Assessing the Transition Risks of Environmental Regulation in the US: Revisiting the Porter Hypothesis

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Introduction

- Over the last decade, the consequences of climate change and global warming have become increasingly significant (Polemis and Stengos, 2018; Kalaitzidakis et al., 2018).
- Global warming directly results from the accumulation of greenhouse gases (carbon dioxide, nitrous oxide and methane) primarily from human activities (Michail et al., 2019).
- Intergovernmental Panel on Climate Change (IPCC): Global temperatures have risen substantially, causing a range of physical risks, including rising sea levels, more frequent droughts and floods, hurricanes, cold snaps, and heat waves—severely affecting economic outcomes.

Introduction

- In 2015, nearly 200 countries joined the Paris Climate Agreement, and more than 70 countries, including the world's largest emitters have pledged to achieve net-zero carbon emissions by 2050 (United Nations, 2022).
- Research focuses on two key areas: (1) evaluating the impact of climate change on economic activity (Dell et al., 2014; Carleton and Hsiang, 2016) and (2) understanding the mechanisms driving climate change to design, implement, and assess the effectiveness of climate policies.
- Climate policies, legislation and regulations are considered transition risk drivers, as they can create financial risks associated with the shift towards a low-carbon economy (European Central Bank, 2022).

Introduction

- Investigate whether transition risk drivers, specifically, the implementation of environmental policies in the US pose risks or foster green innovation and financial performance as firms adjust to a low-carbon economy.

- This concept is central to the Porter Hypothesis, which suggests that well-designed environmental regulations can stimulate innovation and enhance firm competitiveness.

Literature Review

- The relationship between climate change and economic outcomes has traditionally been modelled using two alternative approaches:

- The Integrated Assessment Models (IAM) pioneered by Nordhaus (1991, 1993) characterized by their multidisciplinary nature (Weyant et al., 1996; Tol, 2002) and combine information about climate systems and human behavior to make projections about the future climatic change and its consequences.

- Model structure and assumptions influence their outputs (Pindyck, 2013).

Literature Review

- Examines the relationship between physical risks associated with climate change (such as temperature, precipitation, or extreme weather events) and economic outcomes using a cross-section of countries (Stern, 2007; Hsiang, 2016; Letta and Tol, 2019; Henseler and Schumacher, 2019).

- Research on the effects of climate policies on firm outcomes primarily focuses on two perspectives: The Compliance Cost Hypothesis (Barbera and McConnell, 1990) and the Porter Hypothesis (Porter, 1991; Porter and Linde, 1995).

- Compliance Cost Hypothesis: Strict environmental regulations pose transition risks by increasing compliance costs for firms, thereby diverting capital away from innovation causing delay in technological advancements and reduce firm competitiveness (Albrizio et al., 2017).

- Porter Hypothesis: Environmental regulations do not impose transition risks but encourage firms to innovate due to the cost pressures created by these policies. This innovation, including green innovation, can ultimately yield benefits that exceed compliance costs, making environmental policies a “win-win” strategy for firms.

- Porter Hypothesis: Strong, Weak and Narrow (Ambec et al., 2013).

Literature Review

- “Weak” Porter Hypothesis: Environmental regulations increase the cost of pollution relative to other production costs, hence, firms have a strong incentive to develop new technologies that reduce emissions (Hicks, 1932).
- Porter and Linde (1995)-Environmental policies can induce innovation: regulations signal firms about potential resource inefficiencies and innovation opportunities; regulations reduce uncertainty by ensuring that investments in environmental issues remain valuable; regulations ensure that during the transition to innovation-based solutions, firms gain a competitive advantage via green investments.
- Thus, within the framework of the weak version of the Porter Hypothesis, environmental regulations enhance cost savings and efficiency by encouraging firms to adopt sustainable practices, thereby eliminating any transition risks.

Literature Review

- Studies support that stricter environmental regulations can stimulate green innovation at the firm and country level (Rubashkina et al., 2015; Aghion et al., 2016; Dechezleprêtre and Sato, 2017).
- Wang et al. (2022): Relationship between environmental regulations and green innovation has not received sufficient attention, as past research primarily relied on linear models despite evidence suggesting parameter heterogeneity.
- The initial implementation of mild climate policies does not impose significant investment pressure on firms, allowing them to voluntarily increase green innovation in response to regulatory incentives (Dong and Wang, 2019).

Literature Review

- However, when governments enforce stricter climate policies, firms face significant transition risks and production costs, leading to negative effects on green innovation.
- At what threshold climate policies begin to impose a burden on firms and how policymakers can use this estimated threshold to design and implement effective climate policies that foster green innovation and growth.
- Primary objective: Investigate "weak" Porter Hypothesis in the context of transition risk drivers—specifically, the impact of climate policies on green innovation—within a nonlinear framework using a Threshold Regression Model.

Literature Review

- Significant body of literature examines the “strong” version of the Porter Hypothesis, which explores the impact of environmental regulation transition risks on firm competitiveness and productivity.
- Direct effect: Environmental policies can directly enhance firm performance by optimizing resource allocation and eliminating backward production capacity (Brandt et al., 2012; Tombe and Winter, 2015).
- Indirect mediating effect: “innovation compensation effect” and the “first-mover advantage”.

