FONDAZIONE ARISTIDE MERLONI

ECONOMIA MARCHE **Journal of Applied Economics**

Vol. XLIII, No.3, Dicembre 2024

ESG ratings and green patents: evidence from the top world's R&D investors

N. Balducci, *Università Politecnica delle Marche, Italy*
A. Sterlacchini, *Università Politecnica delle Marche, Italy*

Abstract

By considering over 1,000 large corporations that are among the top R&D investors worldwide, this paper examines the relationship between ESG ratings and green patents over the years 2016-2018. We find significant associations between corporate ESG scores and green patents, indicating that the companies investing heavily in R&D are increasingly adopting and documenting ESG practices by targeting environmentally sustainable innovations.

JEL Classification: F23, O30, Q55

Keywords: *ESG ratings; Green patents; R&D top investors; Large corporations*

Affiliations and attributions

Nicolò Balducci, Department of Economic and Social Sciences, Marche Polytechnic University, Ancona, Italy. E-mail: n.balducci@pm.univpm.it.

Alessandro Sterlacchini, Department of Economic and Social Sciences, Marche Polytechnic University, Ancona, Italy. E-mail: a.sterlacchini@staff.univpm.it

Acknowledgements

We wish to thank Camilla Mazzoli and Claudia Pigini for their help and suggestions.

1. Introduction

Especially in response to the mounting awareness of the risks due to climate change and environmental degradation, publicly listed companies have come under increasing pressure to adopt Environmental, Social and Governance (ESG) practices (Cappucci, 2018; Serafeim, 2020; Hughes et al., 2021; Truant et al., 2023). Hence, many corporations have agreed to be monitored and evaluated by rating agencies. Although common standards are not yet established, ESG ratings have witnessed an increasing diffusion with a view of providing investors with a third-party evaluation of the corporate commitment to sustainable practices.

While many empirical studies have examined the impact of ESG ratings on corporate financial performance (see, among others, Flammer, 2015; Grewal et al., 2019; Bardos et al., 2020; Chouaibi et al., 2022), less attention has been paid to the relationship between such ratings and the extent of environmental or green innovations. Only recently, some studies addressing this issue have been published. Aside from the paper by Cohen et al. (2022) concerned with companies holding US green patens, most of them refer to Chinese companies: see Liu and Lyu (2022), Tan and Zhe (2022), Wang et al. (2023), Zhang and Chen (2023), Yang et al. (2024), Rauf et al. (2024).

Accordingly, there is a need to provide further empirical evidence by considering a wider set of countries. This paper provides an attempt to fill this gap, by examining the relationship between ESG ratings and green patents for over 1,000 large corporations, with headquarters located in different countries, that are among the top R&D investors worldwide.

2. Background and research question

By considering the number and quality of green patents granted by the USPTO to publicly traded firms over the period 1980-2020, Cohen at al. (2021) show that they are negatively correlated with ESG ratings for energy companies while the relationship is not significant for other top sectors in terms of green patents. On the contrary the studies concerned with Chinese listed companies, by using panel data estimations referring to different periods between 2009 and 2022, find a positive effect of ESG ratings on green patents (cf. Liu and Lyu, 2022; Tan and Zhe, 2022; Wang et al., 2023; Zhang and Chen, 2023; Yang et al., 2024, Rauf et al., 2024). Yang et al. (2024) show that such a positive impact is not linear but U-shaped, while Rauf et al. (2024) find that ESG reporting exerts a positive moderating role in the relationship between green R&D expenditures and green patents.

From a theoretical point of view, the positive relationship between ESG and green patens at company level relies mainly upon the agency theory which emphasizes the potential misalignment between managers' and shareholders' goals. ESG ratings alleviate the cost of investors monitoring and then the information asymmetries between corporate managers and shareholders: as far as the pressure for managers to pursue short-term profitability is reduced, this may promote long-term investments, including those for green innovation enhancing corporate sustainability (Wang et al., 2023). In the same vein, Tan et al. (2022) contend that ESG ratings reduce financial constraints which are more stringent for companies wishing to invest in risky innovation projects.

With the increasing demand for investment in innovative activities able to generate new sustainable products and production processes, high-tech or R&D-intensive companies have been particularly scrutinized in this regard not only by investors but also by policy makers and the media (Grewal et al. 2019; Serafeim, 2020). As stressed by Truant et al. (2023, p. 7), "while technological change remains a core foundation of their competitive advantage, the adoption of ESG practice and the intensification of ESG disclosures in high-tech industries have led to companies rethinking their strategy to incorporate

ESG in their competitive orientation more appropriately."

