REA ANNEX

Literature reviewed

Paper	Authors	Country/Region	Year published	Methodology	Key findings	Research question [1]
Environmental Policy and Directed Technological Change: Evidence from the European Carbon Market	Calel and Dechezleprêtre	EU-ETS[2] countries (18)	2016	Matching EU ETS firms with non-EU ETS firms to compare performance before and after EU ETS implementation in 2005	▪ EU ETS has been estimated to account for 9.1% increase in low carbon patenting across 5500 EU ETS firms but only a meagre 0.38% boost to low carbon patenting at the European Patent Office	2
Environmental regulation and competitiveness: Empirical evidence on the Porter Hypothesis from European manufacturing sectors	Rubashkina et al	17 European countries	2015	Regression analysis (IV estimation) using PACE[3] data, R&D expenditure/patent statistics and TFP[4] data at firm level	▪ In no case is the impact of environmental regulation on R&D efforts statistically significant ▪ The effect of PACE on patent applications is always positive and significant. Here a 10% increase in PACE is associated with a 0.3–0.9% increase in patent applications ▪ More stringent environmental regulation does not harm productivity either in one-year or in two-year period. Rather, the overall productivity effect is neutral	2,3
The effect of environmental regulation on firms' competitive performance: The case of the building &	Testa et al	Italy, Netherlands, France	2011	Regression analysis using survey data collected through interviews at firm level	▪ Environmental policy stringency (no. of inspections) is significantly positively correlated with technical innovation and business profitability (productivity) ▪ Technology based standards (direct regulation) have a positive impact on technical innovation	2,3

[1] As listed out in the main body of the report

[2] European Union Emissions Trading System

[3] Pollution Abatement Costs and Expenditures

[4] Total Factor Productivity

construction sector in some EU regions					but an insignificant impact on business performance ▪ Economic instruments (input taxes) have a negative impact on business performance	
Environmental regulation and productivity: testing the porter hypothesis	Lanoie et al	Quebec	2008	Regression analysis (Ordered probit) using manufacturing firm level data on TFP and intensity of investments in pollution control equipment in relation to size of sectors	▪ The contemporaneous effect of a change in environmental norms (standards) is roughly 14% decline in observed TFP ▪ The dynamic effect of a change in environmental norms (standards) is roughly 24% increase in TFP ▪ Sectors more exposed to competition are more likely to conform to the PH	1,2,3
Environmental regulation and firm exports: Evidence from the eleventh Five-Year Plan in China	Shi and Xu	China	2018	Regression analysis (Difference-in-difference-in-differences) at the provincial and industry levels using export output value and pollution targets data	▪ When the pollution reduction target is one standard deviation above the mean, there are one percentage point fewer exporting firms in industries with SO_2 emissions 10% above the mean and the value of exports is 13% lower	3
Environmental regulations and productivity growth: The case of fossil-fueled electric power generation	Gollop and Roberts	U.S.	1983	Regression analysis (MLE) using firm level data on generation costs, output, inputs and regulatory intensity in the electric power industry	▪ A 1% increase in regulatory intensity in 1979 would have raised the average total cost by for firms which faced effective regulation by $478,000 or 0.13%	3
Productivity growth and environmental regulation in Mexican and U.S. food manufacturing	Alpay et al	U.S., Mexico	2002	Regression analysis (MLE) using input price and quantity data from the food manufacturing sector, pollution abatement expenditures, inspections data	▪ Pollution abatement regulations have had a consistently negative impact on profitability in Mexico whereas the results are ambiguous for U.S. ▪ The impact of environmental regulation (inspections) on the productivity of Mexican food processing: a 10% increase in pollution abatement regulation induced an average 2.8% increase in primal productivity growth.	3

The Environment and directed technical change	Acemoglu et al	N/A	2012	Two-sector model of directed, endogenous technical change in a growth model with environmental constraints and limited resources	▪ Both the long-run properties of the equilibrium and optimal policies (or the necessary policies to avoid environmental disaster) are related to the degree of substitutability between clean and dirty inputs, to whether dirty input production uses exhaustible resources, and to initial environmental and resource stocks	1,3
Toward a New Conception of the Environment-Competitiveness Relationship	Porter and Linde	N/A	1995	Framework based on 'Dynamic theory of strategy' (Porter,1991) which links environmental regulation to innovation and to competitiveness	▪ Strict environmental regulation can be fully consistent with competitiveness by triggering innovation offsets through substitution of less costly materials or better utilization of materials in the process and giving early mover advantage internationally ▪ Environmental regulation should focus on outcomes, not technologies in general ▪ Where possible, regulations should include the use of market incentives, including pollution taxes, deposit-refund schemes and tradable permits.	2,3,4
Environmental regulation and innovation: A panel data study	Jaffe and Palmer	U.S.	1997	Regression analysis (panel data) using industry level manufacturing firms data (1973-1991)- Private and govt R&D expenditures, PACE and value added, patents applications.	▪ "High-tech" industries are less pollution-expenditure intensive than low-tech industries on average ▪ Controlling for industry-specific effects and for the impacts of the other variables included in the model, the within-industry elasticity of R&D with respect to lagged PACE expenditures appears to be about 0.15	2
The impact of the European Emission Trading Scheme on multiple measures of economic performance	Marin et al	EU ETS countries	2018	Regression analysis (difference-in-difference with pre-treatment matching) using EU-ETS as treatment and data on economic/financial performance at firm level	▪ Estimates suggest that the EU ETS, despite its negative (but small) impacts on productivity and profitability, has stimulated the growth of firms that own treated establishments. ▪ Compared to their control group in the second phase of the EU ETS, treated firms, have increased their employment by 8.2%, investment	3,4

