The CO2 Question:

Technical Progress and the Climate Crisis[1]

Patrick Bolton*

Marcin Kacperczyk[Ω]

Moritz Wiedemann[Δ]

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Abstract

We analyze green and brown R&D activity worldwide and its effects in reducing carbon emissions. Innovating companies with higher carbon emissions engage more in brown R&D and less in green R&D. Despite a steady rise in the share of green R&D, green innovation does not predict future reductions in carbon emissions of innovating firms, non-innovating firms in the same sector, firms in other sectors, and across countries, whether in the short term (one year after filing a green patent) or in the medium term (three or five years out). Rather, green innovation predicts *higher* indirect emissions in related industries.

JEL codes G12, G23, G30, D62, D83

Keywords: carbon emissions, green patents, brown efficiency patents, path dependence of innovation, Jevons paradox, displacement effect.

* Columbia University, Imperial College, CEPR, and NBER.

Ω Imperial College and CEPR

Δ Imperial College

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We are in the early stages of a sustainability revolution. It will have the magnitude of the industrial revolution yet the speed of the digital revolution. Al Gore (2020)

There is no doubt that the energy sector will only reach net-zero emissions if there is a significant and concerted global push to accelerate innovation Energy Policy Perspectives 2020 IEA

1. Introduction

How are innovation activities and technological advances shaped by the prospect of an approaching climate change crisis? In this paper, we explore corporate green innovation activity around the world and its effects on corporate behavior, in particular on future corporate carbon emissions. According to the latest IPCC (2021) report, to avoid an increase in average temperatures greater than 1.5^{o} C, global net carbon emissions must be reduced to zero by 2050. To have any hope of attaining this goal, governments around the world have stepped up their policies to curb carbon emissions and accelerate the transition to renewable energy sources.

Yet nearly all analysts agree that a successful global decarbonization cannot be founded only on regulations. It necessarily entails major technical advances in substitute energy sources and other technologies to reduce or capture carbon emissions. According to the IEA (2020), "Reducing global CO2 emissions will require a broad range of different technologies working across all sectors of the economy in various combinations and applications. These technologies are at widely varying stages of development."

Much R&D that is touted as green mainly takes the form of efficiency improvements in energy use. Primary examples are fuel efficiency gains in transport, electricity efficiency gains in refrigeration, air-conditioning, computing, lighting, and heating. The promise of these technological improvements is that the environmental impact of consumption in terms of carbon emissions will become smaller and smaller. However, as Jevons (1865) first noted about coal consumption, greater energy efficiency—by lowering the energy cost of consumption—could induce an increase in aggregate demand for energy, which could undo the anticipated reduction in energy use: "It is wholly a confusion of ideas to suppose that the economical use of fuel is equivalent to a diminished consumption." Indeed, despite all the technological improvements in fossil energy use, we have still not seen a global decoupling of economic growth and carbon emissions.

The title of our paper is a reference to the title of Jevon's (1865) book, *The Coal Question*, as the same economic problem he saw for the consumption of coal, which is only available in limited supply, arises for CO2 concentration in the atmosphere, which can only be accumulated

to a limited amount if we are to avoid global overheating. The main question we are concerned with in this study is the impact of green innovation on future corporate carbon emissions. What has come to be known as the *Jevons paradox* (and is also referred to as the *rebound effect*) is a warning that green technological progress is not necessarily synonymous with carbon emission reductions because technological improvements that reduce fossil fuel energy reliance also boost economic activity. It is unclear a priori what the net effect is on carbon emissions of respectively green R&D (that is not related to fossil fuels) and brown efficiency-improving R&D (that improves the energy efficiency of fossil fuel-based technologies), given that consumption and production are endogenous, and that any successful innovation generates additional economic activity. Even pure green innovations, that reduce direct or downstream emissions, may cause an increase in brown electricity production (scope 2 emissions) or emissions in the supply chain (especially upstream), an impact we define as the *displacement effect*.

A related question we are concerned with is the extent to which companies with high carbon emissions move away from fossil fuel-based technologies and embrace green innovation. More generally, how much do corporate characteristics (the line of business the company is in; the technologies it is using) determine the innovation activities a company engages in? What companies, in which sectors, have been the source of most green R&D?

We can address these questions by combining three global datasets on respectively corporate patent filings, corporate financial reports, and corporate (direct and indirect) carbon emissions covering the period from 2005 to 2020. All in all, our data covers more than 136 million patents held by 2.3 million firms. Based on a patent's Cooperative Patent Classification (CPC), we can sort patents into three broad categories, *green patents* (which concern technological improvements in environmental impacts of economic activities), *brown efficiency-improving patents* (which achieve advances in fossil energy efficiency), and other patents that are not directly related to the environment or to energy. For each firm we can determine the intensity of their green or brown innovation activities by calculating the ratio of the number of their green (respectively brown efficiency) patents to the total number of patents they have filed. We calculate these ratios based on either worldwide patent filings or on filings with the European patent office, which are known to be more reliable. We can also weigh the importance of each patent based on the number of citations.

We begin our analysis by exploring how these measures of corporate green (or brown) innovation activity are associated with firm characteristics (our analysis covers corporate innovative activity around the world, which allows us to control for country, sector, and firm characteristics). A first contribution of our study is to provide a picture of green innovation activity across countries, sectors, firms, and over time. For example, we find that 22.3% of publicly listed

companies engage in innovation, while only 1.6% of private companies file patents in a given year. Furthermore, we find that the distribution of countries contributing at least one green patent is highly skewed, with the top ten countries contributing most green patents. This is also true for the distribution across sectors and firms, with some sectors, such as multi-Utilities, Electric Utilities, Oil, Gas & Consumable Fuels, and Independent Power and Renewable Electricity production standing out for their high ratios of green to total number of patents. Across sectors just over 1% of all firms have filed at least one green patent. We also find that green innovation activity has steadily risen over our sample period, with the average patent ratio rising from 0.080 in 2005 to 0.130 in 2020.

A central idea in the economics of innovation literature is the *Arrow replacement effect* (Arrow 1962), which refers to the lower incentive to innovate for an established firm with market power if the innovation replaces an existing technology that is working and is profitable. Another important idea for our analysis is learning-by-doing (Arrow 1971), which means that companies master the technologies they use better, the more they have been using them. A key prediction for our analysis that derives from these two effects is that profitable companies with operations based on fossil fuel energy are less likely to engage in green innovation, a new technology they are less familiar with. If a company engages in green innovation, it is more likely to be a new entrant that is less dependent on fossil fuel-based technologies.

Consistent with these predictions, we find that companies with greater experience with brown technologies (as measured by the stock of brown efficiency patents they already own) are less likely to engage in green innovation and companies with greater experience with green technologies (as measured by the stock of green patents they already own) are less likely to engage in brown efficiency innovation.[1] Furthermore, we find that that brown companies (with higher emissions and that are older) do not tend to engage in green R&D. This is true in particular for companies with higher indirect (scope 3) emissions, which suggests that there is a broader replacement effect at work than the one identified by Arrow: brown companies appear to be locked into fossil-fuel dependent technologies through their production networks. If input suppliers or downstream firms/customers also rely on fossil fuel-dependent technologies, it is more difficult for an individual firm in the supply chain to switch to green technologies. A key implication from this latter finding is that, in order to induce firms to transition from brown to

[1] A case in point is the energy company Halliburton. In response to a recent SEC question on its exposure to carbon transition risk it stated that "We believe that one of the significant risks that we face in energy transition is that we will be unable to innovate in a timely, cost-efficient manner, or at all." (See *Climate risks gain corporate acknowledgment after SEC prodding* by Patrick Temple-West, Financial Times 30 December 2022). We show in Figure IA.II that most of Halliburton's innovation activity in recent years has been in brown innovation, which has steadily increased over time.

green technologies, industrial policy may be necessary to coordinate this transition across all firms linked through the supply chain.

Our findings that green R&D is more likely to be undertaken by new entrants and brown efficiency R&D is more likely for established companies with operations that are based on fossil fuel energy are consistent with earlier studies that find evidence that innovation is path dependent (Acemoglu, 2002, Popp, 2002, and Aghion et al. 2016). Aghion et al. (2016) consider a panel of automobile manufacturers and explore the extent to which these companies produce innovations on combustion-engine cars versus electric, hydrogen or hybrid engine vehicles. Their main finding is that specialization in innovation activity in clean (vs brown) technologies is self-reinforcing. Our study extends this evidence in support of the path-dependency view of innovation to all sectors, across countries, not just the automobile sector.

Even if innovation is path dependent, and even if brown firms are less likely to undertake green R&D, we find that there has been a steady rise in the number of green patent filings (as shown in Figure 2). It is therefore possible that the promise of a *sustainability revolution* could be fulfilled. We explore this question next by looking at the effects of green R&D on future corporate carbon emissions and other policy outcomes. How has green R&D affected corporate carbon emissions, capital expenditures, and other policies? According to the IEA (2020) "Around half of the cumulative emissions reductions that would move the world onto a sustainable trajectory come from four main technology approaches. These are the electrification of end-use sectors such as heating and transport; the application of carbon capture, utilization and storage; the use of low-carbon hydrogen and hydrogen-derived fuels; and the use of bioenergy. However, each of these areas faces challenges in making all parts of its value chain commercially viable in the sectors where reducing emissions is hardest". Another issue is the extent to which the benefits of technological improvements in terms of carbon efficiency are undone by rebound effects (Jevons, 1865). Finally, some of the green innovations may lead to a displacement in emissions.

Our main finding on the effects of green innovation on corporate outcomes is that there has been no significant impact on future carbon emissions reductions. Whether in the short run (one year), or medium run (three & five years ahead), we do not find any significant effect of green innovation on direct and indirect corporate carbon emissions of the innovating firms. Consistent with the Jevons paradox, we find that brown efficiency innovation does result in lower future carbon intensity, but this benefit is undone by higher sales, which overall result in higher future emissions.

We also analyse how aggregate sectoral changes in emissions are associated with green R&D on the presupposition that innovation could be of use not just for the innovator but also for other firms operating in the same sector. However, we do not find any significant spillover effects

of green innovation on the carbon emissions of either innovating or non-innovating firms in the same (GICS-6) sector. Yet, consistent with the displacement effect and the greater reliance on brown electricity, we do find that green innovation is associated with subsequent increases in scope 2 emissions of the same sector. In contrast, brown efficiency innovation does not predict future emission changes of other innovating firms in the same sector. However, it does benefit non-innovating firms whose direct and indirect emissions go down. But this decrease is mostly a consequence of lower sales for this group of firms.

We also find that the association of innovation activity by publicly listed companies and their future emissions is not strongly correlated with the same association of innovation and future emissions by privately held firms. That is, innovation by publicly listed companies has a stronger positive effect on their future scope 2 emissions than the innovation by privately held firms on their future scope 2 emissions. Furthermore, we do not find any spillover effects broadly speaking across sectors or across countries. The one notable exception is our finding that an increase in green innovation predicts subsequent reductions in scope 3 downstream emissions of *broadly* related industries.

Another indirect channel through which innovation can affect future emissions of non-innovating firms is through changes in the market shares of innovating firms. We find that firms with higher green patent ratios tend to lose market share to other firms that have higher emissions, a form of displacement effect. Finally, our third main finding on the effects of green innovation on future corporate carbon emissions is that to a large extent green innovation has little to contribute to decarbonization. Where we see significant reductions in corporate carbon emissions, we find that these reductions are for the most part not due to green innovation. Overall, green innovation contributes only 1% to corporate carbon emission reductions. In sum, green innovation may be necessary for the sustainability revolution, but it is far from sufficient. The overwhelming conclusion of our analysis is that the green industrial revolution has not materialized over our sample period and the promise that green innovation will set the global economy on a sustainable path to net zero has not yet borne fruit.

Our paper contributes to a growing recent literature on the firm-level implications of the transition to a green economy. A closely related study by Cohen et al. (2022), who also look at green innovation by U.S. listed companies, draws somewhat different conclusions. They find that green innovation activity in the energy sector is higher than that in other sectors and conclude that this is evidence against path dependency of innovation. We confirm some of their cross-industry variation, but our main finding is that *within* each sector brown companies (those with higher emissions) do less green R&D. This is true across all sectors and countries. More specific differences are that we extend our sample to firms that also file for patents outside the USPTO,

and to firms that are located outside the U.S. We further distinguish between green and brown efficiency patents, which allows us to evaluate the path-dependency hypothesis more explicitly. In this regard, we note that the classification of green patents used in their study tends to nest what we define as brown efficiency patents. Finally, their study takes ESG scores as a metric of environmental performance, which they motivate by the fact that asset managers tend to focus on such scores in their divestment screens. Our focus instead is on carbon emission outcomes.

A parallel literature in finance explores the effect of green innovation of U.S. firms on firm value (e.g., Hege et al. (2022); Kuang and Liang (2022); Reza and Wu (2022)). More broadly, Bolton and Kacperczyk (2021, 2022a) show that the transition risk, which embeds technological progress, is already reflected to a large extent in equity markets. Ilhan et al. (2021) show that carbon risk is also priced in options. Engle et al. (2020) have constructed an index of climate news through textual analysis of the Wall Street Journal and other media and show how a dynamic portfolio strategy can be implemented that hedges transition risk with respect to climate change news. Sautner et al. (2022) show that companies that report positive sentiment towards climate in their conference calls subsequently produce a greater number of green patents. In contrast to these studies, our focus is on the effects of green patents in decarbonization.

Earlier studies on rebound effects have focused on specific activities or on sector or country-level data. Our study is the first to explore the effects of technological change on carbon emissions based on firm-level data.[2] The findings on rebound effects in this earlier literature are mixed. For example, Schipper and Grubb (2000) have looked at aggregate data on energy use and found that car use and energy use in other activities have not changed much in response to technological improvements in energy efficiency. Based on these findings they conclude that rebound effects are likely to be small. Sorrell et al. (2009) provide a review of prior empirical studies on rebound effects. They argue that many studies only look at partial rebound effects over limited time periods and over restricted consumption responses. For example, studies on the consumption response to fuel-efficiency improvements in automobiles only measure changes in mileage travelled and do not consider more long-term changes in vehicle size. By looking at firm-level data and at cross-firm and cross-industry effects of green innovation we can identify substantially larger and more diverse forms of rebound effects.

[2] An important aspect of green innovation is the role of government policies in supporting innovation (for a literature review, see Greaker and Popp, 2022). These policies are important and can induce a shift to green innovation (e.g., Popp, 2002; Aghion et al., 2016). Our study focuses on firm-level responses and how they depend on their characteristics, especially their carbon emissions. We absorb the impact of innovation policies using industry and country fixed effects, making an implicit assumption here that innovation policies are industry-wide and not firm-specific. Our findings reveal how firms in an industry differentially respond to these policy interventions and how their differential response is linked to firm characteristics such as carbon emissions.

The remainder of the paper is organized as follows. Section 2 provides the conceptual framing for our analysis. Section 3 describes the data and provides summary statistics. Section 4 discusses the results on the drivers of green innovation. Section 5 provides the results on the impact of innovation on future emissions and other corporate decisions. Section 6 concludes.

2. Conceptual Framework

We begin with a conceptual discussion of green innovation and the transition to a net-zero economy. There are three key guiding concepts that help us understand the various connections between green innovation and carbon emissions. The first, as already highlighted, is the Jevons paradox and other rebound effects of green innovation on energy consumption, one of which is the *displacement effect* defined above. The narrow notion of the Jevons paradox is that an energy efficiency gain, or a carbon intensity gain, from a better technology will of course reduce emissions for a given level of operations, but if the new technology invites more users and larger operations then the overall reduction may be limited or may not materialize at all.

We expect to find direct evidence of such a rebound effect if a brown efficiency innovation subsequently improves the carbon intensity of operations, but overall carbon emissions are not significantly affected or are higher. A general reason why one should expect a positive effect on operations and sales from a brown efficiency innovation is that the innovation improves profitability and the competitiveness of the innovating company, which are likely to result in an expansion of the business.

There are other, more indirect, and more subtle, displacement effects to be expected. A concrete and highly relevant example is the transition to electric vehicles (EV). This is one of the major new green innovations. If, as is likely to be the case, the share of EV grows significantly in the next few years then scope 1 emissions from transportation should be expected to decline. However, if the increased demand for electricity is met by increased production from coal-fired power plants, as is likely to be the case in states where coal-fired power plants are still responsible for the lion share of electricity production (such as West Virginia, with a 91% share, Missouri with 75%, Wyoming with 74%, and Kentucky with 71%)[3], then the green EV revolution will result in an increase of scope 2 emissions. What does not get burned by the vehicle will get burned by the power company, with a likely net increase in total emissions given that coal is far more carbon intensive than oil. Similarly, the production of all the parts that go into an EV, from the wheels, tyres, chassis, body, engine, and batteries, etc, will generate carbon emissions, so that green innovation could also result in higher upstream scope 3 emissions. These higher emissions will be

[3] See https://www.eia.gov/todayinenergy/detail.php?id=54919

fully offset by lower scope 1 emissions than a combustion engine vehicle only after the EV has clocked up many thousands of miles.

Other rebound effects operate through product market competition. If green innovation involves higher costs than brown efficiency innovation (or no innovation), then the green innovating firm will be at a cost disadvantage relative to its industry peers. It may as a result lose market share. This would translate into lower carbon emissions for the green innovating firm, but higher carbon emissions for its competitors that are gaining market share. Alternatively, green innovation could spur adoption of green technologies by industry peers, leading to an industry-wide reduction in carbon emissions. In sum, green innovation is likely to have spillover effects, positive or negative, which could affect carbon emissions of non-innovating firms with the industry or across industries. To understand the overall impact of green innovation on carbon emissions it is therefore important to explore the link between green innovation activity and carbon emissions within and across industries.

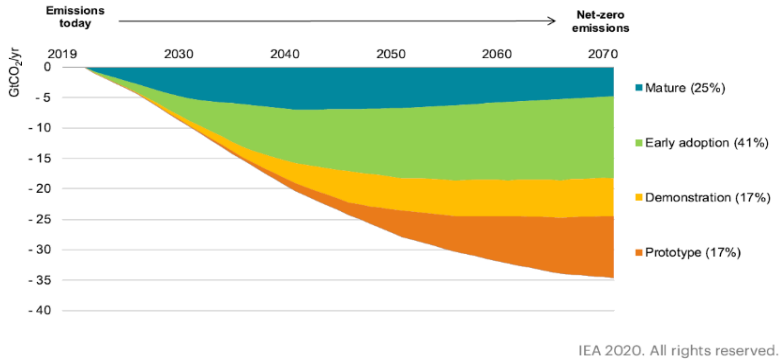
The second and third guiding concepts for our analysis are closely related. They are both associated with founding ideas first proposed by Kenneth Arrow (1962, 1971). One concept is commonly known as Arrow's replacement effect (Arrow 1962), which refers to the idea that established firms, monopolies, have a lower incentive to innovate because their innovation mostly replaces their existing technology that is working and is profitable. The other concept, learning-by-doing (Arrow 1971), has broader applications. But in the context of innovation, it means that companies understand the technologies they already use better, which induces them to continue to improve something they already master rather than explore new directions which seem more obscure. One key general prediction that follows from these two concepts is that profitable companies with operations based on fossil fuel energy (brown companies) are less likely to engage in green innovation, a new technology they are less familiar with, and less likely to replace their brown operations with green operations. A related general prediction is that innovation is likely to be path dependent: a company that has already been actively researching brown efficiency innovations is more likely to continue to do brown R&D. Green innovation, therefore is most likely to be undertaken by companies that are new entrants.

Arrow (1962) focuses his analysis on an individual firm's technology and the replacement of the firm's own technology. When it comes to green and brown innovation, however, replacement has a broader scope and involves complementary technologies upstream and downstream. Replacement is not just confined to one firm. It may require technological changes in an entire ecosystem. Following the development of a new green technology an individual firm might be ready to replace its old technology if all the other firms it depends on also make the switch. A case in point is again electric vehicles. Switching to EV requires major changes not only

in the supply chain but also downstream, with new charging station networks, maintenance, servicing, etc. Thus, the more dependent upstream and downstream industries are on fossil fuels, the less likely it is that an individual firm in one sector will transition to green technologies. A major general prediction that follows from this observation is that an individual company is less likely to do green R&D the higher are its upstream and downstream scope 3 emissions.

Finally, another key consideration in exploring the link between green innovation and future carbon emissions is the timing of deployment of new technologies. There can be a major time-to-build lag between the discovery and development of a new technology and its deployment. Part of this lag may be due to the time it takes to go from a working prototype to a mature technology. According to the latest research by the IEA (2021), many new green technologies in the energy sector are still at the prototype stage. Their impact on future carbon emission reductions is therefore likely to be small in the immediate future (see the IEA figure below).

Figure 3.1 Global energy sector CO_2 emissions reductions by current technology readiness category in the Sustainable Development Scenario relative to the Stated Policies Scenario



Given the relatively short and finite time interval of our study, it is not possible to account for impacts that are far into the future. We cannot rule out the possibility that these impacts will be very large, and that green innovation will fully deliver on its promises. Still, it is important to find out whether, and the extent to which, green innovation is already having an impact on reducing carbon emissions, given the small and rapidly shrinking remaining carbon budget, which according to the latest climate research is less than 300 gigatons (Gt) of CO2 as of 2020 if temperature rise is to be limited to less than 1.5^0C with an 83% probability (IPCC 2021). Given that annual energy-related emissions have been around 31.5 GtCO2 in 2020 (IEA 2021) and given that projected annual energy-related emissions for the next few years will remain at that level, there are only a few years left for green innovation to deliver on its promises before it is too late.

3. Data

Our data construction starts with all global firms, both publicly listed and private, identified between 2005 and 2020 in the following data bases: Orbis Intellectual Property Financial, Orbis, Factset, and Worldscope for financial information (balance sheets and income statements). The financial data for public firms is based on all four. The financial data for private firms is based solely on Orbis IP Financial and Orbis. The latter data sets only cover the ten most recent years. The overall dataset is termed "full sample". We merge these datasets with the Orbis Intellectual Property dataset, which provides a comprehensive coverage of patent filings and corporate ownership of patents by listed and unlisted companies in 81 countries. This dataset includes 136 million patents held by 2.3 million firms. It also provides patent citations, which are a good measure of the importance of the innovation protected by the patent. Henceforth, we refer to this dataset as the "patenting sample".

We further combine the full sample with data from Trucost on firm-level carbon and other greenhouse gas emissions. Trucost reports yearly firm-level carbon and greenhouse gas emissions data for scope 1, 2, and 3 emissions in units of tons of CO2 equivalent. Scope 1 emissions are direct emissions from operations of affiliates that are owned or controlled by the company. Scope 2 emissions are those that come from the generation of purchased heat, steam, and electricity used by the company. Scope 3 emissions are indirect emissions caused by the company's operations and the use of its products. These include emissions from the production of purchased materials, product use, waste disposal, and outsourced activities. Establishing the scope 3 emissions of a company requires a detailed analysis of the share of emissions of producers in the supply chain that is attributable to the company's input purchases. This involves estimating an input-output model with sector-level emission factors. Our data allows us to distinguish between scope 3 emissions coming from upstream and downstream activities although the latter are only available from 2017 onwards; hence, total scope 3 emissions prior to 2017 reflect upstream emissions only. Finally, we include world index constituent data from MSCI. We use the ISIN identifier and company names to match these datasets.

3.1 *Aggregate data by country*

Internet Appendix Table IA.I provides a breakdown of our aggregate data by country. In Panel A, we report a breakdown of the number of firms in each country that are respectively, publicly listed, privately held, and have carbon emissions data. The total number of firms in our sample is 788,983, of which 54,009 are publicly listed companies and 734,974 are privately held firms. There are 18,819 firms for which we have carbon emissions data through Trucost. The limited coverage reflects the fact that Trucost has collected emissions data mostly from listed and larger companies. Countries with the largest number of firms in the full sample include China, Italy, Denmark, and

France, each of them having more than 50,000 companies in the full sample. Even excluding these countries, our sample has a wide cross-country representation. Notably, in the matched Trucost sample, the U.S. has the largest representation of all countries, which is consistent with the fact that it has the relatively larger fraction of publicly listed companies. In columns 5-8, we further restrict the full sample to observations for which we have patent data from Orbis. Throughout our main analysis, we focus on patents registered with the European Patent Office (EUPO). As is well known, the filing process is most rigorous at the EUPO, so that these filings reflect more significant and enduring innovations. In the Appendix, we provide additional robustness results using patents registered with any patent office worldwide. The total number of firms in this subset of patenting firms represents roughly 3% of the universe of companies in our data, which reveals the fact that most companies do not get involved in any innovation activity. Interestingly, publicly listed patenting companies comprise about the same fraction of the sample with patents as privately held patenting firms. Still, private companies represent a significantly larger population of all firms. These numbers therefore indicate that public firms are significantly more likely to engage in innovative activities.

In Panel B we report the distribution of patent counts across countries. Most patents came from publicly listed companies, which provides further evidence that innovation is typically produced within large companies. Notably, the fraction of patents registered by companies that are part of the Trucost data is over 75%. The two countries with the highest number of patents in our sample are the United States and Japan, each one having more than 300,000 patents registered. The next three countries are Germany, France, and South Korea, each with more than 100,000 patents. In columns 5-8, we show the average number of patents per firm, for companies that do engage in patenting activity. An average company in our sample registered more than 17 patents over the sample period. The fraction is significantly larger for public firms, which register more than 24 patents per firm in contrast to private firms where this number is 5.7.

Table IA.II further shows the country-level breakdown into firm-year observations. To be included in the final sample, we require firm-year observations to have values for assets, book leverage, ROE, and country of incorporation. We lose about 3,700,000 firm-year observations due to this restriction. In addition, we require public firms to have records for capex, previous year's December return, volatility, and market capitalization. This leads to another 200,000 firm-year observations being lost. In the paper, we refer to this filtered dataset with 5.3 million firm-year observations as the "full sample". Columns 1-4 present the numbers for the full set of public and private companies. The number of observations in the full sample is 5,318,818, of which 390,985 are observations from public firms and 4,927,833 are observations from private firms. In columns

5-8, we restrict the sample to companies with at least one listed patent. That sample includes 88,727 observations, 63% of which are from publicly listed companies.

3.2 Green and brown innovation

We make a key distinction between *green innovation*, targeting technologies that substitute carbon dioxide emitting technologies for carbon dioxide-free technologies (or that make carbon-dioxide-free technologies more accessible), and *brown innovation*, which targets improvements in fossil-fuel based technologies. For this patent classification we rely on the description of the patent and four technology classification sources on patents relating to the environmental impact of technologies, namely the environmental technologies classified by the Organization of Economic Co-operation and Development (OECD)[4], the International Patent Classification (IPC) Green Inventory[5], the efficiency-improving fossil fuel-technology categories of Lanzi et al. (2011), as well as a self-identified classification based on patents from the Corporate Knights Clean 200. We classify patents into three broad categories[6]: i) green patents for environmental technologies; ii) general efficiency improvement patents that deal with technologies that improve process efficiency and therefore could reduce emission intensity; iii) brown patents that deal with technological innovation for fossil fuel-based technologies. For robustness, we also consider the OECD classification of green patents, which includes technologies related to environmental applications, such as climate mitigation, biodiversity, and wastewater management, as well as green and general efficiency improvements patents.

Prior research (e.g., Cohen et al., 2022; Aghion et al., 2016) has relied on the OECD classification of green patents only. But the OECD classification does not always distinguish between patents on renewable energy technologies and brown efficiency improvement patents. Some green patents within the OECD classification are brown efficiency patents. To illustrate this point, we conduct a cloud-of-words analysis of patent descriptions using the term frequency–inverse document frequency (TFIDF) algorithm. We search for the dominant words in our green patent classifier, stripping out common words in the OECD classification, and we do the same for the OECD classification, searching for the dominant words and stripping out the common words from our classification. We present the resulting clouds in Figure 1.

In the left figure, we show the words that are uniquely dominant to our classification. Words, such as mri, magnetoresistive, or magnetometer are very common to fusion reactions and underlie the green nature of the patent. In the right figure, we start with the OECD words and

[4] https://www.oecd.org/env/indicators-modelling-outlooks/green-patents.htm
[5] https://www.wipo.int/classifications/ipc/green-inventory/home
[6] We provide a detailed description of our approach and the underlying IPC/ CPC classes in the following online document: https://wiedemannm.github.io/documents/DescriptionPatentClassification.pdf

filter out common words from our classification. The dominant words of this process include exhaust gas, internal combustion, or abradable, all three likely attributed to efficiency gains of brown technology. Overall, this analysis suggests that our classification is more accurate in identifying purely green patents. The OECD classification misclassifies some patents as green when they are more likely to be brown patents. For the rest of the analysis, we will thus rely on our classification, but we also check the robustness of our findings to using the OECD classification.

In Table IA.III, we report the distribution of firms and patents conditional on a firm filing a green or brown patent. In Panel A, we analyze the distribution of firms by country. In columns 1-4, we report the statistics for firms which file a green patent, and in columns 5-8 the statistics for firms which file a brown patent. Only about 1% (0.4%) of all firms have at least one green (brown) patent. In the cross-section, the U.S., Japan, and Germany (the U.S., Japan, and China) have the largest number of firms with green (brown) patents, each of them representing 7%-20% (7%-28%) of the total number of patenting firms. The distribution of countries contributing at least one green (brown) patent is skewed, with the top 10 countries contributing most green (brown) patents. Publicly listed companies account for 63% (66%) of firms with green (brown) patents. The fraction of firms with at least one green (brown) patent that is covered by Trucost is roughly 42% (48%).

In Panel B, we provide a similar breakdown for the total and average (per firm) number of green patents. In the full sample, over the period 2005-2020, companies have filed 162,039 green patents. In this group, a large number (144,614) of green patents is registered with publicly listed companies, and only 17,368 patents are registered with private companies. More than 131,000 of green patents have been filed by companies with emission data in Trucost. The highest number of green patents by firm comes from Saudi Arabia, South Korea, and Germany, each of them having more than 10 patents per firm. In Panel C, we provide a similar breakdown for brown patents. In the full sample, we observe 63,689 brown patents in total; 56,556 of those patents have been filed by publicly listed companies and the remaining 7131 are those filed by private companies. Saudi Arabia, Germany, and the United Kingdom are the three countries with the highest number of brown patents per firm.

In Figure 2, Panel A we show the year-by-year distribution of patenting activity, measured by green and brown patent counts, based on the sample of all firms with patent data. We observe a steady increase in patenting activity over time at least until 2018, especially for green patents. Green patents also represent a larger share of patenting activity. We also separate the data into different regions. The two regions with the largest number of either green or brown patents are Asia and Europe. At the peak of 2018, each region contributed almost 10,000 patents each. The

equivalent number for North America is significantly less and accounts for about 5,000 patents. Notably, countries outside these three regions, which include Africa, Australia, and South America, contribute almost no patents to the overall patent count. This fact underlies the importance of any innovation spillovers from patenting to non-patenting regions, especially because these non-patenting regions are responsible for significant fraction of global emissions. Panel B presents observations for all firms that are available in Trucost. The subsample quite closely mimics the behavior of the unconditional sample. We observe a steady increase in observations from 2005 until 2015. More pronounced is the sharp increase in observations starting from 2016. This increase can be largely explained by the change in firm coverage by Trucost that took place post-Paris agreement. This can be better observed in Panel C, in which we restrict our observations to firms that are featured in Trucost prior to 2016. We still observe the increase in firm observations over time but the sharp increase in 2016 is no longer as pronounced.

3.3 *Innovation Capacity: scale & scope*

The summary statistics in Section 3.1 suggest that the probability of a firm filing a patent is skewed towards larger firms. This result is not entirely surprising. To be able to innovate firms need to build research teams, laboratories, and other facilities. It is to be expected that bigger firms can build bigger research facilities, and therefore can produce more patents. What is more, firms are more likely to continue incurring these fixed costs if their innovative activities have been successful. And so, a plausible hypothesis is that the past stock of patents along with the size of the firm predict future patenting activity. If firms' innovation capacities are limited by their size, one would also expect to see some substitution between different R&D directions. Not all promising research and development projects can be pursued at the same time. Firms choose the projects that show the greatest promise given their state of knowledge and know-how. Thus, another plausible hypothesis is that firms specialize in the R&D they become good at.

We begin our analysis by formally exploring these two hypotheses. First, we associate a firm's number of new patent filings at the European patent office in year *t* (ANYCOUNTEP) with its stock of European patents up to year *t* (PASTSTOCKANYEP), its size, number of employees, assets, and its age, using a Poisson pseudo-maximum likelihood model (which allows for non-trivial numbers of zeros in dependent variables). We report our findings in Table 1, Panel A. In columns 1 to 3, we look at the extensive margin by including all firms, whether they have any patents or not. In columns 4 to 6, we look at the intensive margin, by including only firms that have engaged in innovation activities in the past and own some patents. Specifications 1 and 4 include country and year fixed effects, specifications 2 and 5 additionally include industry-year fixed effects, and specifications 3 and 6 use firm fixed effects instead of industry-year fixed effects.

In all models, we double cluster standard errors at the firm and year dimensions to allow for cross-correlation and serial correlation of residuals.

Consistent with our first hypothesis, we find that the stock of patents already owned prior to year *t* (PATSTOCKANYEP), the age of the company, and the three measures of firm size (market cap, number of employees and total assets), all positively predict future patenting activity when we add industry-year fixed effects. This is true both at the extensive and intensive margins. In other words, innovative activities of firms are constrained by their innovative capacity, which is greater for larger firms and for firms that have greater R&D experience (as reflected in the patent stock and firm age variables). As others have pointed out (e.g., Acs and Audretsch 1988, 1991), much innovation activity takes place at large companies. Our findings confirm these observations (albeit based on broader and more recent data). These results provide important context for our other findings below on the path-dependency of R&D activity.

In Panel B of Table 1 we turn to our second hypothesis, specialization through learning-by-doing. Here we distinguish between the number of green patents a firm files in year *t* (GREENCOUNTEP) in columns 1 to 3, and the number of brown patents (BROWNEFFCOUNTEP) it files, in columns 4 to 6. We also break down the patent stock variable into the stock of green patents (PATSTOCKGREENEP) the firm holds up to year *t*, and the stock of brown patents (PATSTOCKBROWNEFFEP). Consistent with our hypothesis, we find strong evidence of specialization, with a higher stock of green patents (resp. brown patents) positively predicting future green innovation activity (resp. brown innovation activity). Moreover, a higher stock of green patents (resp. brown patents) negatively predicts future brown innovation activity (resp. green innovation activity). This latter finding in particular reveals both the presence of scope constraints for innovation and the effects of learning-by-doing. Overall, this latter finding uncovers strong path-dependency for innovation: greater experience with brown technology reduces the likelihood of future green innovation activity; similarly, greater experience with green technology reduces the likelihood of future brown efficiency innovation. This evidence is consistent with the path-dependency findings of Aghion et al. (2016) for the auto industry. Path dependency is not just a feature of that industry. It extends across industries and around the world.

3.4 *Green and brown innovation ratios*

As we have shown, patenting activity in any given year is significantly driven by a firm's innovation capacity. Moreover, the different directions in which a firm can pursue R&D are constrained by the firm's innovation capacity, so that there is some substitution between different R&D directions. Accordingly, new patent filings must be related to the firm's innovation capacity to get a more accurate picture of the intensive margin of innovation activity. For that reason, we

normalize the number of green (respectively brown) patent filings by the total number of patent filings and define the following two variables: GREENRATIOEP is the ratio of green patents filed at EUPO over the total number of patent filings in that year; BROWNEFFRATIOEP is the ratio of brown patents filed at EUPO over the total number of patent filings in that year.

Table IA.IV, Panel A provides information on the ratios of green or brown patent filings for each country. In columns 1-4 we focus on green patent ratios. The average green patent ratio equals approximately 11%. Interestingly, the ratios do not differ greatly between publicly listed and private companies, with the former having an average ratio of 11.4% and the latter 10.3%. For the Trucost sample, the numbers are slightly higher. Furthermore, innovation activity (as measured by the number of firms with at least one patent) is proportional to the size of the economy. Among the countries with more than 300 public or private companies, some of the ones with the highest ratios of green to total number of patents are: Norway with a ratio of 16.4%, Canada with a ratio of 15%, and Denmark with a ratio of 14.5%. In comparison China has a ratio of 12.9%, and the U.S. an even lower ratio of 10%. Notably, Saudi Arabia reports a large fraction of green patents 14.9%, and the UAE an even higher ratio of 23.5%, which is interesting given their strong reliance on oil production. In columns 5-8 we provide respective summary statistics for brown patents. On average, brown patent ratios are significantly smaller. The average number for the EUPO patents equals 3.33%. The unconditional numbers do not deviate much from those based on the Trucost sample. Notable countries for significant brown patenting activity include Malaysia, Australia, India, Greece, Singapore, and the U.K. The numbers for the U.S. and China are about the same 2.61%.

Panel B breaks patent activity down by sector (GICS6-industry). In columns 1-4 we present the results for green patents. Some sectors stand out for the intensity of their innovation activities. The Independent Power and Renewable Electricity Producers industry has the highest ratio of green patents filed at EUPO, with 53.78%, followed by Electric Utilities, Multi-Utilities, and Gas Utilities. These results are broadly consistent with those in Cohen, Gurun, and Nguyen (2022) for the U.S. On the other end of the green R&D spectrum, IT and healthcare sectors are the two industry groups with the lowest green patent ratios. The ratios are broadly within the same range for public and private firms. They are also not markedly different when we restrict our sample to Trucost observations, which is reassuring about any selection concerns one might have. In columns 5-8 we report the results for brown patents. The ratios are generally larger for publicly listed firms, especially in those sectors with higher ratios. Among the most active industries, Energy Equipment & Services leads with the highest ratio of 19.95%, followed by Automobiles at 14.38%, and Independent Power and Renewable Electricity Producers at 12.5%.

In Panel C, we report the distribution of patenting activity by year, with columns 1-4 providing green patenting activity over time and columns 5-8 providing brown patenting activity. Green patent ratios have steadily increased over time. For example, in column 1 we see that this ratio was below the average of 11% in 2005, with a ratio 8%, but above average in 2020 with a ratio of 12.9%. The same increasing trend in green patent activity can be observed for listed companies (in column 2), private companies (column 3), and for Trucost companies, which are mostly listed companies (in column 4). When it comes to brown patent filings, we see the opposite trend and a decline in R&D activity over time for brown technologies, but the rate of reduction is very small. In Figure 3 we display the patent ratios across time by region and find broadly similar patterns.

3.5 Summary Statistics

In this section we provide summary statistics for the main variables in our models, conditional on whether firms file patents. In addition, we report complete summary statistics for publicly listed firms with carbon emissions data (those that can be matched to the Trucost dataset). Our empirical analysis in the subsequent sections is based on this restricted sample. Accordingly, these summary statistics provide information on how the broader universe of firms may differ from the Trucost universe.

We begin by defining all the variables. Our first category is variables related to innovation activity. Besides the variables measuring general innovation activity and respectively green innovation, and brown efficiency improvements that we defined above, we also include variables measuring the impact of patents by how widely cited they are. GREENRATIOEP2 is defined as the number of granted or purchased "green" or "general efficiency" patents over the total number of granted or purchased patents; OECDRATIOEP is a patent ratio based on OECD green Env-tech classification, calculated as the number of granted or purchased OECD patents over the total number of granted or purchased patents; GREENCITMAXEP (BROWNEFFCITMAXEP) is the maximum number of forward citations any green (brown) patent of a firm received; GREENBBCOUNTEP (BROWNEFFBBCOUNTEP) is the number of green (brown) blockbuster patents patent per firm, where blockbuster patents are defined as patents in the 95th percentile based on the number of forward citations in a given grant year and classification.[7]

[7] Measuring the importance of patent value is generally a challenging question and, in this paper, we rely on the most basic measure of citation, particularly because of our global focus in the paper. Kogan et al. (2017) is an excellent study providing a more detailed discussion of these issues.

In our second category we include variables measuring corporate carbon emissions (direct and indirect) when available, and standard variables capturing key corporate characteristics.[8] Thus, LOGS1TOT, LOGS2TOT, LOGS3TOT, LOGS3UPTOT, and LOGS3DOWNTOT respectively stand for the natural logarithm of firm-level scope 1, 2, and 3 (also upstream and downstream) total carbon emissions, and S1INT, S2INT, S3INT, S3UPINT, and S3DOWNINT are firm-level scope 1, 2, and 3 emission intensity variables defined as the level of emission divided by firm sales. In our third category we include the main variables reflecting key corporate characteristics: i) LOGSIZE stands for the natural logarithm of a listed company's market capitalization (price times shares outstanding); ii) LOGPPE is given by the natural logarithm, of the firm's property, plant, and equipment (in $ million); iii) LEVERAGE is the ratio of debt to book value of assets; iv) ROE is given by the ratio of firm *i*'s net yearly income divided by the value of its equity; v) M/B is the end of year market cap divided by the firm's book value; vi) BETA is the market beta of individual companies calculated over the preceding 12-month period; vii) VOLAT is the standard deviation of returns based on the past 12 monthly returns; viii) momentum, MOM is given by the average of the most recent 12 months' returns on stock *i*, leading up to and including month *t-1*; ix) short-term reversal, RET is the past year's December return on stock *i*; x) capital expenditure INVEST/A is the firm's capital expenditures divided by the book value of its assets; xi) MSCI is an indicator variable equal to one if a stock is part of the MSCI ACWI index in year *t*, and zero otherwise; xii) LOGCAPEX is the natural logarithm of firm-level capital expenditures; and xiii) LOGCASH is the natural logarithm of firm-level cash positions. To mitigate the impact of outliers we winsorize M/B, LEVERAGE, INVEST/A, and ROE at the 2.5% level, and MOM and VOLAT at the 0.5% level.

In Table IA.V we report the sample averages, medians, and standard deviations of these variables. Panel A is based on all public and private firms, and Panel B on firms with available emission data. Columns 1 to 3 aggregate all firms with at least one patent. Columns 4 to 6 aggregate firms without any patents. Columns 7 to 9 aggregate firms in the bottom decile based on firms' average GREENRATIOEP across the whole period. The bottom decile covers only firms with no green patents and represents around 35% of observations. Columns 10 to 12 aggregate firms in the top decile based on firms' average GREENRATIOEP across the whole period. Both Panels A and B reveal considerable heterogeneity in innovative activity. Among the firms that hold at least one patent, there is a wide dispersion in green innovation as reflected in the standard deviation of GREENRATIOEP of 26.08% and the standard deviation of GREENCITMAXEP of 155.89.

[8] Note that we do not have a complete coverage of all corporate emissions. The Trucost data covers around 85% of listed companies worldwide, and almost no privately held companies. The numbers we report are therefore an underestimate of total corporate emissions, and since a growing fraction of high emitting companies (or their affiliates) have delisted over the period we cover, this underestimate is likely to be larger in later years.

Interestingly, the average level of emissions of innovating firms is significantly larger than that of non-innovating firms, with the mean of LOGS1TOT equal to 6.13 for innovating firms but only 4.85 for non-innovating firms. A similar difference holds for scope 2 and 3 emissions. Partly this difference could be attributed to the fact that innovating firms are slightly larger (mean LOGSIZE is 7.86 for innovating firms versus 6.93 for non-innovating firms). Patenting firms have also greater values of LOGPPE, LOGCAPEX, and LOGCASH, and slightly higher values of M/B than non-patenting firms do. At the same time, they do not differ much in terms of their BETA, VOLAT, MOM, and INVEST/A. Notably, we observe similar relationships for variables that are observed for the full and restricted samples, which suggests that the relationships we identify based on our restricted samples are not less likely driven by specific selections along different observables.

We now turn to the analysis of innovation and the carbon transition. Our analysis will be guided by three fundamental insights, the *Arrow replacement effect* (Arrow, 1962), *Jevons' paradox* (Jevons 1865), and the *displacement effect*. Arrow (1962) has pointed out that "The pre-invention monopoly power acts as a strong disincentive to further innovation."[9] More generally, the incentive to innovate is reduced if the innovation replaces an existing technology that is working and is profitable. By that principle one should expect companies that master technologies based on fossil fuels to be less motivated to engage in green innovation that would replace a technology and know-how that is already working. This is even more likely if green innovation involves retooling and abandoning a knowledge base around fossil fuel-based technology. If there is an incentive to innovate for an incumbent firm with a fossil fuel-dependent installed base it is more likely to take the form of efficiency improvements in the use of fossil fuels, what we refer to as *brown efficiency improvements*. Indeed, this innovative activity plays into the strengths of the incumbent firm, its expertise with brown technologies, which it has built through learning by doing (Arrow 1971).

Carbon emissions can be reduced by replacing brown with green energy or by improving the carbon efficiency of brown energy. Thus, both green and brown efficiency innovations are central to the drive to decarbonize the economy. But, as Jevons (1865) has pointed out, brown efficiency improvements do not necessarily translate into carbon emission reductions because the very efficiency gain is also inviting greater use. Furthermore, the displacement effect from green innovation may displace scope 1 emissions to scope 2 and scope 3 emissions, as is for example the case for electric vehicles.

In the next section we explore how green innovation activity is shaped by Arrow's replacement effect. In the following section we turn to Jevons' paradox and the displacement

[9] Kenneth Arrow "Economic Welfare and the Allocation of Resources for Invention," page 620, in *The Rate and Direction of Inventive Activity: Economic and Social Factors*, NBER.

effect to explore the link between green innovation and the future decarbonization of the economy.

4. Green Innovation Activity: Arrow's replacement effect and path-dependent innovation

Basic economic analysis would suggest that firms engage in green R&D if it is more profitable than both no R&D and other R&D. Another consideration is comparative advantage—some firms, such as renewable energy companies, may be both better equipped and benefit more from green R&D. Brown companies that rely on fossil fuel energy may be better at squeezing out efficiency gains in brown technologies. Alternatively, "khaki" R&D, that is, green innovation by brown companies, may be most profitable if fossil fuel energy is increasingly regulated and expected to become obsolete. We explore these hypotheses in this section and point to some key factors driving green R&D across sectors and around the world. Overall, the picture that emerges is the importance of path-dependency in understanding green innovation activity at the firm level. As we will show, green firms (that are already familiar with green technologies) are more likely to produce green patents, whereas brown firms (which have expertise in fossil fuel-dependent technologies) are more likely to produce brown patents. Similarly, older companies (the industry incumbents) are more likely to engage in brown efficiency innovation, while younger companies (the new entrants) are more likely to engage in green innovation. We also find that a key predictor of patenting activity is the stock of past patents that a company holds. Companies that have been successful innovators in the past have capacities that allow them to continue to innovate. However, as we have shown, innovation capacities are limited. Companies cannot innovate in all promising directions. If their past innovative activities tended to be specialized in brown efficiency innovations, they will continue to innovate in that direction. In sum, innovation activity is characterized by path-dependence consistent with the findings of (Popp, 2002) and Aghion et al., 2016).

4.1 *Green vs Brown Innovation: Firm type and Path-dependency*

The sustainable energy technological revolution necessarily involves substituting fossil fuel-based technology for green technology. Is this substitution taking place within firms (with the greening of brown firms) or across firms (with the replacement of brown firms by green firms)? This is the question we explore in this section.

Our working definition of a *brown* firm is a firm with high carbon emissions, that is older, may have larger assets, and may be a value company. Similarly, a *green* firm is one that has low carbon emissions, is younger, may have smaller asset size, and may be a growth firm. These characteristics are not the only possible ways to define a firm type, these are more to illustrate the

point that companies' emissions may be systematically driven by some ex-ante metrics. As the histograms in Figure 4 show, our green vs brown firm type classification is broadly descriptive of our universe of companies. Each panel shows the distribution of scope 1 emissions for companies in the lowest and the highest quintile of the distribution that is conditional on three different characteristics. In Panel A we show how younger firms (in the bottom quintile) have a distribution of scope 1 emissions that is skewed towards lower levels than the distribution for older firms (in the top quintile). Similarly, in Panels B and C we show that firms with respectively larger asset size and larger M/B ratios have also lower means and medians of their emissions.

Our question, rephrased with reference to these two firm types, then will be the extent to which we see green innovation activity at *green* versus *brown* firms, and whether we see brown firms greening themselves through green R&D. Given that firms have limited innovation capacities and given that the research projects that are most promising in view of individual firms' accumulated know-how tend to crowd out other R&D, it is natural to measure the amount of green (resp. brown efficiency) R&D in terms of the ratio of green-to-total patent filings (resp. brown efficiency-to-total patent filings).

How are green (resp. brown) patent ratios linked to firm type, specifically the firm's corporate carbon emissions, its age, and green and brown patent stocks? To answer this question, we estimate the following Pseudo Poisson Maximum Likelihood model with firm (*i*) and year (*t*) as units of observation[10]:

$$\text{Patent Ratio}_{i,t} = a + b*\text{Firm Type}_{i,t-1} + c*\text{Controls}_{i,t-1} + \text{Fixed Effects} + \varepsilon_{i,t} \quad (1)$$

where *Patent Ratio* is a generic variable that allows for different types of patents to be related to the total number of patent filings. *Firm Type* (a continuous variable measuring the share of a firm's green and brown activities) is proxied by a combination of i) LOGS1TOT (and other carbon emission variables); ii) PATSTOCKGREENEP and PATSTOCKBROWNEFFEP, and iii) AGE/100. *Controls* is a vector of the following variables: LOGSIZE, LOGPPE, LEVERAGE, ROE, M/B, INVEST/A, BETA, VOLAT, MOM, RET, and MSCI. We include country and year fixed effects. In some specifications, we also include industry-year or firm fixed effects. Our baseline specification uses the Trucost sector classification of 431 industries. To allow for the cross-sectional and serial dependence in the residuals we double cluster standard errors at the firm and year dimensions. Our coefficient of primary interest is *b*.

[10] Since many companies do not report any green patents a standard OLS regression is not suitable to estimate this relationship.

We report our findings for the extensive margin (which includes all firms, whether they own any green, respectively brown, patents or not) in Table 2. In columns 1-3, we present the results for green innovation activity (GREENRATIOEP), and in columns 4-6 the results for brown innovation activity (BROWNEFFRATIOEP). When industry fixed effects are not included (column 1) the coefficients of LOGS1TOT and PATSTOCKGREENEP are positive and statistically significant. The coefficient of AGE is negative and statistically significant. Not controlling for industry, however, is misleading because technological differences (and differences in emissions) across industries are huge. The results of the regressions without industry fixed effects are therefore difficult to interpret. For this reason, we consider specifications that absorb the time-varying differences across industries through industry-year fixed effects.

When industry-year fixed effects are included (column 2) the coefficient of LOGS1TOT is highly significant and negative. The other two coefficients retain the same sign and significance as before. When we further include firm-fixed effects, in column 3, the coefficients of LOGS1TOT and PATSTOCKGREENEP become insignificant.[11] The results flip when we look at brown innovation activity (BROWNEFFRATIOEP) in columns 4-6. For this type of innovation activity, the association with direct carbon emissions is strongly positive across firms within the same industry (when we include firm fixed effects, in column 6, the association for LOGS1TOT becomes negative, suggesting that when direct emissions increase firms tend to reduce their innovation activity). Overall, the combination of these results has a clear interpretation: green companies do more R&D that is green, and brown companies do less; instead, the latter do more brown R&D. What is more, these are cross-firm rather than within-firm effects (when we substitute industry*year FE for firm FE neither the coefficients for carbon emissions nor for the stock of patents are significant). These results further confirm the path-dependency hypothesis for R&D. To the extent that brown companies engage in innovation activities, their innovations are less likely to be directed towards green patents (and the opposite is true for green companies). In addition, green innovation is most likely to be undertaken by new entrants. Incumbents, far from embracing renewable energy technological change, respond by seeking to improve the efficiency of fossil fuel-based technology. The auto industry provides a good illustration of these findings. Indeed, the EV revolution has been driven by new entrants (Tesla, BYD) and incumbents have responded by improving the carbon efficiency of their vehicles.

In Table 3, we further explore the link between green innovation and direct carbon emissions on the *intensive margin*. That is, we restrict the sample to the universe of firms that have engaged in innovation (all the firm-year observations with at least one green patent, in columns 1

[11] In the specification with firm-fixed effects we cannot uniquely identify the coefficient of AGE because its variation is collinear with that of firm and year fixed effects.

to 3, and/or one brown patent, in columns 4 to 6) and explore how the intensity of green (respectively brown) innovative activity is related to the stock of respectively green and brown efficiency patents the firm already owns, firm age, and the firm's direct carbon emissions. The empirical model follows that in Table 2, and it is estimated using OLS with standard errors double clustered at firm and year dimensions. Our findings for the intensive margin are broadly consistent with those for the extensive margin. If anything, they are stronger, except for firm age and scope 1 emissions, which are no longer significant for brown efficiency innovation, suggesting that entry and exit play a more important role in the relationship between the variables in the data.

Patent counts (or patent ratios) are somewhat coarse innovation performance metrics to the extent that many patents have limited applications. Accordingly, we also take patent citations (which reflect the importance of a patent) as an additional measure of innovation activity. In Table 4, Panel A, we associate the citation number of the patent with the maximum citations (respectively our GREENCITMAX and BROWNEFFCITMAX variables) with the same firm characteristics as in our previous regression for the green and brown patent ratios. We find very similar qualitative effects. Companies with higher emissions have lower citations for their green patents but higher citations for their brown patents. Also, companies with a greater stock of green (brown) patents are more likely to receive more citations of their green (brown) patents. Notably, firm age is positively associated with citations of both types of patents. This is to be expected since citations generally take time to accumulate. Similarly, our findings on the path-dependency of green R&D are confirmed when we focus on the most important new patents by citation count, *GREENBBCOUNTEP* and *BROWNEFFBBCOUNTEP*, in Panel B. Companies with a higher stock of green patents are more likely to make further important green innovations, and companies with a higher stock of brown patents are more likely to make additional brown efficiency innovations. The results for firm emissions and age are slightly weaker.

We find more direct evidence of Arrow's replacement effect at work in Table 5, where we explore how the firm's market share affects the path-dependence of innovation. If the replacement effect is at work, we would expect to see firms with larger market share do less green innovation other things equal. In Table 5 we explore how a firm's market share based on its sales relative to total public and private firms' sales in the same Trucost sector (MKTSHRSALES TRUIND) affects its green innovation activity. Strikingly, we find that firms with a larger market share do significantly less green innovation, but they do more brown innovation. Note that when we replace industry*year FE with firm FE market share is no longer a significant variable, so that this effect is entirely driven by selection in the industry. An additional prediction of the model is that firms with greater market share should be in a better position to switch their innovation profile because of their stronger competitive position. To test this hypothesis, we interact the firms' market share

with their type (measured by scope 1 emissions, firm age, and the stock of green and brown efficiency patents). In the model in column 2 that accounts for industry-year fixed effects, we find that green innovation is less path dependent when firms have a larger market share. This result holds for all three measures of firm type. The results based on brown innovation are similar for firm type measured by scope 1 emissions but are weaker when we measure firm type with the stock of brown patents, or firm age. Note that the interaction effect is again driven by selection in the industry. Indeed, when we replace industry*year FE with firm FE we find that a higher stock of green patents induces more green innovation (and a higher stock of brown patents induces more brown efficiency innovation). These findings are all consistent with Arrow's replacement effect: more entrenched firms (as measured by their market share) have lower incentives to do R&D and they are also more likely to switch their type because of their greater flexibility to do so.

Our findings so far are that brown companies (with higher direct emissions) do not tend to engage in green R&D. This may be due to replacement and/or learning-by-doing effects. Another possibility is that brown companies may be locked into fossil-fuel dependent technologies through their production networks. If input suppliers or downstream firms/customers also rely on fossil fuel-dependent technologies, then an individual firm in the supply chain may not be able to easily switch to green technologies. We investigate the presence of such technological complementarities across firms by exploring whether indirect (scope 2, upstream and downstream scope 3) emissions are linked to corporate green R&D. We report the findings of this analysis in Table 6. It is indeed the case that the technological ecosystem in which a firm operates affects its incentives to engage in green R&D. As can be seen in columns 1, 2, and 3 of Panel A, the higher are the firms' indirect levels of emissions along the vertical production chain the less likely the firm is to engage in green R&D. Also (as is shown in Panel B), when it comes to brown efficiency innovation, the higher are firms' upstream scope 3 emissions the stronger are their brown innovation activities. Similar, but slightly weaker results hold for scope 2 and downstream scope 3 emissions. All in all, these latter findings reveal the presence of a much broader replacement effect than the firm-specific replacement effect identified by Arrow (1962): Replacing an old technology with a new one is more costly and less profitable if other firms along the supply chain do not follow in making the switch. This key finding suggests that in order to induce firms to transition from brown to green technologies, industrial policy that helps coordinate this transition across all firms linked through the supply chain may be needed.

We also explore the change in path dependency of R&D over time in response to the rise in climate change awareness and tighter mitigation policy responses following the Paris 2015 landmark agreement. We split our sample into two sub-periods, before and after 2015. We report our results in Table 7. The results in Panel A are for the full sample, and those in Panel B are only

for the legacy sample (the firms for which we have carbon emissions data before 2015). The interactions LOGS1TOT*Post2015, AGE*Post2015, and PATSTOCKGREENEP*Post2015 (resp. PATSTOCKBROWNEP*Post2015) capture the change in path-dependency around the Paris agreement (where Post2015 is an indicator variable taking the value 0 for all observations before 2015 and 1 after 2015). Interestingly, there is no significant change in the link between carbon emissions and green (or brown) patent activity. However, the stock of green patents matters more for future green R&D post 2015, suggesting that green R&D has become more valuable post 2015 and is pursued by the (new entrant) green firms.

4.2 Robustness

We perform several robustness tests and report the findings in the Appendix. In Tables IA.VI and IA.VII we report the findings of our main regression analysis industry by industry for each GICS6 industry to better understand in which industries our results are strongest. Overall, path-dependency results are found in most industries, especially for the regressions with green patents as dependent variable.

Second, we explore how sensitive our path-dependency results are to different patent classifications. In Table IA.VIII we replace our green patent classification with the broader OECD classification of green patents, which includes more general technologies related to environmental applications, biodiversity, and wastewater management, as well as a green classification capturing both green and general efficiency patents. We find that the qualitative predictions uncovered for our green patent classification also hold for this broader green classification. Firms with higher emissions, that are older, larger, and have a smaller stock of green patents do less green R&D.

Third, we explore the sensitivity of our results to different patent filings than European patent office filings. In Table IA.IX we count all patent filings anywhere in the world. The dependent variables now are the ratio of green to total worldwide patent filings in year *t* (GREENRATIOWW in columns 1 to 3) and the ratio of brown to total worldwide patent filings (BROWNEFFRATIOWW in columns 4 to 6). Similarly, the stock of patents (PATSTOCKGREENWW and PATSTOCKBROWNEFFWW) now includes all patents filed anywhere in the world. The results clearly show that the qualitative results on path dependency also obtain when we look at the noisier measure of patent activity based on worldwide filings.

Fourth, we revisit the results of Table 2, using two alternative definitions of industry, based on 6-digit and 8-digit GICS scores. We report the results in Table IA.X. We find that qualitatively changes in industry classification do not affect our results on path dependence. Another robustness test we conduct is to restrict our sample to those firms for which we have carbon emissions data before 2015 (our legacy sample). Again, as reported in Panel A of Table IA.XI (for

the extensive margin) and Panel B of Table IA.XI (for the intensive margin), our qualitative results are unchanged. We also explore how much mergers and acquisitions affect our findings. In Table IA.XII we report the findings of our regressions based on a sample that excludes all companies engaged in mergers and acquisitions (M&A) over our sample period. The results are qualitatively similar to our baseline findings. M&A activity is largely orthogonal to the determinants of corporate innovation activity even if some acquisitions are motivated by access to innovation.

We also explore how green innovation is distributed across firms by the size of their carbon emissions. In Table IA.XIII, we report the findings when we split our sample into terciles based on firms' initial scope 1 emissions (the first year when we observe a firm's scope 1 emissions). In Panel A the dependent variable is the green patent ratio and in Panel B the dependent variable is the brown efficiency ratio. Interestingly, the most significant negative effects of carbon emissions on green innovation are concentrated in the tercile of firms with the lowest emissions. But the stock of green patents has similar predictive effects on green innovation across all three terciles. In contrast, the most significant effects of carbon emissions on brown innovation are concentrated in the tercile of firms with the largest emissions. Again, however, the stock of brown patents has similar predictive effects on brown efficiency innovation across all three terciles.

5. The effects of innovation on future carbon emissions

We have shown that green and brown efficiency innovation is strongly path dependent. Green companies (which tend to be younger) are more likely to produce green patents, while brown companies are more likely to produce brown efficiency patents. That is, brown companies do not redirect their innovation towards green innovations. Rather, they focus on squeezing out efficiency gains in their brown operations. These results suggest that companies are unlikely to decarbonize through the switch of their innovation profiles.

In this section we systematically evaluate the effects of (green and brown) innovation on future carbon emission reductions. Much is predicated on the assumption that technological change is the solution to the climate crisis. But do green and brown efficiency innovation significantly reduce carbon emissions? The archetypal image of a technological change that drastically reduces carbon emissions is the substitution of a coal-fired power plant by a photovoltaic power station, or the substitution of a combustion-engine car by an electric vehicle. Yet even these obvious examples come with questions about the net effects of these technological changes on carbon emissions, since solar panel and electric vehicle production require inputs and use energy that causes upstream and downstream carbon emissions, giving rise to the displacement effects. Similarly, with brown efficiency-improving innovation the effect on carbon emission reductions may be limited because of rebound effects. Fuel economy innovations for combustion

engine cars may be undone by people driving longer distances. Battery life improvements for cell phones may simply result in greater phone usage. It is therefore unclear how much green and brown efficiency innovation has affected direct and indirect carbon emissions. These are the questions we explore in this section by exploring in turn the effects of innovation on: i) the companies' own future direct and indirect emissions; ii) the effects on other companies' direct and indirect emissions in the same industry; iii) the effects on carbon emissions across other, broadly related industries; and iv) the effects on carbon emissions across countries within the same industry.

5.1 Green Innovation and the CO2 Problem

We begin our analysis of the impact of green R&D on carbon emissions by estimating the following regression model linking future firm-level corporate policy outcomes, such as future carbon emissions, to measures of contemporaneous green and brown efficiency patent ratios. Our first model exploits both extensive and intensive margins of patenting. Formally, we estimate the following linear regression model:

$$\text{Corporate Policy}_{i,t+h} = a + b*\text{Patent Ratio}_{i,t} + c*\text{Controls}_{i,t-1} + FE + \varepsilon_{i,t} \quad (2)$$

where *Corporate Policy* is a generic response variable that includes: i) the total level of emissions; ii) emission intensity; iii) INVEST/A; iv) LOGCAPEX; and v) LOGSALES, measured $t+h$ years ahead. We let h take the value of respectively 1, 3, and 5 years to reflect the possibility that there may be a "time to build" lag in corporate adjustments. We also use the average value of patenting activity over the previous 3 years to predict corporate outcomes to take account of the fact that innovation breakthroughs are lumpy. The variable *Patent Ratio* is defined as before, and all regressions include year and firm-fixed effects. We double cluster standard errors at the firm and year dimensions. Our coefficient of primary interest is b, which measures the impact of *Patent Ratio* on future corporate policy outcomes.

The results are reported in Table 8. Panel A reports the effects of green innovation (GREENRATIOEP) on corporate policy outcomes one year (L1), three years (L3), and five years (L5) ahead. We also report the effects of green innovation averaged over the previous three years (3YEARAVGGREENRATIOEP) on these corporate policy outcomes. As shown in column 1, green innovation has no significant effects on firms' direct emissions, one, three, or five years later. The same is true for indirect emissions (scope 2 emissions in column 2, upstream scope 3

emissions in column 3, and downstream scope 3 emissions in column 4[12]), although we observe a small reduction in indirect emissions with a 10% statistically significant negative coefficient of -0.042 for scope 2 emissions three years after the green patent filings. Future emissions are also not significantly related to innovation activity averaged over the past three years. We conclude that green innovation has not resulted in significant carbon emission reductions for the innovating firms even after five years since the patent filing. Columns 4 to 8 further report the lack of any significant effects of green innovation on direct or indirect emission intensity, so that the green technical progress does not appear to have materialized in any significant carbon efficiency gains. The only significant effect of green innovation on future corporate policies has been on future investment (with a three-year lag), with a substantial reduction in investment following the green patent filings. This latter finding is somewhat surprising, given that one expects research breakthroughs to be followed by development (i.e., more investment).

Panel B reports the effects of brown efficiency innovation (BROWNEFFRATIOEP) on corporate policy outcomes again respectively one year (L1), three years (L3), and five years (L5) ahead. As before we also report the effects of brown efficiency innovation averaged over the previous three years (3YEARAVGBROWNEFFRATIOEP) on these corporate policy outcomes. We find few significant effects of innovation on future corporate policies, except for a small increase in direct emissions with a 10% statistically significant positive coefficient of 0.065 for scope 1 emissions five years after the brown efficiency patent filings (in column 1), and a stronger, positive effect of average brown innovation on scope 1 emissions. This finding suggests that far from reducing future emissions, brown efficiency innovations result in increased future emissions. However, we also find a small improvement in scope 2 emission intensity, with a 10% statistically significant negative coefficient of -0.019 for scope 2 emission intensity five years after the brown efficiency patent filings (in column 7). Yet, this latter effect must be set against the significant effects on other corporate policies such as an increase in sales (column 12). Overall, what emerges from these findings is a picture that is consistent with the Jevons paradox: although brown efficiency innovation produces carbon intensity efficiency gains (for scope 2 emissions), these gains are offset by operating expansions (sales), which on net result in higher scope 1 emissions.