Literature Review

- Existing findings on the strong Porter Hypothesis remain controversial (Hamamoto, 2006; Cagatay and Mihci, 2006; Hering and Poncet, 2014; Peuckert, 2014; Wang et al., 2019).

- While prior research acknowledges the existence of parameter heterogeneity and nonlinearities, the empirical literature on the impact of environmental policies on firms' financial performance has largely relied on linear models.

- While mild environmental policies positively influence financial performance, stricter climate policies impose substantial costs and risks on firms, directly or indirectly, affecting key financial outcomes, particularly through their impact on green innovation.

Literature Review

- Secondary objective: Assess the "strong" Porter Hypothesis by examining the impact of transition risk drivers—specifically, climate policies—on firms' financial performance through the mediating mechanism of "innovation compensation effect" in the context of a Threshold Regression Model.

- Climate Policies: Market-based policies and Non-market-based policies.

Literature Review

- Market-based policies: Taxes or cap-and-trade systems, to encourage emissions reduction. Establish a market-driven stimulus for lowering carbon emissions, accomplished by increasing their cost.
- Flexibility to reduce emissions in a manner that best aligns with production processes and allows for cost-effective solutions, leading to a more efficient allocation of resources (Stavins, 2010). Limitations due to challenging choice of an accurate price for carbon emissions.
- Non-market-based policies: Rely on regulations and direct government intervention (Ambec et al., 2013). Less efficient but more easy to implement. Ban in certain materials, investments in renewable energy.
- Focus on market-based policies. United States has not yet implemented a national carbon tax policy.

Literature Review

- Cap-and-trade system: Enforces emission reduction targets by setting a limit on total greenhouse gas emissions.
- Firms are required to buy or sell allowances based on whether they have a shortage or surplus of allocated emissions compared to their verified emissions in order to comply with the cap (Stavins, 2008).
- Consequently, firms that manage to reduce their emissions below their permitted levels can sell their unused allowances to other companies.
- Hence, financial incentive for firms to lower their emissions, while also serving as a disincentive for those firms that fail to reduce their emissions and must purchase additional permits, incurring extra costs.

Contribution

- First empirical examination of both the weak and strong Porter Hypotheses using US data, including 33,219 firm-year observations over the period 1990-2022.
- Responds to the recent calls for research on the heterogeneous effects of climate policies on green innovation and transition risks by employing a purely non-linear setting through a Threshold Regression Model.
- In a nonlinear setting, it examines the impact of climate policies on firms' financial performance while exploring the mediating role of the "innovation compensation effect".
- Practical implications, as they reveal the mechanism through which climate policies affect the firm's green innovation practices and its financial performance. What threshold point exists where climate policies become a burden for a firm's innovation and performance?

Methodology

- Typically investigated following the theoretical framework of the knowledge production function (KPF) proposed by Griliches (1979, 1990) and is based on a panel fixed effects model,

$$y_{it} = \mu_i + \beta' x_{it} + e_{it}$$

- Extends the linear framework and builds on previous literature by considering a green knowledge production function (KPF) estimated using the Panel Threshold Regression Model with interactive fixed effects (Hansen, 2000, 2017; Kourtellos et al., 2016; Miao et al., 2020) to account for cross-sectional dependence.

Methodology

- Panel Threshold Regression allows for the presence of multiple regimes based on a certain threshold variable *q*it,

$$y_{it} = \begin{cases} \mu_i + \beta_1' x_{it} + e_{it}, & q_{it} \leq \gamma \\ \mu_i + \beta_2' x_{it} + e_{it}„ & q_{it} > \gamma \end{cases}$$

- Seo and Shin (2016), bootstrap test based on a supremum Wald statistic for the null hypothesis of a linear model. If null rejected, uncover the impact of market-based climate policies on green innovation under the different climate policy regimes by estimating a Panel Threshold Regression Model.

- Investigate the strong version of the Porter Hypothesis and the impact of climate policies on firm profitability, we also employ the Panel Threshold Regression Model.

Methodology

- United States Patent and Trademark Office (USPTO): Green Innovation Data. Cooperative Patent Classification (CPC), patents classified under the ‘technologies or applications for mitigation or adaptation against climate change’ scheme, which is aligned with the framework of the Kyoto Protocol and the Paris Agreement.

- World Carbon Pricing Database: State-level cap-and-trade system. Average carbon price across all sectors of a jurisdiction’s economy, weighted by each sector’s share of the total emissions.

Methodology

- Compustat and Execucomp: Firm financial data. Firm-specific characteristics, such as firm size, growth rate, asset structure, current and solvency ratio, leverage, and R&D expenditure. Year, state and industry fixed effects.
- Return on Assets (ROA) as a proxy for firm profitability, earnings before interest and taxes scaled by the firm's total assets.
- 33,219 firm–year observations over the period 1990-2022.

