Peer-reviewed research

Environmental Policy and Environmental R&D in the Private Sector: New Evidence on the "Narrow" Porter Hypothesis

Dierk Herzer[1a]

[1] Department of Economics, Helmut Schmidt University, Germany

Keywords: Market-based environmental policies, Non-market-based environmental policies, Environmental R&D, JEL: Q55 Q58

https://doi.org/10.46557/001c.94372

Energy RESEARCH LETTERS

Vol. 6, Issue 1, 2025

We examine the impact of the stringency of market-based and non-market-based environmental policies on private-sector environmental R&D expenditures. We find that the stringency of market-based environmental policies has a positive and statistically significant impact on environmental R&D expenditures in the private sector. In contrast, the stringency of non-market-based environmental policies is statistically insignificant. Thus, our findings provide evidence supporting the "narrow" Porter hypothesis.

I. Introduction

Both scientists and politicians agree on the necessity of increased environmental research and development (R&D) efforts in the private sector to achieve the goal of reducing greenhouse gas emissions to net zero by 2050. The crucial question is how governments can incentivize private firms to increase their environmental R&D activities. The Porter hypothesis provides an answer to this question, positing that stringent environmental policies incentivize firms to develop new production methods that are more environmentally friendly. A variation of this hypothesis is the "narrow" Porter hypothesis, according to which market-based environmental policy instruments, such as emissions taxes and trading schemes, offer stronger incentives for firms to conduct environmental R&D compared to non-market-based policies, such as emission standards and limits.

The logic behind the "narrow" Porter hypothesis is simple: Market-based policies establish a price for emissions, either directly through taxes or indirectly through tradable allowances. This implies that market-based policies offer continuous incentives for environmental R&D because firms can achieve cost savings by reducing their emissions, thus avoiding taxes, or by reducing their emissions and consequently avoiding the need to purchase allowances. Non-market-based policies do not offer such incentives. Once the emission standard is met, firms are not motivated further to reduce their emissions through the development of new technologies. Moreover, rather than searching for new emission-reducing technologies to meet the standard, firms may opt to acquire existing ones. In addition, policies that specify emission standards or even prescribe the use of specific technologies may divert scarce resources away from R&D toward acquiring existing technologies. Theoretically, one would thus expect that market-based policies promote environmental R&D, while non-market-based policies could even discourage R&D in environmental technologies.

Surprisingly, there are only five studies on the "narrow" Porter hypothesis, and their results are conflicting. Using cross-sectional manager survey data on the existence of a firm budget for environmental R&D and the perceived relevance of several environmental policy instruments for production, Lanoie et al. (2011) find that both environmentally related taxes and technology-based standards have no significant impact on the likelihood of investing in environmental R&D, whereas performance-based standards increase the likelihood of such investment. Using the market- and non-market-based components of the 2014 version of the OECD Environmental Policy Stringency Index, Fabrizi et al. (2018) find, in panel data from European countries, that while non-market-based policies have a statistically insignificant effect on green patents in most specifications, the sub-index measuring the stringency of market-based policies is significant and positive in almost all specifications. Both Hassan and Rousselière (2022) and Zhang et al. (2022), using the two components of the 2014 OECD Environmental Policy Stringency Index, find that non-market-based policies have a significant positive relationship with environmentally related patents, while the effect of market-based policies on green innovation is not significantly different from zero. Finally, Prokop et al. (2023) find, based on the two sub-indices of the 2014 OECD Environmental Policy Stringency Index, that above-average stringency of non-market-based policies is significantly positively correlated with green patents, whereas above-average stringency of market-based policies is significantly negatively correlated with green patents.

a Corresponding author email: dierkherzer@gmx.de

A potential limitation of Lanoie et al.'s (2011) study is its reliance on the perceived importance of environmental policy instruments for production, rather than the actual stringency of these instruments. Additionally, the authors consider the existence of a budget for environmental R&D rather than its amount.