For robustness, we consider several alternative specifications. First, in Table IA.XIV we confirm the insignificance of firm-level green and brown innovation in affecting future carbon emissions and other corporate outcomes, for the specification where we include only observations of firms that hold at least one green, respectively brown, patent (intensive margin). Second, in Table IA.XV we show the results from the regressions where we take patent counts rather than

[12] Note that since downstream scope 3 emissions data has become available only in recent years, we do not have sufficient data to explore the effects on downstream scope 3 emissions over a 5-year horizon.

patent ratios as the main independent variable. The main difference is that the average count of green patents *positively* predicts future scope 1, scope 2, and upstream scope 3 emissions (in Panel A). Another related effect is that the average count of green patents *positively* predicts future firm sales. In contrast, we find a strong negative relationship between brown patent counts and scope 2 emissions (in Panel B). We also find a decrease in upstream scope 3 intensities in some specifications. Third, we explore how the importance of the patent matters for future corporate outcomes. In Table IA.XVI we consider the maximum number of cites a firm's patent receives. We find a strong positive effect of green patent cites on future scope 2 emissions, and a slightly weaker effect on upstream scope 3 emissions. In turn, green patent citations negatively predict downstream scope 3 emissions one year and three years into the future. Brown patent citations do not seem to affect future emissions, except for scope 1 emissions which fall in the next 1-3 years for companies with high citations of brown patents. In Table IA.XVII we look at the number of blockbuster patents a firm generates. As before, we find that, if anything, a higher incidence of blockbuster green patents is associated with higher levels of total emissions and particularly upstream scope 3 emissions. All other emissions components are unrelated to this measure. We also find little evidence that blockbuster brown patents lead to any reduction in future emissions. In Table IA.XVIII we restrict our analysis to companies whose cumulative patent ratio falls in the top quintile of the empirical distribution based on the previous 5-year data. Among all these innovation metrics, we find that the only model that predicts a reduction in future emissions is the 3-year moving average measure of green patents, which is negatively associated with scope 2 emissions. For brown patents, we find instead that the moving average of brown innovation strongly predicts a future increase in scope 1 emissions. Finally, in Table IA.XIX we show the results from using alternative, OECD-based, patent classifications. For green patents, we find some evidence of a reduction in future scope 2 emissions based on the ratio of green patents. Still, total future emissions are not negatively associated with this predictor. We also find a reduction in scope 2 emissions for some specifications based on brown patents, but the overall evidence of a link between green innovation and future decarbonization is weak. The conclusion we draw is that companies' green R&D activities are largely divorced from their other operations. Based on this evidence we conclude that the *green industrial revolution* has not yet materialized and that green innovation *per se* as the solution to the energy transition and the path to net-zero is still more of a promise than a reality.

If green or brown innovation does not lead to future carbon emission reductions by the innovating firms, could it be that these innovations are adopted by other firms so that green innovation activity *spills over* to the industry as a whole and materializes in industry-wide emission reductions? We explore this question by linking industry-level direct and indirect carbon emissions,

carbon intensity, and investment, to respectively green and brown efficiency innovation activity in the industry. Our baseline specification uses the GICS-6 industries classification. All regressions include the same controls as before, except that they are now measured at the industry level. We also include year and industry fixed effects. We double cluster standard errors at the industry and year levels. We report our findings for the industry-wide effects of green innovation in Table 9, Panel A, and of brown innovation in Table 9, Panel B.

Consider first the effects of green innovation. In Panel A.1 we consider the effects on all firms within the same industry, whether they are innovators themselves or not. We find that green innovation is positively associated with future scope 1 emissions in the same industry, especially in the longer 5-year horizon. This result is largely driven by an increase in industry sales, in line with Jevons' paradox. In fact, we find that scope 1 emission-intensity at the industry level goes down. We further find that a greater rate of green innovation in the industry is associated with higher future scope 2 emissions, consistent with the displacement effect. Finally, we find that more green innovation is associated with significant upstream carbon emission-intensity improvements.[13] One consistent interpretation of these latter findings could be that reduced upstream scope 3 intensity is achieved by switching energy sources towards electricity, and the increase in electricity usage may have been met by electricity produced by fossil-fuel based power plants, which would increase scope 2 intensity. We note that the above results do not change much if we take as our measure of green innovation the average of green patenting activity over three years (3YEARAVGGREENRATIO) to take account of the fact that innovation is a gradual multi-year process. Finally, we also find a small significant effect on industry-wide investment, with greater green innovation associated with a subsequent slight increase in investment, especially in the longer run.

We also break down within industry spillover effects by looking separately at firms that innovate and those that do not. The reason why we make this distinction is that spillovers among innovating firms could be driven by competition, whereas spillovers from innovating firms to non-innovating firms are driven by adoption of the new green technologies. In Panel A.2 of Table 9 we report the results of the effects of green innovation on corporate policies of all the innovating firms in the industry. Again, we find no effect of green innovation on subsequent carbon emission reductions even though the direction of the effect for scope 1 emissions becomes negative, suggesting a more beneficial effect of green innovation. Still, we find that greater green innovation

[13] Table IA.XX considers green citations. While the results on absolute scope 1 emissions, intensities, and sales have the same sign, they are statistically weaker. Table IA.XXI looks at OECD green patent ratios. The results reported in this table broadly confirm our findings. Scope 3 upstream intensities again improve with more green innovation. Note that we also find small reductions in scope 1 emissions for a 3-year lag for ever-patenting firms, but this effect disappears for a 5-year lag.

is associated with higher scope 2 emissions, especially over the longer 3-year period. In Panel A.3 we report the results of the effects of green innovation on corporate policies of all the non-innovating firms in the industry. We find no evidence of any within-industry *spillover* between green innovators and non-innovators.[14] There is no significant subsequent carbon emission reduction by the non-innovators in the industry. There is, however, a significant increase in scope 2 carbon emission levels and intensity for the non-innovating firms. We also find a positive effect for scope 1 emissions.

In our tests, we assume a particular granularity in which innovation propagates within industries. The choice of a proper sectoral clustering is ex ante difficult even though GICS-6 is the preferred classification of investors. As a robustness, we therefore repeat the same analysis in Panel A of Table IA.XXII, but with a different industry classification: Instead of the coarser GICS-6 classification we use the slightly finer Trucost industry classification. Most of the qualitative results are similar, with some notable exceptions. We now find that most of the industry-level emission metrics are unrelated to industry-level green ratios. The exceptions are for scope 2 intensity and scope 3 downstream emissions, both being positively related to green innovation. In sum, what emerges from these findings is that there is no evidence of significant industry-wide direct and indirect emission reductions following greater green patenting activity and if anything, some of the emissions, especially scope 2 emissions go up, consistent with the displacement effect.

We consider next the industry-wide effects of brown efficiency innovation. The results are reported in Panel B of Table 9. In Panel B.1 we again look at the effects on all firms in the industry, whether they are innovators themselves or not. Interestingly, we find some reduction in direct or indirect carbon emissions following greater brown patenting activity even though the results are statistically insignificant.[15] We further find that scope 1 and scope 3 upstream carbon emission-intensity goes up. Another remarkable finding is the apparent heterogeneity between innovating and non-innovating firms. While emissions of innovating companies in the same GICS-6 industry increase slightly, carbon emissions of the non-innovating firms in the sector (both direct and indirect) go down. Interestingly, this effect is to a large extent driven by a reduction in sales, and investments, of that group of companies. Hence, the carbon emissions reduction of this subset of companies is largely coming from their loss of market share and not from a greater carbon efficiency of production. We again repeat the same analysis in Panel B of Table IA.XXII with the Trucost industry classification. Most of the qualitative results are similar, even though we find that

[14] We confirm these results in Table IA.XX with patent citations as a measure of green innovation. The only notable difference is an increase in scope 3 downstream emissions with a three-year lag.

[15] In Table IA.XX, we explore the robustness of these findings to using patent citations to measure brown innovation. Under this measure, the results are broadly confirmed, although absolute scope 1 emission and intensities increase in the long-run.

scope 2 emissions of innovating companies go down due to increased efficiency of energy production. At the same time, we again find that the market share of non-innovating companies goes down by a significant margin thus explaining some of the reduction in total emissions.

If there are no significant effects of green innovation on industry-wide carbon emissions, could there be cross-industry effects? Could it be that technological improvements in green energy in one industry mainly result in carbon emission reductions in other, closely related industries? We explore this question next (we also look at cross-country spillovers within individual sectors in Tables IA.XXIII-IA.XXVIII of the Appendix). In Table 10 we associate industry-wide direct and indirect carbon emissions, scope 1, 2, and 3 carbon intensity, capital expenditures, and sales in a given industry with green innovation activity by firms outside the narrow sector, but within the broader sector, and ask to what extent green innovation works by reducing emissions across sectors. Specifically, we link innovation activity in a given GICS-8 industry to corporate outcomes in a corresponding GICS-2 industry, excluding the specific GICS-8. In Panel A.1 we include all firms, in Panel A.2 we only look at cross-sector spillovers on innovating firms and in Panel A.3 we only look at cross-sector spillovers on non-innovating firms. Interestingly, we find a significant cross-industry spillover effect on carbon emissions with a 1-year lag for upstream scope 3 emissions, and for downstream scope 3 emissions for green innovation activity averaged over three years (3YEARAVGGREENRATIOEP). This effect works entirely through innovating firms, as is shown in Panels A.2 and A.3.

As for the cross-industry effects of brown efficiency innovation reported in Panel B of Table 10, we find that the only significant cross-industry effect on the level of emissions is an increase in downstream scope 3 emissions. The other cross-industry effect is a significant worsening of scope 1 and scope 2 carbon intensity for patenting firms. These findings point to other channels through which rebound effects can take place. An efficiency gain in brown technology in one sector can result in increased carbon emissions in another sector (through the supply chain) by inducing greater use of a complementary brown technology.

These findings are consistent with the general idea that cross-sector innovation is highly complementary, and that it takes innovation breakthroughs in multiple sectors to be able to implement new technologies that reduce carbon emissions at scale. Moreover, technological innovation in one sector can result in rebound effects in another sector, largely eliminating any reductions in direct emissions from the innovation. This points to the complexity of green innovation as a solution to the CO2 problem. Decentralized, market-based, innovation may not be all that effective in decarbonizing the economy, if adoption and scaling of green technologies is held back by the lack of coordination of innovation across firms and sectors.

5.2 Spillovers from the universe of privately held companies

Our results so far relate firm-level and industry-level emissions to innovation of publicly listed companies. Our focus on publicly listed firms is dictated by the availability of carbon emissions data for these companies. However, one could argue that such firms may benefit from innovation not only of similar publicly listed companies but also from innovation of privately held firms. In this section, we examine this spillover channel by looking at industry-level responses to green and brown innovation by publicly listed and privately held companies, separately.

In Table 11, we report the results from the analysis that considers innovation and output in the same GICS-6 industry, similar to our setting in Table 9. In Panel A, we look at the role of green innovation. We define two new variables: GREENRATIOEP PUBLIC takes innovation activity of all publicly listed companies, GREENRATIOEP PRIVATE uses the innovation of private companies. Both measures incorporate scaling by total innovation activity. In Panel A.1, we focus on all firms with emissions data. We find that neither public nor private innovation is associated with any statistically significant reduction in industry-level emissions. Notably, we find that green innovation in the public sector is more positively correlated with future scope 2 emissions, as well as scope 1 and upstream scope 3 emissions, though the effects for the latter two are statistically insignificant. The stronger positive association of public innovation mostly comes from the subset of innovating companies (as reported in Panel A.2), which are also the ones whose sales go up by more.

In Table 11, Panel B, we repeat the same analysis for brown innovation. The corresponding new variables of interest are BROWNEFFRATIOEP PUBLIC and BROWNEFFRATIOEP PRIVATE. In contrast to the results in Panel A, we find that public and private innovation do not seem to have markedly different impacts on future industry-level emissions. This result is consistent with the common perception that private firms are more involved in green innovation.

In Table 12, we provide additional evidence on the role of public and private innovation through the lens of cross-industry spillovers. Here, our research design follows that in Table 10. In Panel A, we consider green innovation. Several interesting findings emerge. First, in aggregate, private innovation seems to have a large impact on industry-level emission reductions in the public sector. This result largely comes through the reduction of scope 3 emissions, both upstream and downstream. Second, this effect is mostly driven by the fact that an increase in private green innovation predicts a reduction in sales of public firms. It seems that innovating private firms are encroaching on the market position of public firms. Third, the effect on upstream scope 3 emission reductions is mostly due to the impact on innovating firms, while downstream scope 3 emission reductions are more associated with green innovation in public firms. In Panel B, we report corresponding results for brown innovation. We find some evidence that brown innovation, both

in the public and private firms, reduces scope 1 emissions, although the results are generally statistically weak. The only notable exception is the positive effect of innovation of public firms on the reduction in scope 1 emissions of innovating firms. In turn, innovation among public firms positively predicts scope 2 emissions, especially those of innovating firms.

Another channel through which the Jevons paradox can manifest itself is through product market competition. Our measure of competition is the company's market share (in terms of sales) relative to the total sales of both public and private firms within the same GICS-6 industry. As we show in Table 13, green innovation and the adoption of green technologies can be a handicap in product market competition if green firms have higher production costs than brown firms. In Panel A, we estimate a model with industry*year fixed effects and in Panel B a model with firm fixed effects. As is shown in columns 1 to 3, a firm's market share is significantly negatively impacted by past green innovation activity, whether on a 1-year, 3-year, or 5-year lag. This effect is largely due to cross-firm variation, given that the effects become weaker when we account for firm-fixed effects. In contrast, there is no significant effect of brown efficiency innovation activity on firms' market share. If anything, the effect of brown efficiency innovation is to increase market share. Thus, even if green innovation could reduce future carbon emissions of green firms, this positive effect is partially undone by the increased market share of brown firms.

5.3 The relative importance of green innovation for decarbonization

Having highlighted the tenuous association between green (or brown) innovation and future carbon emission reductions, we explore next the extent to which corporate carbon emissions are explained by green innovation. In the first test, reported in Table 14, we conduct a balance test by comparing two samples of firms: those with decreasing emissions and those with increasing emissions. We perform this comparison for scope 1 emissions in Panel A and the total level of direct and indirect emissions in Panel E. In Table IA.XXIX, we also consider scope 2, scope 3 upstream, and scope 3 downstream emissions. In the group of firms that decrease (increase) their emissions over time we further divide firms into the 50% of companies with the largest emission reductions (surges). For each group, we report the means and standard deviations of different characteristics and the test of differences in means between each pair.

In Panel A, we show the results based on scope 1 emissions. We find that companies with extreme increases and decreases in emissions are not very different from each other in terms of their green patent ratios as well as their brown efficiency patent ratios. The two types of companies have also very similar levels of patent citations. On the other hand, firms that decrease their scope 1 emissions are on average larger and older than companies that increase their emissions; they also have lower M/B ratios, and negative sales growth. However, they are not very different in their

ROE or leverage metrics. The similarities in innovation ratios are also observed when we consider the sum of scope 1, scope 2, and scope 3 emissions in Panel B.

In Table IA.XXIX Panel A, we report the results for scope 2 emissions. Results are qualitatively similar to those for scope 1 emissions, except that now emission reducing companies on average have higher brown efficiency patent ratios. They are also less profitable and have lower leverage ratios. In Table IA.XXIX Panel B we look at the differences for upstream scope 3 emissions. For these indirect emissions, we find that emission reducing companies have higher green and brown efficiency patent ratios. These differences, however, disappear when we look at sorts based on downstream scope 3 emissions, as shown in Table IA.XXIX Panel C. Overall, we conclude that companies that reduce their emissions the most are not necessarily more innovative than those that increase their emissions the least. We find that the two sets of companies significantly differ in their sales performance (changes in sales are negative on average for companies reducing emissions and positive for companies increasing emissions across all scopes) pointing again to the limited decoupling of growth and emissions.

In another set of tests, we study the economic significance of green innovation using the two following specifications. First, we look at the relationship between the stock of innovation and subsequent long-term changes in emissions. This test allows us to account for the fact that innovation can be a process with a long gestation period. Specifically, we predict the firm-level absolute change in average emission levels and their intensities between the periods 2005-2014 and 2015-2020 using measures of the stock of innovations (measured either as patent ratios or as patent counts) over two time periods: (i) 1990-2004; and (ii) 1990-2014. We perform the tests separately for green and brown innovation. We show the results of this test in Table 15. Panel A presents the results based on patent ratios. We find that the long-term stock of green or brown innovation measured by patent ratio is not related to long-term changes in emissions. Whether we use the shorter or the longer period to cumulate innovation, the results are not statistically significant. If anything, the correlations between the stock of green innovation and future emission changes is positive, which suggests that companies with greater patenting activity on average increased their emissions. In contrast, we find some albeit weak evidence that over a more prolonged period, companies with higher brown efficiency patents reduced their emissions. The results become slightly stronger when we look at the cumulative number of patents, as presented in Panel B. Now the number of green patents accumulated over a longish period predicts subsequent reductions in future scope 1 and scope 3 upstream emissions. The result is statistically weaker when we look at brown innovation. Overall, even though we find some evidence that over the long-run innovation may lead, in some cases, to reductions in emissions this result may not necessarily offer a silver bullet from the perspective of supporting current innovations, simply

because we do not have that much time to wait for the emissions reductions from innovation to materialize.

Another question of interest is whether the effect of green innovation is economically large. This is the question we try to answer in Table 16. Here we evaluate the partial R2 of the regression model that tries to explain future emissions levels using patent ratios. As before, we focus on green and brown efficiency patents, and consider various predictive horizons. The consistent message that emerges from this analysis is that green innovation activity explains a very small fraction of the variation in future emissions levels. The partial R2s typically do not exceed 1% and more frequently are significantly smaller. We conclude that green innovation is not a primary source of firm-level variation in future carbon emissions. Even if some companies do decarbonize their operations, this decarbonization is explained only to a very limited extent by these firms' green patenting activity.

6. Conclusion

What emerges from our analysis of green innovation is that the predicted sustainability revolution has not yet begun. Although there has been a steady increase in green and brown efficiency innovation, these technological advances have not materialized in lower carbon emissions. Most of the green innovation is done by firms that are already green (with low carbon emissions) but brown companies (with high carbon emissions) tend to engage in brown efficiency innovation. Much of the promise of the latter technological advances in terms of lower carbon intensity has been undone by rebound effects. Furthermore, where we see significant decarbonization, it has little to do with green technological advances.

We cannot determine what the counterfactual would be, had there been much less green innovation. It is possible that in the absence of all this innovation activity, carbon emissions might have been much higher. Also, as the IEA (2020) report contends, the path to decarbonization "will require a broad range of different technologies working across all sectors of the economy in various combinations and applications." What we have found, however, is that green innovation has not yet put the economy on a net zero compatible trajectory. Green innovation may be necessary, but it is not sufficient on its own to bring about a renewable energy transition.

A major obstacle to green innovation is Arrow's (1962) replacement effect. Fossil fuel-based profitable businesses have little incentive to engage in green innovation that might undermine their business model. But we have found a much more pervasive replacement effect at work, through companies' supply chains and ecosystems. When upstream suppliers and downstream clients have fossil-fuel based operations it is very difficult and costly for individual companies to switch to a green technology. Hence, their lack of interest in green innovation. Not

a day goes by without some major announcement of a promising technological breakthrough that might solve the CO2 problem, whether it is molten-salt nuclear reactors, power-to-gas (P2G) renewable hydrogen production, nuclear fusion, modular carbon capture systems, or sodium-sulphur batteries, etc. Yet, as promising as these technological breakthroughs sound, what ultimately matters for the transition to net zero is adoption of these green technologies at scale. And for this to happen in an accelerated way to avoid further overheating of the planet, what may be required is public policy intervention to coordinate adoption. This calls for a new form of industrial policy that breaks through the replacement obstacle by coordinating green technology adoption upstream and downstream throughout firms' ecosystems. Moreover, subsidies for green innovation must be more carefully targeted to where they help unlock a general adoption of green technologies throughout the supply chain. Blanket subsidies for innovation without regard to the likely adoption of new technologies may simply be too wasteful and costly.

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TABLE 1: CAPACITY CONSTRAINTS

The unit of observation is firm-year. The sample period is 2005-2020. In Panel A, the dependent variable is ANYCOUNTEP in columns 1 to 3 and ANYCOUNTEP w/o zeros in columns 4 to 6. ANYCOUNTEP is the number of granted or purchased patents by the European Patent Office (EP) per firm and year. In Panel B the dependent variable is GREENCOUNTEP in columns 1 to 3 and BROWNEFFCOUNTEP in columns 4 to 6. GREENCOUNTEP is the number of granted or purchased "green" patents by the EP per firm and year, while BROWNEFFCOUNTEP covers "brown efficiency" patents. The independent variables are defined as follows: *Age* is the firm age based on its year of incorporation; *PATSTOCKANYEP* (*PATSTOCKGREENEP* and *PATSTOCKBROWNEFFEP*) is the firm's patent stock of all (green and brown efficiency) granted or purchased patents by the EPO from 1990 up to year t; *LOGASSETS* is the natural logarithm of total assets (in $ million); *LOGSIZE* is the natural logarithm of market capitalization (in $ million); *LOGNOEMPL* is the natural logarithm of the number of employees; *LOGPPE* is the natural logarithm of plant, property & equipment (in $ million); *LEVERAGE* is the book value of leverage defined as the book value of debt divided by the book value of assets; *ROE* is the return on equity; *M/B* is the market value of equity divided by the book value of equity; *INVEST/A* is CAPEX divided by the book value of assets; *BETA* is the firm-level market beta estimated over the one-year period; *VOLAT* is the monthly stock return volatility calculated over the one year period; *MOM* is the cumulative stock return over the one-year period; *RET* is the monthly stock return in December; *MSCI* is an indicator variable equal to one if a stock is part of the MSCI ACWI in a given year and zero otherwise. All independent variables are lagged by one year. The model is estimated using Poisson pseudo-maximum likelihood. Columns 1 and 4 include year and country fixed effects. Columns 2 and 5 include country and Trucost industry-year fixed effects and columns 3 and 6 year and firm fixed effects. We double cluster standard errors at the firm and year dimension. *** 1% significance, ** 5% significance * 10% significance.

Panel A: Any innovation	(1)	(2)	(3)	(4)	(5)	(6)
	ANYCOUNTEP w. zeros			*ANYCOUNTEP* w/o zeros		
PATSTOCKANYEP (/100)	0.017***	0.012***	−0.002***	0.016***	0.013***	−0.002***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
LOGASSETS	−0.121***	0.465***	0.192***	0.058**	0.411***	0.178***
	(0.019)	(0.054)	(0.057)	(0.023)	(0.048)	(0.057)
LOGNOEMPL	0.333***	0.127***	0.049**	0.284***	0.132***	0.050**
	(0.015)	(0.020)	(0.024)	(0.017)	(0.018)	(0.024)
AGE (/100)	0.153***	0.115***		0.073**	0.096***	
	(0.032)	(0.026)		(0.030)	(0.025)	
LOGSIZE	0.620***	0.266***	0.028	0.408***	0.238***	0.032
	(0.024)	(0.029)	(0.023)	(0.024)	(0.024)	(0.023)
LOGPPE	−0.026**	0.004	0.114**	−0.116***	−0.038	0.112**
	(0.013)	(0.035)	(0.045)	(0.019)	(0.037)	(0.045)
LEVERAGE	−0.010***	−0.004***	−0.003***	−0.008***	−0.003***	−0.003**
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
ROE	−0.210**	−0.036	−0.086**	−0.123*	−0.011	−0.089**
	(0.087)	(0.069)	(0.041)	(0.070)	(0.057)	(0.041)
M/B	−0.028***	0.007	0.001	−0.015**	−0.001	0.001
	(0.008)	(0.006)	(0.005)	(0.007)	(0.006)	(0.005)
INVEST/A	−0.017***	−0.000	−0.001	0.003	0.007	−0.001
	(0.005)	(0.005)	(0.004)	(0.005)	(0.005)	(0.004)
BETA	0.330***	0.122***	0.029	0.262***	0.153***	0.033
	(0.037)	(0.034)	(0.022)	(0.035)	(0.032)	(0.022)
VOLAT	2.890***	1.458***	−0.313	2.223***	1.123***	−0.265
	(0.251)	(0.273)	(0.242)	(0.327)	(0.328)	(0.244)
MOM	−2.715***	−0.949*	0.199	−2.334***	−0.988*	0.182
	(0.623)	(0.555)	(0.300)	(0.580)	(0.513)	(0.301)
RET	0.000	0.070	−0.009	−0.006	0.035	−0.002
	(0.181)	(0.138)	(0.074)	(0.163)	(0.130)	(0.075)
MSCI	0.025	0.028	0.055*	−0.014	0.013	0.044
	(0.044)	(0.032)	(0.029)	(0.040)	(0.029)	(0.029)
Constant	−4.678***	−4.577***	1.497***	−2.763***	−3.365***	1.621***
	(0.137)	(0.143)	(0.318)	(0.136)	(0.142)	(0.321)
Observations	68496	63945	37250	24960	23699	23828
Pseduo R2	0.654	0.835	0.921	0.642	0.809	0.910
Panel B: Green or brown efficiency innovation						
	GREENCOUNTEP			*BROWNEFFCOUNTEP*		
PATSTOCKGREENEP (/100)	0.121***	0.139***	0.013***	−0.175***	−0.045***	−0.073***
	(0.007)	(0.009)	(0.004)	(0.018)	(0.011)	(0.011)
PATSTOCKBROWNEFFEP (/100)	−0.037***	−0.086***	−0.022***	0.305***	0.135***	0.060***
	(0.012)	(0.010)	(0.008)	(0.017)	(0.012)	(0.015)
AGE (/100)	0.238***	0.041		0.636***	0.342***	
	(0.044)	(0.039)		(0.053)	(0.065)	
LOGSIZE	0.348***	0.362***	0.147***	0.321***	0.380***	0.193***
	(0.027)	(0.037)	(0.029)	(0.047)	(0.062)	(0.049)
LOGPPE	0.190***	0.332***	0.093***	0.272***	0.354***	−0.069
	(0.023)	(0.040)	(0.035)	(0.039)	(0.077)	(0.048)
LEVERAGE	−0.009***	−0.004***	−0.006***	−0.002	0.004	0.016***
	(0.001)	(0.001)	(0.002)	(0.002)	(0.003)	(0.005)
ROE	−0.246**	−0.179**	−0.134**	0.091	0.156	−0.232**
	(0.111)	(0.072)	(0.065)	(0.307)	(0.208)	(0.114)
M/B	−0.017	−0.015	−0.016**	−0.058***	−0.054***	−0.021*
	(0.011)	(0.010)	(0.007)	(0.021)	(0.018)	(0.012)
INVEST/A	0.000	−0.020***	−0.005	−0.003	−0.023***	0.012
	(0.007)	(0.005)	(0.005)	(0.009)	(0.008)	(0.010)
BETA	0.607***	0.226***	0.005	0.567***	0.185***	−0.051
	(0.051)	(0.045)	(0.031)	(0.084)	(0.071)	(0.060)
VOLAT	2.950***	2.769***	−0.252	1.624**	0.732	−0.572
	(0.461)	(0.340)	(0.347)	(0.728)	(0.705)	(0.610)
MOM	−1.522*	−1.751**	−0.923**	−0.087	−1.994	0.442
	(0.814)	(0.716)	(0.388)	(1.357)	(1.244)	(0.672)
RET	0.201	0.207	0.275**	−0.817**	0.080	−0.306
	(0.237)	(0.226)	(0.117)	(0.379)	(0.326)	(0.234)
MSCI	0.234***	0.128***	0.005	0.044	0.184**	0.094
	(0.053)	(0.047)	(0.049)	(0.101)	(0.077)	(0.061)
Constant	−3.770***	−4.186***	1.389***	−5.260***	−5.087***	1.552***
	(0.170)	(0.144)	(0.371)	(0.262)	(0.282)	(0.487)
Observations	27860	24818	20173	27767	20143	12186
Pseudo R2	0.561	0.730	0.832	0.529	0.755	0.825
Country F.E.	yes	yes	no	yes	yes	no
Year F.E.	yes	yes	yes	yes	yes	yes
Industry X Year F.E.	no	yes	no	no	yes	no
Firm F.E.	no	no	yes	no	no	yes

TABLE 2: PATENT RATIOS AND FIRM TYPE

The unit of observation is firm-year. The sample period is 2005-2020. The dependent variable is *GREENRATIOEP* in columns 1 to 3 and *BROWNEFFRATIOEP* in columns 4 to 6. *GREENRATIOEP* is the number of green patents over the total number of patents granted or purchased at the firm and year level based on European Patent Office patents. *BROWNEFFRATIOEP* similarly is the number of brown efficiency patents over the total number of patents at the European Patent Office. *LOGS1TOT* is the natural logarithm of firm-level scope 1 emissions. All other variables are defined in Table 1. All independent variables are lagged by one year. The model is estimated using Poisson pseudo-maximum likelihood. Columns 1 and 4 include year and country fixed effects. Columns 2 and 5 include country and Trucost industry-year fixed effects and columns 3 and 6 year and firm fixed effects. We double cluster standard errors at the firm and year dimension. *** 1% significance, ** 5% significance * 10% significance.

	(1)	(2)	(3)	(4)	(5)	(6)
	GREENRATIOEP			*BROWNEFFRATIOEP*		
LOGS1TOT	0.091***	−0.053***	0.013	0.058***	0.049**	−0.064**
	(0.008)	(0.011)	(0.015)	(0.014)	(0.020)	(0.032)
AGE (/100)	−0.303***	−0.186***		0.235***	0.213***	
	(0.033)	(0.030)		(0.045)	(0.050)	
PATSTOCKGREENEP (/100)	0.052***	0.035***	−0.002			
	(0.004)	(0.004)	(0.003)			
PATSTOCKBROWNEFFEP (/100)				0.099***	0.047***	−0.001
				(0.009)	(0.008)	(0.008)
LOGSIZE	−0.192***	−0.111***	0.048**	−0.303***	−0.083***	−0.071
	(0.016)	(0.018)	(0.022)	(0.032)	(0.031)	(0.045)
LOGPPE	0.124***	0.137***	−0.042*	0.277***	0.039	−0.017
	(0.016)	(0.018)	(0.023)	(0.033)	(0.031)	(0.052)
LEVERAGE	−0.006***	−0.004***	0.001	−0.005***	−0.001	−0.005*
	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.003)
ROE	−0.312***	−0.123**	−0.014	0.406***	0.117	−0.048
	(0.054)	(0.050)	(0.033)	(0.090)	(0.087)	(0.086)
M/B	0.020***	0.020***	−0.004	−0.022**	−0.011	0.004
	(0.006)	(0.006)	(0.005)	(0.011)	(0.011)	(0.014)
INVEST/A	0.010***	0.008**	0.005*	0.001	0.004	0.006
	(0.003)	(0.003)	(0.003)	(0.007)	(0.007)	(0.008)
BETA	0.210***	0.100***	−0.017	0.311***	−0.018	0.034
	(0.035)	(0.037)	(0.027)	(0.062)	(0.058)	(0.047)
VOLAT	1.956***	1.333***	−0.004	0.210	0.154	0.392
	(0.221)	(0.232)	(0.178)	(0.469)	(0.523)	(0.493)
MOM	0.402	−0.011	0.049	1.508*	0.786	0.546
	(0.456)	(0.453)	(0.289)	(0.898)	(0.850)	(0.657)
RET	−0.132	−0.249**	0.041	−0.357	−0.003	−0.167
	(0.121)	(0.116)	(0.073)	(0.232)	(0.236)	(0.179)
MSCI	0.070**	0.042	0.048	0.028	0.124**	−0.080
	(0.032)	(0.031)	(0.035)	(0.057)	(0.053)	(0.064)
Constant	2.482***	3.205***	3.081***	1.287***	2.339***	4.217***
	(0.094)	(0.096)	(0.199)	(0.170)	(0.184)	(0.458)
Country F.E.	yes	yes	no	yes	yes	no
Year F.E.	yes	yes	yes	yes	yes	yes
Industry X Year F.E.	no	yes	no	no	yes	no
Firm F.E.	no	no	yes	no	no	yes
Observations	27860	24818	20173	27767	20143	12186
Pseudo R2	0.0775	0.317	0.516	0.0989	0.439	0.527

TABLE 3: PATENT RATIOS AND FIRM TYPE - INTENSIVE MARGIN

The unit of observation is firm-year. The sample period is 2005-2020 and the sample restricts inclusion to firm-years with *at least one* green patent at the European Patent Office in columns 1 to 3 and one brown efficiency patent at the European Patent Office in columns 4 to 6. The dependent variable is *GREENRATIOEP* in columns 1 to 3 and *BROWNEFFRATIOEP* in columns 4 to 6. All variables are defined in Table 1, Table 2 and Table 2. All independent variables are lagged by one year. The model is estimated using a pooled regression model. Columns 1 and 4 include year and country fixed effects. Columns 2 and 5 include country and Trucost industry-year fixed effects and columns 3 and 6 year and firm fixed effects. We double cluster standard errors at the firm and year dimension. *** 1% significance, ** 5% significance * 10% significance.

	(1)	(2)	(3)	(4)	(5)	(6)
	GREENRATIOEP			*BROWNEFFRATIOEP*		
LOGS1TOT	1.571***	−1.587***	−0.291	0.376*	−0.400	−0.253
	(0.170)	(0.252)	(0.273)	(0.197)	(0.340)	(0.506)
AGE (/100)	−6.809***	−3.153***		−0.989	−0.406	
	(0.601)	(0.603)		(0.649)	(0.803)	
PATSTOCKGREENEP (/100)	0.756***	1.024***	0.477***			
	(0.091)	(0.103)	(0.072)			
PATSTOCKBROWNEFFEP (/100)				1.360***	1.101***	0.266*
				(0.140)	(0.176)	(0.140)
LOGSIZE	−6.749***	−5.387***	0.601	−5.912***	−4.414***	−0.884
	(0.348)	(0.425)	(0.399)	(0.415)	(0.574)	(0.724)
LOGPPE	0.657*	0.178	−1.067**	0.011	−2.183***	−0.977
	(0.342)	(0.396)	(0.450)	(0.382)	(0.469)	(0.769)
LEVERAGE	−0.071***	−0.117***	0.027	−0.006	−0.124***	−0.016
	(0.020)	(0.021)	(0.020)	(0.027)	(0.033)	(0.041)
ROE	−6.178***	−2.141*	0.636	0.388	1.427	−0.809
	(1.269)	(1.276)	(0.736)	(1.804)	(2.027)	(1.307)
M/B	0.530***	0.517***	−0.017	0.169	0.063	0.127
	(0.128)	(0.131)	(0.091)	(0.186)	(0.211)	(0.185)
INVEST/A	0.375***	0.314***	0.088	0.493***	0.250*	0.046
	(0.088)	(0.095)	(0.085)	(0.126)	(0.151)	(0.123)
BETA	1.175	1.230	−0.667	0.266	0.051	−0.185
	(0.724)	(0.827)	(0.480)	(0.898)	(1.121)	(0.681)
VOLAT	37.812***	32.622***	6.636	−3.494	−13.215	−2.030
	(7.437)	(8.186)	(4.126)	(10.481)	(12.975)	(6.867)
MOM	15.039	0.793	−5.105	5.322	15.162	16.336*
	(11.472)	(12.330)	(6.025)	(15.864)	(19.737)	(9.515)
RET	−2.251	−3.345	−0.178	−4.578	1.966	−4.710*
	(3.029)	(3.253)	(1.620)	(3.993)	(4.982)	(2.474)
MSCI	−0.925	−0.650	−1.292**	−0.937	1.520	−1.771*
	(0.665)	(0.693)	(0.594)	(0.839)	(0.975)	(0.925)
Constant	69.208***	83.076***	30.172***	67.068***	80.924***	37.162***
	(2.276)	(2.655)	(3.701)	(2.984)	(4.158)	(6.783)
Country F.E.	yes	yes	no	yes	yes	no
Year F.E.	yes	yes	yes	yes	yes	yes
Industry F.E.	no	yes	no	no	yes	no
Industry X Year F.E.	no	yes	no	no	yes	no
Firm F.E.	no	no	yes	no	no	yes
Observations	12187	10957	11352	5550	4550	5114
R2	0.220	0.534	0.815	0.187	0.526	0.762

TABLE 4: PATENT CITATIONS AND FIRM TYPE

The unit of observation is firm-year. The sample period is 2005-2020. The dependent variable is *GREENCITMAXEP* in columns 1 to 3 and *BROWNEFFCITMAXEP* in columns 4 to 6 in Panel A. In Panel B the dependent variable is *GREENBBCOUNTEP* in columns 1 to 3 and *BROWNEFFBBCOUNTEP* in columns 4 to 6. *GREENCITMAXEP* (*BROWNEFFCITMAXEP*) is the maximum number of forward citations any green (brown efficiency) patent of a firm received in a given year. *GREENBBCOUNTEP* (*BROWNEFFBBCOUNTEP*) is the number of green (brown efficiency) blockbuster patents patent per firm, where blockbuster patents are defined as patents in the 95th percentile based on the number of forward citations in a given grant year and classification. The regressions also include the following controls: LOGSIZE, LOGPPE, LEVERAGE, ROE, M/B, INVEST/A, BETA, VOLAT, MOM, RET, and MSCI. All independent variables are lagged by one year and are defined in Table 1 and Table 2. The model is estimated using Poisson pseudo-maximum likelihood. Columns 1 and 4 include year and country fixed effects. Columns 2 and 5 include country and Trucost industry-year fixed effects and columns 3 and 6 year and firm fixed effects. We double cluster standard errors at the firm and year dimension. *** 1% significance, ** 5% significance * 10% significance.

Panel A: Maximum patent citation	(1)	(2)	(3)	(4)	(5)	(6)
	GREENCITMAXEP			*BROWNEFFCITMAXEP*		
LOGS1TOT	−0.042*	−0.217***	−0.063	0.018	0.097***	0.118
	(0.022)	(0.058)	(0.064)	(0.029)	(0.033)	(0.080)
AGE (/100)	0.412**	0.667***		0.372***	0.086	
	(0.167)	(0.161)		(0.113)	(0.085)	
PATSTOCKGREENEP (/100)	0.064***	0.062***	−0.030**			
	(0.008)	(0.010)	(0.015)			
PATSTOCKBROWNEFFEP (/100)				0.110***	0.084***	0.014
				(0.010)	(0.011)	(0.015)
Observations	27852	24496	19494	27767	19600	11433
Pseudo R2	0.343	0.626	0.707	0.336	0.649	0.665
Panel B: Blockbuster counts						
	GREENBBCOUNTEP			*BROWNEFFBBCOUNTEP*		
LOGS1TOT	−0.034**	−0.015	−0.016	0.081***	0.096**	−0.027
	(0.014)	(0.030)	(0.033)	(0.018)	(0.042)	(0.054)
AGE (/100)	0.052	0.044		0.555***	0.207***	
	(0.068)	(0.073)		(0.059)	(0.076)	
PATSTOCKGREENEP (/100)	0.099***	0.076***	−0.010			
	(0.006)	(0.006)	(0.007)			
PATSTOCKBROWNEFFEP (/100)				0.145***	0.119***	0.030
				(0.011)	(0.012)	(0.020)
Observations	27707	17910	10607	27178	9943	5439
Pseudo R2	0.314	0.444	0.459	0.348	0.564	0.517
Controls.	yes	yes	yes	yes	yes	yes
Country F.E.	yes	yes	no	yes	yes	no
Year F.E.	yes	yes	yes	yes	yes	yes
Industry X Year F.E.	no	yes	no	no	yes	no
Firm F.E.	no	no	yes	no	no	yes

TABLE 5: PATENT RATIOS AND FIRM TYPE: MARKET SHARE INTERACTIONS

The unit of observation is firm-year. The sample period is 2005 to 2020. The dependent variable is GREENRATIOEP in columns 1 to 3 and BROWNEFFRATIOEP in columns 4 to 6. MKTSHR TRUIND is a firm's market share based on its sales relative to total public and private firms' sales in a given Trucost sector. We report the coefficient on MKTSHR TRUIND as well as LOGS1TOT, AGE, PATSTOCKGREENEP (PATSTOCKBROWNEFFEP) and their interactions with MKTSHR TRUIND. The regressions also include the following controls: LOGSIZE, LOGPPE, LEVERAGE, ROE, M/B, INVEST/A, BETA, VOLAT, MOM, RET, and MSCI. All independent variables are lagged by one year. The variables are defined in Table 1 and Table 2. The model is estimated using Poisson pseudo-maximum likelihood. Columns 1 and 4 include year and country fixed effects. Columns 2 and 5 include country and Trucost industry-year fixed effects and columns 3 and 6 year and firm fixed effects. We double cluster standard errors at the firm and year dimension. *** 1% significance, ** 5% significance * 10% significance.

	(1)	(2)	(3)	(4)	(5)	(6)
	GREENRATIOEP			BROWNEFFRATIOEP		
LOGS1TOT	0.090***	−0.058***	0.009	0.085***	0.058***	−0.064*
	(0.008)	(0.012)	(0.015)	(0.015)	(0.021)	(0.034)
AGE (/100)	−0.363***	−0.260***		0.216***	0.192***	
	(0.039)	(0.037)		(0.053)	(0.058)	
PATSTOCKGREENEP (/100)	0.061***	0.059***	−0.006			
	(0.008)	(0.006)	(0.004)			
PATSTOCKBROWNEFFEP (/100)				0.101***	0.058***	−0.015
				(0.013)	(0.012)	(0.009)
MKTSHR TRUIND	−1.372***	−2.142***	−0.473	2.325***	0.689	−0.153
	(0.344)	(0.427)	(0.356)	(0.415)	(0.602)	(0.423)
LOGS1TOT X MKTSHR TRUIND	0.048	0.155***	0.044	−0.323***	−0.115*	0.034
	(0.038)	(0.044)	(0.041)	(0.055)	(0.064)	(0.056)
AGE (/100) X MKTSHR	0.761***	1.085***		0.184	0.224	
TRUIND	(0.152)	(0.182)		(0.196)	(0.284)	
PATSTOCKGREENEP (/100) X	−0.079**	−0.186***	0.037***			
MKTSHR TRUIND	(0.032)	(0.028)	(0.014)			
PATSTOCKBROWNEFFEP X				−0.004	−0.068	0.094***
MKTSHR TRUIND				(0.042)	(0.069)	(0.029)
Controls	yes	yes	yes	yes	yes	yes
Country F.E.	yes	yes	no	yes	yes	no
Year F.E.	yes	yes	yes	yes	yes	yes
Industry X Year F.E.	no	yes	no	no	yes	no
Firm F.E.	no	no	yes	no	no	yes
Observations	27856	24814	20190	27763	20140	12187
Pseudo R2	0.080	0.319	0.516	0.102	0.439	0.525

TABLE 6: PATENT RATIOS AND ALTERNATIVE EMISSIONS

The unit of observation is firm-year. The sample period is 2005-2020. The dependent variable is *GREENRATIOEP* in Panel A and *BROWNEFFRATIOEP* in Panel B. *LOGS2TOT* (*LOGS3UPTOT* and *LOGS3DOWNTOT*) is the natural logarithm of firm-level scope 2 (upstream 3 and downstream 3) emissions; *S1INT* (*S2INT*, *S3UPINT* and *S3DOWNINT*) is the the firm-level scope 1 (2, upstream 3 and downstream 3) emission intensity defined as the level of emission divided by the firm sales. The regressions also include the following controls: LOGSIZE, LOGPPE, LEVERAGE, ROE, M/B, INVEST/A, BETA, VOLAT, MOM, RET, and MSCI. All independent variables are lagged by one year. The other variables are defined in Table 1 and Table 2. The model is estimated using Poisson pseudo-maximum likelihood. All regression include country and Trucost industry-year fixed effects. We double cluster standard errors at the firm and year dimension. *** 1% significance, ** 5% significance * 10% significance.

Panel A: Green innovation	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	GREENRATIOEP						
LOGS2TOT	−0.056***						
	(0.012)						
LOGS3UPTOT		−0.128***					
		(0.018)					
LOGS3DOWNTOT			−0.025**				
			(0.010)				
S1INT (/100)				0.018			
				(0.335)			
S2INT					0.021		
					(0.025)		
S3UPINT						−0.036*	
						(0.018)	
S3DOWNINT							0.005***
							(0.002)
AGE (/100)	−0.189***	−0.176***	−0.186***	−0.195***	−0.194***	−0.194***	−0.193***
	(0.031)	(0.031)	(0.059)	(0.031)	(0.031)	(0.031)	(0.059)
PATSTOCKGREENEP (/100)	0.036***	0.035***	0.031***	0.035***	0.035***	0.034***	0.031***
	(0.004)	(0.004)	(0.006)	(0.004)	(0.004)	(0.004)	(0.006)
Controls	yes	yes	yes	yes	yes	yes	yes
Country F.E.	yes	yes	yes	yes	yes	yes	yes
Industry-Year F.E.	yes	yes	yes	yes	yes	yes	yes
Observations	24818	24818	7681	24818	24818	24818	7681
Pseudo R2	0.317	0.319	0.269	0.316	0.316	0.316	0.270
Panel B: Brown efficiency innovation							
	BROWNEFFRATIOEP						
LOGS2TOT	−0.031						
	(0.023)						
LOGS3UPTOT		0.149***					
		(0.031)					
LOGS3DOWNTOT			0.005				
			(0.023)				
S1INT				0.017***			
				(0.006)			
S2INT					−0.130**		
					(0.053)		
S3UPINT						0.139***	
						(0.028)	
S3DOWNINT							0.001
							(0.003)
AGE (/100)	0.217***	0.204***	0.301***	0.215***	0.213***	0.215***	0.304***
	(0.050)	(0.050)	(0.098)	(0.050)	(0.050)	(0.050)	(0.098)
PATSTOCKBROWNEFFEP (/100)	0.048***	0.047***	0.058***	0.047***	0.047***	0.049***	0.058***
	(0.008)	(0.008)	(0.015)	(0.008)	(0.008)	(0.008)	(0.015)
Controls	yes	yes	yes	yes	yes	yes	yes
Country F.E.	yes	yes	yes	yes	yes	yes	yes
Industry-Year F.E.	yes	yes	yes	yes	yes	yes	yes
Observations	20143	20143	6426	20143	20143	20143	6426
Pseudo R2	0.439	0.440	0.420	0.439	0.439	0.440	0.420

TABLE 7: PATENT RATIOS AND FIRM TYPE POST 2015

The unit of observation is firm-year. The sample period is 2005 to 2020. The dependent variable is GREENRATIOEP in columns 1 to 3 and BROWNEFFRATIOEP in columns 4 to 6. Panel A covers the full sample and Panel B the legacy sample, which restricts inclusion of firms into those that Trucost covers in its database before 2016. POST2015 is a dummy that is equal to 1 for all years after 2015 and zero otherwise. We interact this variable with all control variables. We report the coefficients of the following interactions: LOGS1TOT X POST2015, AGE X POST2015, PATSTOCKGREENEP (PATSTOCKBROWNEFFEP) X POST2015 and the triple interaction LOGS1TOT X AGE X POST2015. The regressions also include the following controls and their POST2015 interaction: LOGSIZE, LOGPPE, LEVERAGE, ROE, M/B, INVEST/A, BETA, VOLAT, MOM, RET, and MSCI. All independent variables other than POST2015 are lagged by one year. The variables are defined in Table 1 and Table 2. The model is estimated using Poisson pseudo-maximum likelihood. Columns 1 and 4 include year and country fixed effects. Columns 2 and 5 include country and Trucost industry-year fixed effects and columns 3 and 6 year and firm fixed effects. We double cluster standard errors at the firm and year dimension. *** 1% significance, ** 5% significance * 10% significance.

Panel A: Full sample	(1)	(2)	(3)	(4)	(5)	(6)
	GREENRATIOEP			BROWNEFFRATIOEP		
LOGS1TOT	0.069***	−0.072***	0.020	0.116***	0.071**	−0.085
	(0.015)	(0.018)	(0.022)	(0.025)	(0.031)	(0.053)
AGE (/100)	−1.036***	−0.914***		0.775***	0.478**	
	(0.146)	(0.135)		(0.187)	(0.191)	
PATSTOCKGREENEP (/100)	0.087***	0.059***	0.008			
	(0.009)	(0.009)	(0.007)			
PATSTOCKBROWNEFFEP (/100)				0.136***	0.021*	0.008
				(0.017)	(0.012)	(0.013)
LOGS1TOT X POST2015	−0.062***	−0.028	−0.013	−0.030	−0.036	−0.003
	(0.021)	(0.025)	(0.013)	(0.036)	(0.045)	(0.023)
LOGS1TOT X Age (/100)	0.081***	0.082***	−0.005	−0.068***	−0.038*	0.033
	(0.016)	(0.014)	(0.036)	(0.021)	(0.021)	(0.067)
AGE (/100) X POST2015	0.012	0.218		0.014	−0.306	
	(0.204)	(0.189)		(0.288)	(0.297)	
LOGS1TOT X POST2015 X Age	0.023	−0.012	0.007	−0.006	0.053	0.014
(/100)	(0.023)	(0.021)	(0.005)	(0.034)	(0.035)	(0.009)
PATSTOCKGREENEP (/100) X	−0.049***	−0.037***	−0.010**			
POST2015	(0.009)	(0.010)	(0.005)			
PATSTOCKBROWNEFFEP X POST2015				−0.046**	0.036**	−0.004
				(0.019)	(0.015)	(0.010)
Observations	27860	24818	20072	27767	20143	12147
Pseudo R2	0.0836	0.321	0.516	0.108	0.443	0.529
Panel B: Legacy sample						
	GREENRATIOEP			BROWNEFFRATIOEP		
LOGS1TOT	0.069***	−0.074***	0.019	0.116***	0.064**	−0.078
	(0.015)	(0.018)	(0.024)	(0.025)	(0.031)	(0.055)
AGE (/100)	−1.061***	−0.945***		0.796***	0.508***	
	(0.147)	(0.136)		(0.188)	(0.194)	
PATSTOCKGREENEP (/100)	0.087***	0.058***	0.008			
	(0.009)	(0.009)	(0.007)			
PATSTOCKBROWNEFFEP (/100)				0.136***	0.022*	0.009
				(0.017)	(0.012)	(0.013)
LOGS1TOT X POST2015	−0.024	0.001	−0.011	−0.015	0.005	−0.002
	(0.023)	(0.026)	(0.013)	(0.039)	(0.046)	(0.023)
LOGS1TOT X Age (/100)	0.082***	0.084***	−0.002	−0.069***	−0.040*	0.023
	(0.016)	(0.014)	(0.038)	(0.021)	(0.022)	(0.069)
AGE (/100) X POST2015	0.343	0.422**		0.098	−0.157	
	(0.227)	(0.204)		(0.311)	(0.323)	
LOGS1TOT X POST2015 X Age	−0.019	−0.034	0.007	−0.006	0.048	0.015*
(/100)	(0.025)	(0.022)	(0.005)	(0.037)	(0.038)	(0.009)
PATSTOCKGREENEP (/100) X	−0.047***	−0.030***	−0.011**			
POST2015	(0.009)	(0.010)	(0.005)			
PATSTOCKBROWNEFFEP X POST2015				−0.034*	0.037**	−0.003
				(0.020)	(0.015)	(0.010)
Observations	22990	20155	18275	22922	16164	11551
Pseudo R2	0.100	0.364	0.509	0.108	0.454	0.524
Controls	yes	yes	yes	yes	yes	yes
Country F.E.	yes	yes	no	yes	yes	no
Year F.E.	yes	yes	yes	yes	yes	yes
Industry X Year F.E.	no	yes	no	no	yes	no
Firm F.E.	no	no	yes	no	no	yes

TABLE 8: PATENT RATIOS AND FIRM-LEVEL OUTCOMES

The unit of observation is firm-year. The sample period is 2005 to 2020. The dependent variables are logs of cumulative sums of S1TOT, S2TOT, S3UPTOT, S3DOWNTOT, S123UPTOT, CAPEX, and SALES over 1, 3 or 5 years, respectively long-term averages of S1INT, S2INT, S3UPINT, S3DOWNINT and INVEST/A for 1, 3 or 5 years. In Panel A, the key independent variable is *GREENRATIOEP* lagged by 1, 3, or 5 years as well as a 3-year rolling ratio lagged by 1 year. In Panel B, the key independent variable similarly is *BROWNEFFRATIOEP*. Controls include: *LOGSIZE*, *LOGPPE*, *LEVERAGE*, *ROE*, *M/B*, *INVEST/A*, *BETA*, *VOLAT*, *MOM*, *RET*, *MSCI*. All variables are defined in Table 1 and Table 2 and are similarly lagged by 1, 3, or 5 years. The model is estimated using pooled regression model. All regressions include year and firm fixed effects. We double cluster standard errors at the firm and year dimension. *** 1% significance, ** 5% significance * 10% significance.

	(1) LOGS1TOT	(2) LOGS2TOT	(3) LOGS3UPTOT	(4) LOGS3DOWNTOT	(5) LOGS123UPTOT	(6) S1INT	(7) S2INT	(8) S3UPINT	(9) S3DOWNINT	(10) INVEST/A	(11) LOGCAPEX	(12) LOGSALES
Panel A: Green innovation												
L1 GREENRATIOEP	0.021	−0.019	0.007	−0.046	0.004	0.019	−0.006	−0.009	−0.018	−0.048	−0.011	0.003
	(0.026)	(0.025)	(0.015)	(0.077)	(0.015)	(0.070)	(0.010)	(0.018)	(0.389)	(0.100)	(0.014)	(0.012)
Observations	29585	29585	29584	10349	29585	29585	29585	29585	10349	29578	29578	29580
R2	0.953	0.948	0.980	0.931	0.981	0.922	0.843	0.961	0.898	0.720	0.917	0.980
L3 GREENRATIOEP	0.002	−0.042*	0.000	0.032	−0.002	0.048	−0.000	0.002	−0.000	−0.166**	−0.009	−0.004
	(0.026)	(0.025)	(0.014)	(0.118)	(0.014)	(0.070)	(0.010)	(0.016)	(0.396)	(0.078)	(0.013)	(0.011)
Observations	22261	22261	22261	4160	22261	22261	22261	22261	4166	25158	25153	25155
R2	0.967	0.962	0.986	0.982	0.986	0.955	0.902	0.974	0.986	0.827	0.945	0.986
L5 GREENRATIOEP	0.015	−0.036	0.009		0.013	0.125*	0.004	0.018		−0.109	−0.015	−0.006
	(0.028)	(0.026)	(0.017)		(0.017)	(0.069)	(0.010)	(0.018)		(0.079)	(0.013)	(0.013)
Observations	15482	15482	15482		15482	15482	15482	15482		18347	18347	18343
R2	0.973	0.965	0.985		0.986	0.972	0.933	0.981		0.888	0.956	0.989
L1 3YEARAVGGREENRATIOEP	0.007	−0.039	0.005	−0.157	−0.004	0.001	−0.003	0.002	0.079	−0.156	−0.004	−0.014
	(0.029)	(0.031)	(0.016)	(0.127)	(0.017)	(0.092)	(0.014)	(0.021)	(0.607)	(0.116)	(0.016)	(0.013)
Observations	38221	38221	38220	14552	38221	38221	38221	38221	14552	38210	38210	38214
R2	0.958	0.951	0.982	0.935	0.982	0.928	0.847	0.965	0.907	0.718	0.923	0.980
Panel B: Brown efficiency innovation												
L1 BROWNEFFRATIOEP	0.031	−0.045	−0.015	−0.241	−0.012	0.044	0.008	0.017	0.392	−0.072	0.007	−0.012
	(0.043)	(0.041)	(0.020)	(0.167)	(0.022)	(0.144)	(0.015)	(0.025)	(0.968)	(0.147)	(0.021)	(0.018)
Observations	29585	29585	29584	10349	29585	29585	29585	29585	10349	29578	29578	29580
R2	0.953	0.948	0.980	0.931	0.981	0.922	0.843	0.961	0.898	0.720	0.917	0.980
L3 BROWNEFFRATIOEP	0.051	−0.001	0.004	−0.105	0.003	−0.095	0.003	0.011	−0.945	−0.093	−0.004	0.006
	(0.037)	(0.038)	(0.020)	(0.110)	(0.021)	(0.135)	(0.013)	(0.022)	(0.761)	(0.125)	(0.018)	(0.016)
Observations	22261	22261	22261	4160	22261	22261	22261	22261	4166	25158	25153	25155
R2	0.967	0.962	0.986	0.982	0.986	0.955	0.902	0.974	0.986	0.827	0.945	0.986
L5 BROWNEFFRATIOEP	0.065*	0.010	0.022		0.020	−0.067	−0.019*	0.004		0.170	0.025	0.029*
	(0.036)	(0.034)	(0.020)		(0.021)	(0.131)	(0.011)	(0.022)		(0.130)	(0.017)	(0.017)
Observations	15482	15482	15482		15482	15482	15482	15482		18347	18347	18343
R2	0.973	0.965	0.985		0.986	0.971	0.933	0.981		0.888	0.956	0.989
L1 3YEARAVGBROWNEFFRATIOEP	0.151***	−0.027	0.012	−0.136	0.028	0.095	0.004	0.024	−1.373	−0.014	−0.005	0.025
	(0.049)	(0.049)	(0.024)	(0.223)	(0.027)	(0.190)	(0.018)	(0.031)	(1.354)	(0.224)	(0.024)	(0.023)
Observations	38221	38221	38220	14552	38221	38221	38221	38221	14552	38210	38210	38214
R2	0.958	0.951	0.982	0.935	0.982	0.928	0.847	0.965	0.907	0.718	0.923	0.980
Controls	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Year F.E.	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Firm F.E.	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes

TABLE 9: PATENT RATIOS AND GICS-6 INDUSTRY-LEVEL OUTCOMES

The unit of observation is GICS-6 industry-year and the sample period is 2005 to 2020. The dependent variables are logs of industry level cumulative sums of S1TOT, S2TOT, S3UPTOT, S3DOWNTOT, CAPEX, and SALES over 1, 3 or 5 years, respectively cumulative sums over sums for S1INT, S2INT, S3UPINT, S3DOWNINT and INVEST/A for 1, 3 or 5 years for the Trucost sample. In Panel A.1 and B.1, dependent variables are calculated across all firms within the given industry. In Panel A.2 and B.2, dependent variables are calculated across all ever patenting firms within the given industry and in Panel A.3 and B.3, dependent variables are calculated across all never patenting firms within the given industry. The key explanatory variables of interest are *GREENRATIOEP* in Panel A and *BROWNEFFRATIOEP* in Panel B. Controls include *LOGSIZE*, *LOGPPE*, *LEVERAGE*, *ROE*, *M/B*, *INVEST/A*, *BETA*, *VOLAT*, *MOM*, *RET*, *MSCI*. Independent variables are either industry level logs of sums (LOGSIZE and LOGPPE), sum over sums (GREENRATIOEP, BROWNEFFRATIOEP, LEVERAGE, ROE, M/B, INVEST/A) or market capitalization weighted averages (BETA, VOLAT, MOM, RET, MSCI). All Independent variables are lagged by 1, 3 or 5 years respectively. The model is estimated using pooled regression model. All regression include year and industry fixed effects. We double cluster standard errors at the GICS-6 industry and year dimension. *** 1% significance, ** 5% significance * 10% significance.

	(1) LOGS1TOT	(2) LOGS2TOT	(3) LOGS3UPTOT	(4) LOGS3DOWNTOT	(5) S1INT	(6) S2INT	(7) S3UPINT	(8) S3DOWNINT	(9) INVEST/A	(10) LOGCAPEX	(11) LOGSALES
Panel A: Green innovation											
Panel A.1: GREENRATIOEP on all firms											
L1 GREENRATIOEP	0.117	0.327*	−0.084	0.073	−0.192	0.195**	−0.289**	1.249	0.001*	0.022	−0.006
	(0.174)	(0.180)	(0.092)	(0.497)	(1.106)	(0.097)	(0.131)	(3.118)	(0.001)	(0.061)	(0.087)
Observations	976	976	976	261	976	976	976	261	976	976	976
R2	0.962	0.932	0.959	0.961	0.988	0.734	0.976	0.842	0.911	0.924	0.936
L3 GREENRATIOEP	0.208	0.321**	−0.003	−1.005	−2.647**	0.264**	−0.339***	−2.551	0.001	0.016	0.085
	(0.156)	(0.129)	(0.081)	(0.915)	(1.207)	(0.111)	(0.114)	(2.939)	(0.001)	(0.057)	(0.080)
Observations	837	837	837	122	837	837	837	122	837	837	837
R2	0.981	0.978	0.990	0.990	0.994	0.784	0.988	0.974	0.957	0.984	0.986
L5 GREENRATIOEP	0.191	0.274***	−0.009		−1.562*	0.191*	−0.153*		0.001	−0.030	0.046
	(0.139)	(0.102)	(0.075)		(0.796)	(0.110)	(0.089)		(0.001)	(0.047)	(0.070)
Observations	708	708	708		708	708	708		708	708	708
R2	0.986	0.986	0.991		0.997	0.852	0.993		0.966	0.984	0.987
L1 3YEARAVGGREENRATIOEP	0.435*	1.273***	0.138	−1.699	−5.143**	0.660***	−0.679***	−7.100	0.003*	0.336*	0.308*
	(0.241)	(0.326)	(0.169)	(1.398)	(2.285)	(0.211)	(0.209)	(10.840)	(0.002)	(0.186)	(0.158)
Observations	988	988	988	267	988	988	988	267	988	988	988
R2	0.962	0.933	0.960	0.967	0.989	0.735	0.977	0.843	0.904	0.914	0.937
Panel A.2: GREENRATIOEP on ever patenting firms											
L1 GREENRATIOEP	−0.257	0.212	−0.146	0.567	−1.984	0.230*	−0.260**	1.521	0.001*	0.045	−0.037
	(0.224)	(0.199)	(0.121)	(0.822)	(1.491)	(0.122)	(0.108)	(3.659)	(0.001)	(0.072)	(0.125)
Observations	974	974	974	261	974	974	974	261	974	974	974
R2	0.962	0.960	0.984	0.954	0.926	0.679	0.973	0.695	0.955	0.979	0.981
L3 GREENRATIOEP	−0.206	0.294	−0.087	−0.388	−4.062**	0.347**	−0.359***	−4.782	0.001**	0.007	0.067
	(0.223)	(0.197)	(0.100)	(0.931)	(1.993)	(0.172)	(0.097)	(7.610)	(0.001)	(0.071)	(0.109)
Observations	834	834	834	122	834	834	834	122	834	834	834
R2	0.976	0.973	0.988	0.986	0.954	0.741	0.984	0.936	0.967	0.982	0.986
L5 GREENRATIOEP	−0.122	0.223	−0.098		−0.574	0.225	−0.193**		0.001*	−0.032	0.005
	(0.243)	(0.171)	(0.100)		(1.489)	(0.152)	(0.088)		(0.000)	(0.059)	(0.108)
Observations	705	705	705		705	705	705		705	705	705
R2	0.982	0.982	0.991		0.970	0.824	0.989		0.975	0.986	0.988
L1 3YEARAVGGREENRATIOEP	−0.416	0.938***	−0.076	−0.218	−6.652**	0.697**	−0.657***	−8.575	0.002	0.126	0.181
	(0.310)	(0.352)	(0.174)	(1.847)	(3.294)	(0.293)	(0.196)	(12.070)	(0.001)	(0.124)	(0.191)
Observations	985	985	985	265	985	985	985	265	985	985	985
R2	0.963	0.962	0.984	0.956	0.928	0.683	0.974	0.695	0.950	0.979	0.982
Panel A.3: GREENRATIOEP on never patenting firms											
L1 GREENRATIOEP	−0.068	0.384*	−0.144	0.168	1.701	0.229**	−0.403**	2.908	0.001	0.006	−0.048
	(0.171)	(0.200)	(0.105)	(0.451)	(1.419)	(0.106)	(0.192)	(2.700)	(0.002)	(0.068)	(0.096)
Observations	964	964	964	261	964	964	964	261	964	964	964
R2	0.941	0.921	0.940	0.972	0.980	0.735	0.630	0.959	0.794	0.938	0.939
L3 GREENRATIOEP	0.127	0.088	−0.050	0.040	−0.835	0.122*	−0.333**	−1.203	0.002	0.004	0.017
	(0.149)	(0.121)	(0.101)	(0.424)	(1.057)	(0.071)	(0.151)	(3.143)	(0.001)	(0.073)	(0.088)
Observations	819	819	819	122	819	819	819	122	819	819	819
R2	0.960	0.948	0.961	0.998	0.993	0.846	0.860	0.996	0.824	0.958	0.960
L5 GREENRATIOEP	0.100	−0.025	−0.066		−1.051	0.088	−0.139		0.001	−0.096	−0.037
	(0.148)	(0.133)	(0.103)		(0.680)	(0.080)	(0.128)		(0.001)	(0.084)	(0.093)
Observations	685	685	685		685	685	685		685	685	685
R2	0.973	0.959	0.967		0.996	0.898	0.929		0.866	0.963	0.966
L1 3YEARAVGGREENRATIOEP	0.110	0.977***	−0.033	−0.303	−1.057	0.437***	−0.823**	6.390	0.005*	0.113	0.064
	(0.276)	(0.349)	(0.215)	(1.072)	(1.746)	(0.154)	(0.362)	(5.121)	(0.003)	(0.138)	(0.191)
Observations	976	976	976	267	976	976	976	267	976	976	976
R2	0.941	0.920	0.939	0.974	0.979	0.736	0.631	0.959	0.793	0.932	0.937
Controls	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Year F.E.	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Industry F.E.	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes

	(1) LOGS1TOT	(2) LOGS2TOT	(3) LOGS3UPTOT	(4) LOGS3DOWNTOT	(5) S1INT	(6) S2INT	(7) S3UPINT	(8) S3DOWNINT	(9) INVEST/A	(10) LOGCAPEX	(11) LOGSALES
Panel B: Brown efficiency innovation											
Panel B.1: BROWNEFFRATIOEP on all firms											
L1 BROWNEFFRATIOEP	−0.082	−0.365	−0.097	1.501	8.373**	−0.184	0.649*	43.304	0.000	−0.134	−0.144
	(0.185)	(0.383)	(0.146)	(2.008)	(3.554)	(0.210)	(0.387)	(41.529)	(0.001)	(0.092)	(0.112)
Observations	976	976	976	261	976	976	976	261	976	976	976
R2	0.962	0.932	0.959	0.961	0.989	0.734	0.976	0.853	0.911	0.924	0.936
L3 BROWNEFFRATIOEP	−0.138	−0.323	−0.228*	2.308	7.251***	−0.069	0.284	23.340	0.000	−0.155*	−0.167*
	(0.175)	(0.247)	(0.127)	(2.795)	(2.645)	(0.227)	(0.315)	(29.000)	(0.001)	(0.091)	(0.095)
Observations	837	837	837	122	837	837	837	122	837	837	837
R2	0.981	0.978	0.990	0.990	0.995	0.782	0.988	0.974	0.957	0.984	0.986
L5 BROWNEFFRATIOEP	0.146	−0.148	−0.142		1.564	0.015	−0.278		0.000	0.001	0.018
	(0.179)	(0.192)	(0.126)		(2.466)	(0.249)	(0.227)		(0.001)	(0.114)	(0.120)
Observations	708	708	708		708	708	708		708	708	708
R2	0.986	0.985	0.991		0.997	0.852	0.993		0.966	0.984	0.987
L1 3YEARAVGBROWNEFFRATIOEP	−0.104	−0.540	−0.130	6.213**	13.254***	−0.183	0.724**	96.369	−0.001	−0.211	−0.166
	(0.245)	(0.380)	(0.171)	(2.568)	(4.362)	(0.191)	(0.359)	(69.150)	(0.001)	(0.139)	(0.159)
Observations	988	988	988	267	988	988	988	267	988	988	988
R2	0.962	0.931	0.960	0.968	0.990	0.733	0.976	0.864	0.903	0.914	0.937
Panel B.2: BROWNEFFRATIOEP on ever patenting firms											
L1 BROWNEFFRATIOEP	0.288	−0.260	−0.078	0.435	13.008**	−0.199	0.573**	82.622	0.002*	0.075	−0.241
	(0.268)	(0.532)	(0.187)	(2.965)	(6.495)	(0.260)	(0.270)	(69.540)	(0.001)	(0.106)	(0.228)
Observations	974	974	974	261	974	974	974	261	974	974	974
R2	0.962	0.960	0.984	0.954	0.932	0.679	0.973	0.727	0.954	0.979	0.981
L3 BROWNEFFRATIOEP	0.094	−0.230	−0.220*	1.391	8.228	−0.182	0.211	24.203	0.001	0.128	−0.235
	(0.251)	(0.397)	(0.115)	(2.703)	(5.915)	(0.301)	(0.200)	(36.508)	(0.001)	(0.097)	(0.149)
Observations	834	834	834	122	834	834	834	122	834	834	834
R2	0.976	0.973	0.988	0.986	0.955	0.740	0.984	0.937	0.967	0.982	0.986
L5 BROWNEFFRATIOEP	0.192	−0.175	−0.151		−4.654	−0.029	−0.308*		0.000	0.183**	0.018
	(0.303)	(0.303)	(0.118)		(3.254)	(0.269)	(0.169)		(0.001)	(0.088)	(0.150)
Observations	705	705	705		705	705	705		705	705	705
R2	0.982	0.982	0.991		0.970	0.824	0.989		0.975	0.986	0.988
L1 3YEARAVGBROWNEFFRATIOEP	−0.106	−0.493	−0.199	9.066**	17.600**	−0.227	0.675**	191.709	0.001	0.184	−0.396
	(0.466)	(0.592)	(0.241)	(4.014)	(8.717)	(0.243)	(0.330)	(131.078)	(0.002)	(0.135)	(0.283)
Observations	985	985	985	265	985	985	985	265	985	985	985
R2	0.963	0.961	0.984	0.959	0.934	0.681	0.973	0.754	0.950	0.979	0.982
Panel B.3: BROWNEFFRATIOEP on never patenting firms											
L1 BROWNEFFRATIOEP	−0.295	−0.728*	−0.113	−0.495	3.302	−0.383**	0.251	−10.842	−0.003	−0.133	−0.087
	(0.285)	(0.391)	(0.234)	(1.423)	(2.278)	(0.177)	(0.583)	(8.039)	(0.003)	(0.140)	(0.170)
Observations	964	964	964	261	964	964	964	261	964	964	964
R2	0.941	0.921	0.940	0.972	0.980	0.735	0.629	0.959	0.794	0.938	0.939
L3 BROWNEFFRATIOEP	−0.585**	−0.712***	−0.467**	−0.109	4.589**	−0.030	0.082	3.322	0.000	−0.275*	−0.278
	(0.268)	(0.263)	(0.231)	(0.761)	(2.047)	(0.142)	(0.417)	(5.100)	(0.003)	(0.143)	(0.174)
Observations	819	819	819	122	819	819	819	122	819	819	819
R2	0.960	0.948	0.961	0.998	0.993	0.846	0.860	0.996	0.824	0.958	0.960
L5 BROWNEFFRATIOEP	−0.615**	−0.655**	−0.675***		2.368	−0.100	−0.404		0.002	−0.319*	−0.374*
	(0.260)	(0.275)	(0.210)		(1.838)	(0.148)	(0.289)		(0.003)	(0.166)	(0.198)
Observations	685	685	685		685	685	685		685	685	685
R2	0.973	0.959	0.967		0.996	0.898	0.929		0.866	0.963	0.966
L1 3YEARAVGBROWNEFFRATIOEP	−0.790**	−1.274***	−0.489*	1.409	8.154*	−0.332*	0.006	−2.571	−0.004	−0.321*	−0.247
	(0.402)	(0.405)	(0.276)	(1.611)	(4.320)	(0.170)	(0.616)	(10.075)	(0.004)	(0.193)	(0.204)
Observations	976	976	976	267	976	976	976	267	976	976	976
R2	0.941	0.920	0.940	0.974	0.980	0.735	0.630	0.959	0.793	0.932	0.937
Controls	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Year F.E.	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Industry F.E.	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes

TABLE 10: PATENT RATIOS AND CROSS-INDUSTRY OUTCOMES

The unit of observation is GICS-8 industry-year. The sample period is 2005 to 2020. We aggregate the dependent variables at a given GICS-8 industry's higher GICS-2 level including all GICS-8 industries but the given GICS-8 industry used for the independent variables. The dependent variables are thus GICS-2 industry level logs of cumulative sums of S1TOT, S2TOT, S3UPTOT, S3DOWNTOT, CAPEX, and SALES over 1, 3 or 5 years, respectively GICS-2 industry level cumulative sums over sums for S1INT, S2INT, S3UPINT, S3DOWNINT and INVEST/A for 1, 3 or 5 years. In Panel A.1 and B1., dependent variables are calculated across all firms in the broader GICS-2 industry except the given GICS-8 industry. In Panel A.2 and B.2, dependent variables are similarly calculated only for ever-patenting firms and in Panel A.3 and B.3 only for never-patenting firms. In Panel A, the key independent variable of interest is the GICS-8 industry level GREENRATIOEP and in Panel B the GICS-8 industry level BROWNEFFRATIOEP. Controls at the GICS-8 all firms (ever-patenting, respectively never patenting) level include *LOGSIZE*, *LOGPPE*, *LEVERAGE*, *ROE*, *M/B*, *INVEST/A*, *BETA*, *VOLAT*, *MOM*, *RET*, *MSCI*. Independent variables are either GICS-8 industry level logs of sums (LOGSIZE and LOGPPE), sum over sums (GREENRATIOEP, BROWNEFFRATIOEP, LEVERAGE, ROE, M/B, INVEST/A) or market capitalization weighted averages (BETA, VOLAT, MOM, RET, MSCI). All Independent variables are lagged by 1, 3 or 5 years respectively. The model is estimated using pooled regression model. All regression include year and industry fixed effects. We double cluster standard errors at the GICS-8 industry and year dimension. *** 1% significance, ** 5% significance * 10% significance.