Following this suggestion, in this paper we inspect whether there is a positive relationship between ESG ratings and green patents by considering the companies that are among the top R&D investors in the world. Along with total ESG scores, as in previous studies, we also use the specific Environmental scores assigned to these companies by the rating agency Refinitiv.

3. Data and variables

The *EU Industrial R&D Investment Scoreboard* (collected and published each year by the Joint Research Centre (JRC) of the European Commission) provides information for 2,500 companies that invest the largest amounts of money in R&D worldwide. These data derive from consolidated figures of very large business groups and conglomerates that operate at the global level. In 2019, the total R&D expenditure of these companies accounted for about 90% of the world's business-funded R&D (cf. Grassano et al., 2020). The sectoral distribution of these companies is derived from the main sector of activity indicated in their annual reports, while the countries are those in which their headquarters are located. About 47% of the companies included in the Scoreboard belong to the most R&D-intensive sectors: Pharmaceuticals & Biotechnology, Software & Computer Services, Technology Hardware & Equipment, and Electronic & Electrical Equipment. These four sectors account together for more than half the business R&D worldwide. Regarding the geographical distribution, 30% of the companies have their headquarter in the US, followed by those located in China (21%), EU (17%), and Japan (12%)[1].

Amoroso et al. (2021) report the results of an JRC-OECD project aimed at collecting the green patent applications pertaining to the above companies. To classify a patent as "green" they use the scheme developed by the European Patent Office (referred as "Y02 tagging scheme"), which identifies green patents as those concerned with "technologies or applications for mitigation or adaptation against climate change". Data on green as well as total patent applications, referring to the year 2016-2018, were found for 2000 top R&D investors worldwide. At the global level, they accounted for 63% of total patent applications meeting the IP5 criterion[2], while being responsible of filing 70% of applications related to green patents. Although, as observed by Amoroso et al. (2021), they appear to be focused on incremental rather than radical inventions, the top R&D investors provide a crucial contribution to innovations targeting climate change mitigation.

The JRC-OECD COR&DIP© database v.3, 2021 (made available to researchers in the OECD website at http://oe.cd/ipstats) provides the raw data on patents and other variables referring to the world's top 2000 R&D investors. After downloading these data, we matched them, by using the company name, with the ESG ratings provided by Refinitiv, one the leading agencies assessing the corporate behaviour in terms of Environmental, Social, and Governance sustainability. For the years 2015-2019, we extracted from the Refinitiv platform (Eikon) the total ESG scores and the specific Environmental scores of the matched companies[3]. Due to missing ESG ratings, the matching procedure was successful for 1,080 companies.

For the matched top R&D investors, Table 1 shows the numbers and shares of green patents by sectors (in descending order by share) for the period 2016-2018. In terms of green patents' shares the top three

[1] Since many companies included in the Scoreboard consist of large and diversified multinational corporations, the imputation of unique countries and sectors of activity represents a clear limitation of the database and, a fortiori, of our study.

[2] Patented inventions were selected only if the same application was filed at two patent offices, with at least one of them among the EPO and USPTO, the JPO for Japan, the KIPO for Korea, and the CNIPA for China. This procedure, termed "IP5 patent families" by the OECD, allows to consider patent applications with a relatively high level of quality and, as such, more comparable at international level.

[3] The ESG rating framework adopted by Refinitiv is based upon 630 metrics at the company level concerned with several aspects of environmental, social and governance practices.

sectors are Energy, Transport equipment and Construction. However, only in Transport equipment the number of green patents is the highest followed by Computer, electronic and optical equipment and Machinery and equipment n.e.c.

Table 2 illustrates the same data by the country in which the headquarters of the top R&D investors are located. Aside from the residual countries labelled "Rest of the world", the top three countries in terms of green patents' shares are Germany, Korea and France. Instead, looking at the number of green patents the leading country is Japan followed by US in which, however, the share of green patents is below the average.