					▪ by 26.7%, turnover by 14.9%, value added by 6% ▪ TFP is reduced by about 1.6% in the first phase and 2.4% in the second phase of the EU-ETS	
Empirical Evidence on the Effects of Environmental Policy Stringency on Productivity Growth	Albrizio et al	OECD countires	2014	Regression analysis (panel) using data on TFP, Environmental Stringency Index (EPS) (1990-2010)	▪ Country level: On average, there is a positive effect of a tightening of environmental policy on MFP growth. For example, In the three years after the policy change, MFP growth in Italy would rebound to 1.22% as compared to the 1.17% in the baseline.	3,4
Environmental regulation and the productivity of Japanese manufacturing industries	Hamamoto	Japan	2006	Regression analysis using data R&D expenditures, govt subsidy, value added and pollution control expenditures from the 5 most pollution intensive industries	▪ Environmental regulations based on command and control approach triggered off R&D activity in Japanese manufacturing industries ▪ The rate of return on total R&D investment is 42.5% i.e. a positive and significant effect on TFP growth	2,3
Environmental regulations, induced R&D, and productivity: Evidence from Taiwan's manufacturing industries	Yang et al	Taiwan	2012	Regression analysis (panel) at the industry level using data on R&D expenditure, pollution abatement fees, PACE, value added, TFP.	▪ Stronger environmental regulations do stimulate firms to increase their R&D investment. R&D expenditures would be triggered by about 0.1% in case of a 1% increase in pollution abatement fees. ▪ There is no significant evidence that more pollution abatement capital expenditures can induce R&D expenditure ▪ Environmentally induced R&D contributes to productivity in Taiwan's manufacturing industries	2,3
An integrated analysis of policies that increase investments in advanced energy-	Hanson and Laitner	U.S.	2004	General equilibrium model- All Modular Industry Growth Assessment (AMIGA) System to quantify	▪ Incorporating the set of cost-effective policies and technologies characterized in the Clean Energy Future (CEF) study's Moderate Energy Policy[5], AMIGA estimates a total carbon reduction of 113 million metric tons (MtC) of	3,4

[5] They used the policy and program cost information specified in the U.S. Department of Energy (DOE) sponsored study, Scenarios for a Clean Energy Future (Interlaboratory Working Group, 2000 as the basis to reduce carbon emissions approximately to 1990 levels by 2050. In other words, while the business-as-usual scenario assumes a continuation of current energy policies and a steady pace of technological progress, the Moderate Energy Policy scenario is defined by a set of program options that are consistent with increasing levels of public commitment and political resolve to solving the nation's energy-related challenges.

efficient/low carbon technologies				macroeconomic benefits of investments in energy efficient and renewables technology	carbon by the year 2010, growing to 992 MtC by 2050. ▪ Investment led strategy can lead to slightly higher gains in the nation's GDP. By 2010, GDP is up US$10 billion (0.08%). By 2050, this grows to US$94 billion (0.26%).	
U.S. energy research and development: Declining investment, increasing need, and the feasibility of expansion	Nemet and Kammen	U.S.	2006	Analysis of time series data R&D investments , patenting activities in the energy sector	▪ Measures of patenting activity reveal widespread declines in innovative activity that are correlated with research and development (R&D) investment—notably in the environmentally significant wind and solar areas.	2
Innovation in the energy sector: Lessons learnt from R&D expenditures and patents in selected IEA countries	Raphael Bointner	IEA[6] countries (14)	2014	Regression analysis using IEA R&D data, patent data	▪ Results indicates an almost linear relation between the GDP and the cumulative knowledge of a country. ▪ The cumulative knowledge stock induced by public R&D expenditures in 14 investigated IEA-countries is 102.3 bn EUR in 2013	2
Linkages between Environmental Policy and Competitiveness	Lankoski	OECD countries	2010	An analytical framework to examine the linkages between environmental policies and competitiveness	▪ The empirical evidence on the on the environment – competitiveness relationship is mixed ▪ The competitiveness impacts depend on the type of environmental policy measure adopted and the details of its implementation; on firm and sector characteristics; and on the environmental domain ▪ Even when implementing the environmental policy is clearly in the overall interest of society despite the adverse competitiveness impacts, the costs and benefits of the policy are unlikely to be equally shared among societal actors	1,3

[6] International Energy Agency

Energy, the environment and technological change	David Popp	U.S.	2003	Regression analysis using patents data and input costs to adhere to Clean Air Act 1990	▪ 1990 CAA had little effect on innovative activity related to SO_2 reduction as measured by successful patent applications ▪ The presence of additional SO2 emissions limits leads to the installation of more efficient scrubbers, but efficiency does not increase as the magnitude of the regulation increases.	2