	(1) LOGS1TOT	(2) LOGS2TOT	(3) LOGS3UPTOT	(4) LOGS3DOWNTOT	(5) S1INT	(6) S2INT	(7) S3UPINT	(8) S3DOWNINT	(9) INVEST/A	(10) LOGCAPEX	(11) LOGSALES
Panel A: Green innovation											
Panel A.1: GREENRATIOEP on all firms											
L1 GREENRATIOEP/100	0.274	1.152	−7.787**	−0.381	18.915	3.968*	−1.746	−24.219	0.005	−2.646	−6.478*
	(4.448)	(4.302)	(3.592)	(13.828)	(20.521)	(2.174)	(3.815)	(87.962)	(0.016)	(1.647)	(3.573)
Observations	1958	1958	1958	561	1958	1958	1958	561	1958	1958	1958
R2	0.986	0.972	0.985	0.982	0.989	0.976	0.983	0.964	0.957	0.982	0.966
L3 GREENRATIOEP/100	6.055*	4.386	−1.757	0.409	4.019	3.694*	0.193	−57.379	−0.007	−1.278	−0.288
	(3.639)	(3.466)	(3.450)	(8.701)	(15.199)	(1.920)	(2.905)	(87.317)	(0.018)	(1.441)	(3.596)
Observations	1649	1649	1649	262	1649	1649	1649	262	1649	1649	1649
R2	0.993	0.984	0.989	0.997	0.993	0.983	0.991	0.995	0.969	0.987	0.974
L5 GREENRATIOEP/100	6.013	7.693**	1.466		9.338	3.574*	−0.715		−0.009	−1.256	2.251
	(3.874)	(3.214)	(3.532)		(14.879)	(2.119)	(2.763)		(0.017)	(1.379)	(3.551)
Observations	1363	1363	1363		1363	1363	1363		1363	1363	1363
R2	0.995	0.990	0.992		0.995	0.989	0.995		0.979	0.991	0.981
L1 3YEARAVGGREENRATIOEP	0.049	0.167**	−0.069	−0.474**	−0.237	0.097***	−0.116**	−4.151***	−0.000	−0.028	−0.020
	(0.064)	(0.068)	(0.055)	(0.203)	(0.309)	(0.029)	(0.058)	(1.430)	(0.000)	(0.025)	(0.056)
Observations	2065	2065	2065	589	2065	2065	2065	589	2065	2065	2065
R2	0.986	0.972	0.985	0.982	0.989	0.976	0.983	0.965	0.956	0.982	0.966
Panel A.2: GREENRATIOEP on ever-patenting firms											
L1 GREENRATIOEP/100	−3.978	1.691	−8.359***	−7.007	−45.317*	4.770*	−3.065	−148.941	0.007	−3.186	−7.948**
	(6.353)	(4.376)	(3.083)	(18.423)	(27.009)	(2.491)	(4.517)	(139.989)	(0.012)	(2.003)	(3.180)
Observations	1949	1949	1949	558	1949	1949	1949	558	1949	1949	1949
R2	0.979	0.975	0.989	0.972	0.971	0.968	0.980	0.903	0.967	0.982	0.974
L3 GREENRATIOEP/100	5.368	2.574	−5.273**	−6.927	−28.576*	3.857	−2.080	−90.323	−0.001	−4.267**	−3.135
	(5.636)	(3.783)	(2.670)	(12.794)	(15.220)	(2.412)	(3.515)	(117.378)	(0.012)	(2.011)	(2.997)
Observations	1640	1640	1640	262	1640	1640	1640	262	1640	1640	1640
R2	0.988	0.984	0.993	0.993	0.985	0.976	0.989	0.985	0.976	0.986	0.981
L5 GREENRATIOEP/100	1.362	4.321	−4.812*		−21.360	3.715	−4.175		−0.006	−4.868**	−1.294
	(6.032)	(3.079)	(2.770)		(17.893)	(2.502)	(3.455)		(0.012)	(2.053)	(2.948)
Observations	1353	1353	1353		1353	1353	1353		1353	1353	1353
R2	0.992	0.991	0.995		0.992	0.984	0.994		0.985	0.990	0.985
L1 3YEARAVGGREENRATIOEP	−0.039	0.088	−0.134***	−0.682**	−1.471***	0.075**	−0.171**	−7.135**	−0.000	−0.094***	−0.065
	(0.095)	(0.064)	(0.048)	(0.337)	(0.390)	(0.032)	(0.071)	(2.909)	(0.000)	(0.030)	(0.048)
Observations	2053	2053	2053	584	2053	2053	2053	584	2053	2053	2053
R2	0.979	0.976	0.990	0.971	0.972	0.968	0.980	0.902	0.967	0.984	0.977
Panel A.3: GREENRATIOEP on never-patenting firms											
L1 GREENRATIOEP/100	2.807	−1.513	−4.849	−6.752	48.319	0.381	3.234	15.569	−0.016	−2.543	−6.171
	(6.418)	(6.789)	(4.666)	(8.003)	(38.510)	(4.259)	(4.524)	(71.305)	(0.043)	(2.830)	(3.832)
Observations	1901	1901	1901	561	1901	1901	1901	561	1901	1901	1901
R2	0.971	0.940	0.970	0.993	0.987	0.965	0.978	0.993	0.923	0.964	0.961
L3 GREENRATIOEP/100	9.768*	0.179	2.869	−2.011	22.789	1.462	3.915	−75.320	−0.083**	−1.346	1.827
	(5.355)	(5.988)	(4.508)	(5.221)	(34.406)	(2.154)	(3.990)	(52.497)	(0.041)	(2.461)	(3.795)
Observations	1579	1579	1579	262	1579	1579	1579	262	1579	1579	1579
R2	0.984	0.954	0.977	0.999	0.992	0.988	0.985	0.999	0.953	0.970	0.968
L5 GREENRATIOEP/100	9.663**	0.665	3.754		33.909	1.466	−0.088		−0.053	−2.322	3.194
	(4.820)	(5.306)	(4.758)		(34.028)	(2.037)	(4.106)		(0.038)	(2.586)	(3.984)
Observations	1285	1285	1285		1285	1285	1285		1285	1285	1285
R2	0.992	0.963	0.982		0.994	0.994	0.992		0.973	0.976	0.975
L1 3YEARAVGGREENRATIOEP	0.172	0.159	0.019	−0.557***	0.729	0.100	−0.005	−4.192***	−0.002***	−0.044	0.012
	(0.107)	(0.112)	(0.074)	(0.161)	(0.536)	(0.070)	(0.070)	(1.185)	(0.001)	(0.041)	(0.060)
Observations	2006	2006	2006	589	2006	2006	2006	589	2006	2006	2006
R2	0.971	0.940	0.970	0.993	0.988	0.965	0.977	0.993	0.924	0.963	0.961
Controls	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Year F.E.	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Industry F.E.	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes

	(1) LOGS1TOT	(2) LOGS2TOT	(3) LOGS3UPTOT	(4) LOGS3DOWNTOT	(5) S1INT	(6) S2INT	(7) S3UPINT	(8) S3DOWNINT	(9) INVEST/A	(10) LOGCAPEX	(11) LOGSALES
Panel B: Brown efficiency innovation											
Panel B.1: BROWNEFFRATIOEP on all firms											
L1 BROWNEFFRATIOEP/100	−2.188	3.363	6.716	−9.622	39.080	2.628	8.503	−219.445	−0.034	−0.060	6.925
	(6.250)	(8.202)	(5.807)	(32.729)	(50.465)	(4.144)	(9.709)	(234.536)	(0.025)	(3.624)	(5.957)
Observations	1958	1958	1958	561	1958	1958	1958	561	1958	1958	1958
R2	0.986	0.972	0.985	0.982	0.989	0.976	0.983	0.964	0.957	0.982	0.966
L3 BROWNEFFRATIOEP/100	−2.626	5.427	1.591	30.222	44.805	4.714	3.224	62.765	−0.013	0.681	2.981
	(5.124)	(5.862)	(5.337)	(20.141)	(37.907)	(3.383)	(7.785)	(248.948)	(0.024)	(3.281)	(5.355)
Observations	1649	1649	1649	262	1649	1649	1649	262	1649	1649	1649
R2	0.993	0.984	0.989	0.997	0.993	0.983	0.991	0.995	0.969	0.987	0.974
L5 BROWNEFFRATIOEP/100	−3.082	3.236	1.976		30.790	−0.465	3.151		−0.043**	0.853	3.844
	(4.496)	(4.740)	(5.199)		(28.161)	(2.502)	(4.550)		(0.020)	(2.327)	(5.216)
Observations	1363	1363	1363		1363	1363	1363		1363	1363	1363
R2	0.995	0.990	0.992		0.995	0.989	0.995		0.979	0.991	0.981
L1 3YEARAVGBROWNEFFRATIOEP	−0.036	−0.015	0.051	0.382**	1.661***	0.024	0.077	1.320	−0.000	0.036	0.079
	(0.083)	(0.105)	(0.077)	(0.162)	(0.632)	(0.063)	(0.113)	(2.356)	(0.000)	(0.040)	(0.071)
Observations	2065	2065	2065	589	2065	2065	2065	589	2065	2065	2065
R2	0.986	0.972	0.985	0.981	0.989	0.976	0.983	0.964	0.956	0.982	0.966
Panel B.2: BROWNEFFRATIOEP on ever-patenting firms											
L1 BROWNEFFRATIOEP/100	−0.658	9.914	9.224*	−7.806	67.476	5.614	9.864	−165.991	−0.006	1.267	9.585*
	(7.179)	(8.810)	(5.575)	(41.345)	(52.164)	(4.597)	(10.708)	(310.706)	(0.018)	(4.037)	(5.638)
Observations	1949	1949	1949	558	1949	1949	1949	558	1949	1949	1949
R2	0.979	0.975	0.989	0.972	0.971	0.968	0.980	0.903	0.967	0.982	0.974
L3 BROWNEFFRATIOEP/100	−4.455	6.194	0.886	25.638	25.937	5.418	4.176	208.613	0.005	1.386	3.324
	(5.905)	(7.620)	(5.421)	(22.319)	(38.253)	(4.025)	(8.566)	(296.275)	(0.015)	(4.182)	(5.227)
Observations	1640	1640	1640	262	1640	1640	1640	262	1640	1640	1640
R2	0.988	0.984	0.993	0.993	0.985	0.976	0.989	0.985	0.976	0.986	0.981
L5 BROWNEFFRATIOEP/100	−5.222	2.829	−0.121		4.514	−0.498	3.030		−0.011	1.877	3.485
	(5.042)	(5.053)	(5.000)		(29.609)	(2.838)	(5.168)		(0.012)	(3.904)	(5.005)
Observations	1353	1353	1353		1353	1353	1353		1353	1353	1353
R2	0.992	0.991	0.995		0.992	0.984	0.994		0.985	0.990	0.985
L1 3YEARAVGBROWNEFFRATIOEP	−0.015	0.141	0.067	0.260	1.652**	0.134***	0.098	2.303	−0.000	0.017	0.109
	(0.111)	(0.101)	(0.081)	(0.248)	(0.690)	(0.050)	(0.127)	(2.823)	(0.000)	(0.050)	(0.070)
Observations	2053	2053	2053	584	2053	2053	2053	584	2053	2053	2053
R2	0.979	0.976	0.990	0.970	0.972	0.968	0.980	0.899	0.967	0.984	0.977
Panel B.3: BROWNEFFRATIOEP on never-patenting firms											
L1 BROWNEFFRATIOEP/100	6.986	−1.889	12.488	−17.850	16.222	−3.298	10.079	−309.372	−0.112	1.836	10.825
	(14.793)	(15.539)	(8.499)	(15.141)	(76.488)	(10.258)	(8.781)	(241.999)	(0.078)	(5.863)	(6.996)
Observations	1901	1901	1901	561	1901	1901	1901	561	1901	1901	1901
R2	0.971	0.940	0.970	0.993	0.987	0.965	0.978	0.993	0.923	0.964	0.961
L3 BROWNEFFRATIOEP/100	0.705	6.288	6.648	−12.721	−27.280	1.284	3.952	−171.316	−0.043	1.270	5.746
	(10.829)	(11.021)	(8.563)	(12.774)	(64.711)	(5.104)	(8.204)	(219.561)	(0.072)	(5.887)	(6.651)
Observations	1579	1579	1579	262	1579	1579	1579	262	1579	1579	1579
R2	0.984	0.954	0.977	0.999	0.992	0.988	0.985	0.999	0.953	0.970	0.968
L5 BROWNEFFRATIOEP/100	−7.126	−2.038	0.479		−2.111	−2.379	4.280		−0.090	−2.578	0.036
	(8.393)	(9.430)	(9.103)		(57.376)	(3.130)	(5.925)		(0.057)	(4.938)	(6.932)
Observations	1285	1285	1285		1285	1285	1285		1285	1285	1285
R2	0.992	0.963	0.982		0.994	0.994	0.992		0.973	0.976	0.975
L1 3YEARAVGBROWNEFFRATIOEP	0.061	−0.253	0.108	0.150	1.150	−0.226	0.071	1.519	−0.001	0.070	0.107
	(0.164)	(0.205)	(0.109)	(0.117)	(0.958)	(0.153)	(0.106)	(2.395)	(0.001)	(0.065)	(0.085)
Observations	2006	2006	2006	589	2006	2006	2006	589	2006	2006	2006
R2	0.971	0.940	0.970	0.993	0.988	0.965	0.977	0.993	0.924	0.963	0.961
Controls	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Year F.E.	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Industry F.E.	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes

TABLE 11: PUBLIC AND PRIVATE PATENT RATIOS AND GICS-6 INDUSTRY-LEVEL OUTCOMES

The unit of observation is GICS-6 industry-year and the sample period is 2005 to 2020. The dependent variables are logs of industry level cumulative sums of S1TOT, S2TOT, S3UPTOT, S3DOWNTOT, CAPEX, and SALES over 1, 3 or 5 years, respectively cumulative sums over sums for S1INT, S2INT, S3UPINT, S3DOWNINT and INVEST/A for 1, 3 or 5 years for the Trucost sample. In Panel A.1 and B.1, dependent variables are calculated across all firms within the given industry. In Panel A.2 and B.2, dependent variables are calculated across all ever patenting firms within the given industry and in Panel A.3 and B.3, dependent variables are calculated across all never patenting firms within the given industry. The key explanatory variables of interest are *GREENRATIOEPPUBLIC* and *GREENRATIOEPPRIVATE*, which are industry level patent ratios for all public firms respectively all private firms in a given industry. Controls include *LOGSIZE*, *LOGPPE*, *LEVERAGE*, *ROE*, *M/B*, *INVEST/A*, *BETA*, *VOLAT*, *MOM*, *RET*, *MSCI*. Independent variables are either industry level logs of sums (LOGSIZE and LOGPPE), sum over sums (GREENRATIOEP, LEVERAGE, ROE, M/B, INVEST/A) or market capitalization weighted averages (BETA, VOLAT, MOM, RET, MSCI). All Independent variables are lagged by 1, 3 or 5 years respectively. The model is estimated using pooled regression model. All regression include year and industry fixed effects. We double cluster standard errors at the given industry and year dimension. *** 1% significance, ** 5% significance * 10% significance.

	(1) LOGS1TOT	(2) LOGS2TOT	(3) LOGS3UPTOT	(4) LOGS3DOWNTOT	(5) S1INT	(6) S2INT	(7) S3UPINT	(8) S3DOWNINT	(9) INVEST/A	(10) LOGCAPEX	(11) LOGSALES
Panel A: Green innovation											
Panel A.1: GREENRATIOEP on all firms											
L1 GREENRATIOEP PUBLIC	0.132	0.330	−0.118	−0.090	1.524	0.287*	−0.102	1.191	0.002**	0.035	−0.047
	(0.219)	(0.211)	(0.130)	(0.801)	(2.042)	(0.157)	(0.172)	(5.795)	(0.001)	(0.082)	(0.112)
L1 GREENRATIOEP PRIVATE	−0.083	0.145	−0.054	0.310	−0.284	0.368*	−0.030	8.751	0.001	−0.026	−0.051
	(0.158)	(0.206)	(0.141)	(0.374)	(0.583)	(0.219)	(0.093)	(8.431)	(0.001)	(0.125)	(0.144)
Observations	840	840	840	227	840	840	840	227	840	840	840
R2	0.963	0.929	0.960	0.962	0.989	0.739	0.981	0.843	0.908	0.926	0.936
L3 GREENRATIOEP PUBLIC	0.180	0.428***	−0.089	−3.676	−3.293*	0.483**	−0.407***	−12.702	0.002*	0.026	0.070
	(0.215)	(0.160)	(0.114)	(2.809)	(1.726)	(0.226)	(0.149)	(10.306)	(0.001)	(0.072)	(0.106)
L3 GREENRATIOEP PRIVATE	0.011	0.185**	−0.021	−0.986	0.552	0.321**	−0.023	−8.185	0.000	0.042	−0.004
	(0.082)	(0.088)	(0.040)	(0.747)	(0.513)	(0.154)	(0.071)	(7.646)	(0.000)	(0.039)	(0.045)
Observations	720	720	720	106	720	720	720	106	720	720	720
R2	0.981	0.977	0.990	0.991	0.995	0.787	0.990	0.974	0.958	0.985	0.986
L5 GREENRATIOEP PUBLIC	0.217	0.288*	−0.021		−0.985	0.244	−0.155		0.002*	−0.045	0.034
	(0.223)	(0.156)	(0.123)		(1.157)	(0.229)	(0.130)		(0.001)	(0.076)	(0.119)
L5 GREENRATIOEP PRIVATE	−0.053	0.170**	−0.041		0.511	0.332*	−0.038		0.000	0.067	−0.017
	(0.060)	(0.080)	(0.046)		(0.350)	(0.194)	(0.063)		(0.000)	(0.043)	(0.049)
Observations	606	606	606		606	606	606		606	606	606
R2	0.985	0.984	0.992		0.997	0.855	0.994		0.967	0.986	0.987
L1 3YEARAVGGREENRATIOEP PUBLIC	0.516	1.339***	0.139	−2.859	−6.385	0.806**	−0.565**	−21.035	0.002	0.325*	0.376**
	(0.324)	(0.334)	(0.208)	(2.322)	(4.415)	(0.336)	(0.282)	(24.789)	(0.002)	(0.181)	(0.183)
L1 3YEARAVGGREENRATIOEP PRIVATE	−0.547	−0.254	−0.378	1.647	0.656	0.510**	0.109	29.347	0.001	−0.378	−0.394
	(0.442)	(0.550)	(0.435)	(1.157)	(1.165)	(0.242)	(0.150)	(26.466)	(0.002)	(0.419)	(0.451)
Observations	874	874	874	239	874	874	874	239	874	874	874
R2	0.962	0.926	0.958	0.967	0.987	0.738	0.978	0.851	0.896	0.912	0.934
Panel A.2: GREENRATIOEP on ever patenting firms											
L1 GREENRATIOEP PUBLIC	−0.001	0.440*	−0.084	1.242	−1.304	0.418**	−0.244	3.074	0.001	0.127	0.010
	(0.333)	(0.264)	(0.178)	(1.110)	(2.743)	(0.205)	(0.154)	(6.872)	(0.001)	(0.087)	(0.164)
L1 GREENRATIOEP PRIVATE	0.016	0.122	−0.010	0.252	0.451	0.348	−0.075	15.399	0.001**	0.026	−0.001
	(0.098)	(0.143)	(0.054)	(0.491)	(0.730)	(0.271)	(0.095)	(13.646)	(0.000)	(0.040)	(0.062)
Observations	838	838	838	227	838	838	838	227	838	838	838
R2	0.962	0.960	0.985	0.958	0.926	0.686	0.977	0.700	0.948	0.981	0.982
L3 GREENRATIOEP PUBLIC	0.290	0.641***	0.026	−3.232	−7.870**	0.650**	−0.489***	−22.143	0.002**	0.107	0.224
	(0.361)	(0.240)	(0.156)	(3.137)	(3.778)	(0.298)	(0.136)	(24.102)	(0.001)	(0.100)	(0.137)
L3 GREENRATIOEP PRIVATE	0.018	0.175	−0.075	−0.877	0.986	0.322*	−0.102	−9.633	0.000	0.005	−0.055
	(0.147)	(0.138)	(0.077)	(0.796)	(0.943)	(0.188)	(0.080)	(12.253)	(0.000)	(0.044)	(0.076)
Observations	717	717	717	106	717	717	717	106	717	717	717
R2	0.974	0.972	0.989	0.989	0.956	0.744	0.988	0.937	0.965	0.984	0.986
L5 GREENRATIOEP PUBLIC	0.419	0.346	0.121		−1.931	0.305	−0.103		0.001	0.000	0.134
	(0.325)	(0.224)	(0.118)		(3.779)	(0.288)	(0.127)		(0.001)	(0.091)	(0.129)
L5 GREENRATIOEP PRIVATE	−0.083	0.146	−0.094		0.046	0.384*	−0.056		0.000	−0.011	−0.089
	(0.096)	(0.103)	(0.058)		(0.944)	(0.229)	(0.070)		(0.000)	(0.042)	(0.066)
Observations	605	605	605		605	605	605		605	605	605
R2	0.981	0.981	0.992		0.969	0.827	0.993		0.977	0.987	0.989
L1 3YEARAVGGREENRATIOEP PUBLIC	0.410	1.604***	0.266	−1.455	−19.084**	1.021**	−0.947***	−37.079	0.001	0.378***	0.571**
	(0.437)	(0.456)	(0.272)	(2.957)	(7.825)	(0.451)	(0.285)	(34.085)	(0.001)	(0.140)	(0.289)
L1 3YEARAVGGREENRATIOEP PRIVATE	−0.140	0.366	−0.071	1.895	−0.504	0.594**	−0.174	60.707	0.001	0.037	0.001
	(0.160)	(0.225)	(0.095)	(1.650)	(2.192)	(0.296)	(0.153)	(46.638)	(0.001)	(0.059)	(0.100)
Observations	871	871	871	237	871	871	871	237	871	871	871
R2	0.961	0.959	0.985	0.955	0.902	0.687	0.977	0.730	0.947	0.981	0.982
Panel A.3: GREENRATIOEP on never patenting firms											
L1 GREENRATIOEP PUBLIC	−0.036	0.238	−0.074	0.138	2.782	0.239*	−0.100	5.491	0.001	−0.011	0.032
	(0.225)	(0.219)	(0.149)	(0.602)	(2.351)	(0.138)	(0.192)	(3.701)	(0.002)	(0.109)	(0.137)
L1 GREENRATIOEP PRIVATE	−0.058	0.405*	0.098	0.461	−0.075	0.249**	0.134	−0.577	−0.000	−0.052	0.045
	(0.174)	(0.213)	(0.141)	(0.292)	(0.699)	(0.110)	(0.088)	(1.732)	(0.001)	(0.147)	(0.143)
Observations	834	834	834	227	834	834	834	227	834	834	834
R2	0.948	0.928	0.945	0.974	0.990	0.755	0.958	0.961	0.765	0.944	0.940
L3 GREENRATIOEP PUBLIC	−0.075	−0.052	−0.167	−0.362	−0.748	0.199	−0.413*	−7.023	0.003	−0.037	−0.044
	(0.241)	(0.210)	(0.174)	(1.001)	(1.423)	(0.151)	(0.221)	(6.421)	(0.002)	(0.134)	(0.151)
L3 GREENRATIOEP PRIVATE	0.186	0.182	0.077	−0.248	0.558	0.230**	0.166	−3.903*	0.001	0.069	0.069
	(0.178)	(0.132)	(0.098)	(0.272)	(0.622)	(0.116)	(0.360)	(2.069)	(0.002)	(0.080)	(0.080)
Observations	710	710	710	106	710	710	710	106	710	710	710
R2	0.961	0.950	0.963	0.998	0.993	0.851	0.859	0.996	0.799	0.960	0.960
L5 GREENRATIOEP PUBLIC	−0.019	−0.225	−0.120		−0.375	0.008	−0.233		0.003	−0.145	−0.042
	(0.277)	(0.222)	(0.207)		(1.051)	(0.127)	(0.236)		(0.002)	(0.149)	(0.178)
L5 GREENRATIOEP PRIVATE	−0.043	0.040	−0.066		0.612	0.183	−0.205		0.003*	0.070	−0.012
	(0.162)	(0.135)	(0.107)		(0.429)	(0.111)	(0.199)		(0.002)	(0.084)	(0.088)
Observations	594	594	594		594	594	594		594	594	594
R2	0.972	0.959	0.968		0.997	0.901	0.931		0.850	0.967	0.966
L1 3YEARAVGGREENRATIOEP PUBLIC	0.158	0.826**	0.145	−1.000	−0.312	0.364*	−0.744	11.009*	0.002	0.235	0.353
	(0.351)	(0.356)	(0.251)	(1.407)	(2.757)	(0.200)	(0.565)	(6.337)	(0.004)	(0.209)	(0.233)
L1 3YEARAVGGREENRATIOEP PRIVATE	−0.174	0.108	−0.045	1.008	1.225	0.358**	0.900	−6.416	0.003	−0.378	−0.177
	(0.456)	(0.459)	(0.391)	(0.876)	(1.371)	(0.162)	(0.666)	(4.506)	(0.004)	(0.436)	(0.395)
Observations	868	868	868	239	868	868	868	239	868	868	868
R2	0.944	0.924	0.942	0.974	0.981	0.740	0.622	0.961	0.768	0.936	0.939
Controls	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Year F.E.	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Industry F.E.	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes

	(1) LOGS1TOT	(2) LOGS2TOT	(3) LOGS3UPTOT	(4) LOGS3DOWNTOT	(5) S1INT	(6) S2INT	(7) S3UPINT	(8) S3DOWNINT	(9) INVEST/A	(10) LOGCAPEX	(11) LOGSALES
Panel B: Brown efficiency innovation											
Panel B.1: BROWNEFFRATIOEP on all firms											
L1 BROWNEFFRATIOEP PUBLIC	−0.230	−0.056	−0.064	1.704	5.613	0.033	0.582	59.264	0.000	0.004	−0.122
	(0.280)	(0.379)	(0.214)	(2.557)	(4.630)	(0.242)	(0.461)	(53.420)	(0.001)	(0.139)	(0.176)
L1 BROWNEFFRATIOEP PRIVATE	−0.117	−0.486	−0.134	−0.039	0.961	−0.288	−0.164	10.508	0.000	0.025	−0.014
	(0.171)	(0.403)	(0.099)	(0.888)	(1.402)	(0.214)	(0.334)	(11.422)	(0.001)	(0.054)	(0.076)
Observations	840	840	840	227	840	840	840	227	840	840	840
R2	0.963	0.929	0.960	0.962	0.989	0.735	0.981	0.855	0.907	0.926	0.936
L3 BROWNEFFRATIOEP PUBLIC	−0.088	0.047	−0.076	−0.712	8.016**	0.219	0.611*	49.857	0.001	−0.042	−0.156
	(0.255)	(0.223)	(0.158)	(6.787)	(3.353)	(0.299)	(0.318)	(58.322)	(0.001)	(0.097)	(0.138)
L3 BROWNEFFRATIOEP PRIVATE	−0.047	−0.347	−0.117	−0.496	−0.091	−0.378*	−0.114	−11.268	−0.001*	−0.039	0.003
	(0.218)	(0.264)	(0.084)	(1.904)	(1.323)	(0.228)	(0.196)	(15.570)	(0.001)	(0.045)	(0.073)
Observations	720	720	720	106	720	720	720	106	720	720	720
R2	0.981	0.977	0.990	0.990	0.995	0.784	0.990	0.974	0.958	0.985	0.986
L5 BROWNEFFRATIOEP PUBLIC	0.251	0.097	−0.091		3.174	0.105	0.086		0.001	0.048	−0.040
	(0.228)	(0.172)	(0.124)		(2.923)	(0.303)	(0.238)		(0.001)	(0.113)	(0.129)
L5 BROWNEFFRATIOEP PRIVATE	−0.061	−0.250	−0.092		−1.364	−0.256	−0.070		−0.001	−0.049	−0.011
	(0.228)	(0.214)	(0.060)		(1.131)	(0.190)	(0.100)		(0.000)	(0.046)	(0.063)
Observations	606	606	606		606	606	606		606	606	606
R2	0.985	0.984	0.992		0.998	0.852	0.994		0.967	0.985	0.987
L1 3YEARAVGBROWNEFFRATIOEP	0.116	−0.406	−0.011	8.975**	21.718***	0.588*	0.429	175.171	0.002	0.215	0.079
PUBLIC	(0.435)	(0.601)	(0.327)	(3.932)	(7.720)	(0.310)	(0.547)	(117.147)	(0.002)	(0.311)	(0.318)
L1 3YEARAVGBROWNEFFRATIOEP	0.034	−0.860	−0.217	−0.387	−3.414	−0.959*	−0.384	13.308	−0.003*	0.036	0.062
PRIVATE	(0.357)	(0.739)	(0.212)	(1.276)	(3.509)	(0.522)	(0.599)	(19.277)	(0.002)	(0.146)	(0.197)
Observations	874	874	874	239	874	874	874	239	874	874	874
R2	0.961	0.925	0.958	0.968	0.989	0.735	0.978	0.872	0.896	0.911	0.933
Panel B.2: BROWNEFFRATIOEP on ever patenting firms											
L1 BROWNEFFRATIOEP PUBLIC	−0.042	−0.194	−0.383	0.674	8.296	0.058	0.303	109.525	0.002**	0.052	−0.466*
	(0.342)	(0.493)	(0.240)	(3.697)	(5.557)	(0.290)	(0.339)	(88.308)	(0.001)	(0.153)	(0.246)
L1 BROWNEFFRATIOEP PRIVATE	−0.175	−0.502	−0.144	0.511	4.056	−0.126	−0.018	18.028	−0.001	0.069	−0.097
	(0.202)	(0.482)	(0.121)	(0.903)	(2.992)	(0.307)	(0.163)	(18.012)	(0.001)	(0.054)	(0.103)
Observations	838	838	838	227	838	838	838	227	838	838	838
R2	0.962	0.960	0.985	0.957	0.928	0.682	0.977	0.728	0.948	0.981	0.982
L3 BROWNEFFRATIOEP PUBLIC	0.324	0.200	−0.028	−1.611	9.439*	0.107	0.538**	60.093	0.001	0.149	−0.309
	(0.501)	(0.367)	(0.280)	(7.674)	(5.578)	(0.359)	(0.239)	(75.092)	(0.001)	(0.148)	(0.268)
L3 BROWNEFFRATIOEP PRIVATE	−0.160	−0.419	−0.120	−0.160	3.084	−0.217	−0.083	−9.388	−0.001	0.084	−0.004
	(0.233)	(0.435)	(0.105)	(1.695)	(2.451)	(0.299)	(0.117)	(17.022)	(0.001)	(0.071)	(0.101)
Observations	717	717	717	106	717	717	717	106	717	717	717
R2	0.974	0.972	0.989	0.988	0.954	0.740	0.988	0.938	0.965	0.984	0.986
L5 BROWNEFFRATIOEP PUBLIC	0.504	0.139	−0.116		−1.333	0.084	0.056		0.001	0.158	−0.168
	(0.449)	(0.307)	(0.196)		(5.360)	(0.322)	(0.199)		(0.001)	(0.122)	(0.219)
L5 BROWNEFFRATIOEP PRIVATE	0.298	−0.275	0.084		1.538	−0.295	−0.008		−0.001**	0.033	0.105
	(0.269)	(0.334)	(0.131)		(1.693)	(0.223)	(0.092)		(0.001)	(0.079)	(0.122)
Observations	605	605	605		605	605	605		605	605	605
R2	0.981	0.981	0.992		0.969	0.823	0.993		0.977	0.987	0.989
L1 3YEARAVGBROWNEFFRATIOEP	0.219	−1.643	−0.242	11.232*	46.438**	0.618*	1.343**	314.088	0.002	0.275	−0.636
PUBLIC	(0.650)	(1.094)	(0.382)	(5.872)	(18.424)	(0.341)	(0.535)	(200.823)	(0.002)	(0.196)	(0.398)
L1 3YEARAVGBROWNEFFRATIOEP	−0.249	−1.173	−0.327	2.156	5.363	−0.791	−0.180	42.598	−0.001	0.270*	−0.109
PRIVATE	(0.473)	(0.762)	(0.267)	(1.581)	(5.332)	(0.675)	(0.382)	(35.265)	(0.001)	(0.160)	(0.247)
Observations	871	871	871	237	871	871	871	237	871	871	871
R2	0.961	0.958	0.985	0.957	0.915	0.681	0.976	0.769	0.947	0.980	0.982
Panel B.3: BROWNEFFRATIOEP on never patenting firms											
L1 BROWNEFFRATIOEP PUBLIC	−0.102	0.242	0.298	−0.648	1.209	−0.134	0.376	−9.431	−0.006	0.228	0.387*
	(0.428)	(0.370)	(0.286)	(1.839)	(3.517)	(0.214)	(0.501)	(9.587)	(0.004)	(0.200)	(0.228)
L1 BROWNEFFRATIOEP PRIVATE	−0.280	−0.723	−0.196	−0.119	0.376	−0.247	−0.368	2.395	−0.002	−0.131	−0.080
	(0.199)	(0.553)	(0.160)	(0.917)	(1.061)	(0.169)	(0.373)	(4.799)	(0.002)	(0.119)	(0.141)
Observations	834	834	834	227	834	834	834	227	834	834	834
R2	0.948	0.928	0.945	0.974	0.990	0.753	0.959	0.961	0.765	0.944	0.940
L3 BROWNEFFRATIOEP PUBLIC	−0.156	0.063	−0.029	−1.433	3.463	0.125	−0.144	8.824	−0.001	0.214	0.234
	(0.380)	(0.283)	(0.254)	(1.865)	(2.437)	(0.206)	(0.501)	(11.134)	(0.005)	(0.180)	(0.199)
L3 BROWNEFFRATIOEP PRIVATE	−0.016	−0.218	−0.036	−0.143	−1.021	−0.336**	−0.225	−10.388	−0.001	−0.050	0.046
	(0.190)	(0.175)	(0.126)	(0.893)	(0.804)	(0.146)	(0.192)	(9.316)	(0.002)	(0.118)	(0.127)
Observations	710	710	710	106	710	710	710	106	710	710	710
R2	0.961	0.950	0.963	0.998	0.994	0.850	0.859	0.996	0.799	0.960	0.960
L5 BROWNEFFRATIOEP PUBLIC	0.015	0.130	−0.128		2.888	−0.032	−0.137		0.003	0.179	0.121
	(0.310)	(0.280)	(0.246)		(1.973)	(0.178)	(0.382)		(0.004)	(0.182)	(0.227)
L5 BROWNEFFRATIOEP PRIVATE	−0.013	−0.045	−0.074		−2.174**	−0.172	−0.150		0.000	−0.014	0.018
	(0.198)	(0.140)	(0.130)		(1.018)	(0.106)	(0.121)		(0.002)	(0.135)	(0.131)
Observations	594	594	594		594	594	594		594	594	594
R2	0.972	0.959	0.968		0.997	0.900	0.931		0.849	0.967	0.966
L1 3YEARAVGBROWNEFFRATIOEP	0.183	−0.007	0.210	2.360	11.620**	0.212	−1.169	−3.051	−0.003	0.440	0.628*
PUBLIC	(0.556)	(0.570)	(0.379)	(2.706)	(5.737)	(0.297)	(1.213)	(14.858)	(0.006)	(0.346)	(0.342)
L1 3YEARAVGBROWNEFFRATIOEP	−0.374	−1.190	−0.114	−0.951	−3.922	−0.811**	−0.988	−6.532	−0.002	−0.172	0.071
PRIVATE	(0.401)	(0.948)	(0.265)	(1.399)	(2.494)	(0.376)	(0.773)	(8.570)	(0.004)	(0.194)	(0.219)
Observations	868	868	868	239	868	868	868	239	868	868	868
R2	0.944	0.924	0.942	0.974	0.981	0.740	0.621	0.960	0.768	0.936	0.939
Controls	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Year F.E.	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Industry F.E.	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes

TABLE 12: PUBLIC AND PRIVATE PATENT RATIOS AND CROSS-INDUSTRY OUTCOMES

The unit of observation is GICS-8 industry-year. The sample period is 2005 to 2020. We aggregate the dependent variables at a given GICS-8 industry's higher GICS-2 level including all GICS-8 industries but the given GICS-8 industry used for the independent variables. The dependent variables are thus GICS-2 industry level logs of cumulative sums of S1TOT, S2TOT, S3UPTOT, S3DOWNTOT, CAPEX, and SALES over 1, 3 or 5 years, respectively GICS-2 industry level cumulative sums over sums for S1INT, S2INT, S3UPINT, S3DOWNINT and INVEST/A for 1, 3 or 5 years for the Trucost sample. In Panel A.1 and B1., dependent variables are calculated across all firms in the broader GICS-2 industry except the given GICS-8 industry. In Panel A.2 and B.2, dependent variables are similarly calculated only for ever-patenting firms and in Panel A.3 and B.3 only for never-patenting firms. In Panel A, the key independent variables of interest are the GICS-8 industry level GREENRATIOEP PUBLIC and GREENRATIOEP PRIVATE and in Panel B the GICS-8 industry level BROWNEFFRATIOEP PUBLIC and BROWNEFFRATIOEP PRIVATE. Controls at the GICS-8 all firms (ever-patenting, respectively never patenting) level include *LOGSIZE*, *LOGPPE*, *LEVERAGE*, *ROE*, *M/B*, *INVEST/A*, *BETA*, *VOLAT*, *MOM*, *RET*, *MSCI*. Independent variables are either GICS-8 industry level logs of sums (LOGSIZE and LOGPPE), sum over sums (GREENRATIOEP, BROWNEFFRATIOEP, LEVERAGE, ROE, M/B, INVEST/A) or market capitalization weighted averages (BETA, VOLAT, MOM, RET, MSCI). All Independent variables are lagged by 1, 3 or 5 years respectively. The model is estimated using pooled regression model. All regression include year and industry fixed effects. We double cluster standard errors at the GICS-8 industry and year dimension. *** 1% significance, ** 5% significance * 10% significance.

	(1) LOGS1TOT	(2) LOGS2TOT	(3) LOGS3UPTOT	(4) LOGS3DOWNTOT	(5) S1INT	(6) S2INT	(7) S3UPINT	(8) S3DOWNINT	(9) INVEST/A	(10) LOGCAPEX	(11) LOGSALES
Panel A: Green innovation											
Panel A.1: GREENRATIOEP on all firms											
L1 GREENRATIOEP PUBLIC/100	8.280*	7.327	2.349	23.432	−16.982	5.085	−6.320	233.107	−0.008	0.047	1.980
	(4.460)	(6.824)	(5.165)	(21.464)	(26.596)	(3.194)	(5.842)	(173.471)	(0.025)	(2.782)	(5.575)
L1 GREENRATIOEP PRIVATE/100	−1.516	4.846	−6.096**	−14.892	−5.725	2.567	−5.545	−8.574	−0.027**	−3.423**	−4.393
	(2.665)	(5.238)	(2.989)	(9.937)	(21.433)	(2.173)	(3.578)	(147.237)	(0.013)	(1.735)	(3.157)
Observations	1314	1314	1314	371	1314	1314	1314	371	1314	1314	1314
R2	0.991	0.975	0.983	0.986	0.989	0.977	0.982	0.957	0.944	0.985	0.964
L3 GREENRATIOEP PUBLIC/100	5.226	−2.191	−1.337	−9.591	−10.427	1.825	−5.960	−304.854*	−0.006	−2.184	−1.071
	(3.366)	(5.038)	(5.440)	(19.128)	(21.717)	(2.685)	(4.491)	(154.208)	(0.028)	(2.536)	(5.731)
L3 GREENRATIOEP PRIVATE/100	−1.683	−0.219	−7.841***	5.560	31.812*	2.215	−1.423	85.377	−0.018	−3.927***	−7.262**
	(1.782)	(3.731)	(2.536)	(12.359)	(18.104)	(1.696)	(3.120)	(126.479)	(0.013)	(1.390)	(2.820)
Observations	1115	1115	1115	172	1115	1115	1115	172	1115	1115	1115
R2	0.996	0.986	0.988	0.998	0.993	0.985	0.990	0.995	0.957	0.989	0.972
L5 GREENRATIOEP PUBLIC/100	3.499	−0.204	1.210	9.621	−3.798	−2.394	−0.442	9.621	−0.039	−2.856	0.999
	(3.835)	(5.103)	(5.461)	(12.575)	(18.064)	(2.454)	(3.431)	(12.575)	(0.027)	(2.335)	(5.707)
L5 GREENRATIOEP PRIVATE/100	−3.581**	−1.040	−9.376***	−14.044*	50.118***	2.427	0.602	−14.044*	−0.010	−4.152***	−9.745***
	(1.388)	(3.139)	(2.255)	(7.314)	(16.161)	(1.616)	(2.447)	(7.314)	(0.011)	(1.407)	(2.551)
Observations	926	926	926	933	926	926	926	933	926	926	926
R2	0.998	0.991	0.991	0.114	0.995	0.990	0.995	0.114	0.970	0.992	0.979
3YEARAVGGREENRATIOEP	0.064	0.097	−0.066	−0.699**	−0.665*	0.075	−0.145	−1.497	0.000	−0.037	−0.081
PUBLIC/100	(0.062)	(0.115)	(0.069)	(0.333)	(0.382)	(0.046)	(0.098)	(2.713)	(0.000)	(0.040)	(0.072)
3YEARAVGGREENRATIOEP	−0.029	−0.042	−0.156***	−0.221**	0.654**	0.020	−0.050	−4.111***	−0.000***	−0.079***	−0.134***
PRIVATE/100	(0.030)	(0.073)	(0.038)	(0.108)	(0.277)	(0.029)	(0.060)	(1.567)	(0.000)	(0.023)	(0.038)
Observations	1460	1460	1460	411	1460	1460	1460	411	1460	1460	1460
R2	0.991	0.970	0.984	0.985	0.990	0.976	0.982	0.957	0.946	0.985	0.967
Panel A.2: GREENRATIOEP on ever patenting firms											
L1 GREENRATIOEP PUBLIC/100	−6.270	3.558	−3.944	39.689	−87.309**	2.512	−13.575*	391.410	−0.004	−3.432	0.086
	(6.171)	(5.953)	(4.779)	(30.401)	(41.507)	(3.209)	(7.329)	(293.564)	(0.017)	(3.240)	(4.970)
L1 GREENRATIOEP PRIVATE/100	−2.901	5.102	−6.466**	−12.979	−36.250	1.550	−7.257*	−24.937	−0.013	−5.737***	−4.190
	(3.659)	(5.134)	(2.931)	(10.961)	(32.315)	(2.103)	(3.829)	(169.707)	(0.009)	(2.129)	(3.018)
Observations	1305	1305	1305	368	1305	1305	1305	368	1305	1305	1305
R2	0.987	0.978	0.988	0.978	0.974	0.969	0.978	0.899	0.959	0.983	0.971
L3 GREENRATIOEP PUBLIC/100	−1.652	−4.825	−5.100	−26.067	−16.046	1.513	−8.714	−485.493**	0.005	−4.854	−4.081
	(4.404)	(4.717)	(3.701)	(32.307)	(18.186)	(3.455)	(5.607)	(226.235)	(0.018)	(2.991)	(4.871)
L3 GREENRATIOEP PRIVATE/100	−0.161	2.635	−7.357***	−48.029	12.540	3.017	−1.887	−240.666	−0.009	−7.142***	−7.149**
	(2.714)	(4.787)	(2.385)	(30.278)	(21.187)	(2.008)	(3.309)	(166.204)	(0.009)	(2.084)	(2.799)
Observations	1109	1109	1109	172	1109	1109	1109	172	1109	1109	1109
R2	0.994	0.987	0.993	0.995	0.988	0.979	0.988	0.984	0.969	0.987	0.979
L5 GREENRATIOEP PUBLIC/100	−6.441	−3.603	−6.005*	31.310***	−7.484	−2.868	−3.682	31.310***	−0.016	−8.008***	−3.650
	(4.595)	(4.004)	(3.403)	(10.169)	(14.257)	(3.132)	(4.699)	(10.169)	(0.017)	(2.768)	(4.901)
L5 GREENRATIOEP PRIVATE/100	−2.107	2.707	−7.677***	4.740	11.067	3.591**	0.496	4.740	−0.008	−6.327***	−8.646***
	(2.185)	(3.659)	(2.206)	(6.465)	(16.615)	(1.800)	(2.594)	(6.465)	(0.007)	(2.005)	(2.660)
Observations	921	921	921	933	921	921	921	933	921	921	921
R2	0.997	0.993	0.995	0.127	0.994	0.985	0.993	0.127	0.980	0.991	0.985
3YEARAVGGREENRATIOEP	−0.107	0.032	−0.131*	−0.654	−1.619**	0.018	−0.227*	−3.801	0.000	−0.150***	−0.122*
PUBLIC/100	(0.089)	(0.107)	(0.074)	(0.437)	(0.663)	(0.041)	(0.117)	(3.433)	(0.000)	(0.047)	(0.066)
3YEARAVGGREENRATIOEP	−0.035	0.011	−0.158***	−0.167	0.276	0.034	−0.042	−3.756**	−0.000**	−0.127***	−0.149***
PRIVATE/100	(0.043)	(0.080)	(0.037)	(0.139)	(0.443)	(0.030)	(0.064)	(1.793)	(0.000)	(0.028)	(0.037)
Observations	1444	1444	1444	404	1444	1444	1444	404	1444	1444	1444
R2	0.987	0.972	0.989	0.977	0.971	0.968	0.977	0.898	0.961	0.984	0.973
Panel A.3: GREENRATIOEP on never patenting firms											
L1 GREENRATIOEP PUBLIC/100	35.560***	1.319	2.843	9.163	16.470	5.087	2.023	155.658	−0.055	−1.432	−1.909
	(10.555)	(10.289)	(7.291)	(18.541)	(51.179)	(5.689)	(7.630)	(148.198)	(0.085)	(5.221)	(6.417)
L1 GREENRATIOEP PRIVATE/100	−4.616	2.819	−3.943	−11.639	77.020*	2.142	−4.752	32.147	−0.036	−4.019	−1.405
	(5.444)	(8.032)	(4.695)	(9.544)	(46.782)	(3.936)	(4.902)	(170.872)	(0.046)	(3.431)	(4.561)
Observations	1273	1273	1273	371	1273	1273	1273	371	1273	1273	1273
R2	0.974	0.941	0.969	0.994	0.987	0.969	0.977	0.993	0.903	0.967	0.958
L3 GREENRATIOEP PUBLIC/100	15.651*	−5.757	0.249	6.655	−15.246	−0.301	−2.337	−85.067	−0.075	−4.572	−0.477
	(8.437)	(7.522)	(7.205)	(12.709)	(38.046)	(2.232)	(6.431)	(108.943)	(0.072)	(3.962)	(6.129)
L3 GREENRATIOEP PRIVATE/100	−2.655	−4.759	−5.924	5.620	86.288**	−0.826	−5.778	50.901	−0.072*	−4.635	−1.276
	(4.746)	(6.039)	(4.104)	(7.333)	(42.279)	(1.578)	(4.411)	(75.653)	(0.041)	(3.133)	(4.037)
Observations	1065	1065	1065	172	1065	1065	1065	172	1065	1065	1065
R2	0.985	0.957	0.977	0.999	0.992	0.990	0.985	1.000	0.939	0.974	0.966
L5 GREENRATIOEP PUBLIC/100	6.583	−9.614	0.169	12.343	20.095	−3.244*	1.678	12.343	−0.082	−7.951**	0.767
	(9.025)	(6.782)	(7.130)	(10.399)	(31.180)	(1.771)	(5.305)	(10.399)	(0.077)	(3.796)	(6.012)
L5 GREENRATIOEP PRIVATE/100	−5.349*	−5.410	−9.010**	−10.096	97.418***	−0.113	−6.898**	−10.096	−0.063*	−6.108**	−4.223
	(2.995)	(5.061)	(3.767)	(7.374)	(36.378)	(1.179)	(3.216)	(7.374)	(0.037)	(2.955)	(3.647)
Observations	872	872	872	899	872	872	872	899	872	872	872
R2	0.993	0.967	0.984	0.103	0.995	0.995	0.992	0.103	0.961	0.980	0.974
3YEARAVGGREENRATIOEP	0.342**	−0.038	−0.125	−0.790***	−0.030	0.137*	−0.043	1.059	−0.001	−0.145**	−0.144*
PUBLIC/100	(0.163)	(0.149)	(0.099)	(0.204)	(0.698)	(0.078)	(0.112)	(2.742)	(0.001)	(0.068)	(0.085)
3YEARAVGGREENRATIOEP	0.068	0.016	−0.013	−0.002	1.575**	−0.010	−0.099	−2.750	−0.001**	−0.013	0.056
PRIVATE/100	(0.082)	(0.124)	(0.065)	(0.100)	(0.616)	(0.047)	(0.074)	(1.705)	(0.001)	(0.057)	(0.068)
Observations	1416	1416	1416	411	1416	1416	1416	411	1416	1416	1416
R2	0.974	0.938	0.969	0.994	0.988	0.968	0.976	0.993	0.906	0.967	0.959
Controls	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Year F.E.	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Industry F.E.	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes

	(1) LOGS1TOT	(2) LOGS2TOT	(3) LOGS3UPTOT	(4) LOGS3DOWNTOT	(5) S1INT	(6) S2INT	(7) S3UPINT	(8) S3DOWNINT	(9) INVEST/A	(10) LOGCAPEX	(11) LOGSALES
Panel B: Brown efficiency innovation											
Panel B.1: BROWNEFFRATIOEP on all firms											
L1 BROWNEFFRATIOEP PUBLIC/100	3.143	−5.589	4.690	7.505	−38.934	−7.519**	20.039	−40.740	−0.059	−2.297	1.827
	(7.946)	(8.013)	(6.451)	(15.392)	(38.663)	(3.423)	(12.226)	(160.160)	(0.038)	(2.940)	(6.992)
L1 BROWNEFFRATIOEP PRIVATE/100	2.876	−5.520	0.794	−26.340	−9.274	−3.897	−3.538	−35.380	−0.091***	−4.719	1.670
	(4.632)	(10.948)	(5.912)	(32.509)	(42.967)	(5.642)	(6.045)	(233.242)	(0.032)	(3.187)	(6.181)
Observations	1314	1314	1314	371	1314	1314	1314	371	1314	1314	1314
R2	0.991	0.975	0.983	0.986	0.989	0.977	0.983	0.956	0.945	0.984	0.964
L3 BROWNEFFRATIOEP PUBLIC/100	−5.693	7.075	0.776	44.946	−31.761	1.157	11.968	191.834	−0.044	−2.740	1.114
	(4.708)	(6.223)	(8.270)	(38.554)	(47.187)	(3.357)	(7.458)	(438.834)	(0.036)	(3.981)	(7.631)
L3 BROWNEFFRATIOEP PRIVATE/100	−1.945	−6.020	2.541	19.015	−67.035	−3.875	−5.271	263.626	−0.076***	−2.106	4.450
	(3.838)	(7.418)	(5.625)	(21.300)	(43.016)	(3.887)	(5.272)	(248.375)	(0.029)	(2.564)	(5.699)
Observations	1115	1115	1115	172	1115	1115	1115	172	1115	1115	1115
R2	0.996	0.986	0.988	0.998	0.993	0.985	0.990	0.994	0.958	0.989	0.972
L5 BROWNEFFRATIOEP PUBLIC/100	−1.139	8.005*	5.655	−20.372	−16.961	0.919	13.238*	−20.372	−0.011	1.879	3.785
	(3.595)	(4.650)	(5.310)	(16.097)	(35.689)	(4.274)	(7.262)	(16.097)	(0.031)	(2.748)	(5.023)
L5 BROWNEFFRATIOEP PRIVATE/100	−5.409	−3.890	−1.033	−4.332	−76.614*	−2.780	−1.532	−4.332	−0.032*	−0.011	−0.075
	(3.724)	(5.267)	(5.155)	(13.816)	(39.504)	(2.841)	(4.727)	(13.816)	(0.018)	(2.234)	(4.681)
Observations	926	926	926	933	926	926	926	933	926	926	926
R2	0.998	0.991	0.991	0.110	0.995	0.990	0.995	0.110	0.970	0.992	0.979
3YEARAVGBROWNEFFRATIOEP	−0.087	0.392***	0.084	−0.092	−0.715	0.028	−0.117	−5.446	−0.001*	0.073	0.173
PUBLIC/100	(0.110)	(0.151)	(0.122)	(0.650)	(0.691)	(0.083)	(0.197)	(9.787)	(0.001)	(0.090)	(0.133)
3YEARAVGBROWNEFFRATIOEP	−0.109	0.188	−0.006	−0.927**	−1.670**	−0.004	−0.150	−11.113**	−0.001***	−0.064	0.024
PRIVATE/100	(0.090)	(0.191)	(0.073)	(0.423)	(0.672)	(0.101)	(0.113)	(4.908)	(0.000)	(0.039)	(0.072)
Observations	1460	1460	1460	411	1460	1460	1460	411	1460	1460	1460
R2	0.991	0.970	0.984	0.985	0.990	0.976	0.982	0.957	0.946	0.985	0.967
Panel B.2: BROWNEFFRATIOEP on ever patenting firms											
L1 BROWNEFFRATIOEP PUBLIC/100	−5.973	−4.313	0.376	16.137	23.796	−6.508	15.818	105.936	−0.042**	−4.507	0.065
	(5.953)	(8.817)	(6.187)	(19.963)	(38.027)	(4.281)	(10.843)	(241.195)	(0.016)	(4.997)	(6.097)
L1 BROWNEFFRATIOEP PRIVATE/100	6.599	−9.218	−1.627	−27.443	5.726	−5.214	−5.865	−44.855	−0.037*	−4.767	−0.542
	(6.259)	(10.445)	(5.907)	(38.540)	(57.902)	(5.261)	(6.617)	(351.823)	(0.022)	(4.954)	(6.371)
Observations	1305	1305	1305	368	1305	1305	1305	368	1305	1305	1305
R2	0.987	0.978	0.988	0.978	0.973	0.969	0.978	0.898	0.959	0.983	0.971
L3 BROWNEFFRATIOEP PUBLIC/100	−12.441**	4.769	−2.352	78.701	−28.108	−1.031	10.614	377.226	−0.000	−1.423	−0.639
	(5.717)	(7.114)	(8.423)	(61.368)	(31.632)	(3.866)	(8.531)	(583.709)	(0.017)	(6.999)	(7.650)
L3 BROWNEFFRATIOEP PRIVATE/100	4.150	−6.583	0.624	60.649	28.185	−2.953	−4.866	644.377**	−0.030	−2.244	1.665
	(5.283)	(9.304)	(4.872)	(65.568)	(38.182)	(4.657)	(4.949)	(306.466)	(0.020)	(4.221)	(5.625)
Observations	1109	1109	1109	172	1109	1109	1109	172	1109	1109	1109
R2	0.994	0.987	0.992	0.995	0.988	0.978	0.988	0.985	0.970	0.987	0.979
L5 BROWNEFFRATIOEP PUBLIC/100	−5.808	6.139	1.654	−1.869	−20.527	0.707	9.848	−1.869	0.010	4.010	2.459
	(4.242)	(4.924)	(5.964)	(16.689)	(25.111)	(5.014)	(8.304)	(16.689)	(0.018)	(4.617)	(5.616)
L5 BROWNEFFRATIOEP PRIVATE/100	−1.059	−5.127	0.047	−0.171	15.585	−3.237	−0.711	−0.171	−0.014	2.361	0.481
	(4.991)	(6.570)	(5.065)	(13.806)	(36.925)	(3.723)	(4.499)	(13.806)	(0.013)	(3.698)	(4.816)
Observations	921	921	921	933	921	921	921	933	921	921	921
R2	0.997	0.993	0.995	0.118	0.994	0.985	0.993	0.118	0.980	0.991	0.984
3YEARAVGBROWNEFFRATIOEP	−0.358**	0.346**	−0.065	−0.318	−1.208	0.050	−0.239	−7.885	−0.000	−0.071	0.097
PUBLIC/100	(0.143)	(0.173)	(0.130)	(0.775)	(0.919)	(0.083)	(0.202)	(11.797)	(0.000)	(0.107)	(0.140)
3YEARAVGBROWNEFFRATIOEP	−0.085	0.129	−0.051	−0.926*	−1.398	−0.031	−0.242**	−10.925*	−0.001**	−0.116**	−0.003
PRIVATE/100	(0.115)	(0.196)	(0.077)	(0.525)	(0.939)	(0.101)	(0.116)	(5.680)	(0.000)	(0.054)	(0.073)
Observations	1444	1444	1444	404	1444	1444	1444	404	1444	1444	1444
R2	0.987	0.972	0.988	0.977	0.971	0.968	0.977	0.898	0.961	0.983	0.972
Panel B.3: BROWNEFFRATIOEP on never patenting firms											
L1 BROWNEFFRATIOEP PUBLIC/100	12.652	−2.111	20.617**	−19.545	−118.973	−10.287*	39.007**	−139.761	−0.104	5.824	9.584
	(20.442)	(14.917)	(9.201)	(12.455)	(91.657)	(5.527)	(18.152)	(128.509)	(0.110)	(5.926)	(10.238)
L1 BROWNEFFRATIOEP PRIVATE/100	−8.080	−3.510	−1.246	−5.726	−26.377	3.235	−3.479	−30.901	−0.237***	−8.896	−0.085
	(11.207)	(13.500)	(8.809)	(18.924)	(120.042)	(8.217)	(7.992)	(158.910)	(0.080)	(6.496)	(7.969)
Observations	1273	1273	1273	371	1273	1273	1273	371	1273	1273	1273
R2	0.973	0.941	0.969	0.994	0.987	0.969	0.977	0.993	0.903	0.967	0.958
L3 BROWNEFFRATIOEP PUBLIC/100	2.472	18.274	11.709	−3.784	−122.015	5.115	19.047*	30.574	−0.160	0.330	7.489
	(16.331)	(14.505)	(11.715)	(17.275)	(88.459)	(4.268)	(11.300)	(234.285)	(0.099)	(7.050)	(10.180)
L3 BROWNEFFRATIOEP PRIVATE/100	−12.779	−0.858	5.306	14.336	−219.660*	−3.741	−7.411	9.582	−0.170**	−0.163	8.324
	(9.820)	(9.069)	(7.818)	(9.087)	(112.214)	(3.786)	(10.121)	(66.457)	(0.067)	(5.520)	(6.713)
Observations	1065	1065	1065	172	1065	1065	1065	172	1065	1065	1065
R2	0.985	0.957	0.977	0.999	0.992	0.990	0.985	1.000	0.939	0.974	0.966
L5 BROWNEFFRATIOEP PUBLIC/100	−8.601	8.703	10.664	−2.721	−87.553	0.533	15.106*	−2.721	−0.118	−0.677	5.337
	(13.621)	(10.220)	(8.099)	(17.038)	(68.480)	(3.521)	(8.936)	(17.038)	(0.086)	(5.297)	(7.212)
L5 BROWNEFFRATIOEP PRIVATE/100	−9.812	15.756**	5.592	18.900	−222.718**	2.056	−2.440	18.900	−0.059	5.602	5.809
	(7.374)	(7.931)	(7.105)	(12.819)	(107.149)	(2.508)	(8.593)	(12.819)	(0.071)	(4.624)	(5.972)
Observations	872	872	872	899	872	872	872	899	872	872	872
R2	0.993	0.967	0.984	0.102	0.995	0.995	0.992	0.102	0.961	0.980	0.974
3YEARAVGBROWNEFFRATIOEP	0.201	0.277	0.273	−0.466	−0.869	−0.019	0.193	−4.757	−0.003	0.189	0.218
PUBLIC/100	(0.273)	(0.252)	(0.184)	(0.443)	(1.379)	(0.130)	(0.216)	(8.060)	(0.002)	(0.133)	(0.172)
3YEARAVGBROWNEFFRATIOEP	−0.204	0.078	−0.102	−0.443	−2.001	0.090	−0.158	−11.054**	−0.002	−0.095	−0.069
PRIVATE/100	(0.185)	(0.237)	(0.122)	(0.276)	(1.752)	(0.139)	(0.152)	(4.943)	(0.001)	(0.094)	(0.116)
Observations	1416	1416	1416	411	1416	1416	1416	411	1416	1416	1416
R2	0.974	0.938	0.969	0.994	0.988	0.968	0.976	0.993	0.906	0.967	0.959
Controls	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Year F.E.	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Industry F.E.	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes

TABLE 13: PATENT RATIOS AND FIRM-LEVEL MARKET SHARE

The unit of observation is firm-year and covers both public and private firms, as we do not rely on public firms' emission data. The sample period is 2005 to 2020. The dependent variable is MKTSHR GICS6, which is a firm's market share based on its sales relative to total public and private firms' sales in a given GICS6 industry. The key dependent variable is *GREENRATIOEP* lagged by 1, 3, or 5 years in columns 1 to 3 and *BROWNEFFRATIOEP* lagged by 1, 3 or 5 years in column 4 to 6. Controls include: *LOGASSETS*, *LOGPPE*, *LEVERAGE*, *ROE*, *INVEST/A*, and, *PUBLIC*. *LOGASSETS* is the log of total assets in million USD and *PUBLIC* is an indicator equal to 1 for public firms. All other variables are defined in Table 1 and Table 2. All independent variables are lagged by 1, 3, or 5 years. The model is estimated using pooled regression model. In Panel A we include country and GICS6 industry-year fixed effects and in Panel B firm and year fixed effects. We double cluster standard errors at the firm and year dimension. *** 1% significance, ** 5% significance * 10% significance.

