Mitigation vs Adaptation: which one benefits the most for firms?

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Abstract: Over the past decades, the relationship between Environmental and Financial Performance has been widely discussed. Using an international sample of listed firms during the period of 2011-2015, the study focuses on the relationship of mitigation and adaptation strategies on financial value. Based on the reputational risk, our results show the presence of a negative relationship between firm-level mitigation and financial value. Surprisingly, environmental policy stringency has a negative effect on firms' economic value. The natural resource-based view (NRBV) provides an appropriate theoretical basis for discussing the effect of resources and capabilities to the financial performance of adaptation. As a result of adopting adaptation strategies, a firm's financial value will increase in the long-term. Given support to the Porter hypothesis, our results show that the positive relationship between firm adaptation and financial value is more likely to prevail in the long term. To the best of our knowledge, this study is the first dealing with the effect of both mitigation and adaptation strategies on listed firms' financial value. We contribute to the literature providing proof of differences of effect between mitigation and adaptation strategies.

Keywords: Mitigation, adaptation, environmental performance, financial performance, climate change.

I. Introduction

We can assert that the Kyoto Protocol will be ineffective in addressing the risks of global climate change (Nordhaus, 2006; Tol, 2009; Hsiang and Jina, 2014). Given the irreversible nature of climate change, even radical reduction targets would not slow down global warming. A concrete example concerns about the effect of rising temperatures. Pal and Eltahir (2016) predict that the temperatures in Southwest Asia will rise beyond the habitable level if global warming is nothing is done. The economic impact of climate change has also been widely discussed (Dell et al., 2009; Bansal and Ochoa, 2012). It exists two ways of dealing with environmental challenges: mitigation and adaptation. The IPCC (2001) defines mitigation as 'anthropogenic intervention to reduce the sources or enhance the sinks of greenhouse gases'. An alternative is reducing vulnerability by adapting to global warming. Adaptation is defined as 'adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploit beneficial opportunities' (IPCC, 2001).

Climate change influences all the economic actors and policy-makers. In this way, it will push firm's managers to rethink their corporate policy. The question facing corporate managers is how green strategies to reduce environmental impacts affect financial performance. In the empirical background, the relationship between Environmental Performance and Financial Performance has been widely discussed without evidence of consensus (King & Lenox, 2001; Konar & Cohen, 2001; Delmas et al. 2015). Horvathova (2010) identified in a meta-analysis 35 positive relationships between EP and FP, 10 negative and 19 insignificant relationships.

Then, this study investigates whether mitigation and adaptation increase a firm's financial value. Based on the reputational risk theory (Davis, 1976; Ambec & Lanoie, 2008), we study the effect of mitigation on financial value measured by ROA and Tobin's q. We used the Environmental Policy Stringency Index (Botta & Kozluk, 2014) and the Total Environmental Damages (Trucost) to measure mitigation strategies at country-level and firm level, respectively. The NRBV theory (Hart, 1995) and the Porter hypothesis (Porter & Van der Linde, 1995) give a theoretical framework to analyse the economic implications of adaptation. We perform our regression model with two adaptation proxies. On one hand, we use the Climate Change Performance Index (developed by Germanwatch) at country-level. On the other hand, we use the Environmental Innovation Score by firm.

A total sample of 8,581 firm/years for the period from 2011 to 2015 was used in the analysis. Consistent with our expectations, we find that mitigation and adaptation have different impact on financial value. We contribute analysing the gap in the literature introducing mitigation and adaptation in the EP/FP relation at two levels: companies and countries. We address the problem of choosing an appropriate proxy for environmental performance. To the best of our knowledge, it is the first paper combining mitigation and adaptation in the assessment of environmental performance in the study of the EP/FP relationship. We find a positive and significant effect between firm-level mitigation and financial value. Surprisingly, at the macro-economic level we find a negative relationship between environmental stringency policies and Tobin's q whereas adaptation proxy has a positive and significant effect. Our results show that adaptation show that the positive relationship between firm adaptation and financial value is more likely to prevail in the long term given support to green literature (Porter & Van der Linde, 1995). In this way, our paper highlights that mitigation and adaptation have different investment time horizon that will affect the financial value of firms (Horvathova, 2012; Lee & Min, 2015).