One limitation of the other studies lies in the use of the two sub-indices of the 2014 version of the OECD Environmental Policy Stringency Index, which inaccurately measure the stringency of market- and non-market-based environmental policies. The 2014 sub-index for the stringency of market-based policies not only takes into account environmentally related taxes and trading schemes but also government support for the deployment of clean energy technologies in the form of feed-in tariffs. If feed-in tariffs do not stimulate environmental innovation, it is possible to observe an insignificant (or even a negative) effect of the sub-index measuring the stringency of market-based policies, even if these policies incentivize firms to conduct environmental R&D. Similarly, since the 2014 sub-index for the stringency of non-market-based policies considers both environmental standards and government funding for clean energy R&D, its estimated effect may be significantly positive even if environmental standards alone do not induce green innovation.

Another concern with these studies is the innovation variable: total patent applications in environmental technologies, which include patent applications from the public sector. However, the Porter hypothesis pertains to innovation incentives for private firms, and there is no plausible reason for researchers in the public sector to be motivated by stringent environmental policies to conduct environmental R&D. Furthermore, patent applications are a measure of R&D output, while the Porter hypothesis pertains to R&D incentives, which are better captured by R&D input, such as R&D expenditures, rather than R&D output. But even R&D output is not accurately measured by patent applications because not all innovations are patentable and not all patentable innovations result in patent applications.

Given these methodological issues, the objective of this study is to reexamine the "narrow" Porter hypothesis. This study differs from previous work, and thus contributes to the sparse literature on the "narrow" Porter hypothesis, in two important ways. *First*, we use as the dependent variable environmental R&D expenditures in the private sector, which we believe is conceptually more reasonable here than total patent applications in environmental technologies. *Second*, we use as explanatory variables the market- and the non-market-based components of the *revised* OECD Environmental Policy Stringency Index (revised in 2022), which is composed of three sub-indices: the first sub-index measures the stringency of market-based policies, the second the stringency of non-market-based policies, and the third sub-index is a measure of the strength of technology support policies (including government support for the deployment of clean energy technologies and government funding of clean energy R&D). Section II describes the methodology and data. Section III presents the results, and Section IV concludes.

II. Methodology and Data

Our basic model, which is estimated by ordinary least squares, is given by

$$\begin{aligned}\log R\&D_{it} &= \mu_i + f_t + \alpha_1 MB_{it} + \alpha_2 NMB_{it} \\ &+ \alpha_3 TE_{it} + \gamma X_{it} + \varepsilon_{it}\end{aligned} \tag{1}$$

where i and t are country and time indicators; μ_i and f_t represent country and year fixed effects; log*R&D* denotes the natural logarithm of real expenditures (in constant PPP US dollars) on environmental R&D conducted by private firms; and *MB*, *NMB*, and *TE* represent the three sub-indices of the revised Environmental Policy Stringency Index of the OECD, measuring the stringency of market-based policies, the stringency of non-market-based policies, and the strength of technology support policies, respectively. The sub-index of the stringency of market-based policies, *MB*, considers environmental trading schemes and environmental related taxes. The sub-index of the stringency of non-market-based policies, *NMB*, considers policies that mandate emission limits and standards. Finally, *TE*, the sub-index of the strength of technology support policies, captures both government funding for clean energy *R&D* and government support for the deployment of renewable energy technologies. While this is not our primary focus, we include the sub-index for the strength of technology support policies for completeness.

X is a vector of control variables chosen based on the previous literature discussed in Section I. We control for population size (measured in logarithms), log*POP*, greenhouse gas emissions (in kilotons of CO_2 equivalent, also measured in logarithms), log*GHG*, and the (logarithm of the) trade share of GDP, log*TRADE*. As a robustness check, we also estimate (for a smaller sample) a specification that includes all the above control variables as well as net foreign direct investment (FDI) as a percentage of GDP, log*FDI*, real *GDP* per capita (in constant PPP US dollars), log*GDPPC*, and real government expenditures on tertiary education (in constant PPP US dollars), log*TERT* (all measured in logarithms).[1]

We use data on (real) environmental R&D expenditures in the business enterprise sector from the OECD Research and Development Statistics (available at https://stats.oecd.org/Index.aspx?DataSetCode=GERD_SEO#). The data on the three sub-indices of the revised Environmental Policy Stringency Index are from the OECD Environment Statistics (available at https://stats.oecd.org/Index.aspx?DataSetCode=EPS#). All other data are from the World Development Indicators

1 To calculate (real) government expenditures on tertiary education, we multiply the ratio of tertiary education expenditures to government expenditure on education by the product of GDP (in constant PPP US dollars) and the ratio of government expenditure on education to GDP.