	(1)	(2)	(3)	(4)	(5)	(6)
	MKTSHR GICS6					
Panel A: Country and Industry-Year Fixed Effects						
L1 GREENRATIOEP	−0.076***					
	(0.028)					
L3 GREENRATIOEP		−0.070**				
		(0.032)				
L5 GREENRATIOEP			−0.122***			
			(0.043)			
L1 BROWNEFFRATIOEP				0.034		
				(0.049)		
L3 BROWNEFFRATIOEP					0.028	
					(0.053)	
L5 BROWNEFFRATIOEP						−0.010
						(0.067)
Observations	44202	34043	25036	44202	34043	25036
R2	0.462	0.469	0.477	0.461	0.469	0.477
Controls	yes	yes	yes	yes	yes	yes
Country F.E.	yes	yes	yes	yes	yes	yes
GICS6-Year F.E.	yes	yes	yes	yes	yes	yes
Panel B: Firm and Year Fixed Effects						
L1 GREENRATIOEP	−0.025					
	(0.021)					
L3 GREENRATIOEP		−0.046*				
		(0.025)				
L5 GREENRATIOEP			−0.042			
			(0.029)			
L1 BROWNEFFRATIOEP				0.017		
				(0.042)		
L3 BROWNEFFRATIOEP					0.040	
					(0.037)	
L5 BROWNEFFRATIOEP						−0.012
						(0.046)
Observations	43346	33147	24189	43346	33147	24189
R2	0.869	0.887	0.903	0.869	0.887	0.903
Controls	yes	yes	yes	yes	yes	yes
Year F.E.	yes	yes	yes	yes	yes	yes
Firm F.E.	yes	yes	yes	yes	yes	yes

TABLE 14: EX-POST CHARACTERISTICS OF EMISSION DECREASING VS INCREASING FIRMS

The unit of observation is firm-year and the sample period is 2005 to 2020. Panel A covers total scope 1 emissions. To split firms in emission reduction samples (column 1 to 4) and emission increase samples (column 5 to 8) we calculate changes in emissions over three years. Panel B defines emission reduction firms as those that decreased emissions across scope 1, 2 and upstream 3 and emission increase firms as all others. We calculate mean, standard deviation, median and the count for each sample as well as the difference and p-value between the two samples for a variety of variables at the three year lag. Panel A.1 and B.1 cover the full Trucost sample. Panel A.2 and B.2 zoom in on the Trucost sample with at least one patent at the European Patent Office and the greatest emission change. Within the emission decrease sample, we focus on the 50% with the greatest emission decrease. Similarly within the emission increase sample, we focus on the 50% with the greatest emission increase. DUMMYANYEP (DUMMYGREENEP, DUMMYBROWNEFFEP, and DUMMYOECDEP) are dummies equal to one if a firm has at least one (one green, one brown efficiency and one OECD env-tech) patent and zero otherwise. SALES3YRCHG is the change in sales across the three year period in decimals. All other variables are defined in Table 1, Table 2 and Table 4.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Emission decrease sample				Emission increase sample				Difference	
	Mean	Std. Dev.	Median	Count	Mean	Std. Dev.	Median	Count	Difference	p-value
Panel A: 3-year changes in scope 1 emissions										
Panel A.1: Patenting and non-patenting firms										
DUMMYANYEP	0.310	0.463	0	32068	0.280	0.449	0	39100	0.030	0.000
DUMMYGREENEP	0.149	0.356	0	32068	0.116	0.321	0	39100	0.032	0.000
DUMMYBROWNEFFEP	0.069	0.253	0	32068	0.054	0.226	0	39100	0.015	0.000
DUMMYOECDEP	0.154	0.361	0	32068	0.120	0.324	0	39100	0.035	0.000
AGE	47.252	38.678	34.000	29809	41.075	35.860	28.000	36468	6.177	0.000
LOGSIZE	7.752	1.667	7.782	32068	7.665	1.565	7.722	39100	0.086	0.000
LOGPPE	6.055	2.336	6.237	32068	5.794	2.298	5.980	39100	0.261	0.000
MB	2.373	2.676	1.588	32068	2.826	2.962	1.903	39100	−0.453	0.000
LEVERAGE	23.937	17.967	22.294	32068	23.249	18.279	21.290	39100	0.688	0.000
ROE	10.749	26.144	10.388	32068	11.872	23.995	11.544	39100	−1.123	0.000
SALES3YRCHG	−0.094	0.524	−0.024	32004	0.327	0.512	0.249	39034	−0.421	0.000
Panel A.2: Firm-years with at least one EP patent & greatest emission decreases, resp. increases										
GREENRATIOEP	11.944	23.526	0	4973	11.589	24.309	0	5478	0.355	0.449
BROWNEFFRATIOEP	3.776	13.151	0	4973	3.542	13.569	0	5478	0.234	0.371
OECDRATIOEP	13.354	24.952	0	4973	11.530	23.606	0	5478	1.823	0.000
GREENCITMAXEP	65.316	561.564	0	4973	56.955	532.163	0	5478	8.361	0.436
BROWNEFFCITMAXEP	14.912	210.829	0	4973	8.502	51.493	0	5478	6.410	0.037
GREENCOUNTBBEP	0.260	1.128	0	4973	0.195	1.007	0	5478	0.066	0.002
BROWNEFFCOUNTBBEP	0.107	0.834	0	4973	0.057	0.472	0	5478	0.049	0.000
AGE	55.569	41.713	44.000	4929	46.442	39.625	32.000	5443	9.127	0.000
LOGSIZE	8.365	1.589	8.363	4973	8.134	1.593	8.133	5478	0.231	0.000
LOGPPE	6.719	2.017	6.813	4973	6.169	2.151	6.312	5478	0.550	0.000
MB	2.609	2.714	1.837	4973	3.312	3.291	2.285	5478	−0.703	0.000
LEVERAGE	22.636	15.588	21.787	4973	22.143	16.984	21.209	5478	0.493	0.122
ROE	9.536	27.992	10.644	4973	9.088	28.816	11.344	5478	0.447	0.421
SALES3YRCHG	−0.110	0.553	−0.020	4968	0.429	0.599	0.350	5474	−0.539	0.000
Panel B: Ex-post characteristics of firms decreasing absolute emissions across scope 1, 2, and upstream 3										
Panel B.1: Patenting and non-patenting firms										
DUMMYANYEP	0.260	0.439	0	16298	0.304	0.460	0	54950	−0.044	0.000
DUMMYGREENEP	0.115	0.319	0	16298	0.136	0.342	0	54950	−0.021	0.000
DUMMYBROWNEFFEP	0.054	0.225	0	16298	0.063	0.242	0	54950	−0.009	0.000
DUMMYOECDEP	0.119	0.324	0	16298	0.140	0.347	0	54950	−0.020	0.000
AGE	44.742	37.286	32.000	15124	43.565	37.259	30	51227	1.177	0.001
LOGSIZE	7.411	1.690	7.461	16298	7.792	1.578	7.826	54950	−0.381	0.000
LOGPPE	5.697	2.406	5.863	16298	5.973	2.289	6.160	54950	−0.276	0.000
MB	2.244	2.588	1.509	16298	2.734	2.907	1.829	54950	−0.490	0.000
LEVERAGE	24.227	18.693	22.417	16298	23.357	17.968	21.546	54950	0.870	0.000
ROE	8.589	28.284	9.361	16298	12.192	23.852	11.467	54950	−3.603	0.000
SALES3YRCHG	−0.299	0.592	−0.168	16254	0.267	0.477	0.204	54864	−0.566	0.000
Panel B.2: Firm-years with at least one EP patent & greatest emission decreases, resp. increases										
GREENRATIOEP	12.232	24.679	0	2256	11.822	23.423	0	8469	0.410	0.478
BROWNEFFRATIOEP	4.187	14.338	0	2256	3.830	13.524	0	8469	0.357	0.288
OECDRATIOEP	13.448	25.767	0	2256	12.285	23.507	0	8469	1.163	0.052
GREENCITMAXEP	58.520	554.662	0	2256	69.971	789.631	0	8469	−11.451	0.429
BROWNEFFCITMAXEP	17.191	306.872	0	2256	10.717	52.799	0	8469	6.474	0.318
GREENCOUNTBBEP	0.236	1.090	0	2256	0.249	1.201	0	8469	−0.013	0.614
BROWNEFFCOUNTBBEP	0.116	0.996	0	2256	0.084	0.637	0	8469	0.032	0.147
AGE	54.519	42.417	43.000	2240	52.884	42.120	39.000	8406	1.634	0.105
LOGSIZE	8.096	1.722	8.086	2256	8.366	1.642	8.333	8469	−0.270	0.000
LOGPPE	6.470	2.300	6.690	2256	6.622	2.158	6.704	8469	−0.152	0.005
MB	2.402	2.613	1.711	2256	3.028	3.113	2.065	8469	−0.625	0.000
LEVERAGE	23.427	16.196	22.574	2256	22.937	16.493	22.141	8469	0.490	0.203
ROE	5.718	32.059	9.094	2256	10.529	27.509	11.311	8469	−4.810	0.000
SALES3YRCHG	−0.402	0.640	−0.258	2252	0.310	0.530	0.225	8465	−0.713	0.000

TABLE 15: LONG PATENT RATIOS AND FIRM LEVEL OUTCOMES

The unit of observation is firm-year. The dependent variables are DIFS1TOT, DIFS2TOT, DIFS3UPTOT, DIFS1INT, DIFS2INT, DIFS3UPINT, DIFCAPEX, DIFINVEST/A, and DIFSALES, which are differences between the 2015 to 2020 average and the 2005 to 2014 average for scope 1 (2 and upstream 3) total emission (in kilo tonnes), scope 1 (2 and upstream 3) intensities, capital expenditures (in million USD), investment/assets, and sales (in million USD). We winsorize all differences at the 2.5% and 97.5% level. In Panel A the key independent variable is a long cumulative green (brown efficiency) patent ratio from 1990 to 2004, respectively 1990 to 2014. In Panel B the key independent variable is similarly a long cumulative green (brown efficiency) patent count from 1990 to 2004, respectively 1990 to 2014. Control variables include *LOGSIZE*, *LOGPPE*, *LEVERAGE*, *ROE*, *M/B*, *INVEST/A*, *BETA*, *VOLAT*, *MOM*, *RET*, *MSCI* and are averages between 2004 and 2014. Logarithmic values are first averaged before taking the logarithm. The model is estimated using pooled regression model. All regression include country and GICS-6 industry fixed effects. We cluster standard errors at the GICS-6 industry dimension. *** 1% significance, ** 5% significance * 10% significance.

	(1) DIFS1TOT	(2) DIFS2TOT	(3) DIFS3UPTOT	(4) DIFS1INT	(5) DIFS2INT	(6) DIFS3UPINT	(7) DIFCAPEX	(8) DIFINVEST/A	(9) DIFSALES
Panel A: Long patent ratios									
Panel A.1: Green innovation									
Panel A.1.1: GREENSTOCKRATIOEP between 1990 and 2004									
GREENSTOCKRATIOEP04	75.203	24.542	102.814	−0.013	−0.003	0.004	0.726	−0.039	55.272*
	(73.411)	(18.622)	(65.778)	(0.009)	(0.004)	(0.007)	(2.814)	(0.024)	(32.521)
Observations	1863	1863	1863	1863	1863	1863	1863	1863	1863
R2	0.157	0.227	0.215	0.179	0.197	0.0987	0.290	0.257	0.322
Panel A.1.2: GREENSTOCKRATIOEP between 1990 and 2014									
GREENSTOCKRATIOEP14	22.870	15.093	46.439	0.009	0.000	−0.001	−1.051	−0.057*	18.040
	(61.876)	(16.411)	(37.061)	(0.011)	(0.003)	(0.004)	(3.432)	(0.029)	(23.007)
Observations	2714	2714	2714	2714	2714	2714	2714	2714	2714
R2	0.158	0.202	0.197	0.157	0.178	0.0824	0.255	0.248	0.291
Panel A.2: Brown efficiency innovation									
Panel A.2.1: BROWNEFFSTOCKRATIOEP between 1990 and 2004									
BROWNEFFSTOCKRATIOEP04	128.610	0.391	−142.637	0.023	−0.002	−0.016*	1.110	0.071*	−13.470
	(169.306)	(33.097)	(136.552)	(0.014)	(0.005)	(0.008)	(4.697)	(0.039)	(45.198)
Observations	1863	1863	1863	1863	1863	1863	1863	1863	1863
R2	0.157	0.226	0.215	0.179	0.197	0.101	0.290	0.257	0.321
Panel A.2.2: BROWNEFFSTOCKRATIOEP between 1990 and 2014									
BROWNEFFSTOCKRATIOEP14	−91.677	−14.699	−104.420	0.011	−0.001	−0.022***	2.663	−0.019	73.016*
	(160.687)	(28.900)	(86.969)	(0.032)	(0.004)	(0.007)	(3.749)	(0.027)	(43.684)
Observations	2714	2714	2714	2714	2714	2714	2714	2714	2714
R2	0.159	0.202	0.197	0.157	0.178	0.0873	0.255	0.246	0.292
Panel B: Long patent counts									
Panel A.1: Green innovation									
Panel B.1.1: GREENSTOCKCOUNTEP between 1990 and 2004									
GREENSTOCKCOUNTEP04/100	−857.522**	−143.944	−917.436***	−0.014	−0.006	−0.015	−42.715*	−0.027	−454.207***
	(394.550)	(98.038)	(314.020)	(0.014)	(0.007)	(0.009)	(21.467)	(0.044)	(165.993)
Observations	1863	1863	1863	1863	1863	1863	1863	1863	1863
R2	0.166	0.229	0.227	0.179	0.197	0.0995	0.302	0.256	0.333
Panel B.1.2: GREENSTOCKCOUNTEP between 1990 and 2014									
GREENSTOCKCOUNTEP14/100	−189.156**	18.559	−79.415	−0.008*	0.001	−0.001	−3.661	−0.002	−40.203
	(74.718)	(22.162)	(63.528)	(0.004)	(0.001)	(0.002)	(3.434)	(0.013)	(31.730)
Observations	2714	2714	2714	2714	2714	2714	2714	2714	2714
R2	0.166	0.203	0.199	0.158	0.178	0.0825	0.257	0.246	0.293
Panel B.2: Brown efficiency innovation									
Panel B.2.1: BROWNEFFSTOCKCOUNTEP between 1990 and 2004									
BROWNEFFSTOCKCOUNTEP04/100	−702.922	−22.974	−1189.932*	0.038	−0.001	−0.062***	−55.714	−0.020	−344.058
	(867.095)	(183.041)	(601.951)	(0.064)	(0.014)	(0.017)	(34.163)	(0.087)	(255.757)
Observations	1863	1863	1863	1863	1863	1863	1863	1863	1863
R2	0.159	0.226	0.220	0.179	0.197	0.104	0.295	0.256	0.323
Panel B.2.2: BROWNEFFSTOCKCOUNTEP between 1990 and 2014									
BROWNEFFSTOCKCOUNTEP14/100	−291.154	3.107	−220.098	0.002	−0.001	−0.008*	−9.221	0.015	−73.058
	(251.204)	(53.174)	(178.476)	(0.016)	(0.003)	(0.004)	(9.044)	(0.023)	(79.393)
Observations	2714	2714	2714	2714	2714	2714	2714	2714	2714
R2	0.161	0.202	0.199	0.157	0.178	0.0833	0.257	0.246	0.292
Controls	yes	yes	yes	yes	yes	yes	yes	yes	yes
Country F.E.	yes	yes	yes	yes	yes	yes	yes	yes	yes
Industry F.E.	yes	yes	yes	yes	yes	yes	yes	yes	yes

TABLE 16: PATENT RATIOS EXPLANATORY POWER

The unit of observation is firm-year. The sample period is 2005 to 2020. The dependent variables are logs of cumulative sums of S1TOT, S2TOT, S3UPTOT, S3DOWNTOT and S123UPTOT over 1, 3 or 5 years, respectively long-term averages of S1INT, S2INT, S3UPINT and S3DOWNINT for 1, 3 or 5 years. The key independent variable is *GREENRATIOEP* lagged by 1, 3, or 5 years as well as a 3-year rolling ratio lagged by 1 year in Panel A. In Panel B, the key independent variable is similarly defined for *BROWNEFFRATIOEP*. The ratios are defined in Table 2. Controls include: *LOGSIZE*, *LOGPPE*, *LEVERAGE*, *ROE*, *M/B*, *INVEST/A*, *BETA*, *VOLAT*, *MOM*, *RET* and *MSCI*. All variables are similarly lagged by 1, 3, or 5 years and defined in Table 1. The model is estimated using pooled regression model. All regressions include country and year fixed effects. We report the partial R2 for the key independent variable GREENRATIOEP or BROWNEFFRATIOEP. We also report the R2 for the full model and the reduced model with all fixed effects and controls except for the patent ratio variable. We double cluster standard errors at the firm and year dimension. *** 1% significance, ** 5% significance * 10% significance.

	(1) LOGS1TOT	(2) LOGS2TOT	(3) LOGS3UPTOT	(4) LOGS3DOWNTOT	(5) LOGS123UPTOT	(6) S1INT	(7) S2INT	(8) S3UPINT	(9) S3DOWNINT
Panel A: Green innovation									
L1 GREENRATIOEP	0.514***	−0.199***	−0.059**	0.153	0.111***	1.385***	0.042***	0.146***	4.168***
	(0.041)	(0.033)	(0.029)	(0.097)	(0.028)	(0.128)	(0.013)	(0.036)	(0.610)
Partial R2	0.00596	0.00167	0.000172	0.000219	0.000628	0.00760	0.000378	0.000552	0.00579
R2 Full Model	0.668	0.742	0.785	0.459	0.810	0.149	0.171	0.226	0.106
R2 Reduced Model	0.666	0.742	0.785	0.459	0.809	0.143	0.171	0.225	0.101
Observations	31049	31049	31048	11600	31049	31049	31049	31049	11600
L3 GREENRATIOEP	0.592***	−0.199***	−0.022	0.172	0.172***	1.553***	0.040**	0.145***	4.720***
	(0.048)	(0.039)	(0.034)	(0.145)	(0.032)	(0.157)	(0.016)	(0.043)	(0.956)
Partial R2	0.00748	0.00163	0.0000243	0.000293	0.00151	0.00868	0.000320	0.000518	0.00712
R2 Full Model	0.659	0.731	0.765	0.493	0.795	0.159	0.187	0.218	0.113
R2 Reduced Model	0.656	0.730	0.765	0.493	0.795	0.152	0.186	0.217	0.106
Observations	23485	23485	23485	5419	23485	23485	23485	23485	5428
L5 GREENRATIOEP	0.695***	−0.253***	0.017		0.234***	1.789***	0.009	0.146***	
	(0.060)	(0.048)	(0.040)		(0.039)	(0.200)	(0.019)	(0.054)	
Partial R2	0.00954	0.00251	0.0000144		0.00270	0.0100	0.0000167	0.000484	
R2 Full Model	0.635	0.701	0.730		0.768	0.168	0.196	0.209	
R2 Reduced Model	0.631	0.700	0.730		0.767	0.159	0.196	0.209	
Observations	16892	16892	16892		16892	16892	16892	16892	
L1 3YEARAVGGREENRATIOEP	0.552***	−0.226***	−0.069**	0.239***	0.129***	1.561***	0.057***	0.185***	5.290***
	(0.038)	(0.032)	(0.027)	(0.091)	(0.027)	(0.126)	(0.013)	(0.035)	(0.603)
Partial R2	0.00620	0.00192	0.000205	0.000480	0.000748	0.00836	0.000626	0.000793	0.00808
R2 Full Model	0.670	0.740	0.782	0.460	0.807	0.150	0.168	0.214	0.111
R2 Reduced Model	0.668	0.739	0.782	0.460	0.807	0.143	0.167	0.213	0.104
Observations	38934	38934	38933	15245	38934	38934	38934	38934	15245
Panel B: Brown efficiency innovation									
L1 BROWNEFFRATIOEP	0.511***	−0.374***	0.578***	1.656***	0.584***	1.604***	−0.210***	0.637***	9.014***
	(0.071)	(0.062)	(0.047)	(0.193)	(0.043)	(0.287)	(0.021)	(0.064)	(1.383)
Partial R2	0.00185	0.00185	0.00519	0.00709	0.00548	0.00320	0.00294	0.00331	0.00744
R2 Full Model	0.667	0.742	0.786	0.463	0.811	0.146	0.173	0.228	0.108
R2 Reduced Model	0.666	0.742	0.785	0.459	0.809	0.143	0.171	0.225	0.101
Observations	31049	31049	31048	11600	31049	31049	31049	31049	11600
L3 BROWNEFFRATIOEP	0.531***	−0.474***	0.571***	1.613***	0.597***	2.030***	−0.229***	0.626***	8.168***
	(0.085)	(0.072)	(0.056)	(0.259)	(0.052)	(0.352)	(0.025)	(0.073)	(1.969)
Partial R2	0.00201	0.00309	0.00534	0.00714	0.00606	0.00494	0.00354	0.00322	0.00588
R2 Full Model	0.657	0.731	0.766	0.497	0.796	0.156	0.189	0.220	0.111
R2 Reduced Model	0.656	0.730	0.765	0.493	0.795	0.152	0.186	0.217	0.106
Observations	23485	23485	23485	5419	23485	23485	23485	23485	5428
L5 BROWNEFFRATIOEP	0.584***	−0.576***	0.589***		0.629***	2.338***	−0.273***	0.659***	
	(0.102)	(0.084)	(0.064)		(0.062)	(0.426)	(0.029)	(0.086)	
Partial R2	0.00245	0.00474	0.00599		0.00705	0.00620	0.00504	0.00359	
R2 Full Model	0.632	0.701	0.732		0.769	0.165	0.200	0.211	
R2 Reduced Model	0.631	0.700	0.730		0.767	0.159	0.196	0.209	
Observations	16892	16892	16892		16892	16892	16892	16892	
L1 3YEARAVGBROWNEFFRATIOEP	0.587***	−0.488***	0.599***	1.528***	0.622***	2.065***	−0.215***	0.720***	8.439***
	(0.068)	(0.060)	(0.045)	(0.176)	(0.042)	(0.283)	(0.021)	(0.060)	(1.279)
Partial R2	0.00212	0.00270	0.00469	0.00575	0.00521	0.00442	0.00274	0.00362	0.00603
R2 Full Model	0.669	0.740	0.783	0.463	0.808	0.146	0.169	0.216	0.109
R2 Reduced Model	0.668	0.739	0.782	0.460	0.807	0.143	0.167	0.213	0.104
Observations	38934	38934	38933	15245	38934	38934	38934	38934	15245
Controls	yes	yes	yes	yes	yes	yes	yes	yes	yes
Country F.E.	yes	yes	yes	yes	yes	yes	yes	yes	yes
Year F.E.	yes	yes	yes	yes	yes	yes	yes	yes	yes

FIGURE 1: COMPARING GREEN AND OECD TITLES

The sample is all patents granted by the European Patent Office from 2005 to 2020 that belong to the Trucost sample. Wordclouds display the top 100 words (unigrams) based on the TF-IDF comparing patent titles of GREEN patents to OECD env-tech patents, respectively OECD env-tech to GREEN patents.

(A) "GREEN" AGAINST "OECD"

(B) "OECD" AGAINST "GREEN"

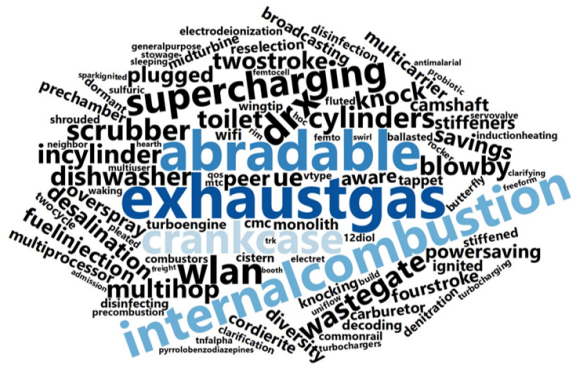
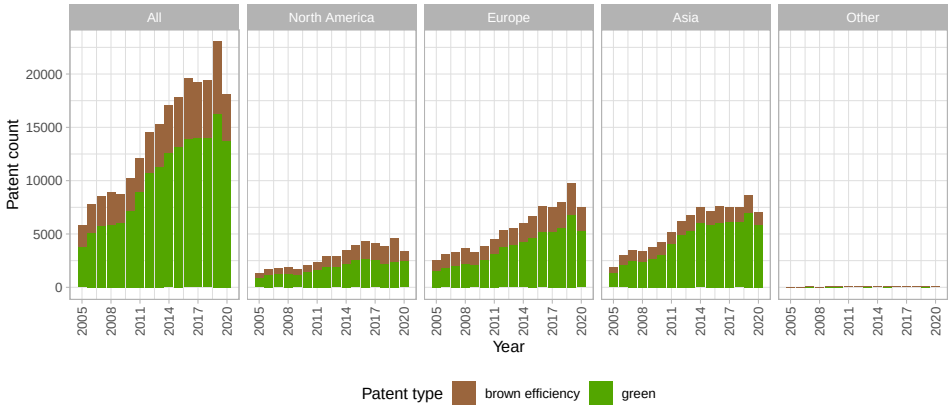


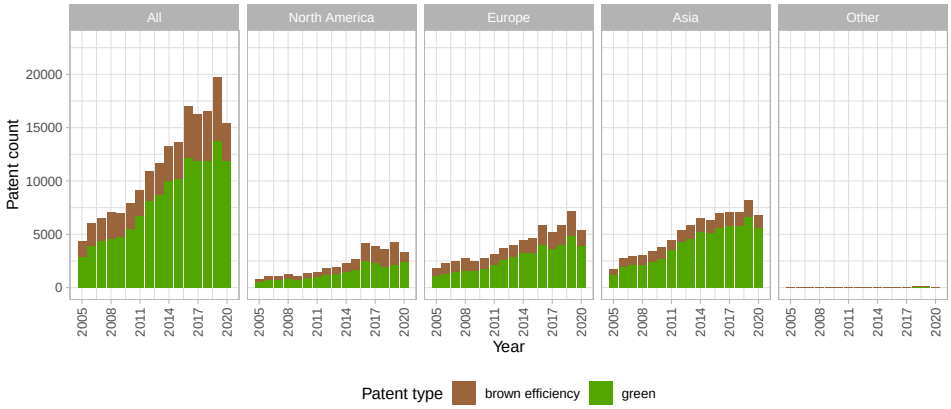
FIGURE 2: GREEN AND BROWN EFFICIENCY EPO PATENT COUNTS ACROSS REGIONS

The sample period is 2005 to 2020. We report the total number of granted or purchased green and brown efficiency EPO patents across all regions and by region, namely North America, Europe, Asia, and other (rest of the world), per year. In Panel A the sample covers the full sample, i.e all public and private firms. In Panel B the sample covers only public firms with emission data from Trucost and in Panel C we restrict the sample inclusion further to those firms that Trucost covers in its database before 2016.

(A) FULL (PUBLIC/PRIVATE) SAMPLE



(B) TRUCOST SAMPLE



(C) TRUCOST (PRE 2016) LEGACY SAMPLE

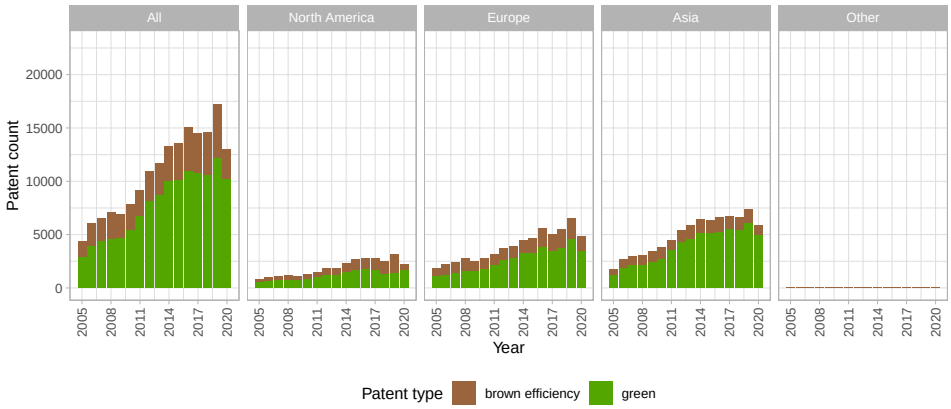
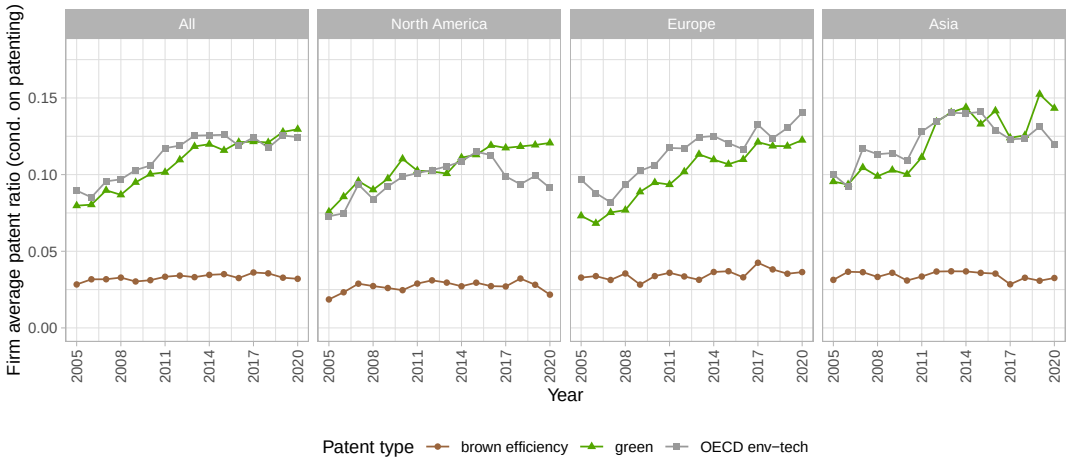


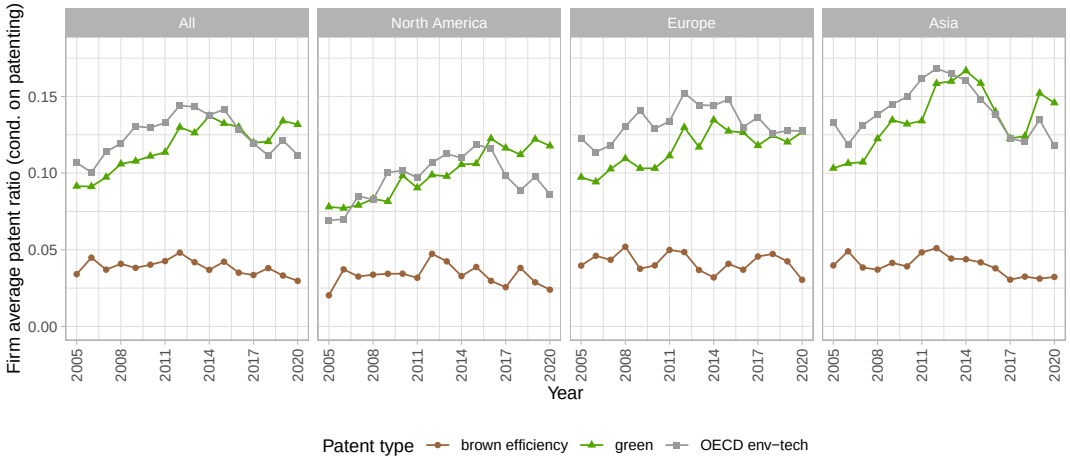
FIGURE 3: GREEN AND BROWN EFFICIENCY EPO PATENT RATIOS ACROSS REGIONS

The sample period is 2005 to 2020. We report the average GREENRATIOEP, BROWNEFFRATIOEP and OECDRATIOEP across all regions and for the regions North America, Europe and Asia per year. Patent ratios are defined in Table 2. In Panel A the sample covers the full sample, i.e all public and private firms. In Panel B the sample covers only public firms with emission data from Trucost and in Panel C we restrict the sample inclusion further to those firms that Trucost covers in its database before 2016.

(A) FULL (PUBLIC/PRIVATE) SAMPLE



(B) TRUCOST SAMPLE



(C) TRUCOST (PRE 2016) LEGACY SAMPLE

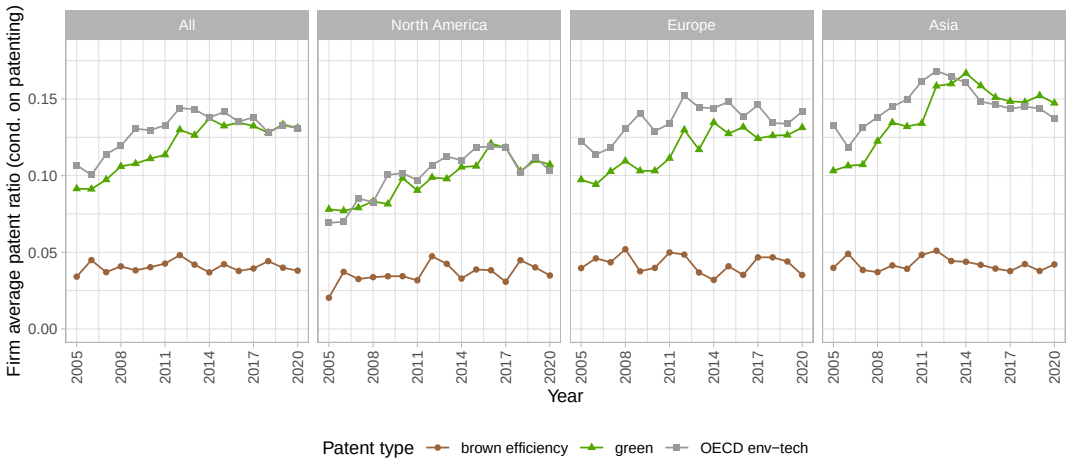
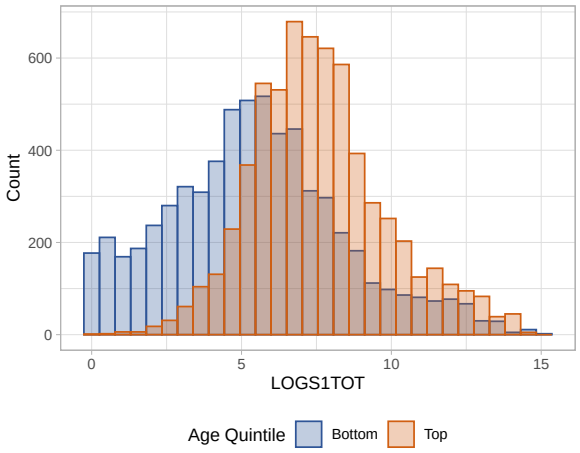


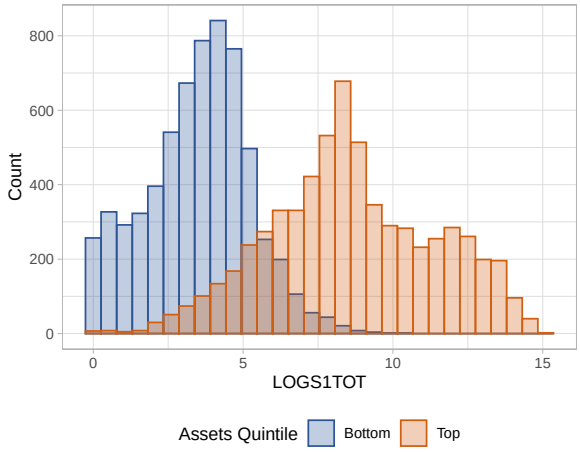
FIGURE 4: EMISSION DISTRIBUTION FOR DIFFERENT QUINTILES

The sample period is 2005 to 2020. We report histograms for LOGS1TOT for unconditional top and bottom quintiles based on "AGE" in Panel A, "ASSETS" in Panel B, and "M/B" in Panel C. All variables are defined in Table 1 and 2.

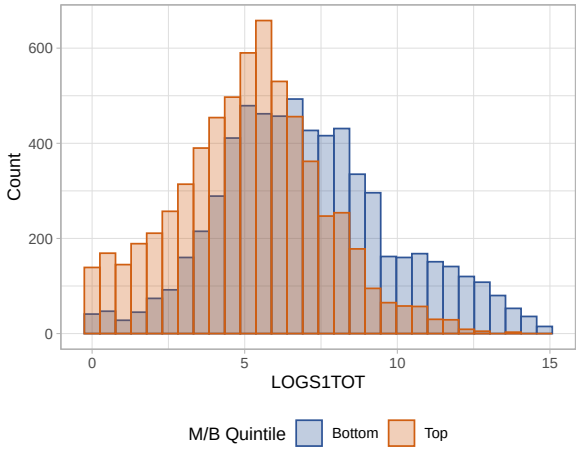
(A) PANEL A: AGE QUINTILES



(B) PANEL B: ASSET QUINTILES



(C) PANEL C: M/B QUINTILES



IA Internet Appendix

TABLE IA.I: PATENT DATA BY COUNTRY

The sample period is 2005-2020. In Panel A, we report the number of firm observations by country for the full (public and private), public, private and Trucost sample. Columns 1 to 4 report unconditional numbers and columns 5 to 8 condition on having at least one granted or purchased patent at the European Patent Office. In Panel B, we report patent counts and average patent counts by firm conditional on patenting. We report the total number of granted or purchased patents at the European Patent Office in a given country in columns 1 to 4 and the average number of patents at the European Patent Office per firm conditional on having at least one patent by country in columns 5 to 8. The full sample is based on firms from Orbis/ Orbis IP, FactSet, Worldscope and Trucost. We report countries with less than 300 firm-year observations in the full sample aggregated by region under "Others". "Others North America" include ANGUILLA, ANTIGUA & BARBUDA, BAHAMAS, BARBADOS, BELIZE, COSTA RICA, CURACAO, DOMINICA, DOMINICAN REPUBLIC, EL SALVADOR, GRENADA, GREENLAND, GUATEMALA, HONDURAS, MARSHALL ISLANDS, NICARAGUA, SAINT BARTHELEMY, SAINT KITTS & NEVIS, SAINT LUCIA , SAINT MARTIN, SAINT PIERRE & MIQUELON, TRINIDAD & TOBAGO; "Others Asia" include ARMENIA, AZERBAIJAN, BAHRAIN, BHUTAN, CAMBODIA, KYRGYZSTAN, LAO PEOPLE'S DEMOCRATIC REPUBLIC, LEBANON, MACAO S.A.R, MYANMAR/BURMA, NEPAL, PALESTINIAN TERRITORIES, SYRIAN ARAB REPUBLIC; "Others Africa" include ALGERIA, BOTSWANA, CAMEROON, CAPE VERDE, COTE D'IVOIRE, ESWATINI, ETHIOPIA, GABON, GAMBIA, GHANA, KENYA, LIBERIA, MALAWI, MALI, MAYOTTE, MOZAMBIQUE, NAMIBIA, SENEGAL, SEYCHELLE, SUDAN, TOGO, TUNISIA, UGANDA, UNITED REPUBLIC OF TANZANIA, ZAMBIA; "Others Europe" include ALBANIA, BELARUS, FAROE ISLANDS, GEORGIA, GIBRALTAR, ISLE OF MAN, LIECHTENSTEIN, MONACO, SAN MARINO, SVALBARD and "Others South America" include FRENCH GUIANA, GUYANA, VENEZUELA.

Panel A: Firm count	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Full sample				Patenting sample			
	Full	Public	Private	Trucost	Full	Public	Private	Trucost
ARGENTINA	179	87	92	18	9	8	1	3
AUSTRALIA	5579	1929	3650	628	520	388	132	155
AUSTRIA	1659	117	1542	49	241	69	172	33
BANGLADESH	184	134	50	7	0	0	0	0
BELGIUM	26834	202	26632	80	635	97	538	52
BERMUDA	805	710	95	67	62	53	9	7
BOLIVIA	33	0	33	0	0	0	0	0
BOSNIA & HERZEGOVINA	1734	39	1695	1	1	0	1	0
BRAZIL	1340	467	873	209	100	66	34	39
BULGARIA	15623	224	15399	5	31	8	23	2
CANADA	5976	5250	726	560	554	504	50	143
CANARY ISLANDS	1441	1	1440	0	1	0	1	0
CAYMAN ISLANDS	1412	723	689	44	55	34	21	6
CHILE	349	213	136	49	24	19	5	9
CHINA	86430	5116	81314	2751	1402	845	557	546
COLOMBIA	210	53	157	18	4	3	1	3
COTE D'IVOIRE	15	12	3	3	0	0	0	0
CROATIA	2452	144	2308	3	7	4	3	0
CYPRUS	1290	128	1162	10	19	3	16	1
CZECH REP	14076	24	14052	8	75	5	70	3
DENMARK	69409	218	69191	66	952	78	874	38
ECUADOR	62	1	61	0	0	0	0	0
EGYPT	710	210	500	41	7	5	2	2
ESTONIA	7286	19	7267	3	25	0	25	0
FINLAND	11009	185	10824	74	379	97	282	49
FRANCE	52481	861	51620	342	1714	401	1313	218
GERMANY	15731	1012	14719	315	1706	442	1264	199
GREECE	1595	278	1317	49	36	27	9	7
GUADELOUPE	109	1	108	0	0	0	0	0
GUERNSEY	103	79	24	14	9	7	2	2
HONG KONG	1360	1242	118	734	130	122	8	83
HUNGARY	4728	44	4684	6	28	6	22	2
ICELAND	2744	28	2716	6	20	4	16	1
INDIA	13529	4148	9381	721	394	286	108	148
INDONESIA	801	610	191	191	3	3	0	2
IRAQ	72	0	72	0	0	0	0	0
IRELAND	2160	126	2034	69	110	52	58	36
ISLAMIC REPUBLIC OF IRAN	470	0	470	0	0	0	0	0
ISLE OF MAN	51	36	15	5	4	2	2	1
ISRAEL	826	704	122	173	259	217	42	76
ITALY	68990	458	68532	181	1758	197	1561	99
JAMAICA	71	27	44	2	0	0	0	0
JAPAN	9292	5964	3328	2535	2507	2168	339	1077
JERSEY	124	87	37	17	17	12	5	6
JORDAN	214	174	40	6	3	3	0	1
KAZAKHSTAN	191	9	182	5	2	0	2	0
KENYA	32	26	6	11	0	0	0	0
KUWAIT	218	200	18	36	4	3	1	1
LATVIA	2550	26	2524	0	6	3	3	0
LIECHTENSTEIN	8	3	5	2	3	0	3	0
LITHUANIA	1246	41	1205	2	12	2	10	0
LUXEMBOURG	5397	97	5300	48	274	26	248	21
MALAYSIA	10471	1209	9262	255	76	55	21	26
MALTA	3719	26	3693	7	18	2	16	1
MARTINIQUE	110	1	109	0	0	0	0	0
MAURITIUS	421	86	335	5	3	2	1	0
MEXICO	257	168	89	89	31	23	8	15
MONGOLIA	259	47	212	2	0	0	0	0
MONTENEGRO	501	23	478	0	0	0	0	0
MOROCCO	143	42	101	18	5	2	3	1
NETHERLANDS	9800	224	9576	122	506	98	408	69
NEW ZEALAND	344	161	183	72	44	31	13	12
NIGERIA	150	109	41	23	0	0	0	0
NORTH MACEDONIA	1148	27	1121	0	3	0	3	0
NORWAY	43073	358	42715	123	617	108	509	51
OMAN	129	70	59	10	1	0	1	0
PAKISTAN	596	372	224	64	1	0	1	0
PALESTINIAN TERRITORIES	36	24	12	0	0	0	0	0
PANAMA	48	3	45	1	1	1	0	0
PARAGUAY	67	0	67	0	2	0	2	0
PERU	264	96	168	21	4	1	3	1
PHILIPPINES	502	296	206	83	13	6	7	6
POLAND	12888	887	12001	79	144	83	61	16
PORTUGAL	14538	65	14473	23	87	12	75	6
QATAR	57	49	8	34	4	2	2	0
REPUBLIC OF MOLDOVA	953	0	953	0	1	0	1	0
REUNION	210	1	209	0	2	0	2	0
ROMANIA	8326	105	8221	8	12	2	10	0
RUSSIA	44172	455	43717	85	119	40	79	19
SAUDI ARABIA	302	265	37	155	11	10	1	7
SERBIA	5521	29	5492	3	3	1	2	0
SINGAPORE	4156	845	3311	192	139	88	51	35
SLOVAKIA	5685	24	5661	0	23	3	20	0
SLOVENIA	3099	44	3055	4	43	7	36	1
SOUTH AFRICA	404	334	70	185	59	55	4	41
SOUTH KOREA	6097	2996	3101	1240	1222	884	338	507
SPAIN	44586	275	44311	115	605	85	520	54
SRI LANKA	268	249	19	5	1	1	0	1
SWEDEN	47755	911	46844	284	1253	378	875	159
SWITZERLAND	606	348	258	243	253	176	77	145
TAIWAN	3330	2508	822	904	684	616	68	288
THAILAND	2867	797	2070	233	33	26	7	14
TUNISIA	41	34	7	2	1	1	0	0
TURKEY	2202	480	1722	120	65	45	20	25
UKRAINE	27602	33	27569	6	2	0	2	0
UNITED ARAB EMIRATES	116	97	19	49	5	5	0	4
UNITED KINGDOM	33578	1939	31639	770	1490	571	919	308
UNITED STATES	15620	12610	3010	3863	4189	3670	519	1774
URUGUAY	120	0	120	0	0	0	0	0
UZBEKISTAN	271	0	271	0	0	0	0	0
VIETNAM	2880	758	2122	24	2	2	0	0
VIRIGIN ISL	194	140	54	2	9	8	1	0
ZIMBABWE	66	10	56	4	1	0	1	0
Others Africa	139	62	77	12	1	0	1	0
Others Asia	126	30	96	13	0	0	0	0
Others Australia	39	7	32	3	0	0	0	0
Others Europe	136	17	119	11	1	0	1	0
Others North America	235	55	180	8	5	5	0	1
Others South America	79	3	76	0	1	0	1	0
Total	801569	62372	739197	18820	25735	13213	12522	6497

Panel B: Patent count and firm average patent count

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Patent count				Average no. of patents cond. on patenting			
	Full	Public	Private	Trucost	Full	Public	Private	Trucost
ARGENTINA	76	75	1	21	4.5	4.7	1.0	2.6
AUSTRALIA	3325	2585	740	1957	2.9	3.0	2.7	4.1
AUSTRIA	12601	7464	5137	5441	13.2	20.0	8.8	24.6
BANGLADESH	0	0	0	0	.	.	.	.
BELGIUM	14726	8352	6374	5961	7.5	18.8	4.2	22.4
BERMUDA	792	777	15	117	4.4	4.6	1.4	10.6
BOLIVIA	0	.	0	.	.	.	.	.
BOSNIA & HERZEGOVINA	3	0	3	0	1.5	.	1.5	.
BRAZIL	1285	1102	183	694	4.3	5.0	2.3	4.4
BULGARIA	49	8	41	2	1.1	1.1	1.1	1.0
CANADA	21968	20795	1173	12958	12.8	13.5	6.9	23.4
CANARY ISLANDS	1	0	1	.	1.0	.	1.0	.
CAYMAN ISLANDS	804	599	205	33	7.2	7.9	5.7	5.5
CHILE	1375	1364	11	768	14.6	15.9	1.4	14.8
CHINA	37617	28891	8726	25049	10.6	11.6	8.2	17.6
COLOMBIA	8	8	0	8	1.1	1.1	.	1.1
COTE D'IVOIRE	0	0	0	0	.	.	.	.
CROATIA	13	7	6	0	1.4	1.2	2.0	.
CYPRUS	45	7	38	5	1.7	1.8	1.7	2.5
CZECH REP	271	11	260	10	1.8	1.4	1.9	1.4
DENMARK	12411	5816	6595	5489	7.0	13.8	4.9	18.5
ECUADOR	0	.	0	.	.	.	.	.
EGYPT	446	436	10	2	21.2	29.1	1.7	2.0
ESTONIA	41	0	41	0	1.2	.	1.2	.
FINLAND	26134	23547	2587	22769	19.0	40.0	3.3	62.4
FRANCE	122478	90499	31979	86106	20.5	45.0	8.1	64.0
GERMANY	157802	120251	37551	109786	22.9	50.7	8.3	83.6
GREECE	115	95	20	35	1.5	1.6	1.1	1.6
GUADELOUPE	0	.	0	.	.	.	.	.
GUERNSEY	44	38	6	9	2.9	3.2	2.0	2.3
HONG KONG	6044	5972	72	5390	14.9	15.4	4.2	21.6
HUNGARY	314	199	115	134	4.6	6.0	3.3	7.4
ICELAND	776	449	327	31	9.7	15.0	6.5	15.5
INDIA	7222	6142	1080	5113	6.0	6.6	4.0	8.7
INDONESIA	4	4	0	3	1.0	1.0	.	1.0
IRAQ	0	.	0	.	.	.	.	.
IRELAND	5213	4249	964	3826	19.0	24.4	9.5	25.2
ISLAMIC REPUBLIC OF IRAN	0	.	0	.	.	.	.	.
ISLE OF MAN	3	1	2	1	1.0	1.0	1.0	1.0
ISRAEL	3388	3095	293	2003	4.6	4.9	2.5	8.1
ITALY	24565	12241	12324	10033	4.6	13.9	2.7	21.5
JAMAICA	0	0	0	0	.	.	.	.
JAPAN	335534	324725	10809	300059	27.3	29.2	9.1	48.0
JERSEY	68	59	9	44	2.6	3.1	1.3	3.1
JORDAN	11	11	0	0	1.2	1.2	.	.
KAZAKHSTAN	4	0	4	0	1.0	.	1.0	.
KENYA	0	0	0	0	.	.	.	.
KUWAIT	5	4	1	1	1.0	1.0	1.0	1.0
LATVIA	35	29	6	.	1.9	2.2	1.2	.
LIECHTENSTEIN	1114	0	1114	0	65.5	.	65.5	.
LITHUANIA	12	3	9	0	1.1	1.0	1.1	.
LUXEMBOURG	5418	944	4474	879	6.7	8.6	6.4	10.0
MALAYSIA	461	359	102	259	2.3	2.3	2.2	2.8
MALTA	65	1	64	1	1.9	1.0	1.9	1.0
MARTINIQUE	0	.	0	.	.	.	.	.
MAURITIUS	3	1	2	0	1.0	1.0	1.0	.
MEXICO	905	876	29	816	6.9	7.7	1.6	8.8
MONGOLIA	0	0	0	0	.	.	.	.
MONTENEGRO	0	0	0	.	.	.	.	.
MOROCCO	24	2	22	0	2.4	1.0	2.8	.
NETHERLANDS	45008	36806	8202	34510	31.6	67.8	9.3	79.9
NEW ZEALAND	364	264	100	177	3.2	3.3	3.0	6.1
NIGERIA	0	0	0	0	.	.	.	.
NORTH MACEDONIA	3	0	3	.	1.0	.	1.0	.
NORWAY	3658	2029	1629	1669	2.7	4.8	1.7	6.6
OMAN	1	0	1	0	1.0	.	1.0	.
PAKISTAN	2	0	2	0	1.0	.	1.0	.
PALESTINIAN TERRITORIES	0	0	0	.	.	.	.	.
PANAMA	0	0	0	0	.	.	.	.
PARAGUAY	2	.	2	.	1.0	.	1.0	.
PERU	5	1	4	1	1.3	1.0	1.3	1.0
PHILIPPINES	136	77	59	53	2.2	2.0	2.6	2.0
POLAND	933	748	185	207	3.1	3.8	1.7	4.9
PORTUGAL	362	39	323	22	1.8	1.5	1.8	1.4
QATAR	5	1	4	0	1.0	1.0	1.0	.
REPUBLIC OF MOLDOVA	1	.	1	.	1.0	.	1.0	.
REUNION	3	0	3	.	1.0	.	1.0	.
ROMANIA	11	2	9	0	1.1	2.0	1.0	.
RUSSIA	602	216	386	181	2.7	3.2	2.5	3.8
SAUDI ARABIA	4815	3226	1589	2488	145.9	119.5	264.8	191.4
SERBIA	4	2	2	0	1.3	2.0	1.0	.
SINGAPORE	1316	924	392	545	3.4	3.6	3.2	3.7
SLOVAKIA	52	12	40	.	1.3	1.7	1.2	.
SLOVENIA	246	153	93	62	2.6	5.7	1.4	6.9
SOUTH AFRICA	1376	1354	22	1322	8.0	8.4	2.2	9.1
SOUTH KOREA	111012	108110	2902	105775	30.4	38.0	3.6	55.0
SPAIN	6425	3573	2852	3118	4.0	9.0	2.4	11.5
SRI LANKA	1	1	0	1	1.0	1.0	.	1.0
SWEDEN	65379	54698	10681	51619	17.6	37.8	4.7	70.0
SWITZERLAND	44713	41808	2905	40503	33.0	39.3	10.0	46.8
TAIWAN	13945	13670	275	12050	7.1	7.5	1.8	11.4
THAILAND	721	705	16	633	6.4	7.0	1.3	7.9
TUNISIA	1	0	1	0	1.0	.	1.0	.
TURKEY	3354	3084	270	2868	15.7	18.0	6.3	23.3
UKRAINE	1	0	1	0	1.0	.	1.0	.
UNITED ARAB EMIRATES	26	25	1	25	2.4	2.5	1.0	2.5
UNITED KINGDOM	42199	29024	13175	27599	9.0	12.2	5.8	15.1
UNITED STATES	361345	353299	8046	301587	19.3	20.5	5.4	33.2
URUGUAY	0	.	0	.	.	.	.	.
UZBEKISTAN	0	.	0	.	.	.	.	.
VIETNAM	1	1	0	0	1.0	1.0	.	.
VIRIGIN ISL	32	31	1	0	1.6	1.6	1.0	.
ZIMBABWE	7	0	7	0	7.0	.	7.0	.
Others Africa	229	0	229	0	28.6	.	28.6	.
Others Asia	0	0	0	0	.	.	.	.
Others Australia	0	0	0	0	.	.	.	.
Others Europe	1	0	1	0	1.0	.	1.0	.
Others North America	139	139	0	7	6.9	6.9	.	2.3
Others South America	13	0	13	.	1.4	.	1.4	.
Total	1514067	1326115	187952	1192835	17.1	23.8	5.7	37.3

TABLE IA.II: PATENT FIRM-YEAR DATA BY COUNTRY

The sample period is 2005-2020. We report the number of firm-year observations by country for the full (public and private), public, private and Trucost sample. The full sample is based on firms from Orbis/ Orbis IP, FactSet, Worldscope and Trucost. Countries with less than 300 firm-year observations in the full sample are aggregated by region under "Others" as in Table IA.I. We report firm-year observations for the entire sample covering patenting and non-patenting firm-year observations in columns 1 to 4 as well as firm-year observations with at least one granted or purchased patent at the European Patent Office in columns 5 to 8.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Full sample				Patenting sample			
	Full	Public	Private	Trucost	Full	Public	Private	Trucost
ARGENTINA	1261	541	720	130	17	16	1	8
AUSTRALIA	28788	8605	20183	4418	1144	865	279	472
AUSTRIA	10544	865	9679	421	958	373	585	221
BANGLADESH	909	415	494	40	0	0	0	0
BELGIUM	235974	1102	234872	595	1968	444	1524	266
BERMUDA	6339	5566	773	193	180	169	11	11
BOLIVIA	356	0	356	0	0	0	0	0
BOSNIA & HERZEGOVINA	13979	64	13915	1	2	0	2	0
BRAZIL	8103	3051	5052	1628	297	219	78	156
BULGARIA	112034	829	111205	31	45	7	38	2
CANADA	38973	33348	5625	3712	1717	1546	171	554
CANARY ISLANDS	11750	6	11744	0	1	0	1	0
CAYMAN ISLANDS	7456	3836	3620	88	112	76	36	6
CHILE	2493	1383	1110	509	94	86	8	52
CHINA	339786	38313	301473	12744	3547	2481	1066	1426
COLOMBIA	1559	369	1190	160	7	7	0	7
COTE D'IVOIRE	70	36	34	17	0	0	0	0
CROATIA	20425	424	20001	22	9	6	3	0
CYPRUS	4250	285	3965	27	26	4	22	2
CZECH REP	87217	117	87100	69	148	8	140	7
DENMARK	296922	1429	295493	541	1771	422	1349	297
ECUADOR	626	0	626	0	0	0	0	0
EGYPT	2475	995	1480	379	21	15	6	1
ESTONIA	57668	116	57552	21	33	0	33	0
FINLAND	85592	1660	83932	606	1374	588	786	365
FRANCE	396609	5270	391339	2628	5978	2013	3965	1346
GERMANY	99925	6314	93611	2248	6899	2373	4526	1313
GREECE	12962	1071	11891	356	78	60	18	22
GUADELOUPE	628	0	628	0	0	0	0	0
GUERNSEY	337	160	177	35	15	12	3	4
HONG KONG	10248	9272	976	3500	406	389	17	249
HUNGARY	40948	249	40699	69	68	33	35	18
ICELAND	22383	149	22234	13	80	30	50	2
INDIA	76694	15831	60863	4317	1210	937	273	590
INDONESIA	4111	3109	1002	1135	4	4	0	3
IRAQ	588	0	588	0	0	0	0	0
IRELAND	10561	571	9990	429	275	174	101	152
ISLAMIC REPUBLIC OF IRAN	3822	0	3822	0	0	0	0	0
ISLE OF MAN	186	72	114	15	3	1	2	1
ISRAEL	5260	4293	967	921	744	629	115	248
ITALY	575420	3026	572394	1307	5363	880	4483	467
JAMAICA	554	161	393	9	0	0	0	0
JAPAN	76771	48139	28632	16199	12311	11128	1183	6247
JERSEY	406	179	227	45	26	19	7	14
JORDAN	1051	630	421	41	9	9	0	0
KAZAKHSTAN	1557	59	1498	33	4	0	4	0
KENYA	208	141	67	88	0	0	0	0
KUWAIT	1103	877	226	129	5	4	1	1
LATVIA	19794	167	19627	0	18	13	5	0
LIECHTENSTEIN	50	20	30	14	17	0	17	0
LITHUANIA	6460	202	6258	15	11	3	8	0
LUXEMBOURG	21286	418	20868	245	809	110	699	88
MALAYSIA	80209	6320	73889	1654	200	153	47	93
MALTA	19845	73	19772	15	35	1	34	1
MARTINIQUE	610	0	610	0	0	0	0	0
MAURITIUS	1235	341	894	20	3	1	2	0
MEXICO	1690	1258	432	738	132	114	18	93
MONGOLIA	1278	4	1274	4	0	0	0	0
MONTENEGRO	3229	38	3191	0	0	0	0	0
MOROCCO	911	282	629	174	10	2	8	0
NETHERLANDS	45112	1392	43720	884	1425	543	882	432
NEW ZEALAND	2033	807	1226	425	113	80	33	29
NIGERIA	759	461	298	176	0	0	0	0
NORTH MACEDONIA	8772	73	8699	0	3	0	3	0
NORWAY	348158	2077	346081	746	1379	423	956	252
OMAN	813	321	492	79	1	0	1	0
PAKISTAN	3074	1533	1541	417	2	0	2	0
PALESTINIAN TERRITORIES	170	57	113	0	0	0	0	0
PANAMA	331	15	316	9	0	0	0	0
PARAGUAY	518	0	518	0	2	0	2	0
PERU	1835	653	1182	204	4	1	3	1
PHILIPPINES	4211	2731	1480	649	62	39	23	27
POLAND	70959	4116	66843	643	305	195	110	42
PORTUGAL	116018	381	115637	196	203	26	177	16
QATAR	390	340	50	205	5	1	4	0
REPUBLIC OF MOLDOVA	5211	0	5211	0	1	0	1	0
REUNION	1298	3	1295	0	3	0	3	0
ROMANIA	69425	455	68970	53	10	1	9	0
RUSSIA	297311	1845	295466	644	224	68	156	48
SAUDI ARABIA	1430	1213	217	390	33	27	6	13
SERBIA	41567	68	41499	16	3	1	2	0
SINGAPORE	17527	4834	12693	1160	382	259	123	149
SLOVAKIA	45549	82	45467	0	41	7	34	0
SLOVENIA	24892	158	24734	31	95	27	68	9
SOUTH AFRICA	2820	2396	424	1828	172	162	10	146
SOUTH KOREA	48207	19499	28708	7492	3651	2848	803	1924
SPAIN	360397	1615	358782	972	1608	398	1210	270
SRI LANKA	1315	1101	214	52	1	1	0	1
SWEDEN	337849	5748	332101	1741	3716	1447	2269	737
SWITZERLAND	4762	2576	2186	1899	1354	1064	290	866
TAIWAN	24896	18442	6454	5551	1975	1820	155	1061
THAILAND	21114	4541	16573	1409	113	101	12	80
TUNISIA	163	81	82	16	1	0	1	0
TURKEY	11677	2495	9182	827	214	171	43	123
UKRAINE	200831	93	200738	35	1	0	1	0
UNITED ARAB EMIRATES	681	532	149	260	11	10	1	10
UNITED KINGDOM	197087	10586	186501	7175	4673	2384	2289	1826
UNITED STATES	98517	81296	17221	24913	18697	17218	1479	9072
URUGUAY	497	0	497	0	0	0	0	0
UZBEKISTAN	1498	0	1498	0	0	0	0	0
VIETNAM	18615	2778	15837	143	1	1	0	0
VIRIGIN ISL	1153	839	314	6	20	19	1	0
ZIMBABWE	494	31	463	21	1	0	1	0
Others Africa	671	137	534	72	8	0	8	0
Others Asia	815	160	655	73	0	0	0	0
Others Australia	290	20	270	9	0	0	0	0
Others Europe	610	53	557	32	1	0	1	0
Others North America	1506	295	1211	21	20	20	0	3
Others South America	512	5	507	0	9	0	9	0
Total	5318818	390985	4927833	124222	88727	55786	32941	31942

TABLE IA.III: GREEN/BROWN EFFICIENCY INNOVATION BY COUNTRY

The sample period is 2005-2020. In Panel A, we report the number of firm observations with at least one green, resepctively brown efficiency, European Patent Office patent by country for the full (public and private), public, private and Trucost sample. In Panel B, we report green European Patent Office patent counts and average green European Patent Office patent counts by firm conditional on green patenting. In Panel C, we report brown efficiency European Patent Office patent counts and average brown efficiency European Patent Office patent counts by firm conditional on brown efficiency patenting. The full sample is based on firms from Orbis/ Orbis IP, FactSet, Worldscope and Trucost. Countries with less than 300 firm-year observations in the full sample are aggregated by region under "Others" as in Table IA.I.