Our research article show the differences of impact of two green strategies: limit its environmental damages and green innovation for the purposes of adapting its firm strategies to climate change. Beyond the empirical contribution, our findings have an important implication for the firms' managers, policymakers and investors. Mitigation and adaptation positive effects on financial value are conditioned by multiple levels. Corporate managers will need to take account the investment time horizon and macro-economic environmental policies before choosing to adopt a mitigation or adaptation strategies.

The remainder of this paper is organized as follows: We next review the literature and then develop our hypothesis in Section II. Section III presents the methodology, gives descriptive statistics. Then, we present and discuss in section IV ours results on the effect of mitigation and adaptation on financial value. Section V concludes the research paper.

II. Literature Review and hypothesis development

Historically, studies have shown that reductions in pollution should lead to a decrease of financial performance. Considering the Friedman's approach (1970), green investments would constitute additional costs affecting profitability. Reductions in pollution are seen more as philanthropy than profit maximization. Throughout the industrialization period, firms have largely managed with little thought to climate change. From this perspective, environmental concerns will divert managers from the maximization of profit. However, proponents of stakeholder theory have criticized Friedman's theory. They argue that neoclassical theory is inconsistent with corporate social responsibility to stakeholders. In this way, Porter and Van der Linde (1995) introduced with the support of some scholars that green investments might increase production efficiency and competitiveness. The authors argue that environmental regulation may stimulate innovation, which can offset the cost of environmental compliance. We therefore have the "Does it pay to be green?" and the win-win hypothesis (Porter and Van der Linde, 1995). Thus, we find a number of studies, which proposed explanations for the existence of a relationship between Environmental Performance and Financial Performance. Since the 1990s, we find a majority of research articles focused on the relationship between corporate social responsibility and financial value. In the empirical background, the EP/FP relationship has been widely discussed without evidence of consensus. Horvathova (2010) demonstrates the uncertainty about the EP/FP relationship in a meta-analysis. Although previous empirical results remain inconclusive, the relationship between environmental performance and financial performance seems to be positive.

Examining the measurement of environmental performance, empirical background studying the relationship between environmental performance and financial value has used a large variety of environmental performance measures. Some have used data from the Toxic Release Inventory (Konar & Cohen, 2001; Elsayed & Paton, 2005). Studies also used greenhouse gas (GHG) emissions as environmental indicator (Chava, 2014; Matsumura and al., 2014). On the other hand, Dowell et al. (2000) used environmental standards to study the relationship between local environmental standards and the market value of firms. The large variety of environmental measures may explain the lack of consensus in the EP/FP relationship. Climate change implies significant challenges for firms. Managers will have to find solutions in terms of mitigation and adaptation (Linnenluecke et al. 2016). To properly represent responses to climate change, we assess in two concepts the environmental performance, distinguishing mitigation and adaptation. In this article, we decide to compare the impact of mitigation and adaptation on financial value of firms. On the empirical side, we find a majority of research articles dealing with mitigation (i.e., reducing impacts on the environment), whereas the impact of adaptation (i.e., adjusting to the impacts of environmental change) has so far received little discussion. We formulated that by testing two main hypotheses.

Effect of mitigation on financial value

Environmental performance is associated with reputational benefits. For example, Davis (1976) suggest that CSR policies may lead to improvements in the firm's image. Environmental-friendly firms gain a competitive advantage by improving their reputation. Firms reducing their environmental damages show to investors that they can be more competitive in a market environmental facing climate change. The investors' perception of future market valuation will be more important. Entering a period of new environmental regulations, a firm that mitigates its environmental damages show a coping capacity to institutional pressure to comply with new regulations. Reduce their environmental damages will be a signal for investors. Mitigating firms will be seen as virtuous firms by investors less vulnerable to climate change. A firm has enhanced reputation for environmental responsibility, such as reduce carbon emissions, can potentially bring economic benefits from the broader stakeholder community. Mitigation may help build a good reputation with customers, investors or regulators. It could also facilitate access to capital and increase customers' loyalty (Ambec and Lanoie, 2008). Consequently, mitigation strategies may improve the reputation of a firm that could lead to increasing revenues. A good environmental reputation could lead a competitive advantage for green firms. In the reverse case, reputational risk is a real threat which can occur through many ways. Firms need to be socially and environmentally responsible to minimize the reputational risk. The PG&E bankruptcy highlights this phenomenon. Suspected as the cause of Californian fires in 2018, it was the first case of bankruptcy linked to climate change. Stakeholders are more and more concerned about the environment (Russo & Fouts, 1997). In this vein, reputation has a strong relationship with economic performance.