(available at https://databank.worldbank.org/source/world-development-indicators).

Combining the data on environmental R&D expenditures in the business enterprise sector with the data on the components of the OECD Environmental Policy Stringency Index results in an unbalanced panel comprising 176 observations across 14 countries (Australia, Austria, Czech Republic, Hungary, Ireland, Korea, Netherlands, Norway, Portugal, Russia, Slovak Republic, Slovenia, South Africa, and Spain) for the period 1990-2015. This is our main sample.

In our main sample, the minimum (maximum) number of observations per country is 1 (20). There are many gaps in the data, and half of the countries in this sample have fewer than ten consecutive observations. Spurious regressions due to non-stationary data in panels with a large time series dimension are therefore unlikely in this application. However, since this problem cannot be entirely ruled out, we also utilize a shorter sample period with a maximum of nine time series observations per country, covering the years from 2007 to 2015. Using this sample period reduces the number of countries to 10 (Australia, Austria, Hungary, Korea, Portugal, Russia, Slovak Republic, Slovenia, South Africa, and Spain). In addition, we estimate a model with lagged explanatory variables to account for potential endogeneity,[2] using a sample with 12 countries (Australia, Austria, Czech Republic, Hungary, Korea, Netherlands, Portugal, Russia, Slovak Republic, Slovenia, South Africa, and Spain).

III. Results

The results are reported in Table 1. In columns (1) – (3), we report results based on specifications that include MB_{it}, NMB_{it}, and TE_{it} separately to account for potential multicollinearity, along with our main control variables. In Column (4), MB_{it}, NMB_{it}, and TE_{it} are included jointly in the regression. For brevity, we do not delve into the results for the control variables in detail, but note that these results are largely as expected, except for those in column (6). Possible explanations for the insignificant and sometimes counterintuitive results for the control variables in this column include endogeneity and multicollinearity.

Turning to our variables of interest in columns (1) – (4), we observe that the coefficient on MB_{it} is positive and statistically significant, whereas the coefficients on NMB_{it} and TE_{it} are statistically insignificant. This finding is robust to the exclusion of control variables (see column (5)), the inclusion of additional control variables (see column (6)), the use of a shorter period (see column (7)) and the use of lagged explanatory variables (see column (8)).

We explicitly note here that we also checked the robustness of our results using the instrumental variable estimator proposed by Lewbel (2012) to account for potential endogeneity. This estimator exploits heteroscedasticity in the data to generate internal instruments and identify causal effects. The results from the Lewbel approach, which are not reported here to save space, align qualitatively with the ordinary least squares results in Table 1.

We thus find a significant positive effect of the stringency of market-based policies and an insignificant effect of non-market-based environmental policies on private sector environmental R&D expenditures, consistent with the logic explained in Section I. This finding is in line with the findings of Fabrizi et al. (2018) but contrasts with those of Hassan and Rousselière (2022), Zhang et al. (2022), and Prokop et al. (2023), who all use the market-based component and non-market-based component of the 2014 OECD Environmental Policy Stringency Index and patent applications in environmental technologies (as discussed in Section I).

IV. Conclusion

Using a panel dataset that covers up to 14 countries with sporadically available data between 1990 and 2015, this study finds that the stringency of market-based environmental policies has a significant positive effect on environmental R&D within the private sector. In contrast, the impact of the stringency of non-market-based environmental policies is statistically insignificant, as is the overall impact of the strength of technology support policies. Thus, our findings support the "narrow" Porter hypothesis, in contrast to most previous studies.