Panel A: Firm count	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	with at least one green patent				with at least one brown efficiency patent			
	Full	Public	Private	Trucost	Full	Public	Private	Trucost
ARGENTINA	4	4	0	1	6	6	0	3
AUSTRALIA	134	106	28	44	51	41	10	20
AUSTRIA	81	36	45	23	55	24	31	16
BANGLADESH	0	0	0	0	0	0	0	0
BELGIUM	151	43	108	26	59	20	39	12
BERMUDA	16	15	1	3	10	10	0	4
BOLIVIA	0	0	0	0	0	0	0	0
BOSNIA & HERZEGOVINA	0	0	0	0	0	0	0	0
BRAZIL	35	21	14	16	11	9	2	6
BULGARIA	8	3	5	1	3	1	2	0
CANADA	164	153	11	53	49	47	2	27
CANARY ISLANDS	0	0	0	0	0	0	0	0
CAYMAN ISLANDS	10	8	2	2	3	2	1	0
CHILE	4	4	0	3	4	4	0	1
CHINA	438	294	144	228	135	99	36	80
COLOMBIA	1	1	0	1	1	1	0	1
COTE D'IVOIRE	0	0	0	0	0	0	0	0
CROATIA	0	0	0	0	1	0	1	0
CYPRUS	4	1	3	1	2	0	2	0
CZECH REP	11	0	11	0	4	0	4	0
DENMARK	227	32	195	23	68	12	56	11
ECUADOR	0	0	0	0	0	0	0	0
EGYPT	3	3	0	1	0	0	0	0
ESTONIA	5	0	5	0	1	0	1	0
FINLAND	124	44	80	32	58	24	34	21
FRANCE	427	174	253	120	172	81	91	66
GERMANY	575	219	356	132	293	115	178	80
GREECE	5	5	0	1	4	3	1	2
GUADELOUPE	0	0	0	0	0	0	0	0
GUERNSEY	2	2	0	1	1	1	0	1
HONG KONG	50	47	3	36	13	13	0	11
HUNGARY	6	2	4	1	4	2	2	0
ICELAND	3	1	2	0	0	0	0	0
INDIA	119	94	25	63	49	37	12	28
INDONESIA	0	0	0	0	0	0	0	0
IRAQ	0	0	0	0	0	0	0	0
IRELAND	32	25	7	18	16	12	4	7
ISLAMIC REPUBLIC OF IRAN	0	0	0	0	0	0	0	0
ISLE OF MAN	1	1	0	0	0	0	0	0
ISRAEL	61	48	13	23	19	17	2	11
ITALY	363	79	284	40	177	54	123	35
JAMAICA	0	0	0	0	0	0	0	0
JAPAN	1046	936	110	565	510	468	42	329
JERSEY	5	3	2	2	0	0	0	0
JORDAN	1	1	0	0	0	0	0	0
KAZAKHSTAN	2	0	2	0	0	0	0	0
KENYA	0	0	0	0	0	0	0	0
KUWAIT	0	0	0	0	0	0	0	0
LATVIA	2	1	1	0	0	0	0	0
LIECHTENSTEIN	1	0	1	0	1	0	1	0
LITHUANIA	1	0	1	0	1	0	1	0
LUXEMBOURG	78	6	72	5	52	8	44	6
MALAYSIA	18	15	3	9	14	8	6	8
MALTA	3	0	3	0	0	0	0	0
MARTINIQUE	0	0	0	0	0	0	0	0
MAURITIUS	0	0	0	0	0	0	0	0
MEXICO	11	9	2	9	8	7	1	6
MONGOLIA	0	0	0	0	0	0	0	0
MONTENEGRO	0	0	0	0	0	0	0	0
MOROCCO	3	1	2	1	0	0	0	0
NETHERLANDS	161	56	105	45	87	41	46	33
NEW ZEALAND	11	6	5	3	2	0	2	0
NIGERIA	0	0	0	0	0	0	0	0
NORTH MACEDONIA	0	0	0	0	0	0	0	0
NORWAY	168	45	123	28	67	23	44	15
OMAN	0	0	0	0	0	0	0	0
PAKISTAN	0	0	0	0	0	0	0	0
PALESTINIAN TERRITORIES	0	0	0	0	0	0	0	0
PANAMA	0	0	0	0	0	0	0	0
PARAGUAY	0	0	0	0	0	0	0	0
PERU	0	0	0	0	0	0	0	0
PHILIPPINES	3	2	1	2	1	0	1	0
POLAND	33	20	13	5	13	9	4	1
PORTUGAL	21	2	19	2	8	2	6	2
QATAR	0	0	0	0	1	0	1	0
REPUBLIC OF MOLDOVA	0	0	0	0	0	0	0	0
REUNION	0	0	0	0	0	0	0	0
ROMANIA	0	0	0	0	2	0	2	0
RUSSIA	23	10	13	5	10	4	6	3
SAUDI ARABIA	6	5	1	3	4	3	1	3
SERBIA	1	0	1	0	0	0	0	0
SINGAPORE	41	27	14	15	16	12	4	8
SLOVAKIA	3	0	3	0	1	0	1	0
SLOVENIA	11	4	7	1	3	1	2	0
SOUTH AFRICA	14	13	1	12	6	6	0	4
SOUTH KOREA	415	327	88	232	115	91	24	65
SPAIN	146	33	113	26	34	14	20	12
SRI LANKA	1	1	0	1	0	0	0	0
SWEDEN	306	125	181	67	124	61	63	39
SWITZERLAND	121	98	23	84	46	37	9	34
TAIWAN	199	186	13	110	29	29	0	19
THAILAND	9	9	0	8	3	3	0	3
TUNISIA	0	0	0	0	0	0	0	0
TURKEY	18	14	4	11	11	9	2	7
UKRAINE	0	0	0	0	0	0	0	0
UNITED ARAB EMIRATES	3	3	0	3	1	1	0	1
UNITED KINGDOM	406	220	186	148	197	107	90	77
UNITED STATES	1559	1414	145	863	539	511	28	366
URUGUAY	0	0	0	0	0	0	0	0
UZBEKISTAN	0	0	0	0	0	0	0	0
VIETNAM	0	0	0	0	0	0	0	0
VIRIGIN ISL	3	3	0	0	0	0	0	0
ZIMBABWE	1	0	1	0	0	0	0	0
Others Africa	1	0	1	0	1	0	1	0
Others Asia	0	0	0	0	0	0	0	0
Others Australia	0	0	0	0	0	0	0	0
Others Europe	0	0	0	0	1	0	1	0
Others North America	1	1	0	0	1	1	0	0
Others South America	1	0	1	0	1	0	1	0
Total	7854	4994	2860	3091	3145	2057	1088	1450

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel B: Patent count and firm average patent count for *green* patents								
	Patent count				Average no. of patents cond. on patenting			
	Full	Public	Private	Trucost	Full	Public	Private	Trucost
ARGENTINA	11	11	0	1	3.7	3.7	.	1.0
AUSTRALIA	308	240	68	162	1.4	1.5	1.2	1.6
AUSTRIA	1070	773	297	519	4.3	5.7	2.7	5.4
BANGLADESH	0	0	0	0	.	.	.	.
BELGIUM	1991	1232	759	885	4.1	6.4	2.6	6.3
BERMUDA	68	67	1	29	2.4	2.5	1.0	9.7
BOLIVIA	0	.	0	.	.	.	.	.
BOSNIA & HERZEGOVINA	0	0	0	0	.	.	.	.
BRAZIL	163	117	46	107	2.0	2.1	2.0	2.2
BULGARIA	14	4	10	1	1.0	1.0	1.0	1.0
CANADA	2071	1998	73	1418	4.7	5.0	2.0	7.0
CANARY ISLANDS	0	0	0	.	.	.	.	.
CAYMAN ISLANDS	119	115	4	1	3.1	3.2	1.3	1.0
CHILE	186	186	0	104	6.0	6.0	.	5.5
CHINA	3260	2660	600	2347	3.9	4.3	2.7	5.2
COLOMBIA	4	4	0	4	1.3	1.3	.	1.3
COTE D'IVOIRE	0	0	0	0	.	.	.	.
CROATIA	0	0	0	0	.	.	.	.
CYPRUS	4	1	3	1	1.0	1.0	1.0	1.0
CZECH REP	16	0	16	0	1.1	.	1.1	.
DENMARK	3051	1689	1362	1663	6.7	11.3	4.5	12.8
ECUADOR	0	.	0	.	.	.	.	.
EGYPT	10	8	2	0	1.7	1.6	2.0	.
ESTONIA	12	0	12	0	1.5	.	1.5	.
FINLAND	1267	1021	246	968	3.3	4.3	1.7	4.7
FRANCE	12412	10239	2173	9892	8.1	12.1	3.2	13.8
GERMANY	19691	15808	3883	14728	10.7	16.6	4.4	20.0
GREECE	6	6	0	1	2.0	2.0	.	1.0
GUADELOUPE	0	.	0	.	.	.	.	.
GUERNSEY	8	8	0	2	2.7	2.7	.	2.0
HONG KONG	891	880	11	827	8.0	8.3	2.2	10.3
HUNGARY	6	3	3	2	1.2	1.5	1.0	2.0
ICELAND	3	1	2	0	1.0	1.0	1.0	.
INDIA	799	711	88	655	3.1	3.4	1.7	3.9
INDONESIA	0	0	0	0	.	.	.	.
IRAQ	0	.	0	.	.	.	.	.
IRELAND	348	311	37	271	5.2	6.0	2.5	5.9
ISLAMIC REPUBLIC OF IRAN	0	.	0	.	.	.	.	.
ISLE OF MAN	0	0	0	0	.	.	.	.
ISRAEL	247	226	21	133	1.8	1.9	1.2	2.0
ITALY	2116	1254	862	1092	2.4	4.3	1.5	5.4
JAMAICA	0	0	0	0	.	.	.	.
JAPAN	43713	41881	1832	39531	9.2	9.4	5.4	11.9
JERSEY	12	9	3	9	2.0	2.3	1.5	2.3
JORDAN	2	2	0	0	1.0	1.0	.	.
KAZAKHSTAN	2	0	2	0	1.0	.	1.0	.
KENYA	0	0	0	0	.	.	.	.
KUWAIT	0	0	0	0	.	.	.	.
LATVIA	4	3	1	.	1.0	1.0	1.0	.
LIECHTENSTEIN	37	0	37	0	2.6	.	2.6	.
LITHUANIA	0	0	0	0	.	.	.	.
LUXEMBOURG	311	100	211	81	1.8	3.2	1.5	3.4
MALAYSIA	35	30	5	23	1.1	1.1	1.0	1.1
MALTA	3	0	3	0	1.0	.	1.0	.
MARTINIQUE	0	.	0	.	.	.	.	.
MAURITIUS	0	0	0	0	.	.	.	.
MEXICO	76	74	2	71	2.1	2.1	1.0	2.2
MONGOLIA	0	0	0	0	.	.	.	.
MONTENEGRO	0	0	0	.	.	.	.	.
MOROCCO	10	1	9	0	1.4	1.0	1.5	.
NETHERLANDS	3916	3331	585	3198	8.3	13.1	2.7	14.8
NEW ZEALAND	27	6	21	3	2.1	1.2	2.6	1.0
NIGERIA	0	0	0	0	.	.	.	.
NORTH MACEDONIA	0	0	0	.	.	.	.	.
NORWAY	539	278	261	231	1.6	2.0	1.3	2.2
OMAN	0	0	0	0	.	.	.	.
PAKISTAN	0	0	0	0	.	.	.	.
PALESTINIAN TERRITORIES	0	0	0	.	.	.	.	.
PANAMA	0	0	0	0	.	.	.	.
PARAGUAY	0	.	0	.	.	.	.	.
PERU	0	0	0	0	.	.	.	.
PHILIPPINES	10	6	4	6	1.7	1.5	2.0	1.5
POLAND	70	59	11	18	1.6	1.7	1.1	1.6
PORTUGAL	33	4	29	4	1.2	1.0	1.2	1.0
QATAR	0	0	0	0	.	.	.	.
REPUBLIC OF MOLDOVA	0	.	0	.	.	.	.	.
REUNION	0	0	0	.	.	.	.	.
ROMANIA	0	0	0	0	.	.	.	.
RUSSIA	166	57	109	50	3.5	4.8	3.0	5.0
SAUDI ARABIA	671	561	110	474	33.5	40.1	18.3	52.7
SERBIA	1	0	1	0	1.0	.	1.0	.
SINGAPORE	219	153	66	109	1.9	2.0	1.8	2.0
SLOVAKIA	3	0	3	.	1.0	.	1.0	.
SLOVENIA	14	5	9	1	1.1	1.3	1.0	1.0
SOUTH AFRICA	149	148	1	144	3.1	3.1	1.0	3.3
SOUTH KOREA	20357	20067	290	19757	17.9	20.6	1.8	24.7
SPAIN	1967	1685	282	1624	6.3	16.0	1.4	17.5
SRI LANKA	1	1	0	1	1.0	1.0	.	1.0
SWEDEN	2720	1860	860	1680	3.4	4.6	2.2	5.6
SWITZERLAND	3826	3535	291	3443	8.2	9.1	3.6	10.0
TAIWAN	1303	1276	27	1124	2.9	3.0	1.2	3.6
THAILAND	99	98	1	97	2.4	2.5	1.0	2.5
TUNISIA	0	0	0	0	.	.	.	.
TURKEY	87	70	17	66	1.9	1.9	1.9	2.0
UKRAINE	0	0	0	0	.	.	.	.
UNITED ARAB EMIRATES	4	4	0	4	1.0	1.0	.	1.0
UNITED KINGDOM	4311	3174	1137	3005	3.8	4.4	2.8	4.9
UNITED STATES	27548	26791	757	21063	5.0	5.2	2.5	5.9
URUGUAY	0	.	0	.	.	.	.	.
UZBEKISTAN	0	.	0	.	.	.	.	.
VIETNAM	0	0	0	0	.	.	.	.
VIRIGIN ISL	5	5	0	0	1.3	1.3	.	.
ZIMBABWE	1	0	1	0	1.0	.	1.0	.
Others Africa	4	0	4	0	1.3	.	1.3	.
Others Asia	0	0	0	0	.	.	.	.
Others Australia	0	0	0	0	.	.	.	.
Others Europe	0	0	0	0	.	.	.	.
Others North America	1	1	0	0	1.0	1.0	.	.
Others South America	11	0	11	.	1.4	.	1.4	.
Total	162420	144848	17572	131630	6.7	8.0	2.9	9.8

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel C: Patent count and firm average patent count for *brown efficiency* patents	Patent count				Average no. of patents cond. on patenting			
	Full	Public	Private	Trucost	Full	Public	Private	Trucost
ARGENTINA	8	8	0	3	1.3	1.3	.	1.0
AUSTRALIA	159	138	21	88	1.6	1.6	1.5	1.7
AUSTRIA	507	121	386	104	3.8	1.6	6.3	1.7
BANGLADESH	0	0	0	0	.	.	.	.
BELGIUM	870	676	194	533	4.8	7.0	2.3	7.4
BERMUDA	28	28	0	5	1.4	1.4	.	1.3
BOLIVIA	0	.	0	.	.	.	.	.
BOSNIA & HERZEGOVINA	0	0	0	0	.	.	.	.
BRAZIL	30	28	2	25	1.4	1.4	1.0	1.5
BULGARIA	2	1	1	0	1.0	1.0	1.0	.
CANADA	407	403	4	264	2.9	2.9	1.0	3.0
CANARY ISLANDS	0	0	0	.	.	.	.	.
CAYMAN ISLANDS	54	53	1	0	4.5	4.8	1.0	.
CHILE	8	8	0	3	1.0	1.0	.	1.0
CHINA	563	330	233	247	2.4	1.9	3.8	1.9
COLOMBIA	1	1	0	1	1.0	1.0	.	1.0
COTE D'IVOIRE	0	0	0	0	.	.	.	.
CROATIA	1	0	1	0	1.0	.	1.0	.
CYPRUS	2	0	2	0	1.0	.	1.0	.
CZECH REP	4	0	4	0	1.0	.	1.0	.
DENMARK	331	43	288	40	2.8	1.4	3.3	1.5
ECUADOR	0	.	0	.	.	.	.	.
EGYPT	0	0	0	0	.	.	.	.
ESTONIA	1	0	1	0	1.0	.	1.0	.
FINLAND	726	632	94	613	4.0	6.0	1.3	6.4
FRANCE	5121	4672	449	4575	8.1	11.5	2.0	12.5
GERMANY	10572	9206	1366	8331	11.7	18.0	3.5	19.3
GREECE	5	4	1	3	1.0	1.0	1.0	1.0
GUADELOUPE	0	.	0	.	.	.	.	.
GUERNSEY	5	5	0	5	2.5	2.5	.	2.5
HONG KONG	115	115	0	113	3.8	3.8	.	4.0
HUNGARY	11	1	10	0	2.8	1.0	3.3	.
ICELAND	0	0	0	0	.	.	.	.
INDIA	302	261	41	219	2.2	2.5	1.2	2.3
INDONESIA	0	0	0	0	.	.	.	.
IRAQ	0	.	0	.	.	.	.	.
IRELAND	133	128	5	122	5.1	5.8	1.3	6.8
ISLAMIC REPUBLIC OF IRAN	0	.	0	.	.	.	.	.
ISLE OF MAN	0	0	0	0	.	.	.	.
ISRAEL	84	82	2	19	2.4	2.5	1.0	1.2
ITALY	1383	914	469	682	2.8	4.2	1.7	4.9
JAMAICA	0	0	0	0	.	.	.	.
JAPAN	15564	15066	498	14258	7.3	7.5	4.2	8.8
JERSEY	0	0	0	0	.	.	.	.
JORDAN	0	0	0	0	.	.	.	.
KAZAKHSTAN	0	0	0	0	.	.	.	.
KENYA	0	0	0	0	.	.	.	.
KUWAIT	0	0	0	0	.	.	.	.
LATVIA	0	0	0	.	.	.	.	.
LIECHTENSTEIN	4	0	4	0	1.0	.	1.0	.
LITHUANIA	0	0	0	0	.	.	.	.
LUXEMBOURG	179	26	153	25	1.9	1.4	2.0	1.4
MALAYSIA	29	22	7	20	1.1	1.2	1.0	1.2
MALTA	0	0	0	0	.	.	.	.
MARTINIQUE	0	.	0	.	.	.	.	.
MAURITIUS	0	0	0	0	.	.	.	.
MEXICO	23	22	1	20	1.3	1.3	1.0	1.3
MONGOLIA	0	0	0	0	.	.	.	.
MONTENEGRO	0	0	0	.	.	.	.	.
MOROCCO	0	0	0	0	.	.	.	.
NETHERLANDS	572	450	122	442	2.9	3.8	1.6	3.9
NEW ZEALAND	2	0	2	0	1.0	.	1.0	.
NIGERIA	0	0	0	0	.	.	.	.
NORTH MACEDONIA	0	0	0	.	.	.	.	.
NORWAY	204	133	71	115	1.5	1.9	1.1	1.9
OMAN	0	0	0	0	.	.	.	.
PAKISTAN	0	0	0	0	.	.	.	.
PALESTINIAN TERRITORIES	0	0	0	.	.	.	.	.
PANAMA	0	0	0	0	.	.	.	.
PARAGUAY	0	.	0	.	.	.	.	.
PERU	0	0	0	0	.	.	.	.
PHILIPPINES	2	0	2	0	2.0	.	2.0	.
POLAND	82	78	4	22	3.4	3.9	1.0	3.1
PORTUGAL	7	2	5	2	1.0	1.0	1.0	1.0
QATAR	1	0	1	0	1.0	.	1.0	.
REPUBLIC OF MOLDOVA	0	.	0	.	.	.	.	.
REUNION	0	0	0	.	.	.	.	.
ROMANIA	2	1	1	0	1.0	1.0	1.0	.
RUSSIA	14	8	6	7	1.3	1.6	1.0	1.8
SAUDI ARABIA	290	255	35	213	16.1	21.3	5.8	26.6
SERBIA	0	0	0	0	.	.	.	.
SINGAPORE	70	50	20	46	1.6	1.7	1.5	1.8
SLOVAKIA	1	0	1	.	1.0	.	1.0	.
SLOVENIA	3	0	3	0	1.0	.	1.0	.
SOUTH AFRICA	18	18	0	15	1.2	1.2	.	1.3
SOUTH KOREA	2041	1942	99	1873	5.3	5.7	2.3	6.1
SPAIN	80	39	41	38	1.4	1.7	1.2	1.7
SRI LANKA	0	0	0	0	.	.	.	.
SWEDEN	1927	1537	390	1465	5.2	6.7	2.7	7.4
SWITZERLAND	541	485	56	467	3.3	3.6	2.1	3.7
TAIWAN	82	81	1	74	1.5	1.6	1.0	1.6
THAILAND	29	29	0	29	1.8	1.8	.	1.8
TUNISIA	0	0	0	0	.	.	.	.
TURKEY	58	54	4	50	1.6	1.6	1.0	1.7
UKRAINE	0	0	0	0	.	.	.	.
UNITED ARAB EMIRATES	0	0	0	0	.	.	.	.
UNITED KINGDOM	4619	2773	1846	2739	8.7	8.5	9.0	9.0
UNITED STATES	15966	15659	307	12878	8.4	8.5	4.3	9.0
URUGUAY	0	.	0	.	.	.	.	.
UZBEKISTAN	0	.	0	.	.	.	.	.
VIETNAM	0	0	0	0	.	.	.	.
VIRIGIN ISL	0	0	0	0	.	.	.	.
ZIMBABWE	0	0	0	0	.	.	.	.
Others Africa	15	0	15	0	3.0	.	3.0	.
Others Asia	0	0	0	0	.	.	.	.
Others Australia	0	0	0	0	.	.	.	.
Others Europe	1	0	1	0	1.0	.	1.0	.
Others North America	1	1	0	0	1.0	1.0	.	.
Others South America	1	0	1	.	1.0	.	1.0	.
Total	63861	56589	7272	50793	6.6	7.6	3.2	8.4

TABLE IA.IV: DISTRIBUTIONS OF PATENT RATIOS

The sample period is 2005-2020. We report average patent ratios for the full (public and private), public, private and Trucost sample by country in Panel A, by GICS 6-Industry in Panel B, and by year in Panel C. Countries with less than 300 firm-year observations in the full sample are aggregated by region under "Others" as in Table IA.I. We report the average *GREENRATIOEP* in columns 1 to 4 and the average *BROWNEFFRATIOEP* in columns 5 to 8. *GREENRATIOEP* is the number of green patents over the total number of patents granted or purchased at the firm and year level based on European Patent Office patents. *BROWNEFFRATIOEP* similarly is the number of brown efficiency patents over the total number of patents at the European Patent Office.

Panel A: Patent ratio by country	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	GREENRATIOEP (in %)				BROWNEFFRATIOEP (in %)			
	Full	Public	Private	Trucost	Full	Public	Private	Trucost
ARGENTINA	3.431	3.646	0	2.083	17.157	18.229	0	21.875
AUSTRALIA	11.820	11.106	14.033	9.587	5.536	6.303	3.159	6.384
AUSTRIA	10.090	11.574	9.143	9.645	4.036	3.823	4.172	4.031
BELGIUM	10.016	12.547	9.278	14.196	2.777	5.042	2.117	5.433
BERMUDA	7.001	6.865	9.091	16.651	7.527	8.017	0	13.912
BOSNIA & HERZEGOVINA	0		0		0		0	
BRAZIL	14.423	11.860	21.616	15.956	1.982	2.156	1.496	2.298
BULGARIA	27.778	50.000	23.684	50.000	3.333	7.143	2.632	0
CANADA	14.952	14.943	15.027	16.274	3.370	3.601	1.288	3.476
CANARY ISLANDS	0		0		0		0	
CAYMAN ISLANDS	17.005	24.333	1.535	2.381	2.279	2.042	2.778	0
CHILE	8.534	9.328	0	11.928	2.777	3.035	0	0.129
CHINA	12.895	12.712	13.320	13.883	2.630	2.742	2.368	2.651
COLOMBIA	42.857	42.857		42.857	14.286	14.286		14.286
CROATIA	0	0	0		2.778	0	8.333	
CYPRUS	6.090	6.250	6.061	12.500	7.692	0	9.091	0
CZECH REP	9.009	0	9.524	0	2.365	0	2.500	0
DENMARK	14.661	13.861	14.911	15.292	3.351	1.971	3.782	2.296
EGYPT	11.003	8.737	16.667	0	0	0	0	0
ESTONIA	24.242		24.242		3.030		3.030	
FINLAND	11.156	12.131	10.426	14.699	5.174	4.937	5.352	6.480
FRANCE	9.410	11.005	8.600	11.561	2.399	2.887	2.151	2.957
GERMANY	9.829	12.580	8.387	14.677	3.670	4.130	3.428	5.142
GREECE	3.846	5.000	0	4.545	5.449	5.417	5.556	10.227
GUERNSEY	6.222	7.778	0	8.333	11.111	13.889	0	41.667
HONG KONG	11.811	11.607	16.492	12.372	0.895	0.934	0	1.158
HUNGARY	4.070	3.788	4.337	5.556	5.719	3.030	8.254	0
ICELAND	1.750	0.667	2.400	0	0	0	0	0
INDIA	9.668	9.765	9.337	11.933	5.432	4.475	8.715	5.691
INDONESIA	0	0		0	0	0		0
IRELAND	7.409	8.122	6.182	7.572	2.190	1.507	3.366	1.020
ISLE OF MAN	0	0	0	0	0	0	0	0
ISRAEL	8.493	7.964	11.390	7.689	1.806	1.818	1.739	1.800
ITALY	8.405	11.101	7.876	11.569	4.470	7.808	3.815	7.857
JAPAN	11.974	11.933	12.363	13.117	4.009	4.190	2.311	4.486
JERSEY	14.853	12.431	21.429	16.871	0	0	0	0
JORDAN	22.222	22.222			0	0		
KAZAKHSTAN	50.000		50.000		0		0	
KUWAIT	0	0	0	0	0	0	0	0
LATVIA	10.648	7.051	20.000		0	0	0	
LIECHTENSTEIN	2.941		2.941		0.307		0.307	
LITHUANIA	0	0	0		0	0	0	
LUXEMBOURG	8.876	7.933	9.024	4.758	5.086	3.172	5.387	2.828
MALAYSIA	10.953	11.377	9.574	12.131	7.248	7.060	7.859	9.465
MALTA	8.571	0	8.824	0	0	0	0	0
MAURITIUS	0	0	0		0	0	0	
MEXICO	11.866	11.986	11.111	14.065	4.499	4.333	5.556	3.967
MOROCCO	44.833	50.000	43.542		0	0	0	
NETHERLANDS	12.803	12.364	13.073	12.195	3.662	3.030	4.050	3.352
NEW ZEALAND	6.245	3.369	13.215	5.271	0.983	0	3.367	0
NORTH MACEDONIA	0		0		0		0	
NORWAY	16.378	13.005	17.870	12.324	5.511	5.150	5.671	5.507
OMAN	0		0		0		0	
PAKISTAN	0		0		0		0	
PARAGUAY	0		0		0		0	
PERU	0	0	0	0	0	0	0	0
PHILIPPINES	9.677	10.256	8.696	14.815	0.645	0	1.739	0
POLAND	8.738	9.714	7.009	8.097	3.534	4.075	2.576	2.749
PORTUGAL	10.755	13.462	10.358	21.875	3.448	7.692	2.825	12.500
QATAR	0	0	0		20.000	0	25.000	
REPUBLIC OF MOLDOVA	0		0		0		0	
REUNION	0		0		0		0	
ROMANIA	0	0	0		15.000	50.000	11.111	
RUSSIA	18.115	15.124	19.419	17.780	1.629	1.779	1.563	1.479
SAUDI ARABIA	14.928	16.602	7.391	19.058	4.057	4.475	2.178	4.298
SERBIA	33.333	0	50.000		0	0	0	
SINGAPORE	16.440	17.319	14.588	19.931	5.226	5.325	5.018	7.019
SLOVAKIA	7.317	0	8.824		2.439	0	2.941	
SLOVENIA	8.574	2.596	10.948	1.852	1.729	0	2.416	0
SOUTH AFRICA	13.326	13.531	10.000	12.959	4.299	4.564	0	3.009
SOUTH KOREA	15.313	16.177	12.250	17.506	2.753	2.880	2.304	3.130
SPAIN	13.898	18.612	12.347	23.800	1.844	1.841	1.845	2.707
SRI LANKA	100.000	100.000		100.000	0	0		0
SWEDEN	10.044	8.926	10.757	7.739	3.387	3.696	3.189	5.302
SWITZERLAND	10.205	9.203	13.881	9.153	1.721	1.844	1.269	1.988
TAIWAN	11.846	11.718	13.346	11.997	0.913	0.936	0.645	1.040
THAILAND	11.684	12.577	4.167	15.567	1.710	1.913	0	2.415
TUNISIA	0		0		0		0	
TURKEY	4.534	4.443	4.895	3.690	2.461	2.493	2.333	3.034
UKRAINE	0		0		0		0	
UNITED ARAB EMIRATES	23.485	25.833	0	25.833	0	0	0	0
UNITED KINGDOM	10.455	11.534	9.330	10.907	4.215	3.933	4.508	4.397
UNITED STATES	10.084	9.975	11.351	10.046	2.594	2.705	1.301	3.205
VIETNAM	0	0			0	0		
VIRIGIN ISL	18.333	19.298	0		0	0	0	
ZIMBABWE	14.286		14.286		0		0	
Others Africa	1.030		1.030		6.425		6.425	
Others Europe	0		0		100.000		100.000	
Others North America	0.333	0.333		0	0.556	0.556		0
Others South America	83.333		83.333		11.111		11.111	
Total	11.025	11.420	10.356	12.108	3.313	3.357	3.238	3.737

Panel B: Patent ratio by GICS-6 industry	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	GREENRATIOEP (in %)				BROWNEFFRATIOEP (in %)			
	Full	Public	Private	Trucost	Full	Public	Private	Trucost
Aerospace & Defense	9.492	9.719	8.443	9.142	5.539	5.787	4.394	6.052
Air Freight & Logistics	8.466	7.540	14.286	6.616	0.140	0.162	0	0.176
Airlines	3.856	4.351	0	3.520	1.318	1.487	0	1.705
Auto Components	9.436	9.159	10.920	10.058	8.571	8.897	6.821	7.116
Automobiles	26.585	25.135	50.806	24.230	14.375	14.882	5.914	15.878
Banks	8.923	7.953	8.963	7.554	3.198	3.142	3.200	2.862
Beverages	11.315	11.483	10.590	12.240	0.445	0.548	0	0.642
Biotechnology	16.187	15.842	17.120	17.474	0.527	0.066	1.770	0.028
Building Products	11.655	12.982	8.336	12.635	6.164	6.110	6.299	4.587
Capital Markets	9.757	9.184	10.002	8.949	3.576	3.096	3.782	2.446
Chemicals	14.032	14.708	11.415	14.545	3.386	3.427	3.227	3.631
Commercial Services & Supplies	9.342	9.728	9.122	9.935	4.887	4.927	4.864	4.980
Communications Equipment	5.010	5.061	4.735	4.859	0.473	0.515	0.245	0.238
Construction Materials	23.040	21.477	29.663	23.978	9.282	9.857	6.845	8.658
Construction & Engineering	20.136	22.291	17.918	25.216	9.106	10.894	7.266	11.395
Consumer Finance	9.115	6.233	9.909	7.222	6.164	8.333	5.566	9.722
Containers & Packaging	3.985	3.590	5.014	3.757	0.509	0.528	0.459	0.471
Distributors	4.788	3.876	6.127	4.832	3.454	1.314	6.596	1.479
Diversified Consumer Services	6.048	0.111	7.571	0.390	2.204	0.297	2.693	1.039
Diversified Financial Services	8.471	8.471		8.671	5.316	5.316		4.935
Diversified Telecommunication Services	3.296	3.354	3.118	2.053	0.200	0.240	0.079	0.099
Electric Utilities	51.136	47.124	63.475	44.165	11.261	12.972	6.000	14.053
Electrical Equipment	28.966	31.305	21.217	32.485	3.620	3.546	3.868	3.780
Electronic Equipment, Instruments & Components	11.617	11.447	13.201	11.268	1.586	1.519	2.212	1.362
Energy Equipment & Services	14.896	13.723	40.333	13.969	19.947	20.498	8.000	20.610
Entertainment	6.579	4.961	22.222	1.755	0	0	0	0
Equity Real Estate Investment Trusts (REITs)	9.201	10.112	9.065	25.532	2.644	0.727	2.932	0
Food Products	12.321	11.457	15.193	11.788	0.580	0.682	0.240	0.959
Food & Staples Retailing	8.831	7.140	10.408	7.078	1.946	0.806	3.008	0
Gas Utilities	36.688	37.006	33.333	40.735	7.004	6.615	11.111	7.446
Health Care Equipment & Supplies	4.054	3.687	5.569	3.969	0.408	0.420	0.362	0.349
Health Care Providers & Services	7.601	8.711	6.123	7.269	0.227	0.398	0	0.108
Health Care Technology	8.689	8.689		8.253	0.040	0.040		0.048
Hotels, Restaurants & Leisure	2.809	1.641	5.286	2.506	2.481	0.794	6.061	0
Household Durables	5.729	5.613	6.643	7.087	2.405	2.512	1.565	3.161
Household Products	5.400	5.400		5.114	1.253	1.253		0.649
IT Services	7.414	4.591	18.511	4.550	2.093	1.558	4.198	1.450
Independent Power and Renewable Electricity Producers	53.779	48.510	65.170	49.417	12.500	14.531	8.108	21.250
Industrial Conglomerates	12.975	12.975		13.045	5.100	5.100		5.065
Insurance	8.517	8.334	8.681	7.572	1.775	3.399	0.318	2.989
Interactive Media & Services	3.000	3.000		3.111	0.143	0.143		0.148
Internet Software & Services (discont. 2018)	2.430	0.544	55.556	0.681	0.007	0.007	0	0.009
Internet & Direct Marketing Retail	4.197	2.861	7.345	3.692	1.183	0.966	1.695	0.327
Leisure Products	8.814	9.868	1.762	12.864	1.277	1.468	0	1.909
Life Sciences Tools & Services	11.390	11.390		11.224	0.431	0.431		0.530
Machinery	8.267	8.156	8.569	8.839	6.890	7.532	5.147	8.299
Marine	15.618	11.964	20.204	12.761	7.920	6.185	10.098	6.597
Media	5.163	4.091	8.333	4.039	0.819	1.096	0	0.031
Media (discont. 2018)	5.066	5.249	3.906	5.908	1.126	1.304	0	0.566
Metals & Mining	12.383	12.883	10.869	12.266	6.881	6.713	7.390	6.877
Multi-Utilities	36.686	36.686		37.253	11.821	11.821		12.005
Multiline Retail	8.252	9.407	0	10.225	0	0	0	0
Oil, Gas & Consumable Fuels	32.787	33.905	27.825	38.453	11.463	11.503	11.284	9.716
Paper & Forest Products	10.728	10.720	10.781	11.814	1.104	1.252	0.062	1.171
Personal Products	4.031	4.381	2.179	2.891	0.172	0.205	0	0.117
Pharmaceuticals	7.661	7.456	8.395	5.992	0.072	0.074	0.063	0.074
Professional Services	10.444	14.152	9.778	8.848	2.790	4.488	2.485	6.967
Real Estate Management & Development	12.212	20.018	10.191	17.834	3.442	2.031	3.807	1.760
Road & Rail	18.871	16.711	22.547	14.477	0.667	0	1.802	0
Semiconductors & Semiconductor Equipment	17.679	17.930	16.305	20.064	0.895	0.669	2.127	0.653
Software	4.186	3.293	6.757	1.935	1.185	0.737	2.473	0.228
Specialty Retail	8.227	6.460	11.112	5.651	1.015	1.329	0.501	0.495
Technology Hardware, Storage & Peripherals	4.723	4.872	3.272	4.816	0.489	0.481	0.574	0.528
Textiles, Apparel & Luxury Goods	5.157	4.702	6.723	3.595	0.700	0.422	1.659	0.245
Thrifts & Mortgage Finance	0	0			0	0		
Tobacco	11.293	11.094	12.941	10.258	2.034	2.279	0	2.417
Trading Companies & Distributors	10.525	10.847	10.360	10.904	3.847	5.536	2.976	3.283
Transportation Infrastructure	7.022	3.427	10.205	2.326	2.273	0	4.286	0
Water Utilities	20.029	19.940	20.238	29.206	5.579	5.291	6.250	1.111
Wireless Telecommunication Services	2.232	2.232		2.016	0.158	0.158		0.166
Total	11.025	11.420	10.356	12.108	3.313	3.357	3.238	3.737

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel C: Patent ratio by year								
	GREENRATIOEP (in %)				BROWNEFFRATIOEP (in %)			
	Full	Public	Private	Trucost	Full	Public	Private	Trucost
2005	7.975	8.363	7.201	9.147	2.835	3.044	2.419	3.408
2006	8.039	8.761	6.590	9.120	3.171	3.386	2.741	4.487
2007	8.975	9.679	7.558	9.734	3.174	3.494	2.531	3.703
2008	8.682	9.736	6.639	10.598	3.282	3.395	3.062	4.080
2009	9.496	10.210	8.131	10.784	3.029	3.294	2.522	3.819
2010	10.036	10.531	9.065	11.105	3.113	3.175	2.991	4.024
2011	10.151	10.747	9.076	11.356	3.337	3.474	3.090	4.261
2012	10.966	11.366	10.353	12.992	3.413	3.758	2.884	4.811
2013	11.839	11.911	11.728	12.626	3.311	3.607	2.854	4.192
2014	11.983	12.264	11.502	13.725	3.460	3.256	3.810	3.688
2015	11.582	12.157	10.625	13.242	3.507	3.451	3.599	4.219
2016	12.117	12.794	11.076	13.012	3.251	3.244	3.263	3.505
2017	12.152	12.094	12.241	11.983	3.615	3.397	3.951	3.353
2018	12.097	12.132	12.046	12.054	3.560	3.484	3.669	3.802
2019	12.783	13.482	11.791	13.404	3.276	3.193	3.393	3.318
2020	12.959	13.064	12.754	13.173	3.203	2.980	3.639	2.970
Total	11.025	11.420	10.356	12.108	3.313	3.357	3.238	3.737

TABLE IA.V: SUMMARY STATISTICS OF QUANTITATIVE VARIABLES

The table reports sample averages, medians, and standard deviations of various firm-level characteristics for the period 2005 to 2020. Panel A reports summary statistics for the entire sample (public and private) firms, while summary statistics in Panel B are based on the Trucost sample. Column 1 to 3 aggregate all firm-years with at least one patent at the European Patent Office. Column 4 to 6 aggregate firm-years without any patent at the European Patent Office. Column 7 to 9 aggregate firm-years in the bottom decile based on a firm's average *GREENRATIOEP* across the whole period. This covers only firms with 0 green patents and represents about about 35% of firm-year observations in Panel B. Column 10 to 12 aggregate firm-years in the top decile based on a firm's average *GREENRATIOEP* across the whole period. *OECDRATIOEP* is a patent ratio based on OECD green Env-tech classification, calculated as the number of granted or purchased OECD patents over the total number of granted or purchased patents; *GREENRATIOEP*2 is defined as the number of granted or purchased "green" or "general efficiency" patents over the total number of granted or purchased patents; other patent variables are defined in Table 2 and Table 4; emission variables are defined in Table 2 and Table 6; LOGCAPEX is the natural logarithm of capital expenditures; LOGCASH is the natural logarithm of cash and short-term equivalents; other financial variables are defined in Table 1.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Panel A: All public and private firms	Patenting Sample			Sample w/o patents			Bottom decile green ratio			Top decile green ratio		
	mean	*p*50	*sd*	*mean*	*p*50	*sd*	*mean*	*p*50	*sd*	*mean*	*p*50	*sd*
GREENRATIOEP (in %)	10.996	0	26.077	.	.	.	0	0	0	75.156	100.000	36.455
BROWNEFFRATIOEP (in %)	3.328	0	14.494	.	.	.	2.719	0	15.267	2.675	0	13.159
GREENRATIOEP2 (in %)	19.594	0	32.851	.	.	.	9.506	0	27.027	78.557	100.000	34.126
OECDRATIOEP (in %)	11.476	0	26.442	.	.	.	5.453	0	20.884	47.628	50.000	45.337
LOGASSETS	4.949	4.878	2.762	1.705	1.144	1.755	4.382	4.335	2.519	4.785	4.661	2.832
LOGPPE	3.517	3.129	3.034	0.824	0.090	1.558	2.957	2.435	2.783	3.505	2.960	3.145
LEVERAGE	15.839	9.308	18.557	10.359	0	18.612	14.768	7.127	18.626	16.585	9.275	19.504
ROE	4.735	7.540	35.930	10.123	5.990	35.817	4.464	7.240	36.837	2.373	6.430	38.912
INVEST/A	5.449	3.296	7.039	4.307	0.431	8.451	5.502	3.144	7.322	5.866	3.478	7.496
LOGCAPEX	2.354	1.900	2.174	0.466	0.010	1.054	1.887	1.423	1.868	2.334	1.751	2.295
LOGCASH	3.123	2.931	2.427	0.546	0.076	1.075	2.580	2.315	2.149	2.948	2.680	2.405
Panel B: Public firms with emission data	Patenting Sample			Sample w/o patents			Bottom decile green ratio			Top decile green ratio		
	mean	*p*50	*sd*	*mean*	*p*50	*sd*	*mean*	*p*50	*sd*	*mean*	*p*50	*sd*
GREENRATIOEP (in %)	12.107	0	24.172	.	.	.	0	0	0	67.280	75.000	35.579
BROWNEFFRATIOEP (in %)	3.737	0	13.298	.	.	.	2.431	0	14.157	4.400	0	14.787
GREENRATIOEP2 (in %)	21.955	8.642	30.406	.	.	.	13.008	0	29.908	72.057	86.667	33.297
OECDRATIOEP (in %)	12.377	0	24.179	.	.	.	4.727	0	18.624	46.206	44.444	41.557
GREENCITMAXEP	61.153	1.000	610.518	.	.	.	0	0	0	57.471	12.000	147.651
BROWNEFFCITMAXEP	15.378	0	155.893	.	.	.	0.748	0	11.176	8.101	0	42.833
GREENCOUNTBBEP	0.238	0	1.256	.	.	.	0	0	0	0.453	0	1.355
BROWNEFFCOUNTBBEP	0.093	0	0.920	.	.	.	0.004	0	0.069	0.042	0	0.270
LOGS1TOT	6.129	5.921	2.765	4.854	4.536	2.780	5.275	5.046	2.561	6.691	6.259	3.462
LOGS2TOT	6.054	6.098	2.241	4.752	4.770	2.029	5.317	5.356	2.101	5.887	5.971	2.501
LOGS3UPTOT	7.964	8.136	2.260	6.315	6.346	1.967	7.141	7.303	2.121	7.841	8.073	2.557
LOGS3DOWNTOT	7.084	7.492	3.440	6.022	6.213	2.907	6.232	6.589	3.137	7.497	7.895	3.826
LOGS3TOT	8.417	8.540	2.652	7.206	7.170	2.188	7.636	7.815	2.419	8.583	8.810	3.027
S1INT	1.606	0.189	4.710	2.264	0.160	6.267	1.362	0.161	4.462	3.285	0.375	6.993
S2INT	0.407	0.211	0.561	0.414	0.195	0.577	0.353	0.176	0.521	0.503	0.245	0.661
S3UPINT	2.086	1.609	1.716	1.486	0.764	1.697	1.791	1.091	1.741	2.281	1.804	1.645
S3DOWNINT	7.273	1.539	14.603	5.793	1.048	13.555	5.837	0.980	13.203	12.128	2.985	19.340
S3INT	9.407	3.704	15.167	7.458	2.412	14.182	7.787	2.791	13.834	14.450	5.478	19.756
LOGSIZE	7.857	7.894	1.761	6.931	6.983	1.553	7.371	7.388	1.713	7.589	7.659	1.881
LOGPPE	6.200	6.275	2.219	5.028	5.208	2.306	5.493	5.562	2.178	6.426	6.363	2.535
LEVERAGE	23.140	21.705	17.162	24.614	22.122	19.727	22.607	20.136	18.443	24.738	23.591	17.608
ROE	8.191	10.122	27.004	8.605	9.484	23.861	6.818	9.705	29.198	3.923	8.717	31.006
M/B	2.799	1.843	3.026	2.421	1.508	2.812	2.940	1.897	3.268	2.558	1.626	2.890
BETA	0.636	0.693	0.381	0.687	0.695	0.277	0.617	0.659	0.331	0.709	0.732	0.385
VOLAT	0.103	0.087	0.070	0.109	0.090	0.081	0.107	0.089	0.075	0.118	0.096	0.088
MOM	0.006	0.007	0.036	0.003	0.004	0.038	0.005	0.006	0.036	0.005	0.005	0.042
RET	0.018	0.013	0.118	0.014	0.005	0.123	0.019	0.011	0.124	0.017	0.007	0.136
INVEST/A	4.705	3.621	4.370	4.533	2.573	5.796	4.604	3.312	4.712	5.651	4.351	5.255
MSCI	0.405	0	0.491	0.189	0	0.391	0.293	0	0.455	0.369	0	0.483
LOGCAPEX	4.596	4.620	2.018	3.431	3.437	1.914	3.968	3.948	1.934	4.665	4.624	2.293
LOGCASH	5.726	5.719	1.776	4.698	4.724	1.719	5.182	5.171	1.670	5.566	5.613	1.826
AGE	49.171	36.000	39.423	35.312	25.000	30.027	41.570	30.000	34.030	41.168	27.000	36.030

TABLE IA.VI: GREEN PATENT RATIO AND FIRM TYPE - INDUSTRY BY INDUSTRY

The unit of observation is firm-year. The sample period is 2005-2020. The dependent variable is *GREENRATIOEP*. The key independent variables of interest are *LOGS1TOT*, *AGE*, and *PATSTOCKGREENEP*. We additionally include the following controls: LOGSIZE, LOGPPE, LEVERAGE, ROE, M/B, INVEST/A, BETA, VOLAT, MOM, RET, and MSCI. All intedependent variabels are lagged by one year and defined in Table 1 and Table 2. We run the regression individually for each 6-digit GICS Industry with a Poisson pseudo-maximum likelihood regression and include country and year fixed effects. We double cluster standard errors at the firm and year dimension. We report the coefficient and standard error for *LOGS1TOT* in column 1, for *AGE* in column 2 and for *PATSTOCKGREENEP* in column 3 with *** representing 1% significance, ** 5% significance * 10% significance. Column 4 reports the Pseudo R2, column 5 the number of observations in the regression and column 6 the industry average absolute scope 1 emissions by which we rank the table.

Industry	(1) coef (std. err) LOGS1TOT	(2) coef (std. err) AGE (/100)	(3) coef (std. err) PATSTOCKGREENEP (/100)	(4) Pseudo R2	(5) N	(6) Industry Scope 1
Electric Utilities	0.013 (0.062)	-1.142*** (0.350)	0.269** (0.118)	0.091	254	21966773
Oil, Gas & Consumable Fuels	0.011 (0.061)	-0.065 (0.094)	0.002 (0.031)	0.052	559	20973912
Independent Power and Renewable Electricity Producers	-1.628*** (0.000)	296.113*** (0.000)	-147.142*** (0.000)	0.221	35	18641614
Metals & Mining	-0.187*** (0.068)	-0.090 (0.207)	0.271* (0.155)	0.090	827	16138911
Construction Materials	0.305 (0.212)	0.433 (0.385)	-1.198 (0.979)	0.149	236	9916635
Multi-Utilities	0.064 (0.080)	-0.615 (0.475)	0.640 (0.411)	0.122	116	7344608
Chemicals	-0.020 (0.031)	-0.140 (0.085)	0.041*** (0.011)	0.037	2128	4744375
Industrial Conglomerates	0.049 (0.035)	0.299 (0.202)	0.021*** (0.007)	0.152	448	1538727
Food Products	0.271*** (0.062)	0.102 (0.191)	1.273*** (0.278)	0.101	719	1141156
Construction & Engineering	0.128* (0.068)	0.376 (0.249)	1.158*** (0.290)	0.093	512	845274
Paper & Forest Products	0.519* (0.299)	0.621 (0.532)	0.867 (1.369)	0.177	223	805302
Diversified Financial Services	-0.018 (0.045)	0.631 (0.476)	0.166 (0.185)	0.151	239	729626
Commercial Services & Supplies	-0.277** (0.129)	-0.558 (0.384)	0.189 (0.831)	0.138	370	696769
Road & Rail	3.472*** (0.000)	na	200.565*** (0.000)	0.208	9	647088
Gas Utilities	0.005 (0.271)	-5.682** (2.758)	-5.525 (3.534)	0.160	55	617602
Trading Companies & Distributors	-0.055 (0.093)	-0.626* (0.348)	0.322 (0.444)	0.172	185	591652
Air Freight & Logistics	0.037 (0.319)	-2.605 (6.275)	-4.720 (3.967)	0.241	39	448489
Hotels, Restaurants & Leisure	7.278*** (0.000)	na	na	0.083	6	426348
Building Products	-0.234*** (0.080)	-0.355* (0.202)	0.483*** (0.091)	0.093	480	380646
Machinery	0.043 (0.058)	-0.097 (0.094)	0.161*** (0.034)	0.046	2420	350582
Energy Equipment & Services	0.124** (0.056)	0.305 (0.229)	-0.106 (0.185)	0.093	414	342478
Containers & Packaging	-0.260 (0.241)	-2.216** (1.007)	1.036 (1.383)	0.253	313	319053
Automobiles	0.021 (0.092)	-0.640*** (0.179)	0.017** (0.008)	0.104	418	264498
Electronic Equipment, Instruments & Components	-0.073 (0.053)	-0.054 (0.191)	0.086*** (0.012)	0.053	1440	255883
Specialty Retail	2.477*** (0.000)	na	9.560*** (0.000)	0.187	6	248423
Beverages	0.152 (0.339)	2.565*** (0.689)	0.738 (0.655)	0.278	170	224142
Semiconductors & Semiconductor Equipment	-0.108*** (0.031)	-0.582** (0.278)	0.274*** (0.067)	0.084	1299	204997
Insurance	0.328 (0.485)	-0.208 (0.631)	2.226 (2.489)	0.321	98	199957
Auto Components	-0.107 (0.093)	-0.344* (0.200)	0.390*** (0.059)	0.067	1013	198076
Real Estate Management & Development	2.663*** (0.000)	na	-34.207*** (0.000)	0.059	14	174526
Pharmaceuticals	-0.079 (0.075)	-0.393** (0.167)	0.185*** (0.048)	0.068	1443	168450
Household Durables	0.095 (0.100)	0.371 (0.332)	0.037*** (0.014)	0.084	626	126895
Entertainment	-1.262** (0.618)	-17.906*** (5.493)	5.241** (2.264)	0.357	41	126049
Textiles, Apparel & Luxury Goods	-0.233 (0.214)	-2.312*** (0.849)	3.064*** (0.969)	0.230	369	125082
Household Products	-0.047 (0.109)	0.941** (0.453)	0.372 (0.381)	0.211	177	111966
Health Care Providers & Services	-0.132 (0.170)	-1.047* (0.612)	8.769** (3.979)	0.248	210	109853
Electrical Equipment	-0.112*** (0.037)	-0.723*** (0.143)	0.151*** (0.023)	0.141	833	109565
Technology Hardware, Storage & Peripherals	-0.011 (0.085)	0.026 (0.325)	0.190*** (0.072)	0.091	674	101589
Aerospace & Defense	0.246*** (0.081)	-0.341* (0.188)	0.177* (0.091)	0.093	569	89730
Wireless Telecommunication Services	-0.555** (0.268)	-1.379 (1.116)	-1.199 (5.829)	0.329	124	88311
Tobacco	-0.782** (0.303)	2.102* (1.123)	0.958 (0.974)	0.238	108	74380
Diversified Telecommunication Services	-1.977*** (0.341)	5.329*** (0.969)	-5.309* (2.872)	0.364	277	55247
Equity Real Estate Investment Trusts (REITs)	0.447*** (0.000)	na	-9.172*** (0.000)	0.091	6	47687
Personal Products	0.300 (0.253)	-1.199 (0.843)	0.579 (1.057)	0.244	190	45429
Banks	0.113 (0.219)	-0.639 (0.474)	-0.214 (0.353)	0.119	279	36212
Internet & Direct Marketing Retail	-10.864** (4.746)	-185.218** (86.651)	45.821*** (17.154)	0.403	48	30579
Health Care Equipment & Supplies	0.273** (0.134)	-0.538 (0.381)	1.264*** (0.441)	0.142	1019	29296
Media (discont. 2018)	0.872*** (0.195)	1.078** (0.477)	-1.298 (2.884)	0.265	206	27369
Media	0.627 (0.605)	-5.134 (3.465)	59.782** (23.360)	0.530	40	26301
IT Services	0.140 (0.181)	-1.578*** (0.592)	0.443* (0.233)	0.213	335	20489
Capital Markets	0.058 (0.121)	-0.502 (0.327)	0.676*** (0.153)	0.187	330	17109
Life Sciences Tools & Services	0.172 (0.110)	-0.599 (0.495)	0.791*** (0.197)	0.101	289	16775
Communications Equipment	-0.346* (0.183)	1.771*** (0.604)	0.469 (0.380)	0.218	400	15302
Leisure Products	0.342** (0.140)	0.688** (0.280)	0.659*** (0.105)	0.310	237	15171
Biotechnology	-0.295*** (0.049)	-1.269* (0.726)	2.206*** (0.197)	0.122	1012	13626
Software	-0.897*** (0.335)	4.866** (2.098)	-0.226 (0.554)	0.244	566	9776
Interactive Media & Services	-0.719*** (0.190)	-85.065* (45.813)	2.841 (1.905)	0.218	33	4414
Health Care Technology	0.611*** (0.000)	na	5.137*** (0.000)	0.263	7	1291

TABLE IA.VII: BROWN EFFICIENCY PATENT RATIO AND FIRM TYPE - INDUSTRY BY INDUSTRY

The unit of observation is firm-year. The sample period is 2005-2020. The dependent variable is *BROWNEFFRATIOEP*. The key independent variables of interest are *LOGS1TOT*, *AGE*, and *PATSTOCKBROWNEFFEP*. We additionally include the following controls: LOGSIZE, LOGPPE, LEVERAGE, ROE, M/B, INVEST/A, BETA, VOLAT, MOM, RET, and MSCI. All intedependent variabels are lagged by one year and defined in Table 1 and Table 2. We run the regression individually for each 6-digit GICS Industry with a Poisson pseudo-maximum likelihood regression and include country and year fixed effects. We double cluster standard errors at the firm and year dimension. We report the coefficient and standard error for *LOGS1TOT* in column 1, for *AGE* in column 2 and for *PATSTOCKBROWNEFFEP* in column 3 with *** representing 1% significance, ** 5% significance * 10% significance. Column 4 reports the Pseudo R2, column 5 the number of observations in the regression and column 6 the industry average absolute scope 1 emissions by which we rank the table.

Industry	(1) coef (std. err) LOGS1TOT	(2) coef (std. err) AGE (/100)	(3) coef (std. err) PATSTOCKBROWNEFFEP (/100)	(4) Pseudo R2	(5) N	(6) Industry Scope 1
Electric Utilities	0.498*** (0.174)	0.916 (0.753)	8.859* (4.843)	0.239	232	21966773
Oil, Gas & Consumable Fuels	0.123 (0.128)	0.103 (0.160)	0.102 (0.113)	0.095	545	20973912
Independent Power and Renewable Electricity Producers	0.210*** (0.000)	na	-0.949*** (0.000)	0.054	8	18641614
Metals & Mining	-0.179** (0.072)	-0.587* (0.309)	0.770*** (0.236)	0.098	822	16138911
Construction Materials	-0.051 (0.229)	-0.090 (0.697)	5.102* (2.987)	0.170	218	9916635
Multi-Utilities	-0.154 (0.286)	-0.096 (0.868)	2.247 (2.478)	0.277	108	7344608
Chemicals	0.024 (0.103)	-0.107 (0.125)	0.357*** (0.092)	0.102	2034	4744375
Industrial Conglomerates	-0.238*** (0.063)	0.585* (0.341)	0.003 (0.028)	0.182	385	1538727
Food Products	0.511 (0.334)	-2.062* (1.061)	25.834*** (7.804)	0.363	471	1141156
Construction & Engineering	-0.031 (0.100)	-0.191 (0.402)	2.691*** (0.833)	0.115	523	845274
Diversified Financial Services	0.076 (0.064)	0.054 (0.698)	0.775 (0.589)	0.257	221	729626
Commercial Services & Supplies	0.029 (0.237)	-3.009** (1.239)	19.910** (8.770)	0.346	273	696769
Gas Utilities	-8.108*** (0.000)	na	-27.317*** (0.000)	0.081	10	617602
Trading Companies & Distributors	-0.647*** (0.191)	-3.213*** (0.697)	-0.807 (0.738)	0.264	94	591652
Building Products	-0.351** (0.152)	0.161 (0.317)	2.054*** (0.488)	0.145	479	380646
Machinery	-0.120** (0.052)	0.326*** (0.111)	0.167*** (0.029)	0.078	2392	350582
Energy Equipment & Services	-0.126** (0.058)	-0.032 (0.217)	0.223*** (0.048)	0.109	437	342478
Containers & Packaging	0.519 (0.547)	-1.205 (1.344)	25.427 (20.988)	0.430	173	319053
Automobiles	-0.073 (0.131)	1.498*** (0.300)	0.000 (0.010)	0.087	415	264498
Electronic Equipment, Instruments & Components	-0.022 (0.110)	2.036*** (0.355)	0.390*** (0.066)	0.155	1278	255883
Semiconductors & Semiconductor Equipment	0.318 (0.237)	1.843 (1.442)	5.967 (4.528)	0.275	1235	204997
Insurance	1.658*** (0.000)	-6.201*** (0.000)	-3.978*** (0.000)	0.286	83	199957
Auto Components	-0.155* (0.084)	0.033 (0.221)	0.273*** (0.047)	0.062	995	198076
Pharmaceuticals	0.382 (0.310)	-1.299 (0.863)	2.399 (1.584)	0.239	811	168450
Household Durables	0.057 (0.166)	-0.452 (0.439)	1.802*** (0.399)	0.293	572	126895
Household Products	-1.445*** (0.344)	-4.200*** (1.162)	2.298 (10.168)	0.620	129	111966
Health Care Providers & Services	-0.246*** (0.000)	na	na	0.010	10	109853
Electrical Equipment	-0.111 (0.113)	0.308 (0.392)	1.137*** (0.227)	0.144	799	109565
Technology Hardware, Storage & Peripherals	-0.216 (0.136)	4.414** (1.985)	2.786 (7.346)	0.500	627	101589
Aerospace & Defense	0.020 (0.129)	0.314 (0.266)	0.105*** (0.029)	0.126	547	89730
Tobacco	-0.863 (0.874)	5.265 (4.827)	4.440 (5.273)	0.307	87	74380
Banks	-2.585** (1.319)	-1.674* (0.875)	-2.420 (1.600)	0.347	186	36212
Health Care Equipment & Supplies	0.478 (0.291)	0.252 (0.991)	12.868*** (4.730)	0.171	774	29296
Media (discont. 2018)	37.065*** (0.000)	-53.910*** (0.000)	-781.612*** (0.000)	0.587	123	27369
IT Services	0.914*** (0.335)	-0.711 (0.932)	27.555*** (10.118)	0.630	298	20489
Capital Markets	0.277 (0.185)	0.287 (0.726)	-1.139 (2.909)	0.406	212	17109
Life Sciences Tools & Services	0.329 (0.341)	2.224 (2.293)	-18.939 (29.499)	0.300	198	16775
Communications Equipment	0.371 (0.416)	4.158*** (1.611)	-17.779** (8.267)	0.262	264	15302
Leisure Products	0.633 (0.527)	0.656 (0.777)	36.615*** (10.973)	0.442	167	15171
Professional Services	-4.365*** (0.000)	na	-75.640*** (0.000)	0.172	6	9864
Software	-5.699*** (1.821)	26.915 (18.620)	104.187*** (33.025)	0.627	198	9776
Interactive Media & Services	0.459*** (0.000)	na	-35.920*** (0.000)	0.103	6	4414

TABLE IA.VIII: PATENT RATIOS AND FIRM TYPE: ALTERNATIVE "GREEN" CLASSIFICATIONS

The unit of observation is firm-year. The sample period is 2005-2020. The dependent variable is OECDRATIOEP in columns 1 to 3 and GREENRATIOEP2 in columns 4 to 6. All variables are defined in Table 1 and Table IA.V. All independent variables are lagged by one year. The model is estimated using Poisson pseudo-maximum likelihood. Columns 1 and 4 include year and country fixed effects. Columns 2 and 5 include country and Trucost industry-year fixed effects and columns 3 and 6 year and firm fixed effects. We double cluster standard errors at the firm and year dimension. *** 1% significance, ** 5% significance * 10% significance.

	(1)	(2)	(3)	(4)	(5)	(6)
	OECDRATIOEP			*GREENRATIOEP2*		
LOGS1TOT	0.095***	−0.017	−0.008	0.038***	−0.029***	−0.001
	(0.007)	(0.010)	(0.015)	(0.005)	(0.007)	(0.010)
AGE (/100)	−0.103***	−0.068**		−0.228***	−0.116***	
	(0.029)	(0.028)		(0.023)	(0.022)	
PATSTOCKGREENEP (/100)	0.044***	0.019***	−0.001	0.030***	0.023***	0.003
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.002)
LOGSIZE	−0.174***	−0.039**	0.023	−0.033***	−0.033***	0.035**
	(0.016)	(0.017)	(0.023)	(0.012)	(0.012)	(0.016)
LOGPPE	0.124***	0.051***	−0.051**	0.043***	0.047***	−0.036**
	(0.016)	(0.016)	(0.025)	(0.011)	(0.011)	(0.016)
LEVERAGE	−0.002***	−0.000	0.003**	−0.002***	−0.002***	0.000
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
ROE	−0.031	−0.063	0.054	−0.087**	−0.070**	0.015
	(0.058)	(0.051)	(0.037)	(0.036)	(0.034)	(0.024)
M/B	0.002	0.006	−0.005	0.000	0.015***	−0.001
	(0.006)	(0.006)	(0.005)	(0.004)	(0.004)	(0.003)
INVEST/A	0.002	0.005*	0.007**	0.008***	0.008***	0.005**
	(0.003)	(0.003)	(0.003)	(0.002)	(0.002)	(0.002)
BETA	0.363***	0.070*	0.018	0.246***	0.062**	−0.027
	(0.035)	(0.036)	(0.026)	(0.025)	(0.026)	(0.019)
VOLAT	1.273***	1.241***	−0.016	1.074***	0.875***	0.008
	(0.235)	(0.272)	(0.241)	(0.180)	(0.181)	(0.143)
MOM	0.850*	−0.598	0.384	0.274	−0.162	−0.058
	(0.473)	(0.460)	(0.299)	(0.329)	(0.333)	(0.220)
RET	−0.227*	−0.182	−0.067	−0.143	−0.109	0.011
	(0.126)	(0.119)	(0.078)	(0.088)	(0.086)	(0.056)
MSCI	0.009	0.029	−0.034	0.045**	0.054**	0.033
	(0.031)	(0.030)	(0.036)	(0.023)	(0.022)	(0.026)
Constant	2.181***	2.932***	3.486***	−1.942***	−1.242***	−1.104***
	(0.093)	(0.098)	(0.206)	(0.069)	(0.070)	(0.137)
Country F.E.	yes	yes	no	yes	yes	no
Year F.E.	yes	yes	yes	yes	yes	yes
Industry F.E.	no	yes	no	no	yes	no
Industry X Year F.E.	no	yes	no	no	yes	no
Firm F.E.	no	no	yes	no	no	yes
Observations	27854	24843	20299	27873	25985	23546
Pseudo R2	0.0930	0.342	0.511	0.0169	0.0986	0.162

TABLE IA.IX: WORLDWIDE PATENT RATIOS AND FIRM TYPE

The unit of observation is firm-year. The sample period is 2005-2020. The dependent variable is *GREENRATIOWW* in columns 1 to 3 and *BROWNEFFRATIOWW* in columns 4 to 6. *GREENRATIOWW* is the number of green patent families over the total number of patent families granted or purchased at the firm and year level from any patent office worldwide. *BROWNEFFRATIOWW* similarly is the number of brown efficiency patent families over the total number of patent families at any patent office worldwide. All other variables are defined in Table 1 and Table 2. All independent variables are lagged by one year. The model is estimated using Poisson pseudo-maximum likelihood. Columns 1 and 4 include year and country fixed effects. Columns 2 and 5 include country and Trucost industry-year fixed effects and columns 3 and 6 year and firm fixed effects. We double cluster standard errors at the firm and year dimension. *** 1% significance, ** 5% significance * 10% significance.

	(1)	(2)	(3)	(4)	(5)	(6)
	GREENRATIOWW			*BROWNEFFRATIOWW*		
LOGS1TOT	0.105***	−0.022**	−0.008	0.094***	0.042***	0.000
	(0.006)	(0.009)	(0.011)	(0.010)	(0.016)	(0.027)
AGE (/100)	−0.289***	−0.118***		0.067	0.049	
	(0.029)	(0.027)		(0.041)	(0.042)	
PATSTOCKGREENWW (/100)	0.013***	0.008***	0.001			
	(0.001)	(0.001)	(0.001)			
PATSTOCKBROWNEFFWW (/100)				0.031***	0.015***	−0.004**
				(0.002)	(0.002)	(0.002)
LOGSIZE	−0.152***	−0.068***	0.001	−0.297***	−0.096***	−0.060
	(0.013)	(0.015)	(0.018)	(0.026)	(0.027)	(0.041)
LOGPPE	0.083***	0.091***	0.008	0.241***	0.056**	0.075
	(0.013)	(0.014)	(0.019)	(0.025)	(0.025)	(0.047)
LEVERAGE	−0.005***	−0.003***	0.001	−0.006***	−0.001	−0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)
ROE	−0.289***	−0.088**	0.050*	0.307***	0.147*	0.036
	(0.046)	(0.041)	(0.027)	(0.074)	(0.076)	(0.065)
M/B	0.013***	0.012**	−0.003	−0.021**	−0.003	−0.010
	(0.005)	(0.005)	(0.004)	(0.009)	(0.009)	(0.011)
INVEST/A	0.015***	0.007***	−0.000	0.013***	0.007	0.006
	(0.002)	(0.003)	(0.002)	(0.005)	(0.005)	(0.005)
BETA	0.190***	0.051	−0.040*	0.270***	−0.013	−0.061
	(0.031)	(0.032)	(0.023)	(0.054)	(0.050)	(0.046)
VOLAT	1.541***	1.353***	0.010	−0.236	−0.594	−0.377
	(0.224)	(0.175)	(0.142)	(0.402)	(0.423)	(0.392)
MOM	−0.007	−0.737**	0.259	0.601	−0.113	−0.244
	(0.383)	(0.358)	(0.234)	(0.671)	(0.657)	(0.553)
RET	0.025	−0.013	−0.016	−0.046	0.205	0.321**
	(0.098)	(0.092)	(0.058)	(0.180)	(0.177)	(0.145)
MSCI	0.029	0.018	0.056*	−0.049	0.062	−0.017
	(0.028)	(0.027)	(0.030)	(0.051)	(0.048)	(0.059)
Constant	1.962***	2.530***	3.058***	1.074***	2.055***	2.660***
	(0.079)	(0.078)	(0.149)	(0.146)	(0.156)	(0.380)
Country F.E.	yes	yes	no	yes	yes	no
Year F.E.	yes	yes	yes	yes	yes	yes
Industry X Year F.E.	no	yes	no	no	yes	no
Firm F.E.	no	no	yes	no	no	yes
Observations	52568	49362	37346	52339	43021	23558
Pseudo R2	0.0948	0.315	0.565	0.140	0.425	0.556

TABLE IA.X: PATH RATIOS AND FIRM TYPE: ALTERNATIVE INDUSTRY SPECIFICATIONS

The unit of observation is firm-year. The sample period is 2005 to 2020. The dependent variable is GREENRATIOEP in columns 1 to 4 and BROWNEFFRATIOEP in columns 5 to 8. We include the following controls: LOGSIZE, LOGPPE, LEVERAGE, ROE, M/B, INVEST/A, BETA, VOLAT, MOM, RET and MSCI. All variables are defined in Table 1 and Table 2. All independent variables are lagged by one year. The model is estimated using Poisson pseudo-maximum likelihood. All regressions include country and year fixed effects. Column 1 and 5 additionally include industry fixed effects based on the 6-digit level GICS Industry, while column 3 and 7 add industry as well as the industry-year interaction. Column 2 and 6 additionally include year fixed effects and industry fixed effects based on the 8-digit level GICS Subindustry, while column 4 and 8 also include the industry-year interaction. We double cluster standard errors at the firm and year dimension. *** 1% significance, ** 5% significance * 10% significance.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	GREENRATIOEP				*BROWNEFFRATIOEP*			
LOGS1TOT	−0.032***	−0.036***	−0.033***	−0.036***	−0.010	0.013	−0.009	0.012
	(0.009)	(0.010)	(0.009)	(0.010)	(0.018)	(0.018)	(0.017)	(0.017)
AGE (/100)	−0.160***	−0.154***	−0.163***	−0.144***	0.193***	0.202***	0.191***	0.199***
	(0.031)	(0.031)	(0.031)	(0.030)	(0.049)	(0.049)	(0.048)	(0.048)
PATSTOCKGREENEP (/100)	0.046***	0.047***	0.046***	0.047***				
	(0.004)	(0.004)	(0.004)	(0.004)				
PATSTOCKBROWNEFFEP (/100)					0.058***	0.056***	0.067***	0.066***
					(0.009)	(0.009)	(0.009)	(0.009)
Controls	yes	yes	yes	yes	yes	yes	yes	yes
Country F.E.	yes	yes	yes	yes	yes	yes	yes	yes
Year F.E.	yes	yes	yes	yes	yes	yes	yes	yes
Industry F.E.	GICS Ind	GICS Sub Ind	GICS Ind	GICS Sub Ind	GICS Ind	GICS Sub Ind	GICS Ind	GICS Sub Ind
Industry-Year F.E.	no	no	GICS Ind	GICS Sub Ind	no	no	GICS Ind	GICS Sub Ind
Observations	27860	27687	27419	26513	27309	26411	23637	22225
Pseudo R2	0.196	0.216	0.224	0.256	0.277	0.301	0.286	0.329

TABLE IA.XI: PATENT RATIOS AND FIRM TYPE: LEGACY SAMPLE

The unit of observation is firm-year. The sample period is 2005-2020 and the sample restricts inclusion of firms into those that Trucost covers in its database before 2016. The dependent variable is GREENRATIOEP in columns 1 to 3 and BROWNEFFRATIOEP in columns 4 to 6. Panel A covers all firm-years, while we further restricts inclusion in Panel B to firm-years with *at least one* green patent at the European Patent Office in columns 1 to 3 and one brown efficiency patent at the European Patent Office in columns 4 to 6. We include the following controls: LOGSIZE, LOGPPE, LEVERAGE, ROE, M/B, INVEST/A, BETA, VOLAT, MOM, RET and MSCI. All variables are defined in Table 1 and Table 2. All independent variables are lagged by one year. The model is estimated using Poisson pseudo-maximum likelihood. Columns 1 and 4 include year and country fixed effects. Columns 2 and 5 include country and Trucost industry-year fixed effects and columns 3 and 6 year and firm fixed effects. We double cluster standard errors at the firm and year dimension. *** 1% significance, ** 5% significance * 10% significance.