On the empirical side, we find a majority of articles dealing with the "mitigation" aspect on the financial value (Hart & Ahuja 1996; King & Lenox 2001; Delmas et al. 2015). Using emission of toxic chemicals by firm, Konar and Cohen (2001) show, that poor environmental performance is negatively correlated with the value of intangible assets. Some researchers developed a more complex relationship adding the impact of environmental issues (Dowell et al., 2000; Delmas et al., 2015). Dowell et al. (2000) found that firms with stringent global environmental standards have much higher market values, as measured by Tobin's q. As scholars have demonstrated, companies that have mitigated their environmental damages gain a competitive advantage and a positive impact on their firm valuation (Derwall et al. 2005). Matsumura et al. (2017) find that, on average, for every additional thousand metric tons of carbon emissions, firm value decreases by $212,000, where the median emissions are 1.07 million metric tons. For purposes of understanding the differences that exist between macroeconomic and microeconomic variables effects, we will test the effect of mitigation at both country-level and company-level. Then, we formulate the following hypotheses:

Hypothesis 1: All else equal, the more we observe mitigation the more positive the firm's financial value.

H1a: All else equal, the more a country has a stringent environmental policy the more positive the firm's financial value.

H1b: All else equal, the more a firm mitigates its environmental damages the more positive its financial value.

Effect of adaptation on financial value

The main alternative to response to global climate change is by adaptation. Increasingly societal concerns about climate change, corporate managers have to think differently. Firms are pushed to change their business practices by developing green strategies. Beyond mitigation strategies, some firms develop green product and change their processes. Thus, the main issue for firms is to adapt to climate change at acceptable costs. According to Porter and Van der Linde

(1995), outcomes from innovation are not immediately apparent and firms need a long-term perspective on the innovation, particularly since "innovation cannot offset the cost of compliance, especially in the short term before learning can reduce the cost of innovation based solutions. In this way, the validation of the Porter and Van der Linde's theory involves the effect of adaptation on financial value study. The authors argue that poor environmental performance is a sign of inefficiency that leads to competitive disadvantages. As a proactive response to climate change requires structural changes, it involves development, acquisition and implementation of new technologies and services to lead to a competitive advantage. Firms cannot just mitigate their environmental damages but they have to restructure their business strategy (Russo and Fouts, 1997; Guenster et al. 2005)

Consequently, we mobilize the natural resource-based view (NRBV) to discuss the impact of adaptation on firm's financial value. Based on the resource-based view theory (RBV), Hart (1995) developed the NRBV theory by including natural environmentally caused constraints and opportunities. The NRBV theory recognizes the importance of resources and capabilities. Firm's innovation strategy lead to opportunities for increasing revenues and reducing costs (Ambec and Lanoie, 2008). Adaptation can lead to an increase in revenues through two different channels. At first, innovation will lead to a differentiation advantage. It will create an opportunity to increase product-selling prices and this will cause revenues to soar (Hart & Ahuja, 1996). Environmental innovation practices will be considered as a way to optimize operations and product characteristics. Green products or services can allow firms to exploit new markets. Even if green products are more expensive to produce, consumers will be able to pay more for eco-products or services. Second, innovation strategies could lead to a first-mover advantage. Integrating the environmental matters into products and processes can create a 'first-mover' effect in emerging green market products (Hart, 1995). This competitive advantage could result from environmental research and development expenses (Lee and Min, 2015). Firms will have a technological advantage and will be the leading light of the market for stakeholders. According to natural resource based theory (Hart, 1995), key resources and capabilities of a firm affect its ability to sustain its competitive advantage. In fact, firms that do not integrate the environment into their strategy are likely to lower investors' market-value expectations calculated by Tobin's q. At the macro-economic level, climate change contributes to heightened income inequality between countries. According to Linnenluecke et al. (2016), the adaptation imperative arises from the need to manage risks in order to minimize the physical impacts of environmental change. The need to adjust to new technological developments for firms will lead to adaptation. Firms adapted to climate change will have a position of market leader for stakeholders. They will also be considered as more prepared to future crisis (Orlitzky et al. 2003).