Table 1: Green patents of matched top R&D investors by sector: 2016-2018

	No. of green patents	**No. of total patents**	**Share of green patents (%)**
Energy	4012	17919	22.39
Transport equipment	24830	111846	22.20
Construction	399	2227	17.92
Electrical equipment	4886	33868	14.43
Basic metals and metal products	2534	19126	13.25
Chemicals and chemical products	7042	63439	11.10
Machinery and equipment n.e.c.	11844	120503	9.83
Textiles, wearing and apparel	128	1610	7.95
Rubber, plastics and other non-metal prods.	1262	16442	7.68
Computer, electronic and optical equipment	15707	240084	6.54
Pharmaceuticals	2357	37739	6.25
Information and communication	3415	58592	5.83
Trade	462	7982	5.79
Professional services	783	13745	5.70
Wood and furniture	856	18258	4.69
Financial and other services	62	1610	3.85
Food, beverages and tobacco	205	7514	2.73
Total	80784	772504	10.46

Along with patent numbers and ESG ratings, the company data taken from the JRC-OECD COR&DIP© database include the value of net sales, R&D expenditures and operating profits[4]. To perform econometric analyses some outliers were excluded. First, a few very large companies with more than 1,500 green patents in a single year. Then, other companies with an intensity of R&D expenditures on net sales greater than one as well as those with a ratio of operating profits on net sales lower than -1 and higher than 1. Similar procedures for excluding firms with abnormal intensities of R&D expenditures and profits are adopted in previous studies using the Scoreboard database (cf. Cincera and Ravet, 2014; Coad, 2019).

4 For many though not all the world's top R&D investors also data on employment were available. However, having net sales as a proxy for the company size, we avoided using them in order not to reduce the number of observations. For the same purpose we did not use data on company market value which were available for a limited set of companies.

Table 2: Green patents of matched top R&D investors by country: 2016-2018

	No. of green patents	No. of total patents	Share of green patents (%)
Germany	10179	63354	16.07
Rest of the World	281	2121	13.25
Korea	2212	16761	13.20
France	2981	23766	12.54
Japan	33065	315275	10.49
UK	1053	10104	10.42
China	3440	34261	10.04
US	21128	212737	9.93
Rest of Asia	279	3440	8.11
Rest of Europe	4414	57406	7.69
Taiwan	1218	19757	6.16
Switzerland	534	13522	3.95
Total	80784	772504	10.46

4. Results of econometric analyses

For the companies included in our panel the number of green patents in each year varies from 0 to 1,354, with a mean of 29 and a standard deviation of 101: due to a remarkable presence of zeros (accounting for 43% of total observations) such a count variable is clearly over-dispersed. Hence, for the number of green patents, we estimated a random-effects negative binomial regression (Hausman, Hall, and Griliches, 1984) in which the number of green patents for firm *i* in year *t* (y_{it}) is Poisson distributed, depending on a set of lagged firm-level variables (x_{it-1}) and a dispersion parameter (δ_i): the latter varies randomly between firms but not within them. ESG ratings, the company size (proxied by the log of sales) and the shares of R&D expenditures and operating profits on company sales are included as regressors with a one-year lag with respect to the number of green patents which is available from 2016 to 2018. Along with sectoral and country dummies we also include time dummies with a view of testing whether there was an increasing attitude towards green inventions common to all the examined companies over time.

In a further empirical analysis, we used as dependent variable the share rather than the number of green patents, while including the same set of regressors. In this case, we estimated a linear regression model with random effects. The results of both estimations are reported in Table 3.

Table 3: Random effect estimations for the number and share of green patents 2016-2018

	Number of green patents (negative binomial regression)		**Share of green patents (linear regression)**	
Constant	-10.504***	10.409***	-0.086	-0.080
	(0.660)	(0.657)	(0.054)	(0.054)
ESG score $_{t-1}$	0.293**		0.028*	
	(0.148)		(0.015)	
Environment score $_{t-1}$		0.146		0.021*
		(0.110)		(0.011)
Ln Sales $_{t-1}$	0.771***	0.772***	0.824**	0.823**
	(0.034)	(0.034)	(0.336)	(0.264)
R&D/Sales $_{t-1}$	2.614***	2.644***	-7.800	-7.824
	(0.578)	(0.577)	(5.425)	(5.425)
Profits/Sales $_{t-1}$	0.625*	0.623*	-2.618	-2.625
	(0.334)	(0.334)	(2.702)	(2.702)
Dummy 2017	1.218***	1.210***	0.531	0.567
	(0.055)	(0.055)	(0.582)	(0.584)
Dummy 2018	0.975***	0.970***	-0.130	-0.064
	(0.054)	(0.054)	(0.568)	(0.571)
LR test vs. pooled	917.36	919.49		
Chibar2 (prob≥chibar2)	(0.000)	(0.000)		
No. of observations	2026		2033	
No. of companies	1012		1014	

*Sector and country dummies included. Standard errors in parentheses. *p<0.1, ** p<0.05, ***p<0.01.*

For the number of green patents, the ESG score of the companies lagged by one year exerts a positive effect, significant at a 5% level[5]. This finding is remarkable because it holds by controlling for many relevant variables such as the company size and the intensity of R&D expenditures and operating profits[6]. All these variables, together with the year dummies, affect positively the number of green patents. Along with the expected impact of sales (which approximates company size) it is worth noting the significant positive effect of the R&D intensity on green patents.