	(1)	(2)	(3)	(4)	(5)	(6)
	GREENRATIOEP			*BROWNEFFRATIOEP*		
Panel A: All firm years						
LOGS1TOT	0.101***	−0.040***	0.014	0.063***	0.056***	−0.065**
	(0.008)	(0.012)	(0.016)	(0.014)	(0.020)	(0.033)
AGE (/100)	−0.311***	−0.185***		0.269***	0.273***	
	(0.034)	(0.032)		(0.046)	(0.052)	
PATSTOCKGREENEP (/100)	0.052***	0.039***	−0.002			
	(0.004)	(0.004)	(0.003)			
PATSTOCKBROWNEFFEP (/100)				0.102***	0.044***	−0.000
				(0.010)	(0.008)	(0.008)
Country F.E.	yes	yes	no	yes	yes	no
Year F.E.	yes	yes	yes	yes	yes	yes
Industry F.E.	no	yes	no	no	yes	no
Industry X Year F.E.	no	yes	no	no	yes	no
Firm F.E.	no	no	yes	no	no	yes
Observations	22990	20155	18374	22922	16164	11588
Pseudo R2	0.0948	0.361	0.509	0.0973	0.450	0.522
Panel B: Firm-years with at least one green/ brown efficiency patent						
LOGS1TOT	1.626***	−1.631***	−0.356	0.370*	−0.122	−0.263
	(0.174)	(0.256)	(0.275)	(0.198)	(0.345)	(0.508)
AGE (/100)	−6.883***	−3.265***		−0.743	−0.141	
	(0.614)	(0.608)		(0.656)	(0.815)	
PATSTOCKGREENEP (/100)	0.720***	0.996***	0.478***			
	(0.090)	(0.109)	(0.072)			
PATSTOCKBROWNEFFEP (/100)				1.316***	0.951***	0.272*
				(0.149)	(0.168)	(0.142)
Country F.E.	yes	yes	no	yes	yes	no
Year F.E.	yes	yes	yes	yes	yes	yes
Industry F.E.	no	yes	no	no	yes	no
Industry X Year F.E.	no	yes	no	no	yes	no
Firm F.E.	no	no	yes	no	no	yes
Observations	11022	9776	10602	5211	4222	4905
R2	0.193	0.551	0.804	0.176	0.533	0.753
Controls	yes	yes	yes	yes	yes	yes
Country F.E.	yes	yes	no	yes	yes	no
Year F.E.	yes	yes	yes	yes	yes	yes
Industry X Year F.E.	no	yes	no	no	yes	no
Firm F.E.	no	no	yes	no	no	yes

TABLE IA.XII: PATENT RATIOS AND FIRM TYPE: EXCLUDING M&A FIRMS

The unit of observation is firm-year. The sample period is 2005-2020 and restricits inclusion to firms without green or brown efficiency M&A activity between 2005 and 2020. Specifically, we drop firms that acquired a target with one or more green patents granted by the EPO between 2005 and 2020 in columns 1 to 3 and one or more brown efficiency patents granted by the EPO between 2005 and 2020 in columns 3 to 6. In Panel A, the dependent variable is GREENRATIOEP in columns 1 to 3 and BROWNEFFRATIOEP in columns 4 to 6. In Panel B, the dependent variable is GREENCITMAXEP in columns 1 to 3 and BROWNEFFCITMAXEP in columns 4 to 6. In Panel C, the dependent variable is GREENCOUNTBBEP in columns 1 to 3 and BROWNEFFCOUNTBBEP in columns 4 to 6. We include the following controls: LOGSIZE, LOGPPE, LEVERAGE, ROE, M/B, INVEST/A, BETA, VOLAT, MOM, RET and MSCI. All variables are defined in Table 1, Table 2 and Table 4. All independent variables are lagged by one year. The model is estimated using Poisson pseudo-maximum likelihood. Columns 1 and 4 include year and country fixed effects. Columns 2 and 5 include country and Trucost industry-year fixed effects and columns 3 and 6 year and firm fixed effects. We double cluster standard errors at the firm and year dimension.

Panel A: Patent ratio	(1)	(2)	(3)	(4)	(5)	(6)
	GREENRATIOEP			BROWNEFFRATIOEP		
LOGS1TOT	0.092***	−0.052***	0.014	0.059***	0.052**	−0.066**
	(0.008)	(0.011)	(0.016)	(0.014)	(0.020)	(0.032)
AGE (/100)	−0.306***	−0.193***		0.231***	0.212***	
	(0.033)	(0.031)		(0.046)	(0.052)	
PATSTOCKGREENEP (/100)	0.051***	0.035***	−0.001			
	(0.004)	(0.004)	(0.003)			
PATSTOCKBROWNEFFEP (/100)				0.102***	0.051***	−0.003
				(0.010)	(0.009)	(0.009)
Observations	27375	24254	19634	27379	19499	11765
Pseudo R2	0.0776	0.317	0.516	0.0990	0.437	0.524
Panel B: Maximum citations						
	GREENCITMAXEP			BROWNEFFCITMAXEP		
LOGS1TOT	−0.041*	−0.193***	−0.068	0.049***	0.083**	0.146
	(0.023)	(0.056)	(0.069)	(0.018)	(0.033)	(0.105)
AGE (/100)	0.391**	0.617***		0.364***	0.100	
	(0.169)	(0.160)		(0.121)	(0.079)	
PATSTOCKGREENEP (/100)	0.063***	0.058***	−0.033**			
	(0.009)	(0.010)	(0.015)			
PATSTOCKBROWNEFFEP (/100)				0.117***	0.085***	0.011
				(0.011)	(0.012)	(0.017)
Observations	27367	23945	18945	27379	18933	11027
Pseudo R2	0.336	0.632	0.702	0.305	0.626	0.635
Panel C: Blockbuster count						
	GREENCOUNTBBEP			BROWNEFFCOUNTBBEP		
LOGS1TOT	−0.035**	−0.010	−0.028	0.080***	0.103**	−0.025
	(0.014)	(0.031)	(0.034)	(0.020)	(0.043)	(0.056)
AGE (/100)	0.077	0.056		0.566***	0.223***	
	(0.071)	(0.076)		(0.061)	(0.080)	
PATSTOCKGREENEP (/100)	0.099***	0.075***	−0.009			
	(0.006)	(0.006)	(0.007)			
PATSTOCKBROWNEFFEP (/100)				0.150***	0.130***	0.025
				(0.012)	(0.013)	(0.018)
Observations	27222	17382	10089	26792	9218	4949
Pseudo R2	0.314	0.448	0.461	0.331	0.553	0.497
Controls	yes	yes	yes	yes	yes	yes
Country F.E.	yes	yes	no	yes	yes	no
Year F.E.	yes	yes	yes	yes	yes	yes
Industry X Year F.E.	no	yes	no	no	yes	no
Firm F.E.	no	no	yes	no	no	yes

TABLE IA.XIII: PATENT RATIO AND FIRM TYPE: SPLITS BASED ON INITIAL FIRM EMISSIONS

The unit of observation is firm-year. The sample period is 2005-2020. We split the Trucost sample with patenting and non-patenting observations into terciles based on firms' initial scope 1 emissions, i.e. the first scope 1 emission we observe. The terciles are calculated within the set of firms entering the sample in a given year. Columns 1 to 3 cover firms with the lowest initial emission tercile, columns 4 to 6 cover firms in the middle group and columns 7 to 9 cover firms in the highest initial emission tercile. The dependent variable is GREENRATIOEP in Panel A and BROWNEFFRATIOEP in Panel B. We include the following controls: LOGSIZE, LOGPPE, LEVERAGE, ROE, M/B, INVEST/A, BETA, VOLAT, MOM, RET and MSCI. All variables are defined in Table 1 and Table 2. All independent variables are lagged by one year. The model is estimated using Poisson pseudo-maximum likelihood. Columns 1, 4 and 7 include year and country fixed effects. Columns 2, 5 and 8 include country and Trucost industry-year fixed effects and columns 3, 6 and 9 year and firm fixed effects. We double cluster standard errors at the firm and year dimension. *** 1% significance, ** 5% significance * 10% significance.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Panel A: GREENRATIOEP									
Initial emission tercile:	Lowest			Middle			Highest		
LOGS1TOT	−0.092**	−0.170***	−0.076*	0.046	−0.006	0.005	0.115***	0.014	0.020
	(0.039)	(0.052)	(0.040)	(0.031)	(0.037)	(0.032)	(0.009)	(0.013)	(0.019)
AGE (/100)	−0.622**	−1.254***		−0.234**	−0.083		−0.249***	−0.113***	
	(0.279)	(0.359)		(0.103)	(0.103)		(0.035)	(0.032)	
PATSTOCKGREENEP (/100)	0.682***	0.349***	−0.182**	1.139***	0.949***	−0.456***	0.042***	0.033***	0.002
	(0.090)	(0.115)	(0.079)	(0.089)	(0.132)	(0.093)	(0.004)	(0.004)	(0.003)
Observations	2990	2189	1277	6928	4984	4020	17878	15276	14852
Pseudo R2	0.145	0.286	0.573	0.129	0.369	0.545	0.0983	0.362	0.494
Panel B: BROWNEFFRATIOEP									
Initial emission tercile:	Lowest			Middle			Highest		
LOGS1TOT	0.166	0.430*	0.179	0.062	0.074	−0.007	0.052***	0.042*	−0.087**
	(0.103)	(0.222)	(0.131)	(0.055)	(0.104)	(0.083)	(0.016)	(0.022)	(0.036)
AGE (/100)	−0.994	−1.381		0.159	0.168		0.206***	0.214***	
	(0.790)	(1.356)		(0.159)	(0.218)		(0.048)	(0.051)	
PATSTOCKBROWNEFFEP (/100)	1.176***	3.377**	−0.093	8.219***	8.113***	−2.391***	0.096***	0.042***	0.003
	(0.272)	(1.648)	(0.353)	(1.460)	(2.014)	(0.726)	(0.009)	(0.008)	(0.008)
Observations	2817	963	272	6818	2460	1772	17803	12125	10132
Pseudo R2	0.289	0.749	0.683	0.191	0.497	0.539	0.0788	0.422	0.525
Controls	yes	yes	yes	yes	yes	yes	yes	yes	yes
Country F.E.	yes	yes	no	yes	yes	no	yes	yes	no
Year F.E.	yes	yes	yes	yes	yes	yes	yes	yes	yes
Industry X Year F.E.	no	yes	no	no	yes	no	no	yes	no
Firm F.E.	no	no	yes	no	no	yes	no	no	yes

TABLE IA.XIV: PATENT RATIOS AND FIRM-LEVEL OUTCOMES - INTENSIVE MARGIN

The unit of observation is firm-year. The sample period is 2005 to 2020. We require firm-year observations to have *at least one* green patent at the EPO in Panel A and one brown efficiency patent at the EPO in Panel B. The dependent variables are logs of cumulative sums of S1TOT, S2TOT, S3UPTOT, S3DOWNTOT, S123UPTOT, CAPEX, and SALES over 1, 3 or 5 years, respectively long-term averages of S1INT, S2INT, S3UPINT, S3DOWNINT and INVEST/A for 1, 3 or 5 years. In Panel A, the key independent variable is *GREENRATIOEP* lagged by 1, 3, or 5 years as well as a 3-year rolling ratio lagged by 1 year. In Panel B, the key independent variable similarly is *BROWNEFFRATIOEP*. Controls include: *LOGSIZE, LOGPPE, LEVERAGE, ROE, M/B, INVEST/A, BETA, VOLAT, MOM, RET, MSCI.* All variables are defined in Table 1 and Table 2 and lagged by 1, 3, or 5 years. The model is estimated using pooled regression model. All regressions include year and firm fixed effects. We double cluster standard errors at the firm and year dimension. *** 1% significance, ** 5% significance * 10% significance.

	(1) LOGS1TOT	(2) LOGS2TOT	(3) LOGS3UPTOT	(4) LOGS3DOWNTOT	(5) LOGS123UPTOT	(6) S1INT	(7) S2INT	(8) S3UPINT	(9) S3DOWNINT	(10) INVEST/A	(11) LOGCAPEX	(12) LOGSALES
Panel A: Green innovation												
L1 GREENRATIOEP	−0.014	−0.011	−0.008	−0.070	−0.019	−0.050	−0.005	0.021	−0.127	−0.119	−0.021	−0.004
	(0.035)	(0.034)	(0.020)	(0.145)	(0.020)	(0.105)	(0.015)	(0.025)	(0.663)	(0.159)	(0.019)	(0.017)
Observations	13226	13226	13224	3868	13226	13226	13226	13226	3868	13226	13226	13225
R2	0.957	0.942	0.978	0.916	0.979	0.940	0.847	0.951	0.889	0.726	0.914	0.979
L3 GREENRATIOEP	−0.003	−0.028	0.001	0.257	0.006	0.116	0.003	0.023	−0.036	−0.131	−0.005	−0.001
	(0.035)	(0.036)	(0.019)	(0.293)	(0.018)	(0.108)	(0.014)	(0.024)	(0.724)	(0.114)	(0.017)	(0.015)
Observations	10830	10830	10830	1514	10830	10830	10830	10830	1514	11718	11718	11714
R2	0.969	0.957	0.984	0.984	0.986	0.965	0.904	0.968	0.986	0.825	0.944	0.986
L5 GREENRATIOEP	−0.044	0.001	0.021		0.013	−0.025	0.004	0.003		0.012	−0.010	0.012
	(0.035)	(0.039)	(0.021)		(0.021)	(0.090)	(0.014)	(0.022)		(0.109)	(0.017)	(0.017)
Observations	8393	8393	8393		8393	8393	8393	8393		9135	9135	9132
R2	0.977	0.965	0.986		0.988	0.979	0.937	0.978		0.884	0.945	0.989
L1 3YEARAVGGREENRATIOEP	−0.027	−0.025	−0.002	−0.100	−0.010	0.009	0.000	0.040	0.058	−0.198	0.018	−0.025
	(0.043)	(0.044)	(0.024)	(0.191)	(0.024)	(0.140)	(0.020)	(0.029)	(0.976)	(0.169)	(0.022)	(0.020)
Observations	16737	16737	16735	5376	16737	16737	16737	16737	5376	16735	16735	16735
R2	0.964	0.950	0.982	0.932	0.983	0.945	0.854	0.958	0.909	0.737	0.932	0.982
Panel B: Brown efficiency innovation												
L1 BROWNEFFRATIOEP	−0.026	0.014	−0.009	0.122	−0.005	0.200	0.015	0.026	2.548	0.069	−0.017	−0.006
	(0.065)	(0.055)	(0.031)	(0.242)	(0.035)	(0.221)	(0.018)	(0.041)	(1.896)	(0.231)	(0.035)	(0.026)
Observations	6167	6167	6167	1629	6167	6167	6167	6167	1629	6167	6167	6166
R2	0.967	0.942	0.977	0.889	0.979	0.939	0.859	0.948	0.859	0.816	0.911	0.979
L3 BROWNEFFRATIOEP	−0.010	0.109*	0.012	−0.082	0.001	−0.250	0.024	0.023	−1.520	−0.109	−0.045	0.012
	(0.049)	(0.056)	(0.027)	(0.317)	(0.030)	(0.202)	(0.018)	(0.031)	(1.540)	(0.199)	(0.028)	(0.022)
Observations	5138	5138	5138	590	5138	5138	5138	5138	590	5443	5443	5442
R2	0.979	0.961	0.984	0.951	0.986	0.964	0.915	0.970	0.981	0.847	0.933	0.988
L5 BROWNEFFRATIOEP	0.026	0.039	0.048		0.037	0.075	−0.021	0.023		0.118	0.058	0.048*
	(0.054)	(0.050)	(0.031)		(0.030)	(0.146)	(0.018)	(0.029)		(0.152)	(0.039)	(0.026)
Observations	4077	4077	4077		4077	4077	4077	4077		4349	4349	4350
R2	0.984	0.970	0.986		0.989	0.982	0.943	0.978		0.896	0.938	0.990
L1 3YEARAVGBROWNEFFRATIOEP	0.050	0.092	0.007	−0.633	0.029	0.295	0.010	0.040	−1.204	−0.192	−0.038	0.020
	(0.067)	(0.069)	(0.034)	(0.465)	(0.042)	(0.319)	(0.024)	(0.048)	(3.088)	(0.277)	(0.033)	(0.030)
Observations	8588	8588	8588	2502	8588	8588	8588	8588	2502	8586	8586	8586
R2	0.976	0.958	0.986	0.938	0.986	0.943	0.876	0.963	0.898	0.795	0.940	0.984
Controls	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Year F.E.	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Firm F.E.	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes

TABLE IA.XV: PATENT COUNT AND FIRM-LEVEL OUTCOMES

The unit of observation is firm-year. The sample period is 2005 to 2020. The dependent variables are logs of cumulative sums of S1TOT, S2TOT, S3UPTOT, S3DOWNTOT, S123UPTOT, CAPEX, and SALES over 1, 3 or 5 years, respectively long-term averages of S1INT, S2INT, S3UPINT, S3DOWNINT and INVEST/A for 1, 3 or 5 years. In Panel A, the key independent variable is *GREENCOUNTEP* lagged by 1, 3, or 5 years as well as a 3-year rolling average lagged by 1 year. In Panel B, the key independent variable similarly is *BROWNEFFCOUNTEP*. Controls include: *LOGSIZE*, *LOGPPE*, *LEVERAGE*, *ROE*, *M/B*, *INVEST/A*, *BETA*, *VOLAT*, *MOM*, *RET*, *MSCI*. All variables are defined in Table 1 and are lagged by 1, 3, or 5 years. The model is estimated using pooled regression model. All regressions include year and firm fixed effects. We double cluster standard errors at the firm and year dimension. *** 1% significance, ** 5% significance * 10% significance.

	(1) LOGS1TOT	(2) LOGS2TOT	(3) LOGS3UPTOT	(4) LOGS3DOWNTOT	(5) LOGS123UPTOT	(6) S1INT	(7) S2INT	(8) S3UPINT	(9) S3DOWNINT	(10) INVEST/A	(11) LOGCAPEX	(12) LOGSALES
Panel A: Green innovation												
L1 GREENCOUNTEP/100	0.041	0.185	0.198**	0.680	0.133*	−0.488**	0.052	−0.372***	11.815**	−1.075**	−0.220***	0.291***
	(0.149)	(0.125)	(0.081)	(0.906)	(0.078)	(0.247)	(0.065)	(0.091)	(4.758)	(0.520)	(0.060)	(0.064)
Observations	29585	29585	29584	10349	29585	29585	29585	29585	10349	29578	29578	29580
R2	0.953	0.948	0.980	0.931	0.981	0.922	0.843	0.961	0.898	0.720	0.918	0.980
L3 GREENCOUNTEP/100	0.068	0.056	0.110	0.003	0.062	−0.222	0.056	−0.257***	2.955	−1.820***	−0.178***	0.140**
	(0.139)	(0.116)	(0.075)	(0.887)	(0.074)	(0.200)	(0.060)	(0.084)	(4.812)	(0.430)	(0.062)	(0.063)
Observations	22261	22261	22261	4160	22261	22261	22261	22261	4166	25158	25153	25155
R2	0.967	0.962	0.986	0.982	0.986	0.955	0.902	0.974	0.986	0.827	0.945	0.986
L5 GREENCOUNTEP/100	−0.066	−0.035	0.091		0.045	−0.257	0.100*	−0.143*		−2.201***	−0.151**	0.081
	(0.128)	(0.108)	(0.072)		(0.069)	(0.177)	(0.057)	(0.076)		(0.408)	(0.063)	(0.065)
Observations	15482	15482	15482		15482	15482	15482	15482		18347	18347	18343
R2	0.973	0.965	0.985		0.986	0.972	0.933	0.981		0.888	0.956	0.989
L1 3YEARAVGGREENCOUNTEP	0.415*	0.737***	0.532***	1.493	0.484***	−0.519	0.200**	−0.743***	10.244	−2.994***	−0.254***	0.672***
	(0.230)	(0.200)	(0.144)	(1.456)	(0.149)	(0.367)	(0.087)	(0.126)	(8.360)	(0.854)	(0.089)	(0.130)
Observations	38221	38221	38220	14552	38221	38221	38221	38221	14552	38210	38210	38214
R2	0.954	0.945	0.974	0.935	0.975	0.928	0.847	0.965	0.907	0.683	0.911	0.970
Panel B: Brown efficiency innovation												
L1 BROWNEFFCOUNTEP/100	−0.159	−1.141***	−0.204	−1.304	−0.328	−0.929	−0.221	−0.574**	15.398	1.081	−0.416**	−0.052
	(0.376)	(0.393)	(0.199)	(2.060)	(0.207)	(0.891)	(0.161)	(0.248)	(13.115)	(0.966)	(0.186)	(0.164)
Observations	29585	29585	29584	10349	29585	29585	29585	29585	10349	29578	29578	29580
R2	0.953	0.948	0.980	0.931	0.981	0.922	0.843	0.961	0.898	0.720	0.918	0.980
L3 BROWNEFFCOUNTEP/100	−0.126	−0.619*	−0.112	0.114	−0.176	−0.659	−0.017	−0.052	−4.847	0.610	−0.388	−0.191
	(0.376)	(0.373)	(0.203)	(2.928)	(0.220)	(0.755)	(0.142)	(0.218)	(9.072)	(0.866)	(0.240)	(0.165)
Observations	22261	22261	22261	4160	22261	22261	22261	22261	4166	25158	25153	25155
R2	0.967	0.962	0.986	0.982	0.986	0.955	0.902	0.974	0.986	0.827	0.945	0.986
L5 BROWNEFFCOUNTEP/100	−0.118	−0.427	−0.002		−0.153	−0.692	−0.035	0.143		1.169	−0.314	−0.054
	(0.399)	(0.367)	(0.187)		(0.215)	(0.803)	(0.143)	(0.203)		(0.799)	(0.285)	(0.157)
Observations	15482	15482	15482		15482	15482	15482	15482		18347	18347	18343
R2	0.973	0.965	0.985		0.986	0.972	0.933	0.981		0.888	0.956	0.989
L1 3YEARAVGBROWNEFFCOUNTEP	0.066	−1.225*	−0.796**	−1.725	−0.793**	−1.108	−0.080	−2.150***	−7.128	1.485	−1.242***	−0.599*
	(0.652)	(0.664)	(0.388)	(4.363)	(0.384)	(1.406)	(0.265)	(0.432)	(24.206)	(1.828)	(0.291)	(0.352)
Observations	38221	38221	38220	14552	38221	38221	38221	38221	14552	38210	38210	38214
R2	0.954	0.945	0.974	0.935	0.975	0.928	0.847	0.965	0.907	0.682	0.911	0.970
Controls	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Year F.E.	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Firm F.E.	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes

TABLE IA.XVI: PATENT MAXIMUM CITATIONS AND FIRM LEVEL OUTCOMES

The unit of observation is firm-year. The sample period is 2005 to 2020. The dependent variables are logs of cumulative sums of S1TOT, S2TOT, S3UPTOT, S3DOWNTOT, S123UPTOT, CAPEX, and SALES over 1, 3 or 5 years, respectively long-term averages of S1INT, S2INT, S3UPINT, S3DOWNINT and INVEST/A for 1, 3 or 5 years. In Panel A, the key independent variable is *GREENCITMAXEP* lagged by 1, 3, or 5 years. In Panel B, the key independent variable similarly is *BROWNEFFCITMAXEP*. Controls include: *LOGSIZE*, *LOGPPE*, *LEVERAGE*, *ROE*, *M/B*, *INVEST/A*, *BETA*, *VOLAT*, *MOM*, *RET*, *MSCI*. All variables are defined in Table 1 and Table 4 and lagged by 1, 3, or 5 years. The model is estimated using pooled regression model. All regressions include year and firm fixed effects. We double cluster standard errors at the firm and year dimension. *** 1% significance, ** 5% significance * 10% significance.

	(1) LOGS1TOT	(2) LOGS2TOT	(3) LOGS3UPTOT	(4) LOGS3DOWNTOT	(5) LOGS123UPTOT	(6) S1INT	(7) S2INT	(8) S3UPINT	(9) S3DOWNINT	(10) INVEST/A	(11) LOGCAPEX	(12) LOGSALES
Panel A: Green innovation												
L1 GREENCITMAXEP/10000	0.074	0.063	0.062*	−0.359***	0.061*	0.011	−0.004	0.019	−0.430	−0.088	0.033	0.045
	(0.063)	(0.057)	(0.036)	(0.060)	(0.035)	(0.035)	(0.012)	(0.023)	(0.401)	(0.117)	(0.027)	(0.030)
Observations	29585	29585	29584	10349	29585	29585	29585	29585	10349	29578	29578	29580
R2	0.953	0.948	0.980	0.931	0.981	0.922	0.843	0.961	0.898	0.720	0.917	0.980
L3 GREENCITMAXEP/10000	0.069	0.055	0.033	−0.162***	0.041	0.042	0.005	0.015	−0.431*	0.048	0.014	0.023
	(0.059)	(0.049)	(0.027)	(0.037)	(0.028)	(0.027)	(0.012)	(0.018)	(0.243)	(0.095)	(0.022)	(0.025)
Observations	22261	22261	22261	4160	22261	22261	22261	22261	4166	25158	25153	25155
R2	0.967	0.962	0.986	0.982	0.986	0.955	0.902	0.974	0.986	0.827	0.945	0.986
L5 GREENCITMAXEP/10000	0.051	0.119**	0.029		0.048	0.051	0.028	0.016		0.159	−0.013	0.023
	(0.076)	(0.058)	(0.035)		(0.035)	(0.032)	(0.017)	(0.021)		(0.132)	(0.016)	(0.037)
Observations	15482	15482	15482		15482	15482	15482	15482		18347	18347	18343
R2	0.973	0.965	0.985		0.986	0.971	0.933	0.981		0.888	0.956	0.989
Panel B: Brown efficiency innovation												
L1 BROWNEFFCITMAXEP/10000	−0.232	0.060	0.547	0.080	0.231	−0.483	−0.287	0.110	14.840	2.153**	−0.089	0.361
	(0.262)	(0.160)	(0.467)	(6.439)	(0.271)	(0.317)	(0.223)	(0.193)	(31.518)	(0.971)	(0.104)	(0.295)
Observations	29585	29585	29584	10349	29585	29585	29585	29585	10349	29578	29578	29580
R2	0.953	0.948	0.980	0.931	0.981	0.922	0.843	0.961	0.898	0.720	0.917	0.980
L3 BROWNEFFCITMAXEP/10000	−0.325**	−0.145	0.516	−1.810	0.164	−0.349	−0.293	−0.015	6.474	2.055***	−0.018	0.356
	(0.157)	(0.134)	(0.403)	(4.749)	(0.180)	(0.259)	(0.206)	(0.128)	(17.012)	(0.760)	(0.068)	(0.234)
Observations	22261	22261	22261	4160	22261	22261	22261	22261	4166	25158	25153	25155
R2	0.967	0.962	0.986	0.982	0.986	0.955	0.902	0.974	0.986	0.827	0.945	0.986
L5 BROWNEFFCITMAXEP/10000	−0.351***	−0.248	0.351		0.015	−0.243	−0.268	−0.024		1.167*	−0.025	0.205
	(0.090)	(0.176)	(0.321)		(0.105)	(0.205)	(0.190)	(0.074)		(0.702)	(0.055)	(0.182)
Observations	15482	15482	15482		15482	15482	15482	15482		18347	18347	18343
R2	0.973	0.965	0.985		0.986	0.971	0.933	0.981		0.888	0.956	0.989
Controls	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Year F.E.	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Firm F.E.	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes

TABLE IA.XVII: PATENT BLOCKBUSTER COUNTS AND FIRM-LEVEL OUTCOMES

The unit of observation is firm-year. The sample period is 2005 to 2020. We keep only firms with at least one green blockbuster patent in Panel A and one brown efficiency blockbuster patent in Panel B. The dependent variables are logs of cumulative sums of S1TOT, S2TOT, S3UPTOT, S3DOWNTOT, S123UPTOT, CAPEX, and SALES over 1, 3 or 5 years, respectively long-term averages of S1INT, S2INT, S3UPINT, S3DOWNINT and INVEST/A for 1, 3 or 5 years. In Panel A, the key independent variable is *GREENCOUNTBBEP* lagged by 1, 3, or 5 years. In Panel B, the key independent variable similarly is *BROWNEFFCOUNTBBEP*. Controls include: *LOGSIZE*, *LOGPPE*, *LEVERAGE*, *ROE*, *M/B*, *INVEST/A*, *BETA*, *VOLAT*, *MOM*, *RET*, *MSCI*. All variables are defined in Table 1 and Table 4 and lagged by 1, 3, or 5 years. The model is estimated using pooled regression model. All regressions include year and firm fixed effects. We double cluster standard errors at the firm and year dimension. *** 1% significance, ** 5% significance * 10% significance.

	(1) LOGS1TOT	(2) LOGS2TOT	(3) LOGS3UPTOT	(4) LOGS3DOWNTOT	(5) LOGS123UPTOT	(6) S1INT	(7) S2INT	(8) S3UPINT	(9) S3DOWNINT	(10) INVEST/A	(11) LOGCAPEX	(12) LOGSALES
Panel A: Green innovation												
L1 GREENCOUNTBBEP	0.027	0.017	0.030**	−0.095	0.028**	−0.059	0.006	0.017	−0.068	−0.077	0.010	0.027***
	(0.023)	(0.021)	(0.012)	(0.089)	(0.013)	(0.052)	(0.009)	(0.013)	(0.319)	(0.060)	(0.013)	(0.010)
Observations	7435	7435	7435	2275	7435	7435	7435	7435	2275	7435	7435	7435
R2	0.948	0.930	0.974	0.904	0.975	0.923	0.828	0.950	0.917	0.731	0.870	0.974
L3 GREENCOUNTBBEP	−0.002	0.016	0.023**	−0.076	0.020*	−0.042	−0.001	0.025**	−0.138	−0.092*	−0.014	0.015
	(0.021)	(0.019)	(0.011)	(0.094)	(0.012)	(0.036)	(0.008)	(0.012)	(0.295)	(0.050)	(0.013)	(0.010)
Observations	5951	5951	5951	1004	5951	5951	5951	5951	1006	6386	6386	6387
R2	0.962	0.949	0.981	0.975	0.981	0.954	0.889	0.967	0.989	0.814	0.911	0.981
L5 GREENCOUNTBBEP	−0.031	0.010	0.015		0.014	−0.006	−0.000	0.022**		−0.050	−0.020	0.004
	(0.020)	(0.019)	(0.011)		(0.011)	(0.032)	(0.008)	(0.011)		(0.048)	(0.014)	(0.010)
Observations	4504	4504	4504		4504	4504	4504	4504		4967	4967	4969
R2	0.971	0.959	0.982		0.984	0.971	0.928	0.977		0.876	0.919	0.985
Panel B: Brown efficiency innovation												
L1 BROWNEFFCOUNTBBEP	−0.032	−0.009	0.008	0.125	−0.005	−0.096	−0.010	−0.016	0.484	0.174*	0.004	0.018
	(0.030)	(0.027)	(0.014)	(0.140)	(0.015)	(0.066)	(0.012)	(0.016)	(0.732)	(0.104)	(0.014)	(0.012)
Observations	4445	4445	4445	1274	4445	4445	4445	4445	1274	4445	4445	4445
R2	0.945	0.909	0.963	0.864	0.968	0.927	0.825	0.944	0.868	0.778	0.832	0.969
L3 BROWNEFFCOUNTBBEP	0.002	0.011	0.016	−0.041	0.008	−0.103*	−0.016	−0.025	0.469	0.157**	0.009	0.022*
	(0.028)	(0.027)	(0.015)	(0.180)	(0.015)	(0.061)	(0.012)	(0.016)	(0.591)	(0.078)	(0.016)	(0.012)
Observations	3685	3685	3685	568	3685	3685	3685	3685	568	3841	3841	3841
R2	0.961	0.934	0.972	0.941	0.976	0.957	0.888	0.964	0.985	0.831	0.873	0.977
L5 BROWNEFFCOUNTBBEP	0.029	0.026	0.016		0.009	−0.042	−0.011	−0.001		0.160**	−0.014	0.019
	(0.029)	(0.025)	(0.017)		(0.016)	(0.056)	(0.012)	(0.015)		(0.073)	(0.018)	(0.013)
Observations	2941	2941	2941		2941	2941	2941	2941		3100	3100	3100
R2	0.971	0.951	0.976		0.981	0.975	0.928	0.975		0.879	0.893	0.981
Controls	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Year F.E.	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Firm F.E.	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes

TABLE IA.XVIII: PATENT RATIOS AND FIRM-LEVEL OUTCOMES - TOP QUINTILE

The unit of observation is firm-year. The sample period is 2005 to 2020. We calculate quintiles based on three 5-year intervals' average patent ratios and keep only the top quintile based on the average GREENRATIOEP in Panel A and based on the average BROWNEFFRATIOEP in Panel B. The dependent variables are logs of cumulative sums of S1TOT, S2TOT, S3UPTOT, S3DOWNTOT, S123UPTOT, CAPEX, and SALES over 1, 3 or 5 years, respectively long-term averages of S1INT, S2INT, S3UPINT, S3DOWNINT and INVEST/A for 1, 3 or 5 years. In Panel A, the key independent variable is *GREENRATIOEP* lagged by 1, 3, or 5 years as well as a 3-year based ratio lagged by 1 year. In Panel B, the key independent variable similarly is *BROWNEFFRATIOEP*. Controls include: *LOGSIZE*, *LOGPPE*, *LEVERAGE*, *ROE*, *M/B*, *INVEST/A*, *BETA*, *VOLAT*, *MOM*, *RET*, *MSCI*. All variables are defined in Table 1 and Table 2 and lagged by 1, 3, or 5 years. The model is estimated using pooled regression model. All regressions include year and firm fixed effects. We double cluster standard errors at the firm and year dimension. *** 1% significance, ** 5% significance * 10% significance.

	(1) LOGS1TOT	(2) LOGS2TOT	(3) LOGS3UPTOT	(4) LOGS3DOWNTOT	(5) LOGS123UPTOT	(6) S1INT	(7) S2INT	(8) S3UPINT	(9) S3DOWNINT	(10) INVEST/A	(11) LOGCAPEX	(12) LOGSALES
Panel A: Green innovation												
L1 GREENRATIOEP	0.010	0.001	0.017	0.025	0.006	0.028	−0.019	0.019	0.254	0.028	−0.011	0.012
	(0.034)	(0.035)	(0.021)	(0.097)	(0.022)	(0.087)	(0.014)	(0.024)	(0.548)	(0.159)	(0.020)	(0.018)
Observations	4850	4850	4849	1992	4850	4850	4850	4850	1992	4850	4850	4850
R2	0.976	0.957	0.984	0.935	0.986	0.962	0.886	0.956	0.887	0.677	0.935	0.984
L3 GREENRATIOEP	−0.045	−0.003	0.005	−0.029	−0.009	−0.110	−0.014	−0.008	0.415	−0.064	−0.005	0.006
	(0.027)	(0.029)	(0.018)	(0.094)	(0.016)	(0.087)	(0.012)	(0.022)	(0.563)	(0.105)	(0.018)	(0.014)
Observations	3633	3633	3633	780	3633	3633	3633	3633	780	4042	4042	4042
R2	0.988	0.975	0.991	0.986	0.993	0.978	0.941	0.969	0.985	0.803	0.961	0.991
L5 GREENRATIOEP	−0.010	−0.024	−0.016		−0.018	0.084	−0.001	−0.027		−0.109	−0.017	−0.014
	(0.028)	(0.036)	(0.019)		(0.017)	(0.084)	(0.012)	(0.020)		(0.106)	(0.015)	(0.015)
Observations	2429	2429	2429		2429	2429	2429	2429		2868	2868	2868
R2	0.990	0.975	0.991		0.994	0.983	0.959	0.976		0.851	0.972	0.993
L1 3YEARAVGGREENRATIOEP	−0.026	−0.141***	0.016	−0.113	−0.021	0.164	−0.052***	0.036	−0.311	−0.201	−0.020	−0.018
	(0.043)	(0.047)	(0.024)	(0.168)	(0.026)	(0.153)	(0.018)	(0.029)	(0.846)	(0.183)	(0.024)	(0.021)
Observations	8671	8671	8670	3547	8671	8671	8671	8671	3547	8669	8669	8671
R2	0.973	0.955	0.984	0.936	0.986	0.946	0.888	0.957	0.896	0.704	0.932	0.985
Panel B: Brown efficiency innovation												
L1 BROWNEFFRATIOEP	0.017	−0.021	−0.011	−0.265	−0.020	−0.025	0.014	0.014	0.253	0.037	−0.001	0.001
	(0.041)	(0.039)	(0.019)	(0.171)	(0.021)	(0.127)	(0.012)	(0.024)	(0.989)	(0.153)	(0.023)	(0.016)
Observations	5964	5964	5964	1957	5964	5964	5964	5964	1957	5964	5964	5964
R2	0.971	0.941	0.980	0.849	0.983	0.941	0.885	0.957	0.865	0.799	0.893	0.982
L3 BROWNEFFRATIOEP	−0.002	0.003	0.001	−0.077	−0.008	−0.147	0.023**	0.020	−0.750	0.040	−0.007	0.008
	(0.035)	(0.037)	(0.019)	(0.099)	(0.020)	(0.121)	(0.011)	(0.023)	(0.832)	(0.137)	(0.021)	(0.014)
Observations	4621	4621	4621	790	4621	4621	4621	4621	790	4919	4919	4920
R2	0.984	0.963	0.987	0.947	0.989	0.968	0.943	0.975	0.982	0.846	0.908	0.989
L5 BROWNEFFRATIOEP	−0.016	−0.005	0.001		−0.017	−0.239*	−0.013	−0.007		0.359**	0.025	0.021
	(0.037)	(0.034)	(0.020)		(0.021)	(0.132)	(0.009)	(0.023)		(0.144)	(0.020)	(0.015)
Observations	3249	3249	3249		3249	3249	3249	3249		3544	3544	3546
R2	0.987	0.972	0.988		0.991	0.978	0.966	0.983		0.888	0.909	0.991
L1 3YEARAVGBROWNEFFRATIOEP	0.151***	−0.027	0.012	−0.136	0.028	0.095	0.004	0.024	−1.373	−0.014	−0.005	0.025
	(0.049)	(0.049)	(0.024)	(0.223)	(0.027)	(0.190)	(0.018)	(0.031)	(1.354)	(0.224)	(0.024)	(0.023)
Observations	38221	38221	38220	14552	38221	38221	38221	38221	14552	38210	38210	38214
R2	0.958	0.951	0.982	0.935	0.982	0.928	0.847	0.965	0.907	0.718	0.923	0.980
Controls	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Year F.E.	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Firm F.E.	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes

TABLE IA.XIX: PATENT RATIOS AND FIRM-LEVEL OUTCOMES - OECD ENV-TECH DEFINITION

The unit of observation is firm-year. The sample period is 2005 to 2020. We keep all firm-year EPO patenting observations in Panel A and require firm-year observations to have *at least one* OECD env-tech patent at the EPO in Panel B. The dependent variables are logs of cumulative sums of S1TOT, S2TOT, S3UPTOT, S3DOWNTOT, S123UPTOT, CAPEX, and SALES over 1, 3 or 5 years, respectively long-term averages of S1INT, S2INT, S3UPINT, S3DOWNINT and INVEST/A for 1, 3 or 5 years. The key independent variable is *OECDRATIOEP* lagged by 1, 3, or 5 years as well as a 3-year rolling ratio lagged by 1 year. Controls include: *LOGSIZE, LOGPPE, LEVERAGE, ROE, M/B, INVEST/A, BETA, VOLAT, MOM, RET, MSCI*. All variables are defined in Table 1 and Table IA.V and lagged by 1, 3, or 5 years. The model is estimated using pooled regression model. All regressions include year and firm fixed effects. We double cluster standard errors at the firm and year dimension. *** 1% significance, ** 5% significance * 10% significance.

	(1) LOGS1TOT	(2) LOGS2TOT	(3) LOGS3UPTOT	(4) LOGS3DOWNTOT	(5) LOGS123UPTOT	(6) S1INT	(7) S2INT	(8) S3UPINT	(9) S3DOWNINT	(10) INVEST/A	(11) LOGCAPEX	(12) LOGSALES
Panel A: All patenting firm-year observations												
L1 OECDRATIOEP	0.026	−0.001	0.004	−0.070	−0.001	−0.068	−0.014	−0.005	0.094	−0.003	0.002	−0.002
	(0.025)	(0.024)	(0.014)	(0.076)	(0.014)	(0.067)	(0.010)	(0.017)	(0.427)	(0.093)	(0.014)	(0.012)
Observations	29585	29585	29584	10349	29585	29585	29585	29585	10349	29578	29578	29580
R2	0.953	0.948	0.980	0.931	0.981	0.922	0.843	0.961	0.898	0.720	0.917	0.980
L3 OECDRATIOEP	0.012	−0.054**	−0.010	0.061	−0.015	−0.047	−0.014	−0.004	−0.286	0.003	−0.001	−0.015
	(0.024)	(0.023)	(0.013)	(0.120)	(0.014)	(0.067)	(0.010)	(0.016)	(0.383)	(0.074)	(0.012)	(0.011)
Observations	22261	22261	22261	4160	22261	22261	22261	22261	4166	25158	25153	25155
R2	0.967	0.962	0.986	0.982	0.986	0.955	0.902	0.974	0.986	0.827	0.945	0.986
L5 OECDRATIOEP	0.010	−0.049**	−0.005		0.002	0.048	−0.006	−0.002		0.041	0.001	−0.010
	(0.026)	(0.024)	(0.015)		(0.015)	(0.072)	(0.010)	(0.016)		(0.072)	(0.011)	(0.012)
Observations	15482	15482	15482		15482	15482	15482	15482		18347	18347	18343
R2	0.973	0.965	0.985		0.986	0.972	0.933	0.981		0.888	0.956	0.989
L1 3YEARAVGOECDRATIOEP	0.006	−0.068**	−0.008	−0.402***	−0.024	−0.040	−0.045***	0.011	−1.096*	0.005	−0.009	−0.028**
	(0.030)	(0.031)	(0.016)	(0.131)	(0.018)	(0.092)	(0.015)	(0.021)	(0.645)	(0.111)	(0.017)	(0.013)
Observations	38221	38221	38220	14552	38221	38221	38221	38221	14552	38210	38210	38214
R2	0.958	0.951	0.982	0.935	0.982	0.928	0.848	0.965	0.907	0.718	0.923	0.980
Panel B: Firm-year observations with at least one OECD env-tech patent												
L1 OECDRATIOEP	−0.037	0.003	−0.006	−0.020	−0.018	−0.217**	−0.009	−0.005	1.003	−0.079	−0.010	−0.006
	(0.036)	(0.035)	(0.019)	(0.169)	(0.019)	(0.106)	(0.015)	(0.025)	(0.802)	(0.144)	(0.019)	(0.015)
Observations	13509	13509	13509	3765	13509	13509	13509	13509	3765	13507	13507	13507
R2	0.957	0.938	0.978	0.889	0.980	0.937	0.854	0.950	0.883	0.751	0.910	0.980
L3 OECDRATIOEP	−0.031	−0.075**	−0.031	0.352	−0.041**	−0.096	−0.018	0.002	0.085	0.114	−0.010	−0.023
	(0.036)	(0.033)	(0.019)	(0.367)	(0.019)	(0.109)	(0.014)	(0.022)	(0.949)	(0.109)	(0.016)	(0.015)
Observations	10978	10978	10978	1350	10978	10978	10978	10978	1350	11868	11868	11863
R2	0.967	0.953	0.982	0.966	0.984	0.960	0.906	0.967	0.985	0.834	0.941	0.986
L5 OECDRATIOEP	0.018	−0.016	0.005		0.021	0.091	−0.000	0.014		0.177*	0.041***	0.004
	(0.034)	(0.034)	(0.020)		(0.019)	(0.086)	(0.014)	(0.020)		(0.099)	(0.015)	(0.016)
Observations	8549	8549	8549		8549	8549	8549	8549		9244	9244	9239
R2	0.975	0.962	0.984		0.987	0.977	0.938	0.979		0.888	0.945	0.988
L1 3YEARAVGOECDRATIOEP	−0.038	−0.007	−0.018	−0.390*	−0.022	−0.101	−0.019	0.015	−0.534	0.053	0.001	−0.038**
	(0.043)	(0.046)	(0.022)	(0.211)	(0.023)	(0.147)	(0.020)	(0.030)	(1.103)	(0.164)	(0.021)	(0.018)
Observations	17197	17197	17197	5343	17197	17197	17197	17197	5343	17191	17191	17194
R2	0.964	0.948	0.983	0.921	0.983	0.941	0.860	0.958	0.906	0.753	0.930	0.983
Controls	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Year F.E.	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Firm F.E.	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes

TABLE IA.XX: GREEN PATENT CITATIONS AND GICS-6 INDUSTRY-LEVEL OUTCOMES

The unit of observation is GICS-6 industry-year and the sample period is 2005 to 2020. The dependent variables are logs of industry level cumulative sums of S1TOT, S2TOT, S3UPTOT, S3DOWNTOT, CAPEX, and SALES over 1, 3 or 5 years, respectively cumulative sums over sums for S1INT, S2INT, S3UPINT, S3DOWNINT and INVEST/A for 1, 3 or 5 years. In Panel A.1 and B.1, dependent variables are calculated across all firms within the given industry. In Panel A.2 and B.2, dependent variables are calculated across all ever patenting firms within the given industry and in Panel A.3 and B.3, dependent variables are calculated across all never patenting firms within the given industry. The key explanatory variables of interest is *AVGGREENCITMAXEP* in Panel A and *AVGBROWNEFFCITMAXEP* in Panel B. Controls include *LOGSIZE*, *LOGPPE*, *LEVERAGE*, *ROE*, *M/B*, *INVEST/A*, *BETA*, *VOLAT*, *MOM*, *RET*, *MSCI*. *AVGGREENCITMAXEP* (*AVGBROWNEFFCITMAXEP*) is an equally weighted average of *GREENCITMAXEP* (*BROWNEFFCITMAXEP*) across all patenting firms in a given year and industry. Other independent variables are calculated as in Table 12 and all are lagged by 1, 3 or 5 years respectively. The model is estimated using pooled regression model. All regression include year and industry fixed effects. We double cluster standard errors at the GICS-6 industry and year dimension. *** 1% significance, ** 5% significance * 10% significance.

	(1) LOGS1TOT	(2) LOGS2TOT	(3) LOGS3UPTOT	(4) LOGS3DOWNTOT	(5) S1INT	(6) S2INT	(7) S3UPINT	(8) S3DOWNINT	(9) INVEST/A	(10) LOGCAPEX	(11) LOGSALES
Panel A: Green innovation											
Panel A.1: AVGGREENCITMAXEP on all firms											
L1 AVGGREENCITMAXEP/10000	5.123	4.892	4.110	39.553*	−4.122	−0.161	0.798	64.779	−0.019	3.144	3.893
	(3.432)	(3.822)	(3.263)	(21.481)	(3.514)	(0.714)	(0.993)	(98.512)	(0.013)	(2.898)	(3.330)
Observations	976	976	976	261	976	976	976	261	976	976	976
R2	0.962	0.932	0.960	0.961	0.988	0.733	0.976	0.842	0.911	0.925	0.936
L3 AVGGREENCITMAXEP/10000	1.423	1.331	1.182	9.856	−3.687	−0.131	0.486	−12.823	−0.002	0.728	0.848
	(1.395)	(0.905)	(0.745)	(12.299)	(2.812)	(0.625)	(0.547)	(57.431)	(0.005)	(0.539)	(0.748)
Observations	837	837	837	122	837	837	837	122	837	837	837
R2	0.981	0.978	0.990	0.990	0.994	0.782	0.987	0.973	0.957	0.984	0.986
L5 AVGGREENCITMAXEP/10000	0.408	−0.009	0.068		−1.638	−0.481	0.521		−0.005	−0.413	−0.238
	(1.393)	(0.745)	(0.717)		(2.411)	(0.515)	(0.453)		(0.005)	(0.543)	(0.686)
Observations	708	708	708		708	708	708		708	708	708
R2	0.986	0.985	0.991		0.997	0.852	0.992		0.966	0.984	0.987
Panel A.2: AVGGREENCITMAXEP on ever patenting firms											
L1 AVGGREENCITMAXEP/10000	3.958**	1.105	1.682	44.726*	−4.992	−0.617	1.750	29.369	−0.007	−0.220	0.701
	(2.017)	(1.165)	(1.072)	(23.675)	(5.705)	(0.879)	(1.330)	(67.699)	(0.005)	(0.622)	(0.752)
Observations	974	974	974	261	974	974	974	261	974	974	974
R2	0.962	0.960	0.984	0.954	0.926	0.678	0.973	0.695	0.954	0.979	0.981
L3 AVGGREENCITMAXEP/10000	2.335	1.434	2.016**	−0.455	−4.844	−0.210	1.411**	20.383	−0.009	0.234	0.956
	(1.471)	(0.975)	(0.897)	(10.797)	(3.849)	(0.715)	(0.685)	(67.914)	(0.006)	(0.526)	(0.807)
Observations	834	834	834	122	834	834	834	122	834	834	834
R2	0.976	0.973	0.988	0.986	0.952	0.740	0.984	0.936	0.967	0.982	0.986
L5 AVGGREENCITMAXEP/10000	2.058	0.999	0.887		0.758	−0.757	1.454*		−0.006	0.660	−0.041
	(2.072)	(1.142)	(1.134)		(4.697)	(0.939)	(0.804)		(0.005)	(0.851)	(1.066)
Observations	705	705	705		705	705	705		705	705	705
R2	0.982	0.982	0.991		0.970	0.824	0.989		0.975	0.986	0.988
Panel A.3: AVGGREENCITMAXEP on never patenting firms											
L1 AVGGREENCITMAXEP/10000	−2.829	−1.218	1.181	26.779	−3.186	−1.131	0.942	32.742	−0.016	−1.487	0.968
	(3.842)	(2.707)	(2.239)	(16.749)	(7.748)	(0.910)	(3.654)	(60.013)	(0.060)	(2.685)	(2.282)
Observations	964	964	964	261	964	964	964	261	964	964	964
R2	0.941	0.921	0.940	0.972	0.979	0.735	0.629	0.959	0.794	0.938	0.939
L3 AVGGREENCITMAXEP/10000	−1.541	0.786	0.123	17.597**	−11.922	−0.626	−4.898	−73.881	−0.054	−1.657	0.850
	(2.217)	(1.994)	(1.892)	(8.022)	(8.273)	(0.750)	(4.933)	(55.735)	(0.054)	(2.604)	(1.900)
Observations	819	819	819	122	819	819	819	122	819	819	819
R2	0.960	0.948	0.961	0.998	0.993	0.846	0.860	0.996	0.825	0.958	0.960
L5 AVGGREENCITMAXEP/10000	0.435	1.864	0.326		−7.476	−0.350	−3.978		−0.050	−1.153	1.055
	(2.699)	(1.514)	(1.541)		(6.280)	(0.583)	(3.570)		(0.035)	(1.274)	(1.449)
Observations	685	685	685		685	685	685		685	685	685
R2	0.973	0.959	0.967		0.996	0.898	0.930		0.867	0.963	0.966
Controls	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Year F.E.	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Industry F.E.	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes

	(1) LOGS1TOT	(2) LOGS2TOT	(3) LOGS3UPTOT	(4) LOGS3DOWNTOT	(5) S1INT	(6) S2INT	(7) S3UPINT	(8) S3DOWNINT	(9) INVEST/A	(10) LOGCAPEX	(11) LOGSALES
Panel B: Brown efficiency innovation											
Panel B.1: AVGBROWNEFFCITMAXEP on all firms											
L1 AVGBROWNEFFCITMAXEP/10000	−0.627	1.283	0.008	33.930	−5.533	−1.974	2.777	345.615	−0.003	−1.345	−1.608
	(3.144)	(2.345)	(1.559)	(27.867)	(15.384)	(2.748)	(3.220)	(277.515)	(0.016)	(1.795)	(1.848)
Observations	976	976	976	261	976	976	976	261	976	976	976
R2	0.962	0.932	0.959	0.961	0.988	0.734	0.976	0.842	0.911	0.924	0.936
L3 AVGBROWNEFFCITMAXEP/10000	1.339	−0.487	−1.414	3.126	−0.590	−2.252	2.272	104.580	−0.000	−1.735	−2.450
	(4.042)	(2.095)	(1.835)	(21.317)	(10.820)	(2.475)	(2.248)	(91.126)	(0.017)	(2.094)	(2.327)
Observations	837	837	837	122	837	837	837	122	837	837	837
R2	0.981	0.978	0.990	0.990	0.994	0.783	0.988	0.973	0.957	0.984	0.986
L5 AVGBROWNEFFCITMAXEP/10000	2.844	−1.244	−1.812		4.477	−2.424	1.212		0.010	−0.909	−2.374
	(3.131)	(1.625)	(1.636)		(8.864)	(2.154)	(1.614)		(0.014)	(1.894)	(1.946)
Observations	708	708	708		708	708	708		708	708	708
R2	0.986	0.985	0.991		0.997	0.852	0.992		0.966	0.984	0.987
Panel B.2: AVGBROWNEFFCITMAXEP on ever patenting firms											
L1 AVGBROWNEFFCITMAXEP/10000	−2.115	0.854	0.667	39.204	−8.492	−2.598	2.820	578.806	0.005	−0.001	−2.477
	(3.535)	(2.816)	(2.352)	(35.840)	(19.671)	(3.220)	(3.205)	(523.196)	(0.009)	(1.794)	(2.469)
Observations	974	974	974	261	974	974	974	261	974	974	974
R2	0.962	0.960	0.984	0.954	0.926	0.678	0.973	0.696	0.954	0.979	0.981
L3 AVGBROWNEFFCITMAXEP/10000	−3.180	−2.018	−1.865	2.681	−1.737	−2.786	1.329	159.525	0.007	−0.770	−3.681
	(4.460)	(3.181)	(2.021)	(24.839)	(13.421)	(2.979)	(1.873)	(188.949)	(0.010)	(1.912)	(2.677)
Observations	834	834	834	122	834	834	834	122	834	834	834
R2	0.976	0.973	0.988	0.986	0.952	0.740	0.984	0.936	0.967	0.982	0.986
L5 AVGBROWNEFFCITMAXEP/10000	−1.055	−1.739	−3.017*		−8.655	−2.763	−0.123		0.011	0.440	−3.389*
	(4.369)	(2.391)	(1.702)		(9.582)	(2.494)	(1.349)		(0.009)	(1.264)	(1.975)
Observations	705	705	705		705	705	705		705	705	705
R2	0.982	0.982	0.991		0.970	0.824	0.989		0.975	0.986	0.988
Panel B.3: AVGBROWNEFFCITMAXEP on never patenting firms											
L1 AVGBROWNEFFCITMAXEP/10000	5.938	−1.590	−3.651	24.852	39.698	−2.262	0.140	92.524	−0.170**	−2.435	−2.796
	(5.709)	(3.318)	(2.622)	(45.298)	(30.177)	(2.037)	(9.520)	(95.387)	(0.079)	(4.001)	(2.027)
Observations	964	964	964	261	964	964	964	261	964	964	964
R2	0.941	0.921	0.940	0.972	0.980	0.734	0.629	0.959	0.795	0.938	0.939
L3 AVGBROWNEFFCITMAXEP/10000	12.857	4.281	0.254	12.429	46.793	−0.013	21.218	13.544	−0.155	−2.026	−0.795
	(9.586)	(4.864)	(3.691)	(10.184)	(30.469)	(2.023)	(23.349)	(57.324)	(0.096)	(3.160)	(1.729)
Observations	819	819	819	122	819	819	819	122	819	819	819
R2	0.960	0.948	0.961	0.998	0.993	0.846	0.861	0.996	0.825	0.958	0.960
L5 AVGBROWNEFFCITMAXEP/10000	13.582*	4.420	1.351		32.154	−0.508	16.545		−0.100	−1.056	0.310
	(7.300)	(3.423)	(2.355)		(19.834)	(1.564)	(15.338)		(0.070)	(2.530)	(1.485)
Observations	685	685	685		685	685	685		685	685	685
R2	0.973	0.959	0.967		0.996	0.898	0.930		0.867	0.963	0.966
Controls	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Year F.E.	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Industry F.E.	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes

TABLE IA.XXI: OECD PATENT RATIOS AND GICS-6 INDUSTRY-LEVEL OUTCOMES

The unit of observation is GICS-6 industry-year. The sample period is 2005 to 2020. The dependent variables are logs of industry level cumulative sums of S1TOT, S2TOT, S3UPTOT, S3DOWNTOT, CAPEX, and SALES over 1, 3 or 5 years, respectively cumulative sums over sums for S1INT, S2INT, S3UPINT, S3DOWNINT and INVEST/A for 1, 3 or 5 years. In Panel A dependent variables are calculated across all firms within the given industry. In Panel B dependent variables are calculated across all ever patenting firms within the given industry and in Panel C dependent variables are calculated across all never patenting firms within the given industry. The key explanatory variables of interest is *OECDRATIOEP*. Controls include *LOGSIZE*, *LOGPPE*, *LEVERAGE*, *ROE*, *M/B*, *INVEST/A*, *BETA*, *VOLAT*, *MOM*, *RET*, *MSCI*. Independent variables are calculated as in Table 12 and IA.XX and are lagged by 1, 3 or 5 years respectivley. All Independent variables are lagged by 1, 3 or 5 years respectively. The model is estimated using pooled regression model. All regression include year and industry fixed effects. We double cluster standard errors at the GICS-6 industry and year dimension. *** 1% significance, ** 5% significance * 10% significance.

	(1) LOGS1TOT	(2) LOGS2TOT	(3) LOGS3UPTOT	(4) LOGS3DOWNTOT	(5) S1INT	(6) S2INT	(7) S3UPINT	(8) S3DOWNINT	(9) INVEST/A	(10) LOGCAPEX	(11) LOGSALES
Panel A: OECDRATIOEP on all firms											
L1 OECDRATIOEP	−0.107	0.064	−0.145*	0.412	0.858	0.145*	−0.033	7.304	0.001*	0.013	−0.129*
	(0.135)	(0.143)	(0.075)	(0.646)	(0.963)	(0.085)	(0.098)	(6.108)	(0.001)	(0.052)	(0.066)
Observations	976	976	976	261	976	976	976	261	976	976	976
R2	0.962	0.932	0.960	0.961	0.988	0.734	0.976	0.843	0.911	0.924	0.936
L3 OECDRATIOEP	0.074	0.033	−0.129*	−0.253	−0.074	0.228**	−0.177*	5.215	0.001**	−0.012	−0.075
	(0.135)	(0.117)	(0.070)	(1.100)	(0.895)	(0.104)	(0.101)	(7.600)	(0.001)	(0.049)	(0.063)
Observations	837	837	837	122	837	837	837	122	837	837	837
R2	0.981	0.978	0.990	0.990	0.994	0.784	0.988	0.974	0.957	0.984	0.986
L5 OECDRATIOEP	0.197*	0.077	−0.063		0.734	0.229*	−0.045		0.001	−0.034	−0.051
	(0.116)	(0.092)	(0.064)		(0.531)	(0.138)	(0.080)		(0.000)	(0.042)	(0.058)
Observations	708	708	708		708	708	708		708	708	708
R2	0.986	0.985	0.991		0.997	0.853	0.992		0.966	0.984	0.987
L1 3YEARAVGOECDRATIOEP	0.152	0.219	−0.077	−0.452	1.273	0.385***	−0.169	10.101	0.001	0.115	−0.030
	(0.205)	(0.189)	(0.111)	(0.957)	(1.425)	(0.133)	(0.111)	(10.754)	(0.001)	(0.103)	(0.101)
Observations	988	988	988	267	988	988	988	267	988	988	988
R2	0.962	0.931	0.960	0.967	0.988	0.734	0.976	0.843	0.903	0.914	0.937
Panel B: OECDRATIOEP on ever patenting firms											
L1 OECDRATIOEP	−0.348	−0.088	−0.180**	1.228	2.249	0.136	0.060	14.481	0.002***	0.067	−0.191**
	(0.229)	(0.204)	(0.079)	(0.864)	(2.305)	(0.114)	(0.092)	(11.915)	(0.001)	(0.063)	(0.075)
Observations	974	974	974	261	974	974	974	261	974	974	974
R2	0.962	0.960	0.984	0.954	0.926	0.679	0.973	0.700	0.955	0.979	0.981
L3 OECDRATIOEP	−0.319*	−0.083	−0.143*	0.733	0.792	0.253*	−0.099	5.961	0.001***	0.041	−0.116
	(0.187)	(0.165)	(0.073)	(1.052)	(1.594)	(0.134)	(0.062)	(9.004)	(0.001)	(0.064)	(0.072)
Observations	834	834	834	122	834	834	834	122	834	834	834
R2	0.976	0.973	0.988	0.986	0.952	0.741	0.984	0.936	0.967	0.982	0.986
L5 OECDRATIOEP	−0.136	−0.126	−0.180**		2.301	0.199	−0.053		0.001***	−0.007	−0.153*
	(0.213)	(0.157)	(0.083)		(1.402)	(0.184)	(0.074)		(0.000)	(0.054)	(0.080)
Observations	705	705	705		705	705	705		705	705	705
R2	0.982	0.982	0.991		0.971	0.824	0.989		0.976	0.986	0.988
L1 3YEARAVGOECDRATIOEP	−0.423	−0.030	−0.111	0.672	3.345	0.372*	−0.012	21.939	0.002***	0.185	−0.109
	(0.312)	(0.288)	(0.121)	(1.324)	(3.332)	(0.195)	(0.125)	(23.179)	(0.001)	(0.114)	(0.118)
Observations	985	985	985	265	985	985	985	265	985	985	985
R2	0.963	0.961	0.984	0.956	0.927	0.682	0.973	0.697	0.950	0.979	0.982
Panel C: OECDRATIOEP on never patenting firms											
L1 OECDRATIOEP	−0.113	0.127	−0.102	0.390	0.765	0.179**	−0.157	−0.424	0.001	0.014	−0.065
	(0.143)	(0.136)	(0.087)	(0.671)	(0.909)	(0.074)	(0.177)	(3.490)	(0.001)	(0.060)	(0.079)
Observations	964	964	964	261	964	964	964	261	964	964	964
R2	0.941	0.921	0.940	0.972	0.980	0.735	0.629	0.959	0.794	0.938	0.939
L3 OECDRATIOEP	0.089	−0.007	−0.081	0.573	0.527	0.152*	−0.227	2.739	0.001	0.010	−0.016
	(0.127)	(0.113)	(0.085)	(0.541)	(0.892)	(0.084)	(0.147)	(2.920)	(0.001)	(0.067)	(0.077)
Observations	819	819	819	122	819	819	819	122	819	819	819
R2	0.960	0.948	0.961	0.998	0.993	0.847	0.860	0.996	0.824	0.958	0.960
L5 OECDRATIOEP	0.108	0.041	−0.019		0.761	0.156**	−0.055		0.000	−0.066	−0.002
	(0.111)	(0.104)	(0.084)		(0.523)	(0.075)	(0.106)		(0.001)	(0.072)	(0.082)
Observations	685	685	685		685	685	685		685	685	685
R2	0.973	0.959	0.967		0.996	0.899	0.929		0.866	0.963	0.966
L1 3YEARAVGOECDRATIOEP	0.073	0.063	−0.102	−0.044	2.193	0.259**	−0.417	−1.584	0.001	0.052	−0.015
	(0.253)	(0.215)	(0.145)	(0.860)	(1.430)	(0.105)	(0.304)	(4.042)	(0.002)	(0.105)	(0.124)
Observations	976	976	976	267	976	976	976	267	976	976	976
R2	0.941	0.920	0.939	0.974	0.979	0.735	0.631	0.959	0.793	0.932	0.937
Controls	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Year F.E.	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Industry F.E.	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes

TABLE IA.XXII: PATENT RATIOS AND TRUCOST INDUSTRY-LEVEL OUTCOMES

The unit of observation is Trucost industry-year and the sample period is 2005 to 2020. The dependent variables are logs of industry level cumulative sums of S1TOT, S2TOT, S3UPTOT, S3DOWNTOT, CAPEX, and SALES over 1, 3 or 5 years, respectively cumulative sums over sums for S1INT, S2INT, S3UPINT, S3DOWNINT and INVEST/A for 1, 3 or 5 years for the Trucost sample. In Panel A.1 and B.1, dependent variables are calculated across all firms within the given industry. In Panel A.2 and B.2, dependent variables are calculated across all ever patenting firms within the given industry and in Panel A.3 and B.3, dependent variables are calculated across all never patenting firms within the given industry. The key explanatory variables of interest are *GREENRATIOEP* and in Panel A and *BROWNEFFRATIOEP* in Panel B. Controls include *LOGSIZE*, *LOGPPE*, *LEVERAGE*, *ROE*, *M/B*, *INVEST/A*, *BETA*, *VOLAT*, *MOM*, *RET*, *MSCI*. Independent variables are either industry level logs of sums (LOGSIZE and LOGPPE), sum over sums (GREENRATIOEP, BROWNEFFRATIOEP, LEVERAGE, ROE, M/B, INVEST/A) or market capitalization weighted averages (BETA, VOLAT, MOM, RET, MSCI). All Independent variables are lagged by 1, 3 or 5 years respectively. The model is estimated using pooled regression model. All regression include year and industry fixed effects. We double cluster standard errors at the given industry and year dimension. *** 1% significance, ** 5% significance * 10% significance.