Drawing on the empirical background, there is a large literature around the effect of mitigation on financial value. However, we do not find plenty of articles about the adaptation-financial value relationship. Lee and Min (2015) used the green research and development investments as proxy for eco-innovation. They show that green R&D is positively related to financial performance at the firm level. These findings support the Porter's theory that considers that early green investments offset operational costs and enhance financial returns in the long-term (Aragon-Correa et al. 2008; Lee and Min, 2015). Rennings and Rammer (2011) study the effects of regulation-driven environmental innovation on firm-level innovation and firm performance. Using a German firm sample, they find that both product and process innovations driven by environmental regulation create more sales with new products and costs savings. In the same way as for mitigation, we make assumptions in order to test the differences between macro-economic and micro-economic level. Consequently, we hypothesize the following:

Hypothesis 2: All else equal, the more we observe adaptation to climate change the more positive the firm's long-term perspective of financial value.

H2a: All else equal, the more a country improves his environmental innovation the more positive its long-term perspective of financial value.

H2b: All else equal, the more a firm adapts to climate change the more positive its long-term perspective of financial value.

III. Methodology

In this section, we describe the data and the methodological approach we used. Appendix I presents the definition of variables used in our study. We acquired financial data from Worldscope database and used environmental data from Trucost. Used in numerous academic research articles (Delmas and al., 2015), Trucost compiles measures of carbon and environmental footprint for more than 6000 listed firms. By covering 93% of the world stock-market capitalization, Trucost offers an effective way to develop models and highlight general trends worldwide. We also used variables from Thomson Reuters ESG – Asset4, one of the major ESG rating agencies. The Thomson Reuters ESG – Asset4 database analyses the majority of publicly traded firms and gives us environmental scores by firm. Asset4 carries out a classification into three categories: emission score, environmental innovation score and resource use score. To test our hypotheses, we mobilize environmental variables from different databases and financial variables which are presented in the following subsections.

Environmental variables

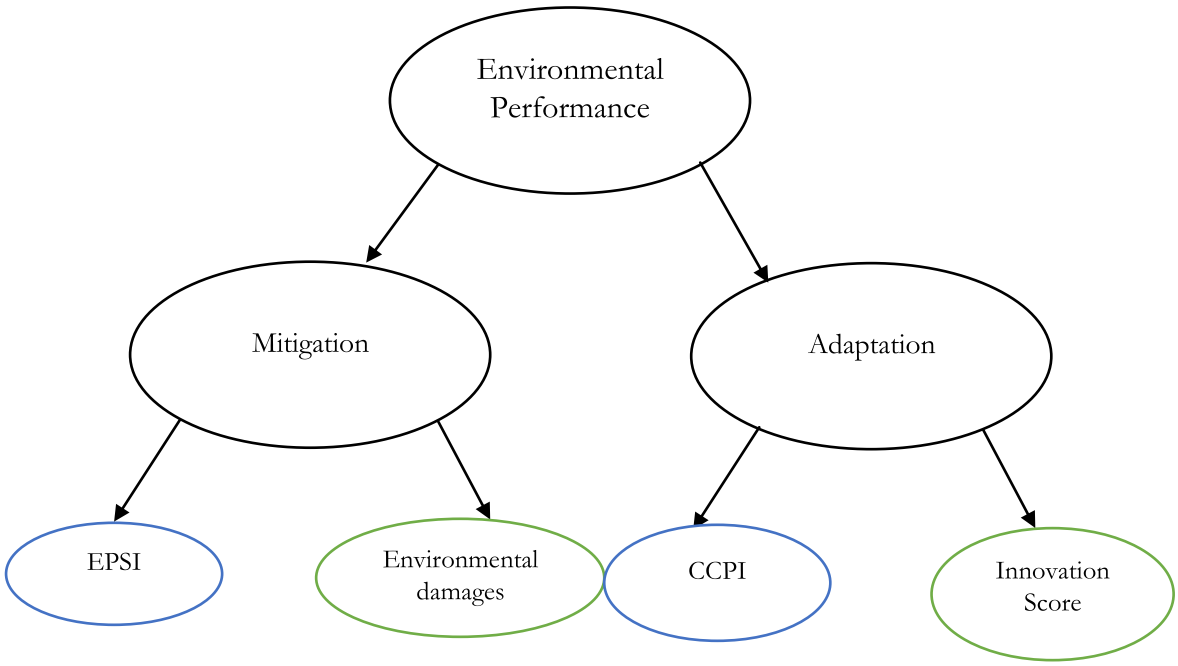
To carry out an empirical analysis and test our hypothesis, we collected for both mitigation and adaptation, one micro-economic variable and one macro-economic variable. For mitigation, we use the total environmental damages by firm given by Trucost that combine the environmental impact of direct operations and the indirect damages of the supply chain by firm. Then, we collected the Environmental Policy Stringency Index developed by the OECD. The OECD Environmental Policy Stringency Index (EPSI) is a country-specific and internationally comparable measure of the stringency of environmental policy (Botta and Kozluk, 2014). Stringency is defined as the degree to which environmental policies put a price on polluting or environmentally harmful behaviour. The index covers 34 countries for the period 1990-2015. Based on the degree of stringency of 14 environmental policy instruments, the EPSI is our proxy for mitigation variable at macro-economic level. At the country level, mitigation will be materialize by environmental regulation.