Submitted: November 13, 2023 AEDT. Accepted: December 16, 2023 AEDT. Published: March 01, 2025 AEDT.

2 Endogeneity arises if governments perceive stricter environmental regulations more politically acceptable when firms invest more in environmental R&D or if governments respond to reductions in environmental R&D by increasing the stringency of environmental policy.

Table 1. Regression results

	(1)	(2)	(3)	(4)	(5) Without controls	(6) Additional Controls	(7) Shorter period	(8) Lagged variables
MB_{it}	0.313** (2.405)			0.325** (2.568)	0.388** (2.038)	0.341** (2.121)	0.405** (2.946)	0.321** (2.498)
NMB_{it}		-0.025 (-0.453)		-0.044 (-0.776)	0.135 (1.609)	-0.034 (-0.425)	-0.287 (-1.805)	-0.010 (-0.112)
TE_{it}			-0.041 (-0.353)	-0.035 (-0.308)	0.044 (0.531)	0.112 (1.357)	0.010 (0.080)	-0.093 (-0.753)
$\log POP_{it}$	8.179*** (4.259)	8.040*** (3.197)	7.779*** (3.039)	8.519*** (4.021)		2.210 (0.749)	0.540 (0.081)	8.137** (2.246)
$\log GHG_{it}$	0.156 (0.158)	0.225 (0.193)	0.253 (0.217)	0.094 (0.093)		0.266 (0.240)	1.566 (1.621)	0.432 (0.461)
$\log TRADE_{it}$	0.969** (2.833)	1.128** (2.539)	1.185** (2.448)	1.097** (2.370)		0.238 (0.464)	0.877 (1.640)	0.658 (0.699)
$\log FDI_{it}$						-0.040 (-0.807)		
$\log GDPPC_{it}$						-3.046*** (-3.663)		
$\log TERT_{it}$						-0.078 (-0.215)		
R^2	0.574	0.561	0.560	0.584	0.339	0.076	0.087	0.643
Sample period	1990-2015	1990-2015	1990-2015	1990-2015	1990-2015	1990-2015	2007-2015	1991-2015
No. of obs.	176	176	176	176	176	133	71	134
No. of countries	14	14	14	14	14	14	10	12

Note: This table reports the results of OLS regressions in which the dependent variable is $\log R\&D_{it}$. All regressions control for country and year fixed effects. Numbers in parentheses are *t*-statistics based on heteroskedasticity-consistent standard errors. *** (**) indicates significance at the 1% (5%) level.

References

Fabrizi, A., Guarini, G., & Meliciani, V. (2018). Green patents, regulatory policies and research network policies. *Research Policy*, *47*(6), 1018–1031. https://doi.org/10.1016/j.respol.2018.03.005

Hassan, M., & Rousselière, D. (2022). Does increasing environmental policy stringency lead to accelerated environmental innovation? A research note. *Applied Economics*, *54*(17), 1989–1998. https://doi.org/10.1080/00036846.2021.1983146

Lanoie, P., Laurent-Lucchetti, J., Johnstone, N., & Ambec, S. (2011). Environmental policy, innovation and performance: new insights on the Porter hypothesis. *Journal of Economics & Management Strategy*, *20*(3), 803–842. https://doi.org/10.1111/j.1530-9134.2011.00301.x

Lewbel, A. (2012). Using heteroscedasticity to identify and estimate mismeasured and endogenous regressor models. *Journal of Business & Economic Statistics*, *30*(1), 67–80. https://doi.org/10.1080/07350015.2012.643126

Prokop, V., Gerstlberger, W., Vrabcova, P., Zapletal, D., & Yee, Y. (2023). Does being stricter mean doing better? Different effects of environmental policy stringency on quality of life, green innovation, and international cooperation. *Heliyon*, *9*(5), e16388. https://doi.org/10.1016/j.heliyon.2023.e16388

Zhang, D., Zheng, M., Feng, G.-F., & Chang, C.-P. (2022). Does an environmental policy bring to green innovation in renewable energy? *Renewable Energy*, *195*, 1113–1124. https://doi.org/10.1016/j.renene.2022.06.074