	(1) LOGS1TOT	(2) LOGS2TOT	(3) LOGS3UPTOT	(4) LOGS3DOWNTOT	(5) S1INT	(6) S2INT	(7) S3UPINT	(8) S3DOWNINT	(9) INVEST/A	(10) LOGCAPEX	(11) LOGSALES
Panel A: Green innovation											
Panel A.1: GREENRATIOEP on all firms											
L1 GREENRATIOEP	−0.067	0.017	−0.032	0.092	0.157	0.046	−0.241***	0.266	−0.001	−0.039	0.009
	(0.071)	(0.073)	(0.055)	(0.133)	(0.437)	(0.136)	(0.083)	(1.606)	(0.001)	(0.054)	(0.052)
Observations	4486	4486	4486	1343	4486	4486	4486	1343	4486	4486	4486
R2	0.939	0.923	0.943	0.951	0.873	0.565	0.880	0.860	0.764	0.942	0.950
L3 GREENRATIOEP	−0.051	0.033	−0.043	−0.020	0.164	0.172*	−0.068	−1.347	−0.001	−0.046	−0.032
	(0.076)	(0.077)	(0.062)	(.)	(0.431)	(0.096)	(0.059)	(.)	(0.001)	(0.053)	(0.058)
Observations	3745	3745	3745	644	3745	3745	3745	644	3745	3745	3745
R2	0.959	0.943	0.954	0.992	0.947	0.731	0.978	0.988	0.848	0.956	0.960
L5 GREENRATIOEP	0.046	0.057	0.005		0.290	0.082	0.002		−0.001	−0.004	−0.006
	(0.081)	(0.074)	(0.068)		(0.362)	(0.052)	(0.049)		(0.001)	(0.054)	(0.063)
Observations	3030	3030	3030		3030	3030	3030		3030	3030	3030
R2	0.971	0.959	0.965		0.965	0.847	0.985		0.890	0.967	0.970
L1 3YEARAVGGREENRATIOEP	−0.036	0.103	−0.012	0.358	0.661	0.207**	−0.213**	−6.362	−0.003**	−0.013	0.035
	(0.089)	(0.098)	(0.071)	(0.224)	(0.513)	(0.100)	(0.098)	(5.112)	(0.001)	(0.055)	(0.066)
Observations	4861	4861	4861	1458	4861	4861	4861	1458	4861	4861	4861
R2	0.936	0.921	0.939	0.950	0.874	0.569	0.886	0.931	0.763	0.935	0.945
Panel A.2: GREENRATIOEP on ever patenting firms											
L1 GREENRATIOEP	0.032	0.092	−0.018	0.508**	0.418	0.025	−0.279	0.925	−0.002*	−0.044	0.030
	(0.107)	(0.106)	(0.079)	(0.224)	(0.593)	(0.285)	(0.171)	(2.559)	(0.001)	(0.067)	(0.072)
Observations	4459	4459	4459	1337	4459	4459	4459	1337	4459	4459	4459
R2	0.923	0.905	0.930	0.919	0.384	0.304	0.822	0.798	0.769	0.904	0.937
L3 GREENRATIOEP	−0.154	−0.029	−0.119	0.275	0.258	0.264	−0.134	−2.049	0.000	−0.049	−0.076
	(0.101)	(0.099)	(0.081)	(.)	(0.405)	(0.173)	(0.085)	(.)	(0.001)	(0.065)	(0.073)
Observations	3702	3702	3702	640	3702	3702	3702	640	3702	3702	3702
R2	0.949	0.932	0.946	0.990	0.923	0.560	0.969	0.983	0.851	0.936	0.951
L5 GREENRATIOEP	0.005	0.025	−0.033		0.214	0.126	−0.089		−0.000	−0.017	−0.025
	(0.096)	(0.087)	(0.076)		(0.268)	(0.078)	(0.087)		(0.001)	(0.058)	(0.070)
Observations	2982	2982	2982		2982	2982	2982		2982	2982	2982
R2	0.965	0.952	0.961		0.955	0.749	0.980		0.883	0.955	0.964
L1 3YEARAVGGREENRATIOEP	−0.012	0.192	−0.084	1.164**	1.143	0.343*	−0.358*	−1.764	−0.002	−0.070	0.003
	(0.151)	(0.151)	(0.112)	(0.469)	(0.716)	(0.177)	(0.213)	(3.907)	(0.002)	(0.082)	(0.101)
Observations	4778	4778	4778	1426	4778	4778	4778	1426	4778	4778	4778
R2	0.917	0.901	0.924	0.920	0.412	0.306	0.830	0.879	0.754	0.901	0.929
Panel A.3: GREENRATIOEP on never patenting firms											
L1 GREENRATIOEP	−0.105	0.001	−0.083	−0.144	0.240	0.029	−0.151	−1.772	−0.000	−0.017	−0.046
	(0.098)	(0.093)	(0.066)	(0.175)	(0.627)	(0.080)	(0.134)	(2.021)	(0.002)	(0.065)	(0.063)
Observations	3112	3112	3112	1226	3112	3112	3112	1226	3112	3112	3112
R2	0.927	0.910	0.931	0.949	0.642	0.656	0.331	0.895	0.622	0.910	0.940
L3 GREENRATIOEP	−0.080	0.025	−0.048	−0.083	−0.075	0.139**	−0.074	−0.484	−0.002	−0.095	−0.034
	(0.094)	(0.092)	(0.074)	(0.081)	(0.509)	(0.062)	(0.111)	(1.423)	(0.001)	(0.060)	(0.073)
Observations	2396	2396	2396	576	2396	2396	2396	576	2396	2396	2396
R2	0.949	0.931	0.942	0.994	0.972	0.840	0.994	0.991	0.713	0.931	0.946
L5 GREENRATIOEP	−0.061	−0.051	−0.030		−0.231	−0.007	0.101		−0.000	−0.026	−0.022
	(0.109)	(0.102)	(0.080)		(0.506)	(0.063)	(0.094)		(0.001)	(0.060)	(0.080)
Observations	1736	1736	1736		1736	1736	1736		1736	1736	1736
R2	0.959	0.941	0.950		0.980	0.897	0.986		0.775	0.947	0.953
L1 3YEARAVGGREENRATIOEP	−0.137	0.123	0.008	−0.349	−0.336	0.131*	−0.083	−7.870**	−0.006***	−0.102	0.019
	(0.116)	(0.111)	(0.083)	(0.299)	(0.517)	(0.071)	(0.163)	(3.776)	(0.002)	(0.072)	(0.079)
Observations	3402	3402	3402	1331	3402	3402	3402	1331	3402	3402	3402
R2	0.925	0.906	0.927	0.945	0.647	0.658	0.336	0.945	0.623	0.908	0.936
Controls	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Year F.E.	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Industry F.E.	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes

	(1) LOGS1TOT	(2) LOGS2TOT	(3) LOGS3UPTOT	(4) LOGS3DOWNTOT	(5) S1INT	(6) S2INT	(7) S3UPINT	(8) S3DOWNINT	(9) INVEST/A	(10) LOGCAPEX	(11) LOGSALES
Panel B: Brown efficiency innovation											
Panel B.1: BROWNEFFRATIOEP on all firms											
L1 BROWNEFFRATIOEP	−0.377**	−0.438***	−0.221*	−0.020	−1.322	−0.111	0.005	−7.431	0.003	−0.046	−0.193*
	(0.185)	(0.139)	(0.119)	(0.341)	(1.011)	(0.075)	(0.190)	(7.885)	(0.002)	(0.102)	(0.109)
Observations	4486	4486	4486	1343	4486	4486	4486	1343	4486	4486	4486
R2	0.939	0.923	0.943	0.951	0.873	0.565	0.880	0.860	0.764	0.942	0.950
L3 BROWNEFFRATIOEP	−0.145	−0.245*	−0.120	−0.242	−1.512	−0.018	−0.092	6.606	0.002	0.005	−0.089
	(0.158)	(0.137)	(0.127)	(.)	(0.946)	(0.065)	(0.128)	(.)	(0.002)	(0.091)	(0.121)
Observations	3745	3745	3745	644	3745	3745	3745	644	3745	3745	3745
R2	0.959	0.943	0.954	0.992	0.947	0.731	0.978	0.988	0.848	0.956	0.960
L5 BROWNEFFRATIOEP	−0.090	−0.160	−0.039		−0.547	0.008	−0.020		0.003*	0.049	−0.035
	(0.146)	(0.135)	(0.123)		(0.733)	(0.050)	(0.083)		(0.002)	(0.100)	(0.123)
Observations	3030	3030	3030		3030	3030	3030		3030	3030	3030
R2	0.971	0.959	0.965		0.965	0.847	0.985		0.890	0.967	0.970
L1 3YEARAVGBROWNEFFRATIOEP	−0.367	−0.474***	−0.305**	0.002	−2.244*	−0.057	−0.168	26.777	0.001	−0.063	−0.231*
	(0.230)	(0.183)	(0.145)	(0.524)	(1.307)	(0.088)	(0.145)	(16.300)	(0.003)	(0.110)	(0.128)
Observations	4861	4861	4861	1458	4861	4861	4861	1458	4861	4861	4861
R2	0.936	0.922	0.939	0.950	0.874	0.569	0.886	0.931	0.763	0.935	0.945
Panel B.2: BROWNEFFRATIOEP on ever patenting firms											
L1 BROWNEFFRATIOEP	−0.254	−0.424***	−0.050	0.164	−0.420	−0.321***	0.113	−1.371	0.004	0.039	−0.049
	(0.182)	(0.160)	(0.135)	(0.464)	(1.004)	(0.117)	(0.141)	(8.440)	(0.003)	(0.113)	(0.125)
Observations	4459	4459	4459	1337	4459	4459	4459	1337	4459	4459	4459
R2	0.923	0.906	0.930	0.919	0.384	0.304	0.822	0.798	0.769	0.904	0.937
L3 BROWNEFFRATIOEP	−0.096	−0.278*	−0.024	−0.377	−0.539	−0.162	−0.076	−2.798	0.004**	0.028	−0.004
	(0.149)	(0.145)	(0.124)	(.)	(0.553)	(0.108)	(0.067)	(.)	(0.002)	(0.103)	(0.119)
Observations	3702	3702	3702	640	3702	3702	3702	640	3702	3702	3702
R2	0.949	0.932	0.946	0.990	0.923	0.559	0.969	0.983	0.851	0.936	0.951
L5 BROWNEFFRATIOEP	−0.105	−0.190	0.010		−0.130	−0.019	0.046		0.004**	0.097	−0.005
	(0.143)	(0.137)	(0.125)		(0.470)	(0.075)	(0.067)		(0.002)	(0.107)	(0.121)
Observations	2982	2982	2982		2982	2982	2982		2982	2982	2982
R2	0.965	0.952	0.961		0.955	0.749	0.980		0.883	0.955	0.964
L1 3YEARAVGBROWNEFFRATIOEP	−0.177	−0.486**	−0.155	−0.180	−0.995	−0.365**	−0.165	−0.177	0.005*	0.043	−0.064
	(0.231)	(0.247)	(0.162)	(0.870)	(1.340)	(0.149)	(0.142)	(23.636)	(0.003)	(0.131)	(0.139)
Observations	4778	4778	4778	1426	4778	4778	4778	1426	4778	4778	4778
R2	0.917	0.901	0.924	0.920	0.412	0.305	0.830	0.879	0.754	0.901	0.929
Panel B.3: BROWNEFFRATIOEP on never patenting firms											
L1 BROWNEFFRATIOEP	0.152	−0.049	−0.195*	−0.568*	2.221	0.287	−0.088	−15.837*	0.002	−0.071	−0.177
	(0.258)	(0.179)	(0.113)	(0.330)	(1.442)	(0.194)	(0.397)	(9.223)	(0.005)	(0.123)	(0.119)
Observations	3112	3112	3112	1226	3112	3112	3112	1226	3112	3112	3112
R2	0.927	0.910	0.931	0.949	0.642	0.656	0.331	0.896	0.623	0.910	0.940
L3 BROWNEFFRATIOEP	−0.044	−0.094	−0.045	0.016	0.179	−0.061	0.025	12.087*	−0.001	−0.003	−0.017
	(0.257)	(0.210)	(0.182)	(0.123)	(1.248)	(0.157)	(0.414)	(6.709)	(0.003)	(0.126)	(0.183)
Observations	2396	2396	2396	576	2396	2396	2396	576	2396	2396	2396
R2	0.949	0.931	0.942	0.994	0.972	0.840	0.994	0.991	0.713	0.931	0.946
L5 BROWNEFFRATIOEP	0.283	0.085	0.087		0.909	−0.097	−0.164		0.000	0.084	0.084
	(0.173)	(0.182)	(0.155)		(1.029)	(0.130)	(0.189)		(0.002)	(0.091)	(0.154)
Observations	1736	1736	1736		1736	1736	1736		1736	1736	1736
R2	0.959	0.941	0.950		0.980	0.897	0.986		0.775	0.947	0.953
L1 3YEARAVGBROWNEFFRATIOEP	−0.102	−0.188	−0.396***	0.252	2.241	0.218	0.147	20.808	0.002	−0.248	−0.414***
	(0.255)	(0.213)	(0.143)	(0.455)	(1.682)	(0.215)	(0.586)	(13.606)	(0.004)	(0.162)	(0.146)
Observations	3402	3402	3402	1331	3402	3402	3402	1331	3402	3402	3402
R2	0.925	0.906	0.927	0.945	0.647	0.658	0.336	0.945	0.622	0.908	0.936
Controls	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Year F.E.	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Industry F.E.	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes

TABLE IA.XXIII: GREEN PATENT RATIOS IN NORTH AMERICA AND CROSS-COUNTRY INDUSTRY-LEVEL OUTCOMES

The unit of observation is GICS-6 industry-year. The sample period is 2005 to 2020. The dependent variables are GICS-6 sector industry level logs of cumulative sums of S1TOT, S2TOT, S3UPTOT, S3DOWNTOT, CAPEX, and SALES over 1, 3 or 5 years, respectively cumulative sums over sums for S1INT, S2INT, S3UPINT, S3DOWNINT and INVEST/A for 1, 3 or 5 years. In Panel A, dependent variables are calculated across all firms with their headquarter in North America. In Panel B, dependent variables are calculated across all firms with their headquarter outside of North America. In addition, in Panel A.1 and B.1, dependent variables are calculated across all firms within the given industry and region. In Panel A.2 and B.2, dependent variables are calculated across all ever patenting firms within the given industry and region and in Panel A.3 and B.3, dependent variables are calculated across all never patenting firms within the given industry and region. All independent variables are calculated based on firms with their headquarter in North America. The key explanatory variables of interest is *GREENRATIOEP*. Controls include *LOGSIZE*, *LOGPPE*, *LEVERAGE*, *ROE*, *M/B*, *INVEST/A*, *BETA*, *VOLAT*, *MOM*, *RET*, *MSCI*. Independent variables are either GICS-6 industry level sums (LOGSIZE and LOGPPE), sum over sums (GREENRATIOEP, LEVERAGE, ROE, M/B, INVEST/A) or market capitalization value weighted averages (BETA, VOLAT, MOM, RET, MSCI). All Independent variables are lagged by 1, 3 or 5 years respectively. The model is estimated using pooled regression model. All regression include year and industry fixed effects. We double cluster standard errors at the GICS-6 industry and year dimension. *** 1% significance, ** 5% significance * 10% significance.

	(1) LOGS1TOT	(2) LOGS2TOT	(3) LOGS3UPTOT	(4) LOGS3DOWNTOT	(5) S1INT	(6) S2INT	(7) S3UPINT	(8) S3DOWNINT	(9) INVEST/A	(10) LOGCAPEX	(11) LOGSALES
Panel A: NA-firm based GREENRATIOEP On NA firms											
Panel A.1: And all firms											
L1 GREENRATIOEP	−0.046	−0.168	−0.057	0.292	−1.364	−0.082	−0.005	3.808**	−0.000	−0.008	−0.066
	(0.138)	(0.181)	(0.087)	(0.411)	(1.326)	(0.071)	(0.127)	(1.870)	(0.001)	(0.061)	(0.063)
Observations	861	861	861	233	861	861	861	233	861	861	861
R2	0.958	0.934	0.974	0.958	0.962	0.910	0.968	0.919	0.924	0.959	0.975
L3 GREENRATIOEP	−0.022	−0.046	−0.049	−0.181	0.418	−0.067	0.009	−1.454	0.000	−0.046	−0.047
	(0.146)	(0.127)	(0.091)	(0.404)	(1.527)	(0.070)	(0.095)	(2.739)	(0.001)	(0.065)	(0.066)
Observations	737	737	737	108	737	737	737	108	737	737	737
R2	0.963	0.964	0.978	0.997	0.970	0.952	0.985	0.995	0.923	0.964	0.979
L5 GREENRATIOEP	0.077	−0.019	0.023		0.794	−0.092	0.067		0.000	−0.019	0.009
	(0.146)	(0.101)	(0.088)		(1.486)	(0.065)	(0.088)		(0.000)	(0.069)	(0.064)
Observations	616	616	616		616	616	616		616	616	616
R2	0.967	0.972	0.980		0.978	0.969	0.990		0.921	0.968	0.979
L1 3YEARAVGGREENRATIOEP	0.018	−0.311	−0.075	−1.948*	1.791	−0.220*	−0.041	−14.001	−0.000	0.023	−0.074
	(0.181)	(0.321)	(0.120)	(1.145)	(1.927)	(0.113)	(0.177)	(12.980)	(0.001)	(0.071)	(0.094)
Observations	907	907	907	255	907	907	907	255	907	907	907
R2	0.959	0.939	0.975	0.960	0.961	0.910	0.967	0.907	0.929	0.957	0.975
Panel A.2: And ever-patenting firms											
L1 GREENRATIOEP	0.001	−0.039	−0.085	0.728	0.146	0.013	0.006	3.554	0.000	−0.008	−0.097
	(0.135)	(0.304)	(0.076)	(0.474)	(2.735)	(0.117)	(0.164)	(2.958)	(0.001)	(0.067)	(0.063)
Observations	861	861	861	233	861	861	861	233	861	861	861
R2	0.948	0.917	0.975	0.941	0.930	0.878	0.961	0.876	0.916	0.943	0.975
L3 GREENRATIOEP	−0.060	−0.143	−0.111	0.270	1.020	−0.037	−0.007	3.512	0.000	−0.038	−0.102
	(0.148)	(0.274)	(0.078)	(0.749)	(2.037)	(0.123)	(0.104)	(3.750)	(0.001)	(0.076)	(0.063)
Observations	737	737	737	108	737	737	737	108	737	737	737
R2	0.955	0.936	0.978	0.995	0.963	0.922	0.981	0.994	0.913	0.953	0.978
L5 GREENRATIOEP	0.044	−0.130	−0.045		1.574	−0.062	−0.032		−0.000	−0.076	−0.025
	(0.137)	(0.220)	(0.068)		(1.450)	(0.110)	(0.091)		(0.001)	(0.089)	(0.056)
Observations	616	616	616		616	616	616		616	616	616
R2	0.961	0.955	0.980		0.978	0.948	0.988		0.929	0.963	0.979
L1 3YEARAVGGREENRATIOEP	−0.030	0.035	−0.130	−1.774	−1.291	−0.246*	−0.292	−23.729	−0.001	0.063	−0.048
	(0.209)	(0.464)	(0.123)	(1.459)	(5.802)	(0.149)	(0.246)	(20.617)	(0.001)	(0.091)	(0.106)
Observations	907	907	907	255	907	907	907	255	907	907	907
R2	0.945	0.927	0.977	0.946	0.928	0.879	0.961	0.845	0.909	0.948	0.977
Panel A.3: And never-patenting firms											
L1 GREENRATIOEP	0.033	−0.210	0.122	0.059	−4.563	−0.041	0.182	2.641	0.000	−0.003	0.094
	(0.173)	(0.264)	(0.149)	(0.451)	(3.853)	(0.125)	(0.255)	(2.204)	(0.002)	(0.113)	(0.130)
Observations	696	696	696	233	696	696	696	233	696	695	696
R2	0.942	0.884	0.925	0.967	0.854	0.804	0.908	0.962	0.771	0.888	0.916
L3 GREENRATIOEP	0.178	0.240	0.202	−0.431	−1.754	0.030	0.229	−6.160**	−0.001	−0.055	0.131
	(0.181)	(0.171)	(0.150)	(0.280)	(4.574)	(0.068)	(0.275)	(2.384)	(0.001)	(0.108)	(0.130)
Observations	557	557	557	108	557	557	557	108	557	557	557
R2	0.964	0.937	0.954	0.999	0.894	0.888	0.959	0.999	0.885	0.944	0.949
L5 GREENRATIOEP	0.078	0.103	0.171		1.513	0.019	0.414		0.001	−0.038	0.050
	(0.167)	(0.169)	(0.148)		(3.916)	(0.063)	(0.268)		(0.001)	(0.107)	(0.117)
Observations	426	426	426		426	426	426		426	426	426
R2	0.976	0.966	0.969		0.931	0.942	0.970		0.931	0.963	0.968
L1 3YEARAVGGREENRATIOEP	0.415*	−0.190	0.388*	−0.885	4.226	0.042	0.349	−4.551	−0.000	0.121	0.261
	(0.234)	(0.437)	(0.210)	(0.998)	(6.175)	(0.127)	(0.402)	(4.916)	(0.002)	(0.163)	(0.200)
Observations	738	738	738	255	738	738	738	255	738	737	738
R2	0.944	0.883	0.923	0.967	0.822	0.803	0.904	0.955	0.773	0.888	0.913
Controls	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Year F.E.	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Industry F.E.	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes

	(1) LOGS1TOT	(2) LOGS2TOT	(3) LOGS3UPTOT	(4) LOGS3DOWNTOT	(5) S1INT	(6) S2INT	(7) S3UPINT	(8) S3DOWNINT	(9) INVEST/A	(10) LOGCAPEX	(11) LOGSALES
Panel B: NA-firm based GREENRATIOEP On Non-NA firms											
Panel B.1: And all firms											
L1 GREENRATIOEP	−0.162	0.004	−0.197**	0.083	−2.534	0.730	−0.517***	1.083	0.001	0.039	−0.045
	(0.103)	(0.191)	(0.085)	(0.421)	(1.908)	(0.533)	(0.141)	(2.726)	(0.001)	(0.049)	(0.083)
Observations	863	863	863	233	863	863	863	233	863	863	863
R2	0.967	0.951	0.968	0.958	0.985	0.715	0.968	0.807	0.934	0.936	0.950
L3 GREENRATIOEP	−0.041	−0.052	−0.042	−0.772	−1.915	0.479	−0.226*	−4.179	0.000	0.026	−0.005
	(0.099)	(0.182)	(0.078)	(0.612)	(1.609)	(0.353)	(0.136)	(4.187)	(0.001)	(0.046)	(0.072)
Observations	740	740	740	108	740	740	740	108	740	740	740
R2	0.985	0.978	0.990	0.987	0.993	0.754	0.982	0.966	0.940	0.982	0.984
L5 GREENRATIOEP	−0.000	−0.010	−0.041		0.549	0.564	−0.112		0.000	0.005	0.003
	(0.089)	(0.164)	(0.078)		(0.693)	(0.487)	(0.143)		(0.000)	(0.047)	(0.067)
Observations	619	619	619		619	619	619		619	619	619
R2	0.989	0.984	0.992		0.997	0.834	0.989		0.951	0.982	0.986
L1 3YEARAVGGREENRATIOEP	−0.229	−0.211	−0.258*	−1.003	−4.702	1.260*	−0.530***	−4.315	0.001	0.071	−0.138
	(0.185)	(0.331)	(0.148)	(0.637)	(3.342)	(0.647)	(0.189)	(3.307)	(0.001)	(0.088)	(0.143)
Observations	910	910	910	257	910	910	910	257	910	910	910
R2	0.968	0.949	0.968	0.964	0.986	0.721	0.967	0.808	0.930	0.926	0.950
Panel B.2: And ever-patenting firms											
L1 GREENRATIOEP	−0.326**	−0.075	−0.237**	0.638	−2.021	0.911	−0.435***	1.460	0.000	−0.065	−0.093
	(0.146)	(0.199)	(0.105)	(0.619)	(1.926)	(0.672)	(0.132)	(3.095)	(0.001)	(0.055)	(0.116)
Observations	855	855	855	233	855	855	855	233	855	855	855
R2	0.969	0.965	0.982	0.950	0.933	0.663	0.964	0.644	0.947	0.976	0.974
L3 GREENRATIOEP	−0.369**	−0.095	−0.177*	−1.582	−1.107	0.593	−0.148	−5.855	0.000	−0.132**	−0.123
	(0.179)	(0.189)	(0.101)	(1.111)	(2.418)	(0.395)	(0.142)	(4.896)	(0.001)	(0.064)	(0.112)
Observations	731	731	731	108	731	731	731	108	731	731	731
R2	0.976	0.973	0.985	0.981	0.937	0.708	0.975	0.922	0.951	0.980	0.977
L5 GREENRATIOEP	−0.271	−0.088	−0.247**		2.258	0.705	−0.056		0.000	−0.173***	−0.209*
	(0.174)	(0.179)	(0.104)		(1.959)	(0.576)	(0.172)		(0.001)	(0.062)	(0.108)
Observations	609	609	609		609	609	609		609	609	609
R2	0.980	0.979	0.987		0.952	0.803	0.983		0.966	0.981	0.979
L1 3YEARAVGGREENRATIOEP	−0.985***	−0.273	−0.522***	−1.224	−4.592	1.653**	−0.471*	−4.645	0.000	−0.224**	−0.348
	(0.309)	(0.324)	(0.199)	(0.781)	(3.385)	(0.796)	(0.246)	(4.056)	(0.001)	(0.110)	(0.214)
Observations	900	900	900	254	900	900	900	254	900	900	900
R2	0.964	0.959	0.977	0.954	0.906	0.675	0.955	0.656	0.938	0.965	0.966
Panel B.3: And never-patenting firms											
L1 GREENRATIOEP	−0.075	0.122	0.003	0.063	−2.467	0.204	−0.950	2.999	0.001	0.129*	0.112
	(0.121)	(0.218)	(0.097)	(0.321)	(3.269)	(0.248)	(0.589)	(2.324)	(0.001)	(0.074)	(0.086)
Observations	845	845	845	233	845	845	845	233	845	845	845
R2	0.944	0.937	0.952	0.972	0.949	0.702	0.449	0.972	0.796	0.939	0.954
L3 GREENRATIOEP	−0.043	−0.093	0.065	0.107	−2.647	0.216	−0.321	−1.809	0.001	0.125	0.098
	(0.114)	(0.191)	(0.093)	(0.317)	(2.565)	(0.295)	(0.202)	(2.069)	(0.001)	(0.077)	(0.080)
Observations	717	717	717	108	717	717	717	108	717	717	717
R2	0.961	0.959	0.970	0.998	0.981	0.824	0.752	0.997	0.820	0.955	0.969
L5 GREENRATIOEP	−0.016	−0.085	0.071		−1.138	0.233	−0.010		0.001	0.079	0.072
	(0.113)	(0.156)	(0.101)		(1.669)	(0.247)	(0.220)		(0.001)	(0.088)	(0.088)
Observations	593	593	593		593	593	593		593	593	593
R2	0.973	0.970	0.977		0.990	0.882	0.857		0.845	0.961	0.973
L1 3YEARAVGGREENRATIOEP	−0.208	−0.068	0.117	−0.322	−10.059*	0.299	−0.888	−0.152	0.001	0.234**	0.140
	(0.181)	(0.377)	(0.151)	(0.453)	(5.467)	(0.340)	(0.563)	(2.332)	(0.002)	(0.104)	(0.136)
Observations	891	891	891	257	891	891	891	257	891	891	891
R2	0.946	0.935	0.953	0.974	0.954	0.696	0.455	0.968	0.797	0.934	0.953
Controls	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Year F.E.	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Industry F.E.	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes

TABLE IA.XXIV: BROWN EFFICIENCY PATENT RATIOS IN NORTH AMERICA AND CROSS-COUNTRY INDUSTRY-LEVEL OUTCOMES

The unit of observation is GICS-6 industry-year. The sample period is 2005 to 2020. The dependent variables are GICS-6 sector industry level logs of cumulative sums of S1TOT, S2TOT, S3UPTOT, S3DOWNTOT, CAPEX, and SALES over 1, 3 or 5 years, respectively cumulative sums over sums for S1INT, S2INT, S3UPINT, S3DOWNINT and INVEST/A for 1, 3 or 5 years. In Panel A, dependent variables are calculated across all firms with their headquarter in North America. In Panel B, dependent variables are calculated across all firms with their headquarter outside of North America. In addition, in Panel A.1 and B.1, dependent variables are calculated across all firms within the given industry and region. In Panel A.2 and B.2, dependent variables are calculated across all ever patenting firms within the given industry and region and in Panel A.3 and B.3, dependent variables are calculated across all never patenting firms within the given industry and region. All independent variables are calculated based on firms with their headquarter in North America. The key explanatory variables of interest is *BROWNEFFRATIOEP*. Controls include *LOGSIZE*, *LOGPPE*, *LEVERAGE*, *ROE*, *M/B*, *INVEST/A*, *BETA*, *VOLAT*, *MOM*, *RET*, *MSCI*. Independent variables are either GICS-6 industry level sums (LOGSIZE and LOGPPE), sum over sums (BROWNEFFRATIOEP, LEVERAGE, ROE, M/B, INVEST/A) or market capitalization value weighted averages (BETA, VOLAT, MOM, RET, MSCI). All Independent variables are lagged by 1, 3 or 5 years respectively. The model is estimated using pooled regression model. All regression include year and industry fixed effects. We double cluster standard errors at the GICS-6 industry and year dimension. *** 1% significance, ** 5% significance * 10% significance.

	(1) LOGS1TOT	(2) LOGS2TOT	(3) LOGS3UPTOT	(4) LOGS3DOWNTOT	(5) S1INT	(6) S2INT	(7) S3UPINT	(8) S3DOWNINT	(9) INVEST/A	(10) LOGCAPEX	(11) LOGSALES
Panel A: NA-firm based BROWNEFFRATIOEP On NA firms											
Panel A.1: And all firms											
L1 BROWNEFFRATIOEP	0.124	0.086	0.216	−0.992	4.714**	0.071	0.456**	−4.241	0.001	−0.046	0.067
	(0.226)	(0.410)	(0.131)	(1.213)	(2.274)	(0.120)	(0.223)	(5.090)	(0.001)	(0.112)	(0.085)
Observations	861	861	861	233	861	861	861	233	861	861	861
R2	0.958	0.934	0.974	0.958	0.963	0.909	0.968	0.918	0.924	0.959	0.975
L3 BROWNEFFRATIOEP	−0.087	0.025	0.035	0.807	0.109	0.077	0.047	5.496	0.001	0.010	0.041
	(0.213)	(0.200)	(0.124)	(0.805)	(2.466)	(0.086)	(0.154)	(3.746)	(0.001)	(0.095)	(0.075)
Observations	737	737	737	108	737	737	737	108	737	737	737
R2	0.963	0.964	0.978	0.997	0.970	0.951	0.985	0.995	0.923	0.964	0.979
L5 BROWNEFFRATIOEP	−0.410*	−0.037	−0.200		−2.194	0.103	−0.189		0.000	−0.054	−0.064
	(0.212)	(0.160)	(0.134)		(2.762)	(0.097)	(0.162)		(0.001)	(0.117)	(0.090)
Observations	616	616	616		616	616	616		616	616	616
R2	0.967	0.972	0.980		0.979	0.969	0.990		0.921	0.968	0.979
L1 3YEARAVGBROWNEFFRATIOEP	−0.089	0.190	0.152	−2.331	−1.126	0.217	0.302	−9.378	0.001	−0.175	0.089
	(0.292)	(0.479)	(0.204)	(2.104)	(3.342)	(0.168)	(0.342)	(12.702)	(0.001)	(0.128)	(0.133)
Observations	907	907	907	255	907	907	907	255	907	907	907
R2	0.959	0.939	0.975	0.959	0.961	0.909	0.967	0.903	0.929	0.958	0.975
Panel A.2: And ever-patenting firms											
L1 BROWNEFFRATIOEP	−0.041	0.224	0.129	0.364	5.783	0.137	0.465*	5.776	0.001*	−0.062	−0.007
	(0.199)	(0.653)	(0.110)	(0.978)	(6.409)	(0.188)	(0.276)	(8.275)	(0.001)	(0.097)	(0.089)
Observations	861	861	861	233	861	861	861	233	861	861	861
R2	0.948	0.917	0.975	0.940	0.932	0.878	0.962	0.875	0.916	0.943	0.975
L3 BROWNEFFRATIOEP	−0.202	−0.063	−0.033	2.669	1.707	0.099	0.028	7.051	0.001*	−0.021	−0.013
	(0.205)	(0.458)	(0.098)	(1.948)	(3.445)	(0.161)	(0.148)	(4.818)	(0.001)	(0.078)	(0.067)
Observations	737	737	737	108	737	737	737	108	737	737	737
R2	0.955	0.936	0.978	0.995	0.964	0.923	0.981	0.994	0.913	0.953	0.978
L5 BROWNEFFRATIOEP	−0.549***	−0.069	−0.250**		−1.263	0.172	−0.133		0.001**	−0.032	−0.132*
	(0.208)	(0.357)	(0.107)		(2.395)	(0.181)	(0.148)		(0.001)	(0.079)	(0.070)
Observations	616	616	616		616	616	616		616	616	616
R2	0.961	0.955	0.981		0.977	0.948	0.988		0.929	0.963	0.979
L1 3YEARAVGBROWNEFFRATIOEP	−0.530	−0.441	0.029	−0.996	13.335	0.349	0.592	−12.710	0.001	−0.206*	−0.079
	(0.441)	(0.913)	(0.193)	(2.159)	(11.931)	(0.259)	(0.441)	(21.131)	(0.002)	(0.118)	(0.135)
Observations	907	907	907	255	907	907	907	255	907	907	907
R2	0.945	0.928	0.977	0.945	0.933	0.878	0.961	0.836	0.909	0.948	0.977
Panel A.3: And never-patenting firms											
L1 BROWNEFFRATIOEP	0.434	0.119	0.366	−0.091	8.692	−0.145	0.307	−0.672	−0.004**	−0.047	0.258
	(0.298)	(0.510)	(0.238)	(1.495)	(9.226)	(0.175)	(0.375)	(4.111)	(0.002)	(0.218)	(0.245)
Observations	696	696	696	233	696	696	696	233	696	695	696
R2	0.942	0.884	0.925	0.967	0.855	0.804	0.908	0.961	0.772	0.888	0.916
L3 BROWNEFFRATIOEP	0.294	0.093	0.196	0.088	0.355	0.005	−0.106	9.683**	−0.003	0.091	0.247
	(0.239)	(0.311)	(0.210)	(0.861)	(9.156)	(0.137)	(0.291)	(3.981)	(0.002)	(0.154)	(0.204)
Observations	557	557	557	108	557	557	557	108	557	557	557
R2	0.964	0.937	0.954	0.998	0.894	0.888	0.959	0.998	0.886	0.944	0.949
L5 BROWNEFFRATIOEP	−0.067	−0.143	−0.138		−5.613	−0.073	−0.419*		−0.002*	−0.125	0.010
	(0.259)	(0.295)	(0.234)		(8.455)	(0.110)	(0.248)		(0.001)	(0.194)	(0.198)
Observations	426	426	426		426	426	426		426	426	426
R2	0.976	0.966	0.969		0.933	0.942	0.970		0.932	0.963	0.968
L1 3YEARAVGBROWNEFFRATIOEP	0.261	0.467	0.449	−1.276	−16.281	−0.062	−0.336	−2.625	−0.004	−0.008	0.595*
	(0.386)	(0.561)	(0.305)	(2.178)	(11.656)	(0.164)	(0.521)	(6.986)	(0.003)	(0.302)	(0.323)
Observations	738	738	738	255	738	738	738	255	738	737	738
R2	0.944	0.883	0.923	0.967	0.826	0.803	0.904	0.955	0.773	0.888	0.914
Controls	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Year F.E.	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Industry F.E.	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes

	(1) LOGS1TOT	(2) LOGS2TOT	(3) LOGS3UPTOT	(4) LOGS3DOWNTOT	(5) S1INT	(6) S2INT	(7) S3UPINT	(8) S3DOWNINT	(9) INVEST/A	(10) LOGCAPEX	(11) LOGSALES
Panel B: NA-firm based BROWNEFFRATIOEP On Non-NA firms											
Panel B.1: And all firms											
L1 BROWNEFFRATIOEP	0.092	−0.058	0.132	−1.443	6.233	−0.133	0.366	−10.327	−0.001	0.017	0.007
	(0.107)	(0.312)	(0.121)	(1.221)	(4.410)	(0.089)	(0.255)	(9.043)	(0.001)	(0.071)	(0.095)
Observations	863	863	863	233	863	863	863	233	863	863	863
R2	0.967	0.951	0.968	0.958	0.986	0.703	0.967	0.808	0.934	0.936	0.950
L3 BROWNEFFRATIOEP	0.199**	−0.047	0.171	4.328	4.893	−0.120	0.212	18.206	−0.000	0.063	0.094
	(0.096)	(0.278)	(0.116)	(2.666)	(3.026)	(0.077)	(0.218)	(15.748)	(0.001)	(0.060)	(0.088)
Observations	740	740	740	108	740	740	740	108	740	740	740
R2	0.985	0.978	0.990	0.988	0.993	0.749	0.982	0.967	0.940	0.982	0.984
L5 BROWNEFFRATIOEP	0.254**	0.163	0.194*		−1.241	−0.080	−0.206		0.000	0.170**	0.210**
	(0.116)	(0.226)	(0.107)		(1.566)	(0.080)	(0.166)		(0.001)	(0.071)	(0.090)
Observations	619	619	619		619	619	619		619	619	619
R2	0.989	0.984	0.992		0.997	0.825	0.989		0.951	0.983	0.986
L1 3YEARAVGBROWNEFFRATIOEP	0.256	−0.437	0.141	1.676	15.149**	−0.204	0.187	20.710	−0.001	0.063	0.070
	(0.171)	(0.435)	(0.167)	(1.612)	(6.084)	(0.146)	(0.341)	(14.639)	(0.001)	(0.122)	(0.148)
Observations	910	910	910	257	910	910	910	257	910	910	910
R2	0.968	0.949	0.968	0.964	0.988	0.703	0.966	0.810	0.930	0.926	0.950
Panel B.2: And ever-patenting firms											
L1 BROWNEFFRATIOEP	0.270	0.069	0.202	−4.139**	3.537	−0.130	0.369*	−15.405	0.000	0.133	0.036
	(0.175)	(0.309)	(0.192)	(1.994)	(4.694)	(0.104)	(0.205)	(13.999)	(0.001)	(0.093)	(0.210)
Observations	855	855	855	233	855	855	855	233	855	855	855
R2	0.969	0.965	0.982	0.952	0.933	0.647	0.963	0.646	0.947	0.976	0.974
L3 BROWNEFFRATIOEP	0.429***	−0.026	0.232**	3.772	2.542	−0.167*	0.207	22.021	−0.000	0.169*	0.140
	(0.157)	(0.267)	(0.113)	(2.546)	(4.711)	(0.093)	(0.177)	(19.141)	(0.001)	(0.102)	(0.146)
Observations	731	731	731	108	731	731	731	108	731	731	731
R2	0.976	0.973	0.985	0.981	0.938	0.701	0.975	0.923	0.951	0.980	0.977
L5 BROWNEFFRATIOEP	0.301	0.136	0.339***		−5.066	−0.160	−0.257		−0.000	0.220**	0.416***
	(0.204)	(0.178)	(0.102)		(3.780)	(0.100)	(0.173)		(0.001)	(0.088)	(0.118)
Observations	609	609	609		609	609	609		609	609	609
R2	0.980	0.979	0.987		0.954	0.791	0.983		0.966	0.981	0.979
L1 3YEARAVGBROWNEFFRATIOEP	0.771***	−0.441	0.255	−0.211	13.340**	−0.228	0.421	34.788	−0.001	0.216	0.040
	(0.295)	(0.453)	(0.282)	(2.755)	(6.456)	(0.178)	(0.355)	(22.755)	(0.001)	(0.202)	(0.333)
Observations	900	900	900	254	900	900	900	254	900	900	900
R2	0.963	0.959	0.977	0.954	0.912	0.647	0.955	0.659	0.938	0.965	0.965
Panel B.3: And never-patenting firms											
L1 BROWNEFFRATIOEP	0.001	0.170	−0.037	−1.487*	2.857	−0.153	−0.427	−10.906*	−0.002	−0.031	−0.020
	(0.173)	(0.389)	(0.147)	(0.780)	(7.796)	(0.194)	(0.804)	(6.564)	(0.002)	(0.099)	(0.126)
Observations	845	845	845	233	845	845	845	233	845	845	845
R2	0.944	0.937	0.952	0.973	0.949	0.702	0.448	0.972	0.796	0.939	0.954
L3 BROWNEFFRATIOEP	−0.007	0.110	−0.056	0.824	5.600	0.067	−0.178	1.804	−0.000	−0.012	−0.077
	(0.177)	(0.331)	(0.152)	(0.944)	(4.852)	(0.102)	(0.479)	(7.106)	(0.002)	(0.095)	(0.127)
Observations	717	717	717	108	717	717	717	108	717	717	717
R2	0.961	0.959	0.970	0.998	0.982	0.823	0.752	0.997	0.820	0.955	0.969
L5 BROWNEFFRATIOEP	−0.099	0.152	−0.176		2.529	0.055	−0.539		0.003	0.053	−0.075
	(0.212)	(0.273)	(0.172)		(3.111)	(0.113)	(0.487)		(0.003)	(0.127)	(0.144)
Observations	593	593	593		593	593	593		593	593	593
R2	0.973	0.970	0.977		0.990	0.880	0.857		0.845	0.961	0.973
L1 3YEARAVGBROWNEFFRATIOEP	0.097	0.102	−0.152	0.808	22.034**	0.112	−1.164	3.081	0.002	−0.035	−0.153
	(0.285)	(0.611)	(0.235)	(1.056)	(11.014)	(0.218)	(1.749)	(7.716)	(0.004)	(0.151)	(0.170)
Observations	891	891	891	257	891	891	891	257	891	891	891
R2	0.946	0.935	0.953	0.974	0.956	0.695	0.454	0.968	0.797	0.934	0.953
Controls	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Year F.E.	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Industry F.E.	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes

TABLE IA.XXV: GREEN PATENT RATIOS IN EUROPE AND CROSS-COUNTRY INDUSTRY-LEVEL OUTCOMES

The unit of observation is GICS-6 industry-year. The sample period is 2005 to 2020. The dependent variables are GICS-6 sector industry level logs of cumulative sums of S1TOT, S2TOT, S3UPTOT, S3DOWNTOT, CAPEX, and SALES over 1, 3 or 5 years, respectively cumulative sums over sums for S1INT, S2INT, S3UPINT, S3DOWNINT and INVEST/A for 1, 3 or 5 years. In Panel A, dependent variables are calculated across all firms with their headquarter in Europe. In Panel B, dependent variables are calculated across all firms with their headquarter outside of Europe. In addition, in Panel A.1 and B.1, dependent variables are calculated across all firms within the given industry and region. In Panel A.2 and B.2, dependent variables are calculated across all ever patenting firms within the given industry and region and in Panel A.3 and B.3, dependent variables are calculated across all never patenting firms within the given industry and region. All independent variables are calculated based on firms with their headquarter in Europe. The key explanatory variables of interest is *GREENRATIOEP*. Controls include *LOGSIZE*, *LOGPPE*, *LEVERAGE*, *ROE*, *M/B*, *INVEST/A*, *BETA*, *VOLAT*, *MOM*, *RET*, *MSCI*. Independent variables are either GICS-6 industry level sums (LOGSIZE and LOGPPE), sum over sums (GREENRATIOEP, LEVERAGE, ROE, M/B, INVEST/A) or market capitalization value weighted averages (BETA, VOLAT, MOM, RET, MSCI). All Independent variables are lagged by 1, 3 or 5 years respectively. The model is estimated using pooled regression model. All regression include year and industry fixed effects. We double cluster standard errors at the GICS-6 industry and year dimension. *** 1% significance, ** 5% significance * 10% significance.

	(1) LOGS1TOT	(2) LOGS2TOT	(3) LOGS3UPTOT	(4) LOGS3DOWNTOT	(5) S1INT	(6) S2INT	(7) S3UPINT	(8) S3DOWNINT	(9) INVEST/A	(10) LOGCAPEX	(11) LOGSALES
Panel A: EU-firm based GREENRATIOEP On EU firms											
Panel A.1: And all firms											
L1 GREENRATIOEP	0.415**	0.102	0.141	0.149	1.753	−0.035	−0.173	−2.930	0.000	0.175*	0.170
	(0.177)	(0.216)	(0.141)	(0.534)	(1.896)	(0.102)	(0.157)	(4.169)	(0.001)	(0.098)	(0.152)
Observations	887	887	887	241	887	887	887	241	887	887	887
R2	0.961	0.941	0.965	0.950	0.931	0.909	0.922	0.867	0.946	0.924	0.955
L3 GREENRATIOEP	0.356***	0.094	0.169	−0.057	0.315	0.017	−0.129	−0.060	0.001	0.153*	0.219
	(0.133)	(0.189)	(0.134)	(0.301)	(1.208)	(0.041)	(0.081)	(0.918)	(0.001)	(0.090)	(0.139)
Observations	757	757	757	114	757	757	757	114	757	757	757
R2	0.978	0.967	0.983	0.988	0.971	0.953	0.947	0.993	0.946	0.968	0.977
L5 GREENRATIOEP	0.081	0.039	0.079		−0.585	0.008	−0.066		−0.000	0.066	0.113
	(0.114)	(0.126)	(0.103)		(0.757)	(0.032)	(0.077)		(0.001)	(0.066)	(0.104)
Observations	634	634	634		634	634	634		634	634	634
R2	0.986	0.980	0.987		0.988	0.972	0.960		0.952	0.976	0.982
L1 3YEARAVGGREENRATIOEP	0.601***	0.105	0.276*	0.453	4.197*	0.004	−0.014	−0.490	0.001	0.215*	0.244
	(0.202)	(0.248)	(0.164)	(1.413)	(2.358)	(0.093)	(0.191)	(6.282)	(0.001)	(0.119)	(0.172)
Observations	924	924	924	252	924	924	924	252	924	924	924
R2	0.960	0.938	0.963	0.948	0.933	0.907	0.921	0.870	0.945	0.921	0.953
Panel A.2: And ever-patenting firms											
L1 GREENRATIOEP	0.262	0.150	0.124	−0.021	−1.819	−0.050	−0.323	−1.889	−0.000	0.195**	0.183
	(0.241)	(0.233)	(0.154)	(0.676)	(3.187)	(0.152)	(0.256)	(4.032)	(0.002)	(0.095)	(0.174)
Observations	884	884	884	241	884	884	884	241	884	884	884
R2	0.957	0.947	0.970	0.950	0.835	0.876	0.891	0.868	0.902	0.948	0.964
L3 GREENRATIOEP	0.350*	0.117	0.224	−0.194	−0.326	0.033	−0.157*	−0.616	0.000	0.129	0.268
	(0.186)	(0.204)	(0.156)	(0.328)	(2.042)	(0.049)	(0.086)	(1.104)	(0.001)	(0.094)	(0.165)
Observations	751	751	751	114	751	751	751	114	751	751	751
R2	0.974	0.966	0.982	0.986	0.926	0.944	0.936	0.993	0.935	0.964	0.975
L5 GREENRATIOEP	0.060	−0.026	0.065		0.363	−0.007	−0.104		−0.000	0.006	0.125
	(0.187)	(0.138)	(0.125)		(1.803)	(0.036)	(0.080)		(0.001)	(0.084)	(0.125)
Observations	628	628	628		628	628	628		628	628	628
R2	0.982	0.979	0.987		0.956	0.966	0.952		0.958	0.972	0.981
L1 3YEARAVGGREENRATIOEP	0.374	0.033	0.221	0.611	−1.220	−0.013	−0.231	3.091	0.001	0.101	0.212
	(0.272)	(0.300)	(0.149)	(1.859)	(3.826)	(0.142)	(0.288)	(6.455)	(0.002)	(0.141)	(0.180)
Observations	917	917	917	252	917	917	917	252	917	917	917
R2	0.955	0.942	0.971	0.949	0.828	0.873	0.891	0.870	0.902	0.943	0.963
Panel A.3: And never-patenting firms											
L1 GREENRATIOEP	0.198	−0.325	0.159	0.297	5.213	0.063	0.004	2.382	0.001	0.062	0.126
	(0.749)	(0.366)	(0.382)	(0.507)	(7.713)	(0.145)	(0.221)	(2.376)	(0.003)	(0.163)	(0.266)
Observations	756	756	756	217	756	756	756	217	756	754	756
R2	0.889	0.855	0.878	0.964	0.780	0.697	0.908	0.875	0.725	0.881	0.899
L3 GREENRATIOEP	−0.083	0.300	0.038	0.065	3.235	0.133	−0.021	0.264	0.003	0.273	0.094
	(0.688)	(0.373)	(0.244)	(0.274)	(7.664)	(0.100)	(0.199)	(1.553)	(0.003)	(0.177)	(0.177)
Observations	614	614	614	96	614	614	614	96	614	614	614
R2	0.915	0.878	0.900	0.998	0.816	0.817	0.942	0.990	0.833	0.889	0.909
L5 GREENRATIOEP	−0.016	0.195	−0.136		−4.681	0.099	−0.145		0.003	0.147	−0.014
	(0.665)	(0.338)	(0.211)		(7.282)	(0.105)	(0.182)		(0.003)	(0.153)	(0.135)
Observations	494	494	494		494	494	494		494	494	494
R2	0.938	0.915	0.928		0.868	0.868	0.964		0.877	0.940	0.941
L1 3YEARAVGGREENRATIOEP	−0.416	−0.134	−0.292	0.301	6.112	0.247	−0.005	2.937	0.006	0.255	−0.187
	(1.139)	(0.533)	(0.566)	(1.164)	(13.497)	(0.202)	(0.330)	(4.325)	(0.004)	(0.224)	(0.351)
Observations	790	790	790	228	790	790	790	228	790	788	790
R2	0.885	0.854	0.876	0.964	0.763	0.696	0.909	0.874	0.728	0.880	0.898
Controls	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Year F.E.	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Industry F.E.	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes

	(1) LOGS1TOT	(2) LOGS2TOT	(3) LOGS3UPTOT	(4) LOGS3DOWNTOT	(5) S1INT	(6) S2INT	(7) S3UPINT	(8) S3DOWNINT	(9) INVEST/A	(10) LOGCAPEX	(11) LOGSALES
Panel B: EU-firm based GREENRATIOEP On Non-EU firms											
Panel B.1: And all firms											
L1 GREENRATIOEP	−0.038	0.180	−0.060	0.103	1.573	0.028	−0.002	−6.386	0.000	−0.015	−0.053
	(0.145)	(0.160)	(0.061)	(0.536)	(1.246)	(0.097)	(0.132)	(9.593)	(0.000)	(0.038)	(0.048)
Observations	888	888	888	241	888	888	888	241	888	888	888
R2	0.955	0.916	0.952	0.959	0.988	0.603	0.976	0.840	0.887	0.923	0.930
L3 GREENRATIOEP	0.074	0.054	−0.019	−2.444*	0.194	0.043	−0.076	−28.824	0.001	0.021	0.004
	(0.126)	(0.114)	(0.060)	(1.317)	(0.583)	(0.091)	(0.128)	(20.879)	(0.000)	(0.033)	(0.044)
Observations	759	759	759	114	759	759	759	114	759	759	759
R2	0.976	0.972	0.989	0.991	0.995	0.651	0.991	0.979	0.960	0.980	0.986
L5 GREENRATIOEP	0.094	0.174*	−0.039		−0.578	0.119	−0.030		0.000	−0.031	−0.033
	(0.119)	(0.097)	(0.059)		(0.511)	(0.100)	(0.082)		(0.000)	(0.037)	(0.044)
Observations	636	636	636		636	636	636		636	636	636
R2	0.982	0.980	0.990		0.997	0.732	0.995		0.969	0.980	0.987
L1 3YEARAVGGREENRATIOEP	−0.061	0.319	0.004	−0.363	1.260	0.131	−0.031	−2.040	0.001	0.056	0.013
	(0.168)	(0.229)	(0.090)	(1.267)	(1.660)	(0.110)	(0.167)	(11.719)	(0.001)	(0.066)	(0.073)
Observations	926	926	926	254	926	926	926	254	926	926	926
R2	0.955	0.917	0.953	0.962	0.989	0.603	0.976	0.837	0.873	0.920	0.931
Panel B.2: And ever-patenting firms											
L1 GREENRATIOEP	−0.050	0.037	−0.003	0.636	2.647	0.002	0.120	−12.975	0.000	−0.080	−0.063
	(0.147)	(0.212)	(0.070)	(0.873)	(2.958)	(0.133)	(0.089)	(16.256)	(0.000)	(0.058)	(0.069)
Observations	879	879	879	241	879	879	879	241	879	879	879
R2	0.973	0.945	0.990	0.951	0.939	0.515	0.980	0.672	0.963	0.976	0.987
L3 GREENRATIOEP	0.051	0.144	−0.023	−4.516***	0.110	0.167	−0.002	−82.719**	0.000	−0.074	−0.041
	(0.151)	(0.208)	(0.076)	(1.282)	(1.650)	(0.141)	(0.057)	(32.811)	(0.000)	(0.055)	(0.068)
Observations	749	749	749	114	749	749	749	114	749	749	749
R2	0.978	0.958	0.990	0.990	0.977	0.565	0.991	0.967	0.964	0.978	0.988
L5 GREENRATIOEP	0.134	0.192	−0.056		−0.462	0.183	0.012		−0.000	−0.093*	−0.065
	(0.148)	(0.160)	(0.061)		(1.066)	(0.127)	(0.043)		(0.000)	(0.056)	(0.057)
Observations	626	626	626		626	626	626		626	626	626
R2	0.982	0.972	0.991		0.990	0.648	0.995		0.968	0.981	0.990
L1 3YEARAVGGREENRATIOEP	−0.178	−0.019	−0.030	1.287	3.484	0.164	0.175	−5.809	0.001	−0.125	−0.109
	(0.222)	(0.328)	(0.107)	(2.169)	(4.455)	(0.178)	(0.154)	(21.070)	(0.001)	(0.084)	(0.102)
Observations	916	916	916	252	916	916	916	252	916	916	916
R2	0.969	0.943	0.989	0.946	0.944	0.520	0.980	0.668	0.955	0.977	0.987
Panel B.3: And never-patenting firms											
L1 GREENRATIOEP	−0.112	0.250	−0.069	−0.046	1.795	0.135	0.058	1.962	−0.001	−0.120*	−0.086
	(0.154)	(0.177)	(0.100)	(0.402)	(1.348)	(0.085)	(0.189)	(2.190)	(0.001)	(0.065)	(0.085)
Observations	867	867	867	241	867	867	867	241	867	867	867
R2	0.932	0.911	0.933	0.969	0.972	0.690	0.584	0.961	0.788	0.922	0.932
L3 GREENRATIOEP	0.002	0.017	−0.031	0.131	−0.136	0.052	−0.004	0.442	0.000	−0.008	−0.048
	(0.146)	(0.141)	(0.105)	(0.451)	(0.635)	(0.061)	(0.177)	(2.921)	(0.001)	(0.070)	(0.090)
Observations	726	726	726	114	726	726	726	114	726	726	726
R2	0.951	0.945	0.960	0.998	0.989	0.814	0.839	0.996	0.832	0.950	0.960
L5 GREENRATIOEP	−0.042	−0.018	−0.089		−0.813	0.081	0.001		0.001	−0.056	−0.102
	(0.136)	(0.136)	(0.097)		(0.625)	(0.075)	(0.137)		(0.001)	(0.067)	(0.083)
Observations	593	593	593		593	593	593		593	593	593
R2	0.966	0.960	0.966		0.995	0.875	0.922		0.889	0.953	0.967
L1 3YEARAVGGREENRATIOEP	−0.021	0.560**	0.080	−0.510	0.410	0.214**	−0.012	4.372	0.000	−0.037	0.042
	(0.177)	(0.237)	(0.142)	(1.129)	(1.810)	(0.091)	(0.226)	(4.600)	(0.002)	(0.103)	(0.123)
Observations	905	905	905	254	905	905	905	254	905	905	905
R2	0.932	0.912	0.933	0.972	0.974	0.691	0.591	0.961	0.786	0.917	0.931
Controls	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Year F.E.	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Industry F.E.	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes

TABLE IA.XXVI: BROWN EFFICIENCY PATENT RATIOS IN EUROPE AND CROSS-COUNTRY INDUSTRY-LEVEL OUTCOMES

The unit of observation is GICS-6 industry-year. The sample period is 2005 to 2020. The dependent variables are GICS-6 sector industry level logs of cumulative sums of S1TOT, S2TOT, S3UPTOT, S3DOWNTOT, CAPEX, and SALES over 1, 3 or 5 years, respectively cumulative sums over sums for S1INT, S2INT, S3UPINT, S3DOWNINT and INVEST/A for 1, 3 or 5 years. In Panel A, dependent variables are calculated across all firms with their headquarter in Europe. In Panel B, dependent variables are calculated across all firms with their headquarter outside of Europe. In addition, in Panel A.1 and B.1, dependent variables are calculated across all firms within the given industry and region. In Panel A.2 and B.2, dependent variables are calculated across all ever patenting firms within the given industry and region and in Panel A.3 and B.3, dependent variables are calculated across all never patenting firms within the given industry and region. All independent variables are calculated based on firms with their headquarter in Europe. The key explanatory variables of interest is *BROWNEFFRATIOEP*. Controls include *LOGSIZE*, *LOGPPE*, *LEVERAGE*, *ROE*, *M/B*, *INVEST/A*, *BETA*, *VOLAT*, *MOM*, *RET*, *MSCI*. Independent variables are either GICS-6 industry level sums (LOGSIZE and LOGPPE), sum over sums (BROWNEFFRATIOEP, LEVERAGE, ROE, M/B, INVEST/A) or market capitalization value weighted averages (BETA, VOLAT, MOM, RET, MSCI). All Independent variables are lagged by 1, 3 or 5 years respectively. The model is estimated using pooled regression model. All regression include year and industry fixed effects. We double cluster standard errors at the GICS-6 industry and year dimension. *** 1% significance, ** 5% significance * 10% significance.

	(1) LOGS1TOT	(2) LOGS2TOT	(3) LOGS3UPTOT	(4) LOGS3DOWNTOT	(5) S1INT	(6) S2INT	(7) S3UPINT	(8) S3DOWNINT	(9) INVEST/A	(10) LOGCAPEX	(11) LOGSALES
Panel A: EU-firm based BROWNEFFRATIOEP On EU firms											
Panel A.1: And all firms											
L1 BROWNEFFRATIOEP	−1.129***	−0.624***	−0.549**	−5.308**	−1.399	0.091	−0.077	−2.971	−0.001	−0.407***	−0.452**
	(0.338)	(0.227)	(0.270)	(2.276)	(0.950)	(0.101)	(0.232)	(15.640)	(0.001)	(0.115)	(0.215)
Observations	887	887	887	241	887	887	887	241	887	887	887
R2	0.962	0.941	0.965	0.951	0.931	0.909	0.922	0.867	0.946	0.924	0.955
L3 BROWNEFFRATIOEP	−0.679***	−0.207	−0.170*	−0.161	−1.382**	0.071	−0.067	7.416	0.000	−0.127	−0.087
	(0.238)	(0.175)	(0.094)	(2.372)	(0.624)	(0.079)	(0.182)	(9.685)	(0.001)	(0.088)	(0.084)
Observations	757	757	757	114	757	757	757	114	757	757	757
R2	0.978	0.967	0.983	0.988	0.971	0.953	0.947	0.993	0.945	0.967	0.977
L5 BROWNEFFRATIOEP	−0.420*	−0.157	−0.160*		−0.443	0.008	−0.284		0.001	0.153*	−0.010
	(0.221)	(0.121)	(0.090)		(0.595)	(0.058)	(0.223)		(0.001)	(0.087)	(0.102)
Observations	634	634	634		634	634	634		634	634	634
R2	0.986	0.980	0.987		0.988	0.972	0.960		0.952	0.976	0.982
L1 3YEARAVGBROWNEFFRATIOEP	−1.764***	−0.540	−0.686	−0.762	−3.214**	0.188	−0.505	10.431	0.000	−0.259	−0.253
	(0.537)	(0.495)	(0.434)	(3.481)	(1.441)	(0.127)	(0.411)	(26.899)	(0.003)	(0.236)	(0.400)
Observations	924	924	924	252	924	924	924	252	924	924	924
R2	0.960	0.938	0.963	0.948	0.931	0.907	0.921	0.870	0.945	0.921	0.952
Panel A.2: And ever-patenting firms											
L1 BROWNEFFRATIOEP	−0.940***	−0.341	−0.340	−5.034**	0.049	0.112	0.089	−2.971	−0.001	−0.047	−0.324
	(0.313)	(0.267)	(0.262)	(2.209)	(1.135)	(0.104)	(0.252)	(15.815)	(0.001)	(0.096)	(0.227)
Observations	884	884	884	241	884	884	884	241	884	884	884
R2	0.958	0.947	0.970	0.951	0.834	0.876	0.891	0.868	0.902	0.948	0.964
L3 BROWNEFFRATIOEP	−0.631**	−0.142	−0.085	1.637	−0.259	0.083	−0.042	0.717	−0.000	0.083	−0.022
	(0.252)	(0.213)	(0.097)	(2.228)	(0.771)	(0.086)	(0.191)	(8.122)	(0.001)	(0.091)	(0.094)
Observations	751	751	751	114	751	751	751	114	751	751	751
R2	0.974	0.966	0.981	0.986	0.926	0.944	0.935	0.993	0.935	0.964	0.975
L5 BROWNEFFRATIOEP	−0.520**	−0.209	−0.135		−0.162	0.021	−0.189		0.000	0.124	−0.042
	(0.260)	(0.156)	(0.093)		(0.616)	(0.066)	(0.214)		(0.001)	(0.118)	(0.107)
Observations	628	628	628		628	628	628		628	628	628
R2	0.982	0.979	0.987		0.956	0.966	0.952		0.958	0.972	0.981
L1 3YEARAVGBROWNEFFRATIOEP	−1.585***	−0.036	−0.138	1.155	−2.138	0.231	−0.086	12.825	−0.002	0.278	0.036
	(0.558)	(0.539)	(0.449)	(4.517)	(1.349)	(0.145)	(0.474)	(29.626)	(0.002)	(0.216)	(0.400)
Observations	917	917	917	252	917	917	917	252	917	917	917
R2	0.955	0.942	0.971	0.949	0.828	0.873	0.891	0.871	0.902	0.943	0.963
Panel A.3: And never-patenting firms											
L1 BROWNEFFRATIOEP	−0.402	−0.296	−0.263	−4.659*	−2.865	−0.246	0.068	−16.731	0.001	−0.248	−0.288
	(0.516)	(0.628)	(0.393)	(2.560)	(2.221)	(0.253)	(0.203)	(19.783)	(0.007)	(0.280)	(0.358)
Observations	756	756	756	217	756	756	756	217	756	754	756
R2	0.889	0.855	0.878	0.964	0.778	0.698	0.908	0.875	0.725	0.881	0.899
L3 BROWNEFFRATIOEP	0.392	0.396	0.125	−0.142	1.442	0.026	0.290*	7.935	0.010	0.113	0.007
	(0.437)	(0.575)	(0.351)	(2.087)	(2.033)	(0.221)	(0.174)	(19.643)	(0.007)	(0.298)	(0.359)
Observations	614	614	614	96	614	614	614	96	614	614	614
R2	0.915	0.877	0.900	0.998	0.815	0.817	0.942	0.990	0.834	0.888	0.909
L5 BROWNEFFRATIOEP	0.973***	0.551	0.586**		3.259**	−0.166	0.233		−0.003	0.295	0.578**
	(0.357)	(0.431)	(0.282)		(1.656)	(0.148)	(0.160)		(0.004)	(0.238)	(0.291)
Observations	494	494	494		494	494	494		494	494	494
R2	0.939	0.915	0.929		0.866	0.868	0.964		0.876	0.940	0.941
L1 3YEARAVGBROWNEFFRATIOEP	0.951	1.092	0.557	0.083	2.004	−0.186	0.415	−6.119	0.017	0.747	0.572
	(0.971)	(1.205)	(0.760)	(3.851)	(3.538)	(0.434)	(0.373)	(33.942)	(0.011)	(0.608)	(0.714)
Observations	790	790	790	228	790	790	790	228	790	788	790
R2	0.885	0.854	0.876	0.964	0.761	0.695	0.909	0.874	0.728	0.880	0.898
Controls	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Year F.E.	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Industry F.E.	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes

	(1) LOGS1TOT	(2) LOGS2TOT	(3) LOGS3UPTOT	(4) LOGS3DOWNTOT	(5) S1INT	(6) S2INT	(7) S3UPINT	(8) S3DOWNINT	(9) INVEST/A	(10) LOGCAPEX	(11) LOGSALES
Panel B: EU-firm based BROWNEFFRATIOEP On Non-EU firms											
Panel B.1: And all firms											
L1 BROWNEFFRATIOEP	−0.016	−0.549	−0.169	−3.850**	0.142	−0.350	0.054	−24.655	−0.000	−0.179	−0.080
	(0.247)	(0.388)	(0.236)	(1.627)	(0.871)	(0.451)	(0.114)	(17.004)	(0.001)	(0.175)	(0.205)
Observations	888	888	888	241	888	888	888	241	888	888	888
R2	0.955	0.916	0.952	0.960	0.988	0.603	0.976	0.840	0.887	0.923	0.930
L3 BROWNEFFRATIOEP	−0.013	−0.316	−0.101	2.868	−0.193	0.158	0.094	−11.787	−0.001	−0.091	−0.037
	(0.200)	(0.253)	(0.174)	(2.735)	(0.736)	(0.434)	(0.080)	(14.795)	(0.001)	(0.130)	(0.146)
Observations	759	759	759	114	759	759	759	114	759	759	759
R2	0.976	0.972	0.989	0.990	0.995	0.651	0.991	0.969	0.960	0.980	0.986
L5 BROWNEFFRATIOEP	0.005	−0.290	−0.093		−0.098	0.344	−0.040		−0.001	−0.036	−0.035
	(0.174)	(0.188)	(0.134)		(0.618)	(0.533)	(0.076)		(0.001)	(0.097)	(0.104)
Observations	636	636	636		636	636	636		636	636	636
R2	0.982	0.980	0.990		0.997	0.732	0.995		0.969	0.980	0.987
L1 3YEARAVGBROWNEFFRATIOEP	0.194	−1.057**	−0.453*	−2.313	−0.244	−0.298	0.223	−28.662	0.002	−0.128	−0.381
	(0.448)	(0.445)	(0.260)	(3.815)	(1.474)	(0.437)	(0.195)	(21.357)	(0.003)	(0.223)	(0.252)
Observations	926	926	926	254	926	926	926	254	926	926	926
R2	0.955	0.917	0.953	0.962	0.989	0.603	0.976	0.838	0.873	0.920	0.932
Panel B.2: And ever-patenting firms											
L1 BROWNEFFRATIOEP	0.189	−0.574	−0.092	−3.630**	0.291	−0.313	0.097	−20.988	0.000	−0.033	−0.114
	(0.238)	(0.355)	(0.166)	(1.786)	(0.789)	(0.631)	(0.132)	(19.673)	(0.001)	(0.133)	(0.171)
Observations	879	879	879	241	879	879	879	241	879	879	879
R2	0.973	0.945	0.990	0.951	0.938	0.515	0.980	0.668	0.963	0.976	0.987
L3 BROWNEFFRATIOEP	0.444*	−0.324	0.056	−0.444	0.014	0.229	0.156*	−24.582	−0.000	0.063	−0.004
	(0.255)	(0.289)	(0.138)	(2.989)	(0.665)	(0.592)	(0.089)	(20.226)	(0.001)	(0.133)	(0.155)
Observations	749	749	749	114	749	749	749	114	749	749	749
R2	0.978	0.958	0.990	0.987	0.977	0.564	0.991	0.918	0.964	0.978	0.988
L5 BROWNEFFRATIOEP	0.538	−0.150	0.166		0.164	0.494	−0.015		−0.002	0.176	0.156
	(0.327)	(0.284)	(0.174)		(0.539)	(0.765)	(0.079)		(0.001)	(0.165)	(0.162)
Observations	626	626	626		626	626	626		626	626	626
R2	0.982	0.972	0.991		0.990	0.649	0.995		0.968	0.981	0.990
L1 3YEARAVGBROWNEFFRATIOEP	0.833**	−0.868*	−0.121	−5.686	−0.857	−0.447	0.307	−12.975	−0.000	0.010	−0.272
	(0.413)	(0.498)	(0.236)	(3.687)	(1.113)	(0.642)	(0.196)	(31.582)	(0.003)	(0.201)	(0.242)
Observations	916	916	916	252	916	916	916	252	916	916	916
R2	0.969	0.944	0.989	0.946	0.943	0.520	0.980	0.668	0.954	0.976	0.987
Panel B.3: And never-patenting firms											
L1 BROWNEFFRATIOEP	0.425	−0.173	0.153	−6.750***	1.535	−0.365	0.031	−26.138	−0.004	0.062	0.216
	(0.362)	(0.355)	(0.216)	(1.881)	(2.302)	(0.231)	(0.217)	(19.851)	(0.003)	(0.163)	(0.205)
Observations	867	867	867	241	867	867	867	241	867	867	867
R2	0.932	0.911	0.933	0.971	0.972	0.690	0.584	0.962	0.788	0.922	0.932
L3 BROWNEFFRATIOEP	−0.074	−0.233	−0.104	2.660**	1.020	0.116	0.124	11.144	−0.001	−0.074	0.014
	(0.294)	(0.273)	(0.197)	(1.159)	(1.924)	(0.229)	(0.268)	(7.109)	(0.002)	(0.170)	(0.184)
Observations	726	726	726	114	726	726	726	114	726	726	726
R2	0.951	0.945	0.960	0.998	0.989	0.814	0.839	0.996	0.832	0.950	0.960
L5 BROWNEFFRATIOEP	−0.421	−0.520**	−0.459**		0.645	0.123	0.010		0.002	−0.258*	−0.335*
	(0.296)	(0.243)	(0.205)		(1.164)	(0.200)	(0.174)		(0.002)	(0.149)	(0.177)
Observations	593	593	593		593	593	593		593	593	593
R2	0.966	0.960	0.966		0.995	0.875	0.922		0.889	0.953	0.967
L1 3YEARAVGBROWNEFFRATIOEP	0.342	−0.692	−0.120	−1.504	3.401	−0.222	0.217	−36.969	−0.006	0.021	0.067
	(0.529)	(0.443)	(0.337)	(4.967)	(2.152)	(0.235)	(0.343)	(26.568)	(0.004)	(0.265)	(0.317)
Observations	905	905	905	254	905	905	905	254	905	905	905
R2	0.932	0.912	0.933	0.972	0.974	0.690	0.591	0.962	0.786	0.917	0.931
Controls	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Year F.E.	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Industry F.E.	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes

TABLE IA.XXVII: GREEN PATENT RATIOS IN ASIA AND CROSS-COUNTRY INDUSTRY-LEVEL OUTCOMES

The unit of observation is GICS-6 industry-year. The sample period is 2005 to 2020. The dependent variables are GICS-6 sector industry level logs of cumulative sums ofS1TOT, S2TOT, S3UPTOT, S3DOWNTOT, CAPEX, and SALES over 1, 3 or 5 years, respectively cumulative sums over sums for S1INT, S2INT, S3UPINT, S3DOWNINT and INVEST/A for 1, 3 or 5 years. In Panel A, dependent variables are calculated across all firms with their headquarter in Asia. In Panel B, dependent variables are calculated across all firms with their headquarter outside of Asia. In addition, in Panel A.1 and B.1, dependent variables are calculated across all firms within the given industry and region. In Panel A.2 and B.2, dependent variables are calculated across all ever patenting firms within the given industry and region and in Panel A.3 and B.3, dependent variables are calculated across all never patenting firms within the given industry and region. All independent variables are calculated based on firms with their headquarter in Asia. The key explanatory variables of interest is *GREENRATIOEP*. Controls include *LOGSIZE*, *LOGPPE*, *LEVERAGE*, *ROE*, *M/B*, *INVEST/A*, *BETA*, *VOLAT*, *MOM*, *RET*, *MSCI*. Independent variables are either GICS-6 industry level sums (LOGSIZE and LOGPPE), sum over sums (GREENRATIOEP, LEVERAGE, ROE, M/B, INVEST/A) or market capitalization value weighted averages (BETA, VOLAT, MOM, RET, MSCI). All Independent variables are lagged by 1, 3 or 5 years respectively. The model is estimated using pooled regression model. All regression include year and industry fixed effects. We double cluster standard errors at the GICS-6 industry and year dimension. *** 1% significance, ** 5% significance * 10% significance.