Concerning the adaptation proxies, at micro and macroeconomic scale, we use the Innovation Score by firm and the Climate Change Performance Index by country, respectively. Developed by

Thomson Reuters – ESG Asset 4, the Innovation Score reflects a company's capacity to reduce the environmental costs and burdens for its customers, thereby creating new market opportunities through new environmental technologies and processes or eco-designed products. Developed by Germanwatch (reference CCPI), the Climate Change Performance Index (CCPI) is an independent monitoring tool of countries' climate protection performance. It aims to enhance transparency in international climate politics and enables the comparability of climate protection efforts and progress made by individual countries.

Knowing that micro- and macro-economic variables would not have the same impact on firms' financial value, we use for both mitigation and adaptation, an environmental variable by firm and by country. Then, we use four environmental variables in our model. The following Figure 1 represents variables we used to assess environmental performance. Blue ellipses represent macro-economic variables and green ellipses stand for micro-economic variables.

Figure 1 Assessment of environmental performance distinguishing mitigation and adaptation



Financial variables

In the literature background, scholars dissociate short-term and long-term perspective, measured by return-on-assets (ROA) and Tobin's q, respectively. Using return-on-assets, Peloza (2009) found a positive relationship between corporate social performance and financial performance. On the other hand, some studies have been interested in long-term effects of reducing carbon footprint (Konar and Cohen, 2001; King & Lenox, 2002). For example, Konar and Cohen (2001) show that intangible assets valuation is negatively associated with level of emitted toxically chemicals. Delmas et al. (2015) used both financial indicators. They showed that a decrease in the greenhouse gases emissions decreases a company's short-term value, whereas a decrease in carbon emissions increases a company's long-term value. In our study, we use accounting and market-based measures of financial performance but not interchangeably. We chose to use Return-on-Assets and Tobin's q to approximate short and long-term view of financial performance. We obtained these variables by Worldscope database. Return on assets is an accounting indicator of how profitable a firm is relative to its total assets. Higher ROA indicates more asset efficiency. Tobin's q is defined as the ratio of a firm's market value to the replacement cost of its assets (Chung and Pruitt, 1994). Tobin's q incorporates the market value of firms. Climate change has attracted the attention of investors and Tobin's q represents a well-founded indicator for market perception of a firm's long-term value. To shed light of the robustness of results, we use both the market-to-book and the return on equity as the dependent variable.

Controls

We include a series of variables to control for other potential influences of environmental performance on financial value. In step with previous studies (Dowell et al., 2000; Delmas al., 2015), we control for firm specifications including the financial performance by return on assets (ROA), the leverage, the natural logarithm of a firm's total assets (Size), the sales growth (Sales Growth) and research & development ratio (R&D). Leverage is the ratio between book value of total debt and total assets. Sales growth represents total sales divided by sales in previous year. R&D is calculated by research and development expenditures divided by total sales. Beyond the standard set of financial variables, we also control at the country-level. The natural logarithm of GDP per capita (ln_GDP) and the GDP growth (GDP_growth) are added to the model as previously done by Huang et al. (2017).

