026*	0.026*	0.027*
	(0.015)	(0.015)	(0.015)
(FirmAge) $_{t-1}$	-0.067***	-0.067***	-0.067***
	(0.005)	(0.005)	(0.005)
Crisis	6.925***	6.904***	6.909***
	(0.504)	(0.504)	(0.505)
(Advertising) $_{t-1}$	-0.008***	-0.008***	-0.008***
	(0.001)	(0.001)	(0.001)
(Patents/Total assets) $_{t-1}$	0.124***	0.128***	0.127***
	(0.031)	(0.033)	(0.032)
(TM/Sales) $_{t-1}$	0.079***	0.075***	0.076***
	(0.019)	(0.019)	(0.019)
(TM/ R&D) $_{t-1}$		0.318***	0.271***
		(0.091)	(0.097)
(Patents/ R&D) $_{t-1}$	0.145**		0.045
	(0.059)		(0.080)
Observations	6,802	6,802	6,802
R-squared	0.289	0.289	0.289
Year FE	YES	YES	YES
Sector FE	YES	YES	YES
ROBUST	YES	YES	YES

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Figure A.1: Average R&D, 2007 - 2016

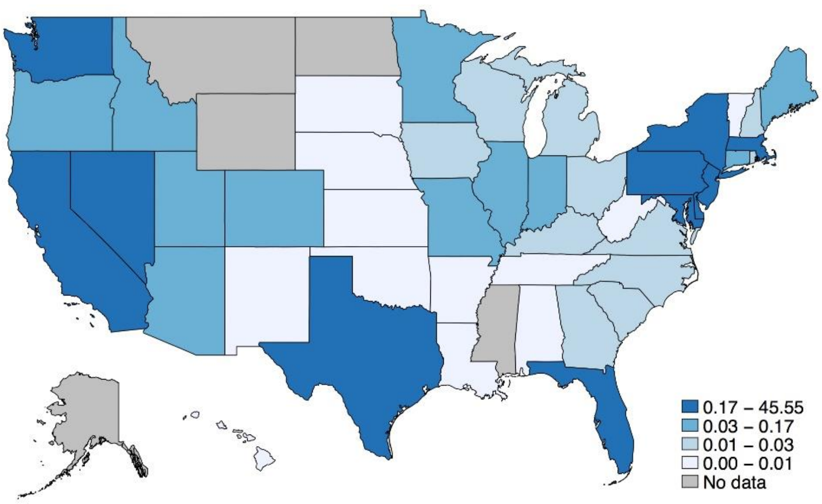

Figure A.2: Average Patents, 2007 - 2016

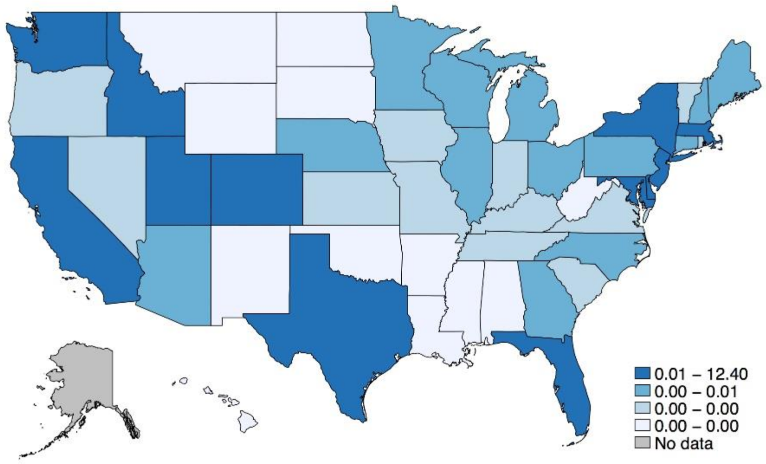

Figure A.3: Average Trademarks, 2007 - 2016