	(1) LOGS1TOT	(2) LOGS2TOT	(3) LOGS3UPTOT	(4) LOGS3DOWNTOT	(5) S1INT	(6) S2INT	(7) S3UPINT	(8) S3DOWNINT	(9) INVEST/A	(10) LOGCAPEX	(11) LOGSALES
Panel A: ASIA-firm based GREENRATIOEP On Asian firms											
Panel A.1: And all firms											
L1 GREENRATIOEP	0.302**	0.352**	−0.007	1.071*	2.199*	0.031	−0.109	−2.105	0.002	0.052	0.055
	(0.132)	(0.160)	(0.088)	(0.610)	(1.329)	(0.139)	(0.119)	(6.086)	(0.001)	(0.069)	(0.089)
Observations	835	835	835	240	835	835	835	240	835	835	835
R2	0.957	0.933	0.960	0.960	0.981	0.524	0.932	0.806	0.922	0.930	0.950
L3 GREENRATIOEP	0.183	0.251*	0.006	−0.418	−0.824	0.178	−0.193*	−1.742	0.000	0.003	0.069
	(0.129)	(0.134)	(0.078)	(0.809)	(0.687)	(0.136)	(0.110)	(2.169)	(0.001)	(0.060)	(0.073)
Observations	704	704	704	114	704	704	704	114	704	704	704
R2	0.973	0.956	0.981	0.987	0.994	0.567	0.967	0.960	0.940	0.965	0.976
L5 GREENRATIOEP	0.125	0.202	0.021		−0.407	0.183	−0.002		0.000	−0.045	0.025
	(0.124)	(0.136)	(0.077)		(0.823)	(0.163)	(0.126)		(0.001)	(0.070)	(0.076)
Observations	586	586	586		586	586	586		586	586	586
R2	0.978	0.964	0.983		0.997	0.645	0.978		0.949	0.965	0.975
L1 3YEARAVGGREENRATIOEP	0.539**	0.810***	0.098	1.320	0.257	0.331**	−0.276*	−2.279	−0.000	0.175	0.210
	(0.221)	(0.244)	(0.146)	(1.102)	(1.416)	(0.159)	(0.145)	(10.147)	(0.002)	(0.114)	(0.145)
Observations	878	878	878	255	878	878	878	255	878	878	878
R2	0.957	0.936	0.960	0.966	0.978	0.529	0.933	0.807	0.907	0.920	0.950
Panel A.2: And ever-patenting firms											
L1 GREENRATIOEP	0.529**	0.156	−0.038	1.603*	−1.329	−0.055	−0.245	0.777	0.003	0.121	0.058
	(0.266)	(0.211)	(0.128)	(0.859)	(1.671)	(0.175)	(0.203)	(5.695)	(0.002)	(0.090)	(0.098)
Observations	832	832	832	240	832	832	832	240	832	832	832
R2	0.944	0.942	0.972	0.950	0.922	0.451	0.946	0.599	0.869	0.948	0.968
L3 GREENRATIOEP	0.401*	0.314*	0.076	−1.032	−3.344**	0.254	−0.253	−3.705	0.001	0.082	0.143
	(0.226)	(0.168)	(0.111)	(1.205)	(1.596)	(0.179)	(0.202)	(4.935)	(0.001)	(0.072)	(0.093)
Observations	698	698	698	114	698	698	698	114	698	698	698
R2	0.955	0.950	0.975	0.974	0.954	0.488	0.964	0.891	0.912	0.964	0.971
L5 GREENRATIOEP	0.426**	0.333**	0.155*		−1.334	0.371	0.070		0.001	0.024	0.135
	(0.194)	(0.152)	(0.091)		(2.018)	(0.256)	(0.225)		(0.001)	(0.079)	(0.091)
Observations	578	578	578		578	578	578		578	578	578
R2	0.965	0.961	0.979		0.969	0.567	0.975		0.924	0.971	0.975
L1 3YEARAVGGREENRATIOEP	0.739*	0.666**	0.043	1.671	−3.860	0.239	−0.314	−4.530	0.003	0.212	0.182
	(0.430)	(0.289)	(0.188)	(1.128)	(2.351)	(0.195)	(0.282)	(12.135)	(0.004)	(0.134)	(0.156)
Observations	869	869	869	250	869	869	869	250	869	869	869
R2	0.945	0.945	0.975	0.957	0.917	0.453	0.946	0.598	0.881	0.951	0.970
Panel A.3: And never-patenting firms											
L1 GREENRATIOEP	0.009	0.419**	0.026	0.953*	3.261*	0.370*	−0.199	2.588	0.003*	−0.024	0.112
	(0.169)	(0.169)	(0.116)	(0.528)	(1.734)	(0.206)	(0.318)	(2.608)	(0.002)	(0.088)	(0.109)
Observations	804	804	804	240	804	804	804	240	804	804	804
R2	0.938	0.917	0.942	0.969	0.935	0.437	0.355	0.977	0.822	0.928	0.945
L3 GREENRATIOEP	−0.303	0.000	−0.200*	0.180	−1.233	0.221	−0.591	−1.906	0.001	−0.173*	−0.078
	(0.189)	(0.159)	(0.115)	(0.439)	(1.026)	(0.136)	(0.367)	(1.958)	(0.002)	(0.094)	(0.096)
Observations	665	665	665	114	665	665	665	114	665	665	665
R2	0.948	0.931	0.958	0.997	0.977	0.645	0.693	0.997	0.871	0.941	0.956
L5 GREENRATIOEP	−0.369**	−0.140	−0.221*		−0.745	0.120	−0.523		0.002	−0.171*	−0.152
	(0.162)	(0.168)	(0.122)		(1.009)	(0.126)	(0.366)		(0.002)	(0.096)	(0.107)
Observations	543	543	543		543	543	543		543	543	543
R2	0.962	0.941	0.961		0.989	0.757	0.838		0.906	0.946	0.954
L1 3YEARAVGGREENRATIOEP	−0.014	0.521**	−0.001	1.500	1.536	0.696**	−0.381	7.747*	0.004	−0.134	0.122
	(0.232)	(0.257)	(0.160)	(1.100)	(1.832)	(0.304)	(0.302)	(4.450)	(0.002)	(0.125)	(0.144)
Observations	846	846	846	255	846	846	846	255	846	846	846
R2	0.938	0.908	0.939	0.973	0.932	0.445	0.359	0.977	0.812	0.919	0.939
Controls	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Year F.E.	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Industry F.E.	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes

	(1) LOGS1TOT	(2) LOGS2TOT	(3) LOGS3UPTOT	(4) LOGS3DOWNTOT	(5) S1INT	(6) S2INT	(7) S3UPINT	(8) S3DOWNINT	(9) INVEST/A	(10) LOGCAPEX	(11) LOGSALES
Panel B: ASIA-firm based GREENRATIOEP On Non-Asian firms											
Panel B.1: And all firms											
L1 GREENRATIOEP	0.058	0.091	0.008	1.040	−1.232	−0.018	−0.071	3.476	−0.000	−0.014	0.078
	(0.137)	(0.098)	(0.054)	(0.803)	(0.882)	(0.028)	(0.065)	(2.817)	(0.000)	(0.048)	(0.051)
Observations	834	834	834	240	834	834	834	240	834	834	834
R2	0.964	0.940	0.959	0.946	0.967	0.954	0.977	0.916	0.939	0.924	0.940
L3 GREENRATIOEP	−0.003	0.125*	0.023	0.143	−2.377***	−0.015	−0.172***	1.538	−0.001	−0.011	0.111**
	(0.133)	(0.075)	(0.048)	(0.451)	(0.829)	(0.022)	(0.056)	(2.017)	(0.000)	(0.037)	(0.045)
Observations	702	702	702	114	702	702	702	114	702	702	702
R2	0.980	0.975	0.982	0.990	0.979	0.975	0.985	0.994	0.950	0.978	0.981
L5 GREENRATIOEP	0.008	0.112*	−0.001		−0.916	−0.003	−0.100*		−0.001	−0.053	0.057
	(0.151)	(0.063)	(0.050)		(0.790)	(0.020)	(0.058)		(0.000)	(0.042)	(0.046)
Observations	584	584	584		584	584	584		584	584	584
R2	0.986	0.984	0.985		0.990	0.986	0.990		0.953	0.980	0.983
L1 3YEARAVGGREENRATIOEP	0.224	0.417**	0.094	−0.114	−3.299**	0.002	−0.237**	−1.320	−0.001	0.025	0.180**
	(0.166)	(0.170)	(0.078)	(1.315)	(1.454)	(0.042)	(0.104)	(6.565)	(0.001)	(0.063)	(0.084)
Observations	876	876	876	253	876	876	876	253	876	876	876
R2	0.965	0.944	0.961	0.953	0.968	0.954	0.976	0.916	0.943	0.927	0.944
Panel B.2: And ever-patenting firms											
L1 GREENRATIOEP	0.053	0.045	−0.001	1.054	−1.656*	−0.044	−0.085	0.901	0.000	0.071	0.071
	(0.152)	(0.117)	(0.066)	(1.085)	(0.971)	(0.033)	(0.072)	(5.648)	(0.000)	(0.045)	(0.063)
Observations	833	833	833	240	833	833	833	240	833	833	833
R2	0.958	0.950	0.971	0.938	0.935	0.942	0.972	0.863	0.950	0.970	0.968
L3 GREENRATIOEP	−0.107	0.024	−0.017	0.072	−2.643**	−0.036	−0.196***	1.135	−0.000	0.006	0.082
	(0.145)	(0.109)	(0.061)	(0.323)	(1.136)	(0.029)	(0.069)	(2.276)	(0.000)	(0.041)	(0.059)
Observations	701	701	701	114	701	701	701	114	701	701	701
R2	0.974	0.966	0.977	0.990	0.950	0.966	0.980	0.994	0.963	0.976	0.978
L5 GREENRATIOEP	−0.121	0.021	−0.011		−0.556	−0.022	−0.079		−0.000	−0.028	0.038
	(0.171)	(0.091)	(0.057)		(1.258)	(0.026)	(0.069)		(0.000)	(0.045)	(0.057)
Observations	583	583	583		583	583	583		583	583	583
R2	0.982	0.980	0.984		0.965	0.981	0.986		0.967	0.980	0.982
L1 3YEARAVGGREENRATIOEP	0.069	0.286	0.079	−0.294	−3.519**	−0.031	−0.252**	−12.296	−0.000	0.102	0.163
	(0.202)	(0.201)	(0.104)	(1.710)	(1.724)	(0.048)	(0.117)	(15.825)	(0.001)	(0.074)	(0.109)
Observations	875	875	875	253	875	875	875	253	875	875	875
R2	0.961	0.955	0.973	0.948	0.937	0.942	0.971	0.866	0.953	0.973	0.971
Panel B.3: And never-patenting firms											
L1 GREENRATIOEP	0.036	0.053	−0.031	0.086	0.187	0.017	−0.043	0.318	0.002	−0.265**	0.002
	(0.188)	(0.173)	(0.116)	(0.463)	(1.634)	(0.037)	(0.102)	(1.767)	(0.002)	(0.128)	(0.102)
Observations	790	790	790	240	790	790	790	240	790	789	790
R2	0.933	0.903	0.913	0.969	0.924	0.863	0.940	0.962	0.733	0.922	0.920
L3 GREENRATIOEP	0.201	0.044	0.013	0.358	−0.941	−0.005	−0.080	0.393	0.002	−0.122	0.038
	(0.159)	(0.121)	(0.098)	(0.304)	(1.241)	(0.049)	(0.074)	(0.725)	(0.002)	(0.080)	(0.082)
Observations	648	648	648	114	648	648	648	114	648	648	648
R2	0.957	0.941	0.943	0.998	0.953	0.929	0.961	0.998	0.758	0.953	0.946
L5 GREENRATIOEP	0.244*	0.091	0.007		−1.440	−0.007	−0.100		−0.001	−0.130	0.062
	(0.143)	(0.099)	(0.103)		(0.996)	(0.044)	(0.064)		(0.001)	(0.094)	(0.094)
Observations	524	524	524		524	524	524		524	524	524
R2	0.976	0.968	0.963		0.974	0.962	0.973		0.822	0.966	0.960
L1 3YEARAVGGREENRATIOEP	0.252	0.242	−0.138	−0.297	−1.461	0.143	−0.155	1.557	0.006*	−0.386***	−0.118
	(0.296)	(0.272)	(0.177)	(1.020)	(2.097)	(0.094)	(0.127)	(3.324)	(0.003)	(0.146)	(0.159)
Observations	829	829	829	253	829	829	829	253	829	828	829
R2	0.934	0.903	0.915	0.971	0.925	0.846	0.941	0.961	0.738	0.922	0.921
Controls	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Year F.E.	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Industry F.E.	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes

TABLE IA.XXVIII: BROWN EFFICIENCY PATENT RATIOS IN ASIA AND CROSS-COUNTRY INDUSTRY-LEVEL OUTCOMES

The unit of observation is GICS-6 industry-year. The sample period is 2005 to 2020. The dependent variables are GICS-6 sector industry level logs of cumulative sums of S1TOT, S2TOT, S3UPTOT, S3DOWNTOT, CAPEX, and SALES over 1, 3 or 5 years, respectively cumulative sums over sums for S1INT, S2INT, S3UPINT, S3DOWNINT and INVEST/A for 1, 3 or 5 years. In Panel A, dependent variables are calculated across all firms with their headquarter in Asia. In Panel B, dependent variables are calculated across all firms with their headquarter outside of Asia. In addition, in Panel A.1 and B.1, dependent variables are calculated across all firms within the given industry and region. In Panel A.2 and B.2, dependent variables are calculated across all ever patenting firms within the given industry and region and in Panel A.3 and B.3, dependent variables are calculated across all never patenting firms within the given industry and region. All independent variables are calculated based on firms with their headquarter in Asia. The key explanatory variables of interest is *BROWNEFFRATIOEP*. Controls include *LOGSIZE*, *LOGPPE*, *LEVERAGE*, *ROE*, *M/B*, *INVEST/A*, *BETA*, *VOLAT*, *MOM*, *RET*, *MSCI*. Independent variables are either GICS-6 industry level sums (LOGSIZE and LOGPPE), sum over sums (BROWNEFFRATIOEP, LEVERAGE, ROE, M/B, INVEST/A) or market capitalization value weighted averages (BETA, VOLAT, MOM, RET, MSCI). All Independent variables are lagged by 1, 3 or 5 years respectively. The model is estimated using pooled regression model. All regression include year and industry fixed effects. We double cluster standard errors at the GICS-6 industry and year dimension. *** 1% significance, ** 5% significance * 10% significance.

	(1) LOGS1TOT	(2) LOGS2TOT	(3) LOGS3UPTOT	(4) LOGS3DOWNTOT	(5) S1INT	(6) S2INT	(7) S3UPINT	(8) S3DOWNINT	(9) INVEST/A	(10) LOGCAPEX	(11) LOGSALES
Panel A: ASIA-firm based BROWNEFFRATIOEP On Asian firms											
Panel A.1: And all firms											
L1 BROWNEFFRATIOEP	−0.013	−0.545**	−0.095	1.048	5.499**	−0.296	0.580**	25.500	0.002	−0.106	−0.162
	(0.184)	(0.275)	(0.164)	(1.374)	(2.748)	(0.380)	(0.294)	(25.426)	(0.002)	(0.131)	(0.158)
Observations	835	835	835	240	835	835	835	240	835	835	835
R2	0.957	0.933	0.960	0.959	0.981	0.525	0.933	0.813	0.922	0.930	0.950
L3 BROWNEFFRATIOEP	0.070	−0.097	0.001	2.021	2.767	−0.585	0.306	23.884	0.002	−0.009	−0.012
	(0.188)	(0.203)	(0.111)	(2.231)	(2.035)	(0.439)	(0.323)	(29.066)	(0.002)	(0.090)	(0.108)
Observations	704	704	704	114	704	704	704	114	704	704	704
R2	0.973	0.956	0.981	0.987	0.994	0.568	0.967	0.962	0.940	0.965	0.976
L5 BROWNEFFRATIOEP	0.371*	−0.093	0.038		1.756	−0.638	0.082		0.001	0.065	0.025
	(0.190)	(0.208)	(0.096)		(1.647)	(0.418)	(0.317)		(0.002)	(0.088)	(0.120)
Observations	586	586	586		586	586	586		586	586	586
R2	0.978	0.964	0.983		0.997	0.648	0.978		0.949	0.965	0.975
L1 3YEARAVGBROWNEFFRATIOEP	0.212	−0.387	−0.052	4.553**	8.146*	−0.936	0.626*	52.914	0.000	−0.217	−0.085
	(0.238)	(0.306)	(0.191)	(2.237)	(4.257)	(0.674)	(0.342)	(42.805)	(0.002)	(0.201)	(0.194)
Observations	878	878	878	255	878	878	878	255	878	878	878
R2	0.957	0.935	0.960	0.967	0.978	0.531	0.933	0.818	0.907	0.920	0.950
Panel A.2: And ever-patenting firms											
L1 BROWNEFFRATIOEP	0.189	−0.753**	−0.070	−0.228	11.615***	−0.426	1.044**	37.607	0.006	−0.199	−0.241
	(0.420)	(0.353)	(0.214)	(1.972)	(4.230)	(0.494)	(0.454)	(39.020)	(0.004)	(0.167)	(0.174)
Observations	832	832	832	240	832	832	832	240	832	832	832
R2	0.944	0.943	0.972	0.949	0.929	0.452	0.947	0.609	0.869	0.948	0.968
L3 BROWNEFFRATIOEP	0.254	−0.451	−0.051	1.591	8.650*	−0.897	0.687	42.693	0.005	−0.092	−0.176
	(0.372)	(0.282)	(0.172)	(2.791)	(4.752)	(0.610)	(0.586)	(57.516)	(0.004)	(0.141)	(0.159)
Observations	698	698	698	114	698	698	698	114	698	698	698
R2	0.954	0.950	0.975	0.973	0.957	0.491	0.964	0.898	0.912	0.964	0.971
L5 BROWNEFFRATIOEP	0.548	−0.123	0.073		4.752	−0.810	0.409		0.006	0.055	−0.055
	(0.358)	(0.281)	(0.141)		(5.114)	(0.573)	(0.596)		(0.004)	(0.149)	(0.174)
Observations	578	578	578		578	578	578		578	578	578
R2	0.965	0.961	0.979		0.970	0.569	0.975		0.925	0.971	0.975
L1 3YEARAVGBROWNEFFRATIOEP	0.097	−1.069***	−0.044	3.407	18.429***	−1.235	1.306**	96.704	0.001	−0.354*	−0.235
	(0.487)	(0.381)	(0.231)	(2.690)	(5.820)	(0.876)	(0.542)	(84.731)	(0.004)	(0.191)	(0.171)
Observations	869	869	869	250	869	869	869	250	869	869	869
R2	0.945	0.945	0.975	0.957	0.926	0.456	0.948	0.626	0.881	0.951	0.970
Panel A.3: And never-patenting firms											
L1 BROWNEFFRATIOEP	0.089	−0.329	0.151	0.608	6.483*	−0.232	1.069**	0.104	0.003	0.006	−0.019
	(0.190)	(0.283)	(0.167)	(0.987)	(3.442)	(0.450)	(0.515)	(5.464)	(0.002)	(0.142)	(0.155)
Observations	804	804	804	240	804	804	804	240	804	804	804
R2	0.938	0.917	0.942	0.968	0.935	0.435	0.356	0.977	0.822	0.928	0.945
L3 BROWNEFFRATIOEP	0.257	0.147	0.227	0.492	3.807*	−0.086	0.739	2.691	0.001	0.058	0.119
	(0.226)	(0.231)	(0.187)	(0.770)	(2.208)	(0.251)	(0.616)	(5.176)	(0.002)	(0.119)	(0.147)
Observations	665	665	665	114	665	665	665	114	665	665	665
R2	0.948	0.931	0.958	0.997	0.977	0.643	0.692	0.997	0.871	0.941	0.956
L5 BROWNEFFRATIOEP	0.215	−0.105	0.129		1.956	−0.482*	0.435		0.002	0.087	0.050
	(0.226)	(0.218)	(0.191)		(1.781)	(0.254)	(0.594)		(0.002)	(0.108)	(0.144)
Observations	543	543	543		543	543	543		543	543	543
R2	0.962	0.941	0.961		0.989	0.759	0.837		0.906	0.945	0.954
L1 3YEARAVGBROWNEFFRATIOEP	0.225	0.085	0.413*	3.375*	8.178	−0.458	0.491	9.997	0.003	−0.083	0.281
	(0.262)	(0.347)	(0.223)	(1.797)	(5.045)	(0.465)	(0.822)	(8.253)	(0.003)	(0.213)	(0.211)
Observations	846	846	846	255	846	846	846	255	846	846	846
R2	0.939	0.908	0.939	0.973	0.933	0.442	0.359	0.977	0.812	0.919	0.939
Controls	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Year F.E.	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Industry F.E.	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes

	(1) LOGS1TOT	(2) LOGS2TOT	(3) LOGS3UPTOT	(4) LOGS3DOWNTOT	(5) S1INT	(6) S2INT	(7) S3UPINT	(8) S3DOWNINT	(9) INVEST/A	(10) LOGCAPEX	(11) LOGSALES
Panel B: ASIA-firm based BROWNEFFRATIOEP On Non-Asian firms											
Panel B.1: And all firms											
L1 BROWNEFFRATIOEP	0.126	−0.159	−0.006	−0.760	4.276	−0.158*	0.185	−8.662*	0.001	0.001	−0.144
	(0.104)	(0.187)	(0.077)	(1.341)	(2.658)	(0.093)	(0.145)	(5.228)	(0.001)	(0.081)	(0.094)
Observations	834	834	834	240	834	834	834	240	834	834	834
R2	0.964	0.940	0.959	0.945	0.968	0.954	0.977	0.916	0.939	0.924	0.940
L3 BROWNEFFRATIOEP	−0.079	−0.146	−0.085	1.430	4.972**	−0.107	0.208**	6.432	0.001	−0.061	−0.172**
	(0.103)	(0.121)	(0.070)	(1.913)	(2.170)	(0.075)	(0.098)	(9.528)	(0.001)	(0.074)	(0.081)
Observations	702	702	702	114	702	702	702	114	702	702	702
R2	0.980	0.975	0.982	0.990	0.980	0.975	0.985	0.994	0.950	0.978	0.981
L5 BROWNEFFRATIOEP	−0.065	−0.098	−0.009		1.661	−0.088	0.144		0.000	−0.028	−0.050
	(0.083)	(0.081)	(0.081)		(2.017)	(0.054)	(0.094)		(0.001)	(0.079)	(0.098)
Observations	584	584	584		584	584	584		584	584	584
R2	0.986	0.984	0.985		0.990	0.986	0.990		0.953	0.980	0.983
L1 3YEARAVGBROWNEFFRATIOEP	0.250	−0.188	0.194	3.476**	8.198**	−0.318**	0.410*	9.146	0.001	−0.064	−0.099
	(0.188)	(0.238)	(0.146)	(1.710)	(3.475)	(0.148)	(0.211)	(7.366)	(0.001)	(0.124)	(0.165)
Observations	876	876	876	253	876	876	876	253	876	876	876
R2	0.965	0.944	0.961	0.954	0.971	0.955	0.976	0.917	0.942	0.927	0.944
Panel B.2: And ever-patenting firms											
L1 BROWNEFFRATIOEP	0.130	−0.288	−0.093	−0.882	5.801**	−0.152	0.230	−5.320	0.000	−0.015	−0.238*
	(0.112)	(0.289)	(0.101)	(1.374)	(2.665)	(0.099)	(0.162)	(6.453)	(0.001)	(0.075)	(0.122)
Observations	833	833	833	240	833	833	833	240	833	833	833
R2	0.958	0.950	0.971	0.937	0.939	0.942	0.972	0.863	0.950	0.970	0.968
L3 BROWNEFFRATIOEP	0.010	−0.178	−0.108	−0.878	6.216**	−0.098	0.298**	−2.894	0.000	−0.023	−0.227*
	(0.101)	(0.162)	(0.092)	(1.372)	(3.003)	(0.082)	(0.128)	(10.363)	(0.000)	(0.072)	(0.116)
Observations	701	701	701	114	701	701	701	114	701	701	701
R2	0.974	0.966	0.977	0.990	0.953	0.966	0.980	0.994	0.963	0.976	0.978
L5 BROWNEFFRATIOEP	0.008	−0.063	0.033		1.374	−0.093	0.164		−0.000	0.033	−0.014
	(0.087)	(0.117)	(0.090)		(3.582)	(0.061)	(0.131)		(0.000)	(0.061)	(0.125)
Observations	583	583	583		583	583	583		583	583	583
R2	0.982	0.980	0.984		0.965	0.981	0.986		0.967	0.980	0.982
L1 3YEARAVGBROWNEFFRATIOEP	0.321*	−0.063	0.140	4.766**	8.468**	−0.298*	0.414*	24.659	0.001	0.198*	−0.109
	(0.184)	(0.286)	(0.194)	(2.345)	(4.007)	(0.153)	(0.230)	(17.383)	(0.001)	(0.119)	(0.214)
Observations	875	875	875	253	875	875	875	253	875	875	875
R2	0.961	0.954	0.973	0.950	0.941	0.944	0.971	0.867	0.953	0.973	0.971
Panel B.3: And never-patenting firms											
L1 BROWNEFFRATIOEP	0.191	0.108	−0.046	1.398	1.913	−0.049	−0.361*	2.880	0.000	0.104	0.066
	(0.178)	(0.276)	(0.137)	(0.871)	(6.497)	(0.069)	(0.200)	(4.012)	(0.002)	(0.176)	(0.122)
Observations	790	790	790	240	790	790	790	240	790	789	790
R2	0.933	0.903	0.913	0.970	0.924	0.863	0.941	0.962	0.733	0.921	0.920
L3 BROWNEFFRATIOEP	−0.211	−0.011	−0.275**	0.036	1.077	−0.040	−0.378**	−0.037	0.002	−0.085	−0.090
	(0.149)	(0.199)	(0.125)	(1.207)	(4.322)	(0.048)	(0.180)	(3.477)	(0.002)	(0.126)	(0.094)
Observations	648	648	648	114	648	648	648	114	648	648	648
R2	0.957	0.941	0.943	0.998	0.953	0.929	0.961	0.998	0.758	0.953	0.946
L5 BROWNEFFRATIOEP	−0.092	0.020	−0.154		2.047	−0.030	−0.155		0.002	−0.047	−0.063
	(0.115)	(0.133)	(0.115)		(2.741)	(0.034)	(0.140)		(0.002)	(0.113)	(0.091)
Observations	524	524	524		524	524	524		524	524	524
R2	0.976	0.968	0.963		0.974	0.962	0.973		0.822	0.966	0.960
L1 3YEARAVGBROWNEFFRATIOEP	0.251	−0.342	−0.181	1.493	7.455	−0.166	−0.536*	−0.612	−0.000	−0.120	0.079
	(0.298)	(0.372)	(0.235)	(1.284)	(6.683)	(0.110)	(0.294)	(4.285)	(0.004)	(0.242)	(0.217)
Observations	829	829	829	253	829	829	829	253	829	828	829
R2	0.934	0.903	0.915	0.971	0.927	0.845	0.941	0.961	0.738	0.922	0.921
Controls	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Year F.E.	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Industry F.E.	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes

TABLE IA.XXIX: EX-POST CHARACTERISTICS OF INDIRECT EMISSION DECREASING VS INCREASING FIRMS

The unit of observation is firm-year and the sample period is 2005 to 2020. To split firms in emission reduction samples (column 1 to 4) and emission increase samples (column 5 to 8) we calculate changes in emissions over three years. Panel A covers total scope 2 emissions, Panel B upstream scope 3 emissions and Panel C downstream scope 3 emissions. We calculate mean, standard deviation, median and the count for each sample as well as the difference and p-value between the two samples for a variety of variables at the three year lag. Panel A.1, B.1 and C.1 cover the full Trucost sample. Panel A.2, B.2 and C.2 zoom in on the Trucost sample with at least one patent at the European Patent Office and the greatest emission change. Within the emission decrease sample, we focus on the 50% with the greatest emission decrease. Similarly within the emission increase sample, we focus on the 50% with the greatest emission increase. DUMMYANYEP (DUMMYGREENEP, DUMMYBROWNEFFEP, and DUMMYOECDEP) are dummies equal to one if a firm has at least one (one green, one brown efficiency and one OECD env-tech) patent and zero otherwise. SALES3YRCHG is the change in sales across the three year period in decimals. All other variables are defined in Table 1, Table 2 and Table 4.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Emission decrease sample				Emission increase sample				Difference	
	Mean	Std. Dev.	Median	Count	Mean	Std. Dev.	Median	Count	Difference	p-value
Panel A: 3-year changes in scope 2 emissions										
Panel A.1: Patenting and non-patenting firms										
DUMMYANYEP	0.296	0.457	0	29199	0.292	0.455	0	42027	0.004	0.228
DUMMYGREENEP	0.138	0.345	0	29199	0.126	0.332	0	42027	0.012	0.000
DUMMYBROWNEFFEP	0.065	0.247	0	29199	0.057	0.232	0	42027	0.008	0.000
DUMMYOECDEP	0.144	0.351	0	29199	0.129	0.335	0	42027	0.015	0.000
AGE	47.280	38.773	34.000	27271	41.438	35.990	28.000	39054	5.842	0.000
LOGSIZE	7.690	1.701	7.723	29199	7.714	1.548	7.762	42027	−0.023	0.062
LOGPPE	5.962	2.376	6.162	29199	5.871	2.278	6.051	42027	0.092	0.000
MB	2.402	2.706	1.606	29199	2.774	2.927	1.859	42027	−0.373	0.000
LEVERAGE	24.072	18.132	22.416	29199	23.187	18.131	21.237	42027	0.885	0.000
ROE	10.519	27.006	10.359	29199	11.960	23.463	11.477	42027	−1.441	0.000
SALES3YRCHG	−0.117	0.537	−0.038	29138	0.314	0.501	0.241	41957	−0.431	0.000
Panel A.2: Firm-years with at least one EP patent & greatest emission decreases, resp. increases										
GREENRATIOEP	12.646	24.618	0	4325	12.119	24.608	0	6136	0.527	0.281
BROWNEFFRATIOEP	4.305	14.269	0	4325	3.406	13.053	0	6136	0.898	0.001
OECDRATIOEP	13.876	25.314	0	4325	12.233	24.368	0	6136	1.643	0.001
GREENCITMAXEP	44.640	187.160	0	4325	65.211	573.680	0	6136	−20.571	0.009
BROWNEFFCITMAXEP	13.322	223.038	0	4325	9.421	47.241	0	6136	3.901	0.257
GREENCOUNTBBEP	0.230	1.042	0	4325	0.212	1.018	0	6136	0.018	0.373
BROWNEFFCOUNTBBEP	0.093	0.794	0	4325	0.063	0.431	0	6136	0.030	0.024
AGE	56.880	42.765	45.000	4281	47.383	39.415	33.000	6094	9.496	0.000
LOGSIZE	8.353	1.688	8.361	4325	8.291	1.575	8.271	6136	0.062	0.058
LOGPPE	6.747	2.209	6.847	4325	6.446	2.143	6.508	6136	0.300	0.000
MB	2.551	2.717	1.778	4325	3.174	3.171	2.211	6136	−0.623	0.000
LEVERAGE	23.615	15.744	22.637	4325	22.291	16.697	21.329	6136	1.325	0.000
ROE	8.585	29.419	10.271	4325	9.604	28.328	11.476	6136	−1.019	0.076
SALES3YRCHG	−0.163	0.579	−0.075	4321	0.401	0.587	0.324	6132	−0.564	0.000
Panel B: 3-year changes in upstream scope 3 emissions										
Panel B.1: Patenting and non-patenting firms										
DUMMYANYEP	0.298	0.458	0	28408	0.290	0.454	0	42885	0.008	0.026
DUMMYGREENEP	0.140	0.347	0	28408	0.125	0.330	0	42885	0.015	0.000
DUMMYBROWNEFFEP	0.069	0.253	0	28408	0.055	0.228	0	42885	0.013	0.000
DUMMYOECDEP	0.146	0.353	0	28408	0.128	0.334	0	42885	0.018	0.000
AGE	46.931	38.457	34.000	26627	41.749	36.293	29.000	39765	5.182	0.000
LOGSIZE	7.631	1.672	7.690	28408	7.754	1.569	7.785	42885	−0.124	0.000
LOGPPE	6.062	2.356	6.255	28408	5.808	2.290	6.000	42885	0.254	0.000
MB	2.248	2.547	1.528	28408	2.869	3.000	1.931	42885	−0.621	0.000
LEVERAGE	24.414	18.091	22.840	28408	22.983	18.146	20.968	42885	1.430	0.000
ROE	9.732	26.444	9.981	28408	12.452	23.891	11.721	42885	−2.720	0.000
SALES3YRCHG	−0.198	0.507	−0.102	28347	0.360	0.473	0.266	42815	−0.558	0.000
Panel B.2: Firm-years with at least one EP patent & greatest emission decreases, resp. increases										
GREENRATIOEP	13.261	25.164	0	4237	11.883	24.392	0	6229	1.377	0.005
BROWNEFFRATIOEP	4.592	14.783	0	4237	3.370	13.040	0	6229	1.222	0.000
OECDRATIOEP	14.522	26.082	0	4237	11.960	24.008	0	6229	2.561	0.000
GREENCITMAXEP	47.269	187.291	0	4237	54.588	327.325	0	6229	−7.320	0.147
BROWNEFFCITMAXEP	19.165	317.144	0	4237	8.678	42.631	0	6229	10.487	0.032
GREENCOUNTBBEP	0.243	1.098	0	4237	0.216	0.925	0	6229	0.026	0.198
BROWNEFFCOUNTBBEP	0.123	0.928	0	4237	0.067	0.496	0	6229	0.056	0.000
AGE	57.208	43.746	46.000	4215	45.397	39.138	31.000	6168	11.812	0.000
LOGSIZE	8.234	1.696	8.227	4237	8.294	1.611	8.285	6229	−0.060	0.070
LOGPPE	6.889	2.256	7.039	4237	6.222	2.139	6.266	6229	0.667	0.000
MB	2.215	2.428	1.601	4237	3.526	3.384	2.512	6229	−1.310	0.000
LEVERAGE	24.170	16.037	23.076	4237	21.742	16.918	20.308	6229	2.428	0.000
ROE	7.362	29.766	9.306	4237	10.395	29.696	11.984	6229	−3.033	0.000
SALES3YRCHG	−0.315	0.528	−0.217	4232	0.497	0.533	0.392	6226	−0.812	0.000

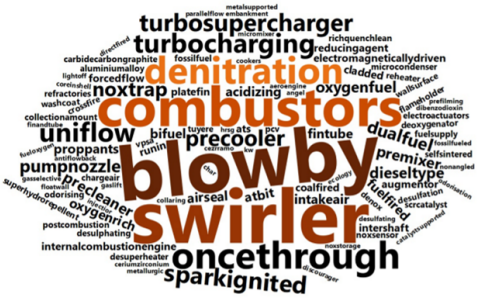
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Emission decrease sample				Emission increase sample				Difference	
	Mean	Std. Dev.	Median	Count	Mean	Std. Dev.	Median	Count	Difference	p-value
Panel C: 3-year changes in downstream scope 3 emissions										
Panel C.1: Patenting and non-patenting firms										
DUMMYANYEP	0.244	0.430	0	6412	0.210	0.407	0	4628	0.034	0.000
DUMMYGREENEP	0.094	0.292	0	6412	0.082	0.275	0	4628	0.012	0.026
DUMMYBROWNEFFEP	0.041	0.198	0	6412	0.033	0.179	0	4628	0.008	0.036
DUMMYOECDEP	0.094	0.292	0	6412	0.079	0.270	0	4628	0.015	0.005
AGE	42.999	33.724	32.000	5865	37.566	32.005	26.000	4219	5.433	0.000
LOGSIZE	7.128	1.550	7.053	6412	7.218	1.631	7.115	4628	−0.090	0.003
LOGPPE	5.214	2.232	5.306	6412	4.933	2.374	5.030	4628	0.282	0.000
MB	2.609	2.827	1.735	6412	2.971	3.225	1.879	4628	−0.362	0.000
LEVERAGE	22.372	18.573	19.725	6412	22.749	18.804	20.577	4628	−0.377	0.296
ROE	9.932	22.883	9.682	6412	9.211	25.840	9.994	4628	0.721	0.130
SALES3YRCHG	−0.012	0.526	0.061	6408	0.268	0.603	0.184	4624	−0.280	0.000
Panel C.2: Firm-years with at least one EP patent & greatest emission decreases, resp. increases										
GREENRATIOEP	11.955	23.128	0	784	13.742	26.184	0	486	−1.787	0.217
BROWNEFFRATIOEP	2.861	11.181	0	784	2.346	9.927	0	486	0.516	0.392
OECDRATIOEP	12.019	23.823	0	784	9.269	21.192	0	486	2.750	0.032
GREENCITMAXEP	16.356	103.591	0	784	72.142	1115.594	0	486	−55.786	0.272
BROWNEFFCITMAXEP	3.171	14.083	0	784	2.891	13.033	0	486	0.280	0.718
GREENCOUNTBBEP	0.255	1.489	0	784	0.226	0.853	0	486	0.029	0.662
BROWNEFFCOUNTBBEP	0.101	1.160	0	784	0.109	1.062	0	486	−0.008	0.896
AGE	54.055	39.770	45.000	781	46.300	39.119	31.000	477	7.755	0.001
LOGSIZE	7.760	1.680	7.706	784	8.113	1.850	8.094	486	−0.354	0.001
LOGPPE	5.916	2.111	5.913	784	5.629	2.519	5.744	486	0.287	0.036
MB	2.916	2.942	2.071	784	3.981	3.858	2.817	486	−1.065	0.000
LEVERAGE	21.707	16.440	21.170	784	21.921	18.852	19.407	486	−0.214	0.837
ROE	8.980	26.828	9.502	784	5.596	38.696	10.700	486	3.384	0.091
SALES3YRCHG	−0.038	0.552	0.045	784	0.440	0.830	0.203	486	−0.478	0.000

FIGURE IA.I: PATENTS FROM SPECIFIC PATENT CLASSIFICATIONS VS ALL OTHER PATENTS

The sample is all patents granted by the European Patent Office from 2005 to 2020 that belong to the Trucost sample. The wordclouds display the top 100 words (unigrams) based on the TF-IDF comparing patent titles of patents in the given classification to all other patents. We compare "green" patent titles to all other patent titles in Panel A, "brown efficiency" to all others in Panel B, "general efficiency" to all others in Panel C, OECD-env tech to all others in Panel D, IPC green inventory to all others in Panel E, Corporate Knights self classified to all others in Panel F, and Fossil Fuel technologies to all others in Panel G.

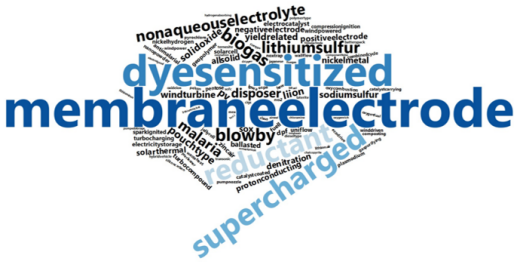
(A) GREEN AGAINST ALL OTHERS

(B) BROWN EFFICIENCY AGAINST ALL OTHERS

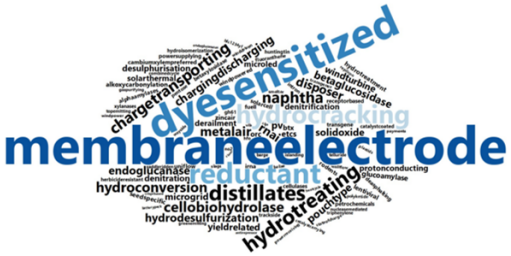


(C) GENERAL EFFICIENCY AGAINST ALL OTHERS

(D) OECD AGAINST ALL OTHERS



(E) IPC AGAINST ALL OTHERS



(F) CK AGAINST ALL OTHERS

(G) FF AGAINST ALL OTHERS

FIGURE IA.II: PATENT RATIOS FOR HALLIBURTON COMPANY

We report GREENRATIOEP, BROWNEFFRATIOEP and OECDRATIOEP for Halliburton Company per year between 2005 and 2020. The variables are defined in Table 2 and Table IA.V.

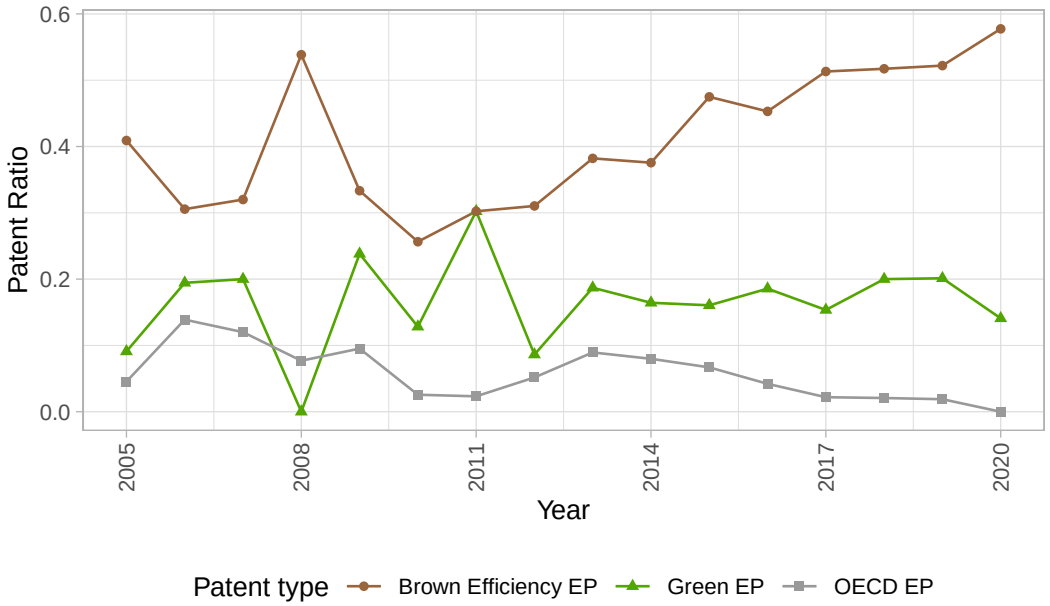
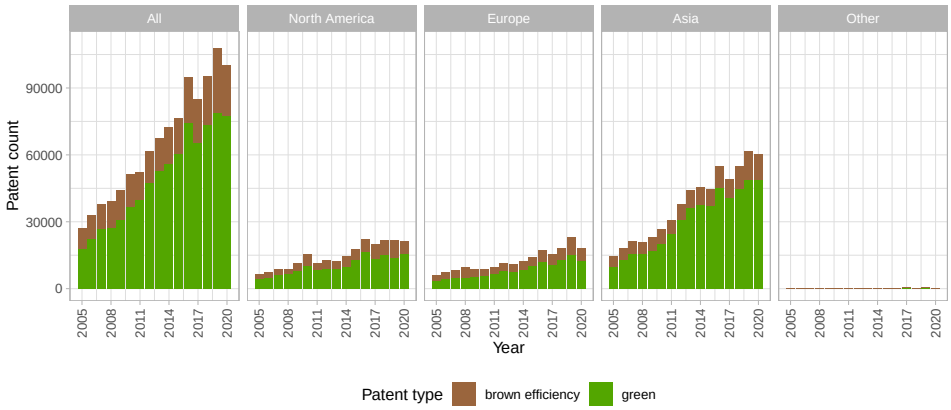


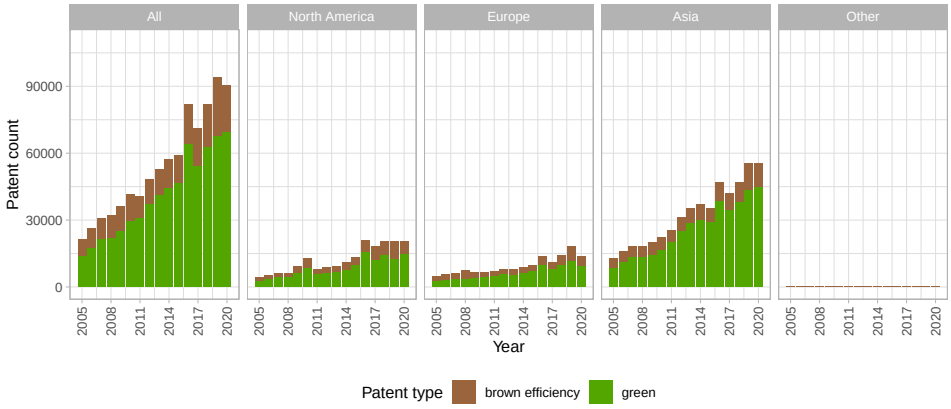
FIGURE IA.III: GREEN AND BROWN EFFICIENCY WORLDWIDE PATENT COUNTS ACROSS REGIONS

The sample period is 2005 to 2020. We report the total number of granted or purchased green and brown efficiency patent families from world wide patent offices. We report the total across all regions and by region, namely North America, Europe, Asia, and other (rest of the world), per year. In Panel A the sample covers the full sample, i.e all public and private firms. In Panel B the sample covers only public firms with emission data from Trucost and in Panel C we restrict the sample inclusion further to those firms that Trucost covers in its database before 2016.

(A) FULL (PUBLIC/PRIVATE) SAMPLE



(B) TRUCOST SAMPLE



(C) TRUCOST (PRE 2016) LEGACY SAMPLE

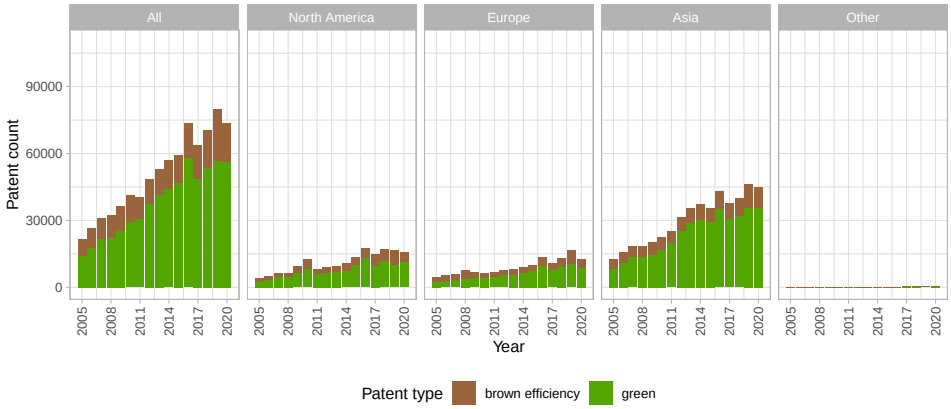
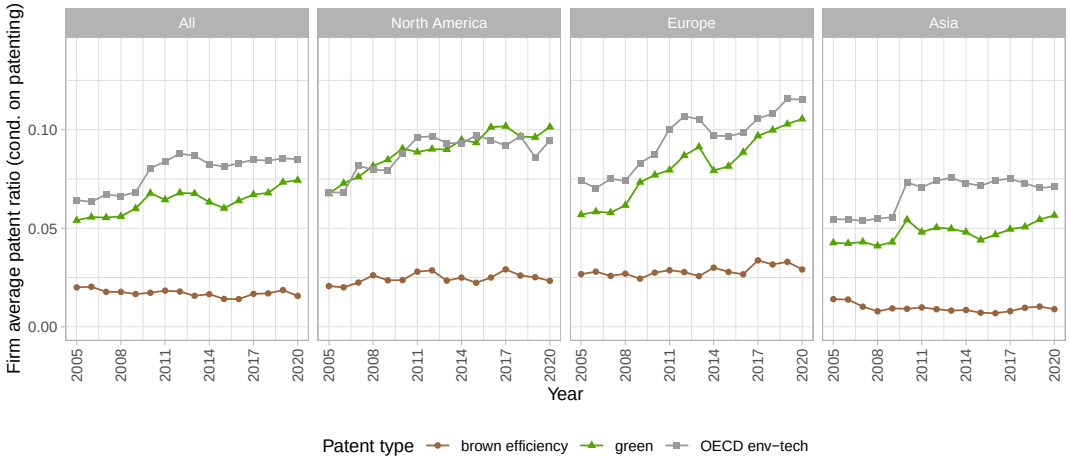


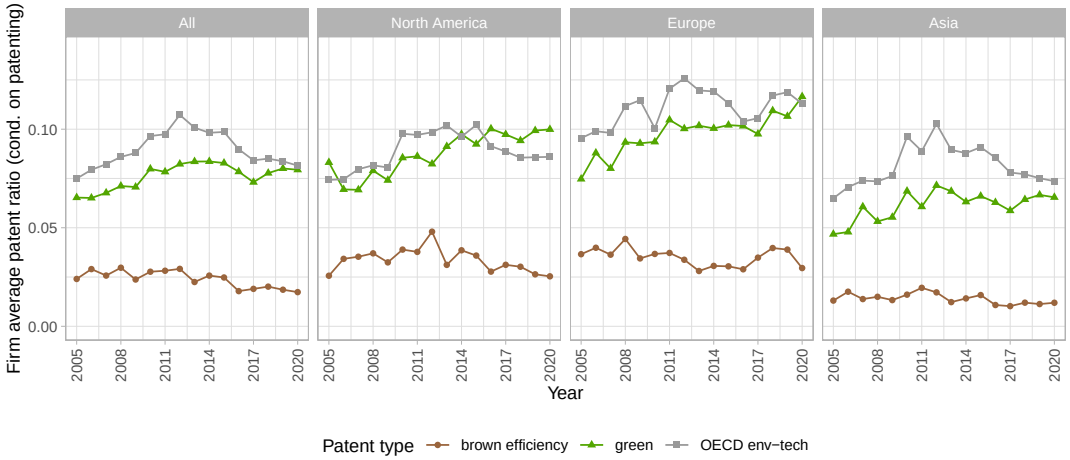
FIGURE IA.IV: GREEN AND BROWN EFFICIENCY WORLDWIDE PATENT RATIOS ACROSS REGIONS

The sample period is 2005 to 2020. We report the average GREENRATIOWW, BROWNEFFRATIOWW and OECDRATIOWW across all regions and for the regions North America, Europe and Asia per year. The patent ratios are defined in Table IA.IX and capture worldwide patent office activity. In Panel A the sample covers the full sample, i.e all public and private firms. In Panel B the sample covers only public firms with emission data from Trucost and in Panel C we restrict the sample inclusion further to those firms that Trucost covers in its database before 2016.

(A) FULL (PUBLIC/PRIVATE) SAMPLE



(B) TRUCOST SAMPLE



(C) TRUCOST (PRE 2016) LEGACY SAMPLE

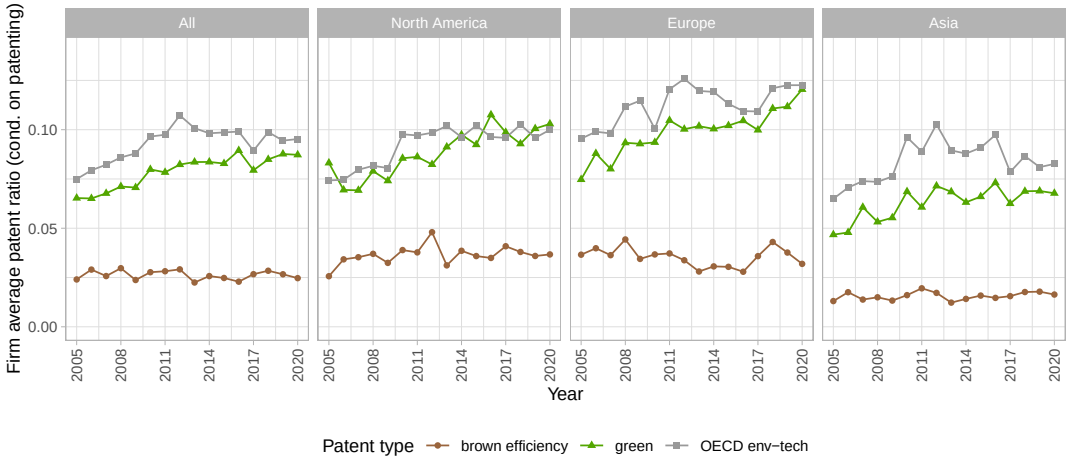
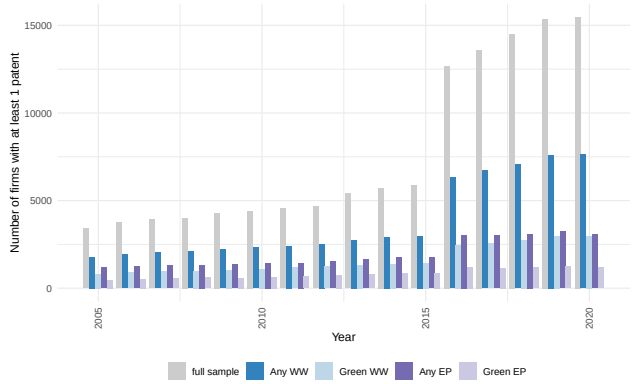


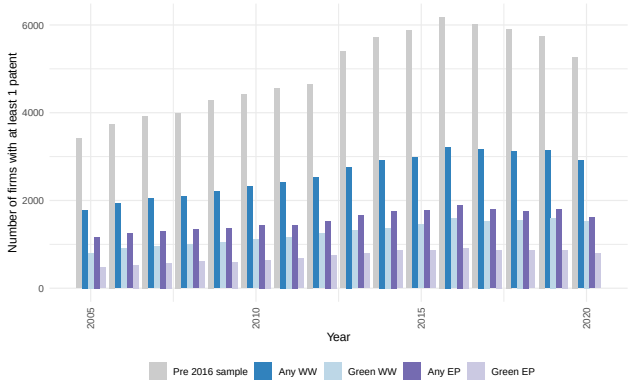
FIGURE IA.V: FIRM-YEAR OBSERVATIONS WITH AT LEAST ONE GRANTED/PURCHASED PATENT PER YEAR

Each graph presents the annual number of firms from the whole Trucost sample (full sample - grey bars), that have a patent granted or purchased at any patent office world wide (Any WW - dark blue bars), that have a green patent granted or purchased at any patent office world wide (Green WW - light blue bars), that have a patent granted or purchased at the European Patent Office wide (Any EP - dark purple bars), that have a green patent granted or purchased at the European Patent Office (Green EP - light purple bars). Panel A covers the full sample. Panel B is restricted to firms with emission data from Trucost prior to 2016. Panel C is restricted to firms with emission data from Trucost in 2006.

(A) FULL SAMPLE



(B) PRE 2016 LEGACY SAMPLE



(C) PRE 2006 LEGACY SAMPLE

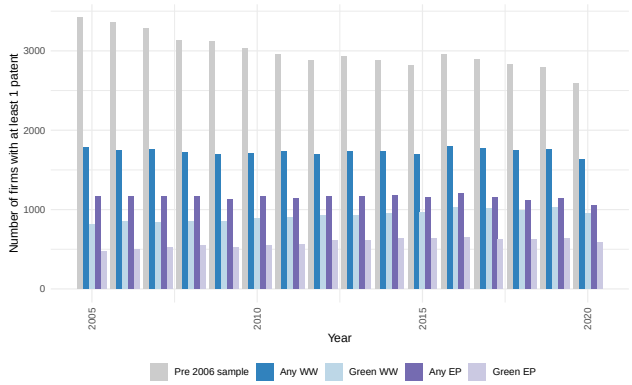


FIGURE IA.VI: FIRM COUNT BY FIRST YEAR WITH A GRANTED/PURCHASED PATENT

Each graph covers the Trucost sample and documents a firm's first year with a granted or purchased patent. The bars represent the number of firms with their first patent in the given year. Dark blue bars cover any patent from any patent office world wide (Any WW), light blue bars cover green patents from any patent office world wide (Green WW), dark purple bars cover any patent from the European Patent Office (Any EP) and light purple bars cover green patents from the European Patent Office (Green EP). Panel A covers the full sample. Panel B is restricted to firms with emission data from Trucost prior to 2016. Panel C is restricted to firms with emission data from Trucost in 2006.

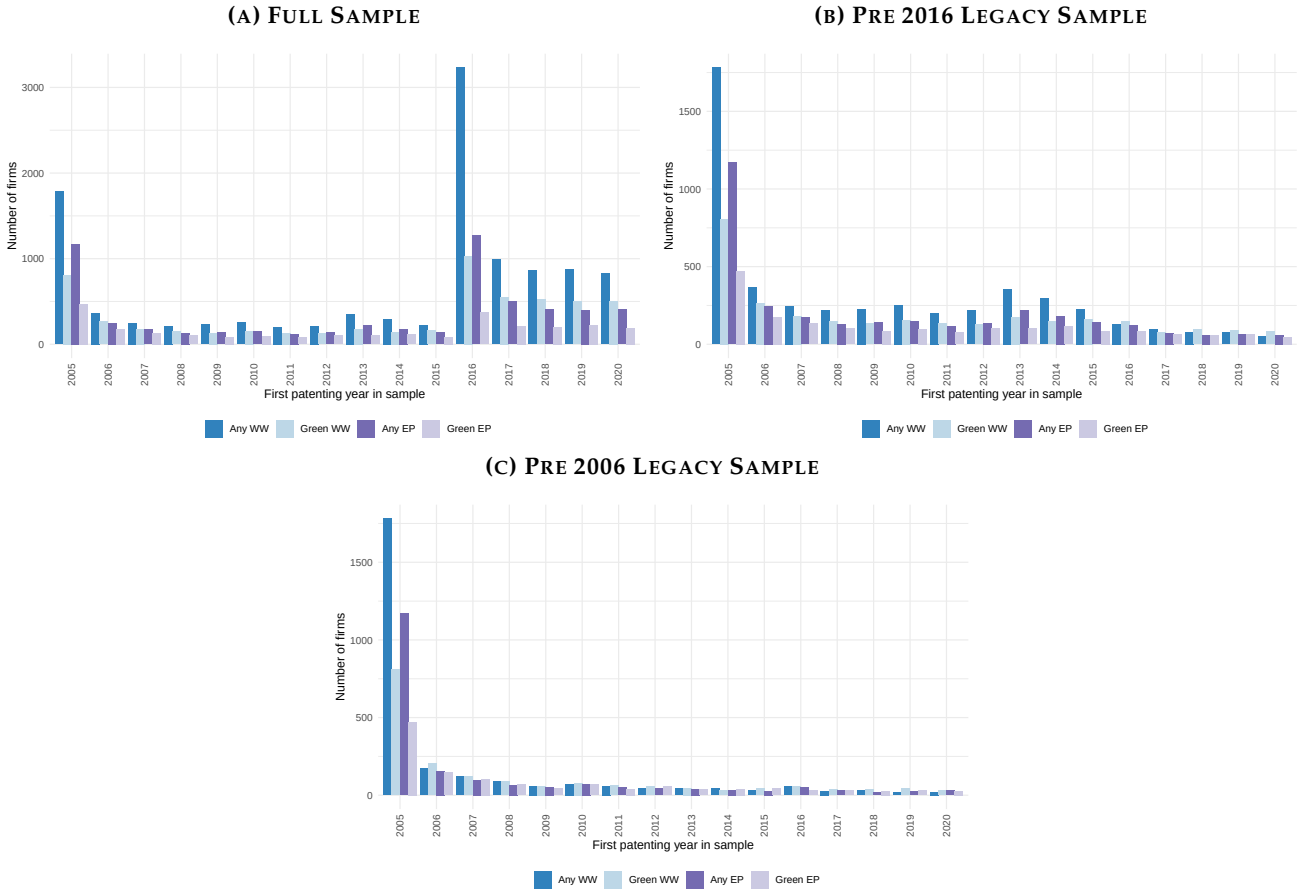


FIGURE IA.VII: HISTOGRAMS OF PATENT COUNTS FOR FIRM-YEAR OBSERVATIONS

The histograms plot the proportion of firm-year observations in bins based on the number of granted/purchased patents for the Trucost sample between 2005 and 2020. In Panel A, the patent count is based on patents granted or purchased at any patent office worldwide accounting for patent families. The binwidth is 5 patents. The last bin is an overflow bin with 499 patents and more. In Panel B, the patent count is based on patents granted or purchased by the European Patent Office and the binwidth is 2 patents. The last bin is an overflow bin with 149 patents and more.