Data analysis

We use an unbalanced panel data to estimate the effects of mitigation and adaptation on climate change on financial value of firms. To conduct our study, we used the following model:

$$\begin{aligned} Tobin's\ q_{\ t} = {} & \beta_0 + \beta_1 Environmental\ Damages_{t-1} + \beta_2 EPSI_{t-1} \\ & + \beta_3 Innovation\ Score_{t-1} + \beta_4 CCPI_{t-1} + \beta_5 ROA_{t-1} + \beta_6 Leverage_{t-1} \\ & + \beta_7 Sales\ Growth_{t-1} + \beta_8 Size_{t-1} + \beta_9 R\&D_{t-1} + \beta_{10} R\&D\ dummy_{t-1} \\ & + \beta_{11} GDP\ per\ capita_{t-1} + \beta_{12} GDP\ Growth_{t-1} + Industry + Year \\ & + Region + \varepsilon. \end{aligned}$$

Using Tobin's q as dependent variable to estimate the effect of mitigation and adaptation of long-term financial value, we used the following model for short-term perspective:

$$\begin{aligned} ROA_{\ t} = {} & \beta_0 + \beta_1 Environmental\ Damages_{t-1} + \beta_2 EPSI_{t-1} + \beta_3 Innovation\ Score_{t-1} \\ & + \beta_4 CCPI_{t-1} + \beta_5 Leverage_{t-1} + \beta_6 Sales\ Growth_{t-1} + \beta_7 Size_{t-1} \\ & + \beta_8 R\&D_{t-1} + \beta_9 R\&D\ dummy_{t-1} + \beta_{10} GDP\ per\ capita_{t-1} \\ & + \beta_{11} GDP\ Growth_{t-1} + Industry + Year + Region + \varepsilon. \end{aligned}$$

In both models, panel data include observations on N cross section units (firms) over T time-periods. β_0 represents the unobserved firm level modelled by the constant of the model. β_n are the estimated regression coefficients for each of the independent variables. This analysis contains a total sample of 8,581 firms/years from 2011 to 2015. Our study period was driven by the availability of data and represents a period of large debate on energy transition worldwide. Regressions include the region, industry and year fixed-effects. Based on the OECD classification, we define 6 regions in our sample: East Asia, Europa, Latin America, North America, South Asia and Sub-Saharan Africa. The standard errors are also clustered by firm. Yearly data are used for both environmental and financial variables. Environmental performance can take time to improve financial performance. We use lagged independent variables in our model consistent with previous studies. Konar and Cohen (2001) found different results with or without a lagged environmental variable. All the continuous variables were winsorized at the 1 and 99% levels.

IV. Results

Descriptive statistics

Appendix 2 provides the correlation coefficients among variables that compose our model. Correlations between explanatory variables are not so important as to suspect a multi-collinearity bias. In the same vein, correlation coefficients between our environmental variables allow us to regress our mitigation and adaptation proxies in the same model. *Table 1* provides descriptive statistics of our study. Our sample have an average Tobin's q of 1.69. The ratio is greater than 1, meaning that in average firms of our sample are in good position to increase their stock of fixed assets. In order to compare the effect of our environmental variables, we standardized our environmental variables to have values between 0 and 1. The mean and standard deviation of Total Environmental Damages are 0.47 and 0.21. The average level of Environmental Policy Stringency is 0.65.Adaptation proxies have a mean of 0.52 and 0.57 (Environment Innovation Score by firm and Climate Change Performance Index by country). Our sample firms have a mean return-on-assets (ROA) and Leverage of 5.42 and 24.41, respectively. The mean of natural log of their assets (Size) is 15.77. Observing the macro-economic variables, the average natural logarithm of GDP per capita of our sample is 29.07 and 2.35 for average GDP growth.