Threshold Tests and Threshold Estimates for Green Innovation

Threshold variable	P-value	Threshold
Carbon price (single threshold)	0.0010	5.0
Carbon price (double threshold)	0.6830	3.7

Empirical Results

Threshold Regression-Green Innovation

Variable	Linear Model		Threshold Regression Model			
			Low carbon price regime ≤ 5		High carbon price regime > 5	
	(1)	(2)	(3)	(4)	(5)	(6)
	Coef.	SE	Coef.	SE	Coef.	SE
Carbon Price	0.0212***	0.0057	0.0643***	0.0105	-0.0231**	0.0109
Size (revenue)	0.0091*	0.0052	0.0062	0.0051	0.0366*	0.0199
Size (assets)	0.0967***	0.0097	0.0889***	0.0096	0.0991**	0.0388
Growth	0.0057	0.0744	-0.0900	0.0684	-0.2469	0.3142
Asset structure	0.0853*	0.0518	0.0025	0.0426	0.2171	0.2628
Current ratio	0.0025***	0.0008	0.0001	0.0000	0.0007	0.0024
Solvency ratio	-0.0000	0.0000	-0.0000***	0.0000	-0.0001***	0.0000
Leverage	-0.0002***	0.0001	-0.0002***	0.0001	-0.0009	0.0009
R&D expenditure	0.0003***	0.0001	0.0004***	0.0001	0.0003***	0.0001
Constant	-0.2090***	0.0275	-0.2215***	0.0307	-0.0939	0.1573

Threshold Tests and Threshold Estimates for ROA

Threshold variable	P-value	Threshold
Carbon price (single threshold)	0.0002	8.0
Carbon price (double threshold)	0.6739	4.3

Threshold Regression-ROA Part A

Variable	Linear Model		Threshold Regression Model			
			Low carbon price regime ≤ 8		High carbon price regime > 8	
	(1)	(2)	(3)	(4)	(5)	(6)
	Coef.	SE	Coef.	SE	Coef.	SE
Carbon Price	0.0275**	0.0111	0.0725**	0.0289	-0.0974***	0.0315
Green Innovation	-	-	-	-	-	-
Size (revenue)	0.1441***	0.0196	0.1562***	0.0190	0.0270	0.0616
Size (assets)	0.0661	0.0527	0.0443	0.0506	0.6914*	0.3924
Growth	0.3421	0.2795	0.3552	0.2806	0.2455	0.6775
Asset structure	1.2239**	0.5616	1.2161**	0.5628	1.0346	0.7559
Current ratio	0.0168***	0.0047	0.0172***	0.0050	0.0032	0.0089
Solvency ratio	-0.0045	0.0033	-0.0055	0.0042	-0.0003	0.0003
Leverage	-0.0003*	0.0001	-0.0003*	0.0002	-0.0004***	0.0001
R&D expenditure	0.0001***	0.0000	0.0002***	0.0001	0.0001*	0.0000
Constant	-0.7659***	0.0647	-0.7104***	0.0648	-3.3930**	1.4096

Empirical Results

Threshold Regression-ROA Part B

Variable	Linear Model		Threshold Regression Model			
			Low carbon price regime ≤ 8		High carbon price regime > 8	
	(1)	(2)	(3)	(4)	(5)	(6)
	Coef.	SE	Coef.	SE	Coef.	SE
Carbon Price	0.0342***	0.0110	0.1371***	0.0277	-0.0983***	0.0313
Green Innovation	0.1434***	0.0315	0.0646**	0.0286	0.0503***	0.0151
Size (revenue)	0.1423***	0.0198	0.1541***	0.0192	0.0281	0.0525
Size (assets)	0.0800	0.0554	0.0573	0.0529	0.6953***	0.0826
Growth	0.3117	0.2733	0.3165	0.2738	0.2366	0.6383
Asset structure	1.2133**	0.5590	1.1995**	0.5594	1.0478**	0.5200
Current ratio	0.0164***	0.0047	0.0169***	0.0050	0.0032	0.0080
Solvency ratio	-0.0045	0.0032	-0.0055	0.0042	-0.0003**	0.0001
Leverage	-0.0003*	0.0001	-0.0003*	0.0002	-0.0007***	0.0001
R&D expenditure	0.0001**	0.0000	0.0001***	0.0000	0.0001**	0.0000
Constant	-0.7968***	0.1960	-0.7396***	0.1910	-3.3754***	0.5017

Conclusions

- Examine if the implementation of cap-and-trade carbon prices in the US fosters green innovation and financial performance or introduces transition risks, as framed by the Porter Hypothesis.
- Moderate carbon pricing enhances green innovation and financial performance.
- However, excessively high carbon prices introduce significant risks with negative consequences, providing important insights for policymakers for consideration of optimal carbon pricing, gradual implementation of environmental policies and encouraging green innovation.

Thank you!!

Questions?

Appendix

Variable	Description
Size (sales)	Natural log of total sales.
Size (assets)	Natural log of total assets.
Growth	Ratio of intangible assets to total assets.
Asset structure	Ratio of fixed assets to total assets.
Current ratio	Ratio of current assets to current liability.
Solvency ratio	Ratio of long-term debt to long term assets.
Leverage	Ratio of long-term debt to shareholder's equity.
R&D expenditure	Natural log of R&D expenditure.