By considering Environment ratings only (i.e. neglecting those concerned with Social and Governance sustainable practices) the impact on the number of green patents is not statistically significant. Since, to our knowledge, none of the previous empirical studies used the Environment rating as explanatory variable, comparable results cannot be found. In any case, for a tentative explanation of this finding, it could be argued that, to take a favourable attitude towards long-term and risky investments by corporate managers, external investors consider the global ESG rating of companies rather than that specific to environmental practices.

When the dependent variable is the share of green patents, both the ESG and Environment scores have a positive effect although barely significant from a statistical point view. However, aside from the log of company sales, the estimated parameters of all the other control variables turn out to be not significant, suggesting that the share of green patents is mainly affected by the sector of activity of companies. Consistently with the descriptive evidence illustrated in Table 1, the estimated parameters of sector dummies (not reported in Table 3) are positive and statistically significant (at 1% level of confidence) for,

[5] It must be stressed that when the ESG scores are not lagged their effect turn out to be not statistically significant.

[6] Moreover, the Likelihood-ratio test rejects the null hypothesis of a pooled model.

Energy, Transport equipment, Construction, and Electrical equipment.

In the above regressions it is assumed that the relationship goes from ESG ratings to green patents. Although we have used lagged explanatory variables, the problem of endogeneity remains unsolved so that it cannot be ruled out that the relationship could go in the opposite direction. To test if this is the case, we ran a further regression in which as dependent variables we take both the ESG and Environment score referring to the years 2017-2019 while, as explanatory variable, the log of green patens over 2016-2018[7]. The latter is computed by adding one to the number of corporate green patents.

Table 4: Panel regression (random eff.): ESG and Environment scores 2017-2019.

	ESG score	**Environment score**
Constant	39.214***	20.583***
	(5.114)	(7.329)
Ln Green Patents $_{t-1}$	0.626**	1.354***
	(0.281)	(0.403)
Ln Sales $_{t-1}$	2.588***	3.739***
	(0.286)	(0.411)
Dummy 2018	1.273*	1.519
	(0.750)	(1.062)
Dummy 2019	0.199	1.637
	(2.847)	(4.076)
No. of observations	2,808	
No. of companies	1,286	

*Sector and country dummies included. Standard errors in parentheses. *p<0.1, ** p<0.05, ***p<0.01.*

Controlling for the log of company sales as well as for the year, sector and country dummies, Table 4 shows a positive impact of the lagged log of green patents on both ESG and Environment ratings. Interestingly, the magnitude and statistical significance of the effect exerted by green patents is higher when the Environment scores are considered. This may suggest that when evaluating the environmental practices of high-tech or R&D-intensive companies, rating agencies (or at least that exploited in our case) can resort, along with other metrics, to specific indicators of inventive activities.

5. Concluding remarks

So far, the evidence of a positive relationship between ESG ratings and green innovations, proxied by patents, has been mainly found for Chinese listed companies. In this paper we have shown that this is the case also when considering large corporations that are among the top R&D investors in the world. By adopting corporate strategies for enhancing their ESG performance (and by agreeing to be rated by third-party agencies in this respect) these companies have increasingly targeted their inventive activities to the goal of environmental sustainability.

It must be stressed that, due to the type of data at our disposal, we cannot contend that there is a causal effect of ESG ratings on the extent of green patents. Indeed, although in a tentative way, we have shown that the relationship could go in the opposite direction. Hence, at this stage, we can only conclude that there is a significant positive association between corporate ESG ratings and green patents. For more

7 To our knowledge, only Cao et al. (2023) have performed a similar analysis although they do not use green patents but the amount of corporate green investment. For Chinese listed companies, they find a positive effect of green investment on ESG ratings.

robust and reliable results further research is needed: in particular, companies should be observed over a longer period and additional control variables should be used, especially to account for different corporate characteristics and strategies.

References

Amoroso, S., Aristodemou, L., Criscuolo, C., Dechezleprêtre, A., Dernis, H., Grassano, N., Moussiegt, L., Napolitano, L., Nawa, D., Squicciarini, M., Tübke, A. (2021). World Corporate Top R&D investors: Paving the way for climate neutrality. A joint JRC and OECD report. Publications Office of the European Union, Luxembourg. doi:10.2760/49552, JRC126788.