Table 1 Descriptive Statistics

Variable	Observations	Mean	Std. Dev.	Min	Max
Tobin's q	8581	1.69	1.20	0.57	7.89
ROA	8581	5.42	7.86	-35.65	31.61
ROE	8581	11.05	21.52	-94.35	84.91
Market-to-Book	8581	2.73	3.09	0	19.97
Total Env. Damages	8581	0.47	0.21	0.12	1.00
Mitigation Score	8581	0.56	0.26	0	1.00

EPSI	8581	0.65	0.23	0	1.00
Innovation Score	8581	0.52	0.26	0	1.00
CCPI	8581	0.57	0.13	0.34	0.87
Leverage	8581	24.41	17.66	0.00	83.19
Firm Size	8581	15.77	1.59	10.68	19.70
Sales Growth	8581	1.09	0.26	0.44	3.05
R&D	8581	1.82	4.70	0	34.28
R&D dummy	8581	0.54	0.50	0	1.00
GDP per capita	8581	29.07	1.14	25.67	30.49
GDP Growth	8581	2.35	1.83	-9.13	11.11

Table 2 Average macroeconomic measures by region

Region	EPSI	CCPI	GDP per capita	GDP growth	Observations
East Asia	0.71	0.51	28.81	2.68	2678
Europa	0.77	0.74	28.38	1.77	1883
Latin America	0.01	0.74	28.55	2.36	264
North America	0.67	0.50	30.09	2.09	3143
South Asia	0.28	0.69	28.26	6.45	252
SubSaharan Africa	0.09	0.60	26.66	2.38	361
Total	0.65	0.57	29.07	2.35	8581

Table 2 presents the average macroeconomic measures by region. There are a total of 8,851 observations, 36% of which come from North America. In terms of country-level environmental variables, we find some important characteristics of our sample. Data show that Europa has the highest EPSI and CCPI. European countries have the highest level of environmental standards stringency and the highest level of climate change innovation, respectively. On the other hand, we find no proof of strong correlation between these two country-level variables. For example, North America (mainly represented by United States of America) has an environmental standards stringency above average and represent the region the less climate change innovative.

Main results

This section contains the results on the effect of mitigation and adaptation on financial performance. Our regression results are organized in *Table 3* Columns (1) and (2). Column (1) presents the results with Return-on-Assets as dependent variable. Column (2) show results with Tobin's q as dependent variable.

Table 3 Regression analysis of mitigation and adaptation on ROA and Tobin's q.

VARIABLES	(1) Past	(2) Future
Total Damages	-2.597***	-0.534***
	(0.923)	(0.118)
EPSI	-5.035***	-0.489***
	(0.983)	(0.163)
Innovation Score	0.391	0.252***
	(0.413)	(0.069)
CCPI	4.054***	0.666***
	(1.376)	(0.229)
ROA		0.073***
		(0.004)
Leverage	-0.035***	-0.001
	(0.007)	(0.001)
Firm Size	-0.934***	-0.176***
	(0.105)	(0.014)
Sales Growth	1.867***	0.042
	(0.538)	(0.056)
R&D	-0.181***	0.038***
	(0.043)	(0.008)
R&D dummy	-1.549***	-0.027
	(0.273)	(0.036)
GDP per capita	0.490***	0.003
	(0.173)	(0.026)
GDP Growth	0.195***	0.010
	(0.060)	(0.007)
Industry/ Year/ Region	Yes	Yes
Cluster by firm	Yes	Yes
Constant	8.537*	3.824***
	(5.125)	(0.788)
R-squared	0.147	0.434
Observations	8,581	8,581

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Observing the financial control variables, firm size is statistically significant across both models. This result is consistent with literature (Elsayed & Paton, 2005; Delmas and al. 2015). Regarding the results, in a long-term perspective Return on Assets and Research & Development expenses have a positive and significant effect on Tobin's q. Surprisingly, Sales Growth does not have a significant impact on Tobin's q whereas it has a significant and positive impact on ROA. Findings suggest that both GDP per capita and GDP growth have a significant and positive effect on Return-on-assets. Observing the macroeconomic control variables, none of them has a significant impact in a long-term perspective. The explanatory of our model (1) is 14.7% (R-squared = 0.147). In the long-term, we find that the explanatory power of the model regressed on Tobin's q is relatively significant in order to explain the investors' long-term perspective of a firm. (R-squared = 43.4%).