Bardos, K., Ertugrul, M., Gao, L. S. (2020). Corporate Social Responsibility, Product Market Perception and Firm Value. Journal of Corporate Finance, Vol. 62, 101588.

Cao, M., Duan, K., Ibrahim, H. (2023). Green investments and their impact on ESG ratings: An evidence from China. Economics Letters, Vol. 232: 111365. doi: 10.1016/j.econlet.2023.111365.

Cappucci, M. (2018). The ESG integration paradox. Journal of Applied Corporate Finance, Vol. 30, pp. 22-28.

Chouaibi, S., Rossi, M., Siggia, D., Chouaibi, J. (2022). Exploring the Moderating Role of Social and Ethical Practices in the Relationship between Environmental Disclosure and Financial Performance: Evidence from ESG Companies. Sustainability, Vol. 14, No. 1, 209.

Coad, A. (2019). Persistent heterogeneity of R&D intensities within sectors: Evidence and policy implications. Research Policy, Vol. 48, pp. 37-50.

Cohen, L., Gurun, U. G., Nguyen,m Q. H. (2022). The ESG-Innovation Disconnect: Evidence from Green Patenting. NBER Working Paper 27990.

Cincera, M., Ravet J. (2014). Globalisation, industrial diversification and productivity growth in large European R&D companies. Journal of Productivity Analysis. Vo. 41, pp. 227-246.

Flammer, C. (2015). Does corporate social responsibility lead to superior financial performance? A regression discontinuity approach. Management science, Vo. 61, No. 11; pp. 2549-2568

Grassano, N., Hernandez Guevara, H., Tuebke, A., Amoroso, S., Dosso, M., Georgakaki, A., Pasimeni. F. (2020). The 2020 EU Industrial R&D Investment Scoreboard. Publications Office of the European Union. Luxembourg.

Grewal, J., Riedl, E. J., Serafeim, G. (2019). Market reaction to mandatory nonfinancial disclosure. Management Science, Vo. 65, No. 7; pp 3061-3084.

Hausman, J. A., Hall, B. H., Griliches, Z. (1984) Econometric models for count data with an application to the patents–R&D relationship. Econometrica, Vol 52; pp. 909–938.

Hughes, A., Urban, M. A., Wojcik, D. (2021). Alternative ESG ratings: how technological innovation is reshaping sustainable investment. Sustainability, Vol. 13, No. 6, 3551.

Liu, H., Lyu, C. (2022). Can ESG Ratings Stimulate Corporate Green Innovation? Evidence from China. Sustainability, Vol. 14, 12516; doi: 10.3390/su141912516.

Rauf, F., Wanqiu, W., Naveed, K., Zhang, Y. (2024) Green R&D investment, ESG reporting, and corporate green innovation performance. PLOS ONE Vol. 19, No.3; e0299707. https://doi.org/10.1371/journal.pone.0299707.

Serafeim, G. (2020). Public sentiment and the price of corporate sustainability. Financial Analist Journal, Vol. 76, No. 2, pp. 26–46.

Tan, Y., Zhu, Z. (2022). The effect of ESG rating events on corporate green innovation in China: The mediating role of financial constraints and managers' environmental awareness. Technology in Society, Vol. 68.101906; doi: 10.1016/j.techsoc.2022.101906.

Truant, E., Borlatto, E., Crocco, E., Bhatia, M. (2023). ESG performance and technological change: Current state-of-the-art, development and future directions. Journal of Cleaner Production, Vol. 429, 139493. doi: 10.1016/j.jclepro.2023.139493.

Wang, J., Ma, M., Dong, T., Zhang, Z. (2023). Do ESG ratings promote corporate green innovation? A quasi-natural experiment based on SynTao Green Finance's ESG ratings. International Review of Financial Analysis, Vol. 87, 102623. doi: 10.1016/j.irfa.2023.102623.

Yang, C., Zhu, C., Kalbitar, K. (2024). ESG ratings and green innovation: A U-shaped journey towards sustainable development. Business Strategy and the Environment, Vol. 33; pp. 4108–4129.

Zhang, C., Chen, D. (2023). Do environmental, social, and governance scores improve green innovation? Empirical evidence from Chinese-listed companies. PLOS ONE, Vol. 18, No. 5; e0279220. doi: 10.1371/journal.pone.0279220.