Economic effect of Mitigation on financial value

Regarding mitigation effect on financial value, we can see that both our micro- and macro-economic variables have a significant impact on ROA and Tobin's q. However, we highlight contradictory results. Supported hypothesis H1b, we find that Total Environmental Damages has a negative and significant effect ($p < 0.01$) on ROA and Tobin's q. A 1% decrease in the Environmental Damages increases a company's Return-on-Assets by 2.597 (Column 1) and a company's Tobin's q by 0.534 (Column 2). Our results are consistent with prior literature (Matsumura et al. 2014). A firm that mitigate its environmental damages will benefit a higher financial value. Mitigation strategies will signal the market about good environmental management performance. Then reduce its environmental impact will increase the financial value. We can explain that positive economic impact by the firm's image strengthen (Davis, 1976). The results indicate that a firm that mitigates its environmental damages increases its financial value. The latter finding is confirmed in a short- and long-term perspective.

Surprisingly, our country-level mitigation variable has a negative and significant effect on financial value ($p < 0.01$). A 1% increase in EPSI decreases a company's ROA by -5.035 and a firm's Tobin's q by -0.489. In the light of the results, we reject the hypothesis H1a and accept the hypothesis H1b. Environmental policy stringency will have a negative impact on firms' financial value. The more a country has stringent environmental policies the more negative the firm's financial value. Environmental policies by country will be seen as a cost burden for firms. Then, investors will penalize firms for the environmental stringency of countries. Therefore, our findings do not accord fully with previous literature. We find a negative effect of environmental standards stringency; whereas Dowell et al. (2000) show that firms adopting stringent standards have much higher market values than firms adopting less stringent standards. Regulation calls expenses and transformations creating additional costs (Porter & Van der Linde, 1995). However, the response to these constraints tend to stimulate innovation. In the next section, we will discuss our findings about the effect of adaptation on financial value.

Effect and characteristics of adaptation on financial value

Column (1) in *Table 3* shows the effect of adaptation on Return-on-Assets. The results indicate that climate change innovation of countries (CCPI) is positive and significant ($p < 0.01$). The results reveal that a 1% increase in CCPI increases the Return-on-assets by 4.054. The coefficient of Innovation Score by firm is not significant at the 5% level. This result implies that companies leading environmental innovation to adapt themselves to climate change may suffer an economic loss in the short-term.

Column (2) shows the effects estimates using Tobin's q as dependent variable to materialize the long-term perspective. As predicted, the results remain unchanged for our macroeconomic variable. CCPI is positive and significant ($p < 0.01$). Climate change innovation by country has a positive and significant effect on short-term and long-term financial value, consistent with our hypothesis H2a. At firm-level, innovation (Innovation Score) is positive and significant ($p < 0.01$). A 1% increase in green innovation increases a firm's Tobin's q by 0.191. Supported the hypothesis 2b, our results indicate that higher adaptation increase financial value, but only in the long-term. Green innovation's coefficient is significant and positive when we regress on Tobin's q. Therefore, our results give support to the Porter hypothesis. The positive relationship between green innovation and financial value is more likely to prevail in the long-term. Horvathova (2012) put forward that Porter hypothesis is verified only in the long-term. In contrast to previous literature, our findings show that only adaptation has a positive and significant effect of financial value in the long-term. Investors recognize a financial advantage from green innovation in the long-term, whereas the relationship is not significant from a short-term perspective. To adopt eco-innovation at a firm level, firms need to make a long-term commitment.

Further analysis and robustness tests

Appendix 2 presents the robustness tests results with Market-to-Book and Return-on-Equity as dependent variable, respectively. Our results remain unchanged using the Market-to-Book and the ROE as dependent variable in a robustness test. From a short-term perspective, Total Environmental Damages and EPSI have a negative and significant effect on ROE. About adaptation variables, only CCPI has a significant and positive effect on ROE. From a long-term perspective, mitigation variables have a significant and negative impact on Market-to-Book. Observing the adaptation effect, coefficients of Innovation Score and CCPI both are significant and positive.

Horvathova (2010) underlines the problems to evaluate environmental performance and that a lack of objective environmental criteria exists. To address this issue, we ran a robustness test with a new Mitigation Score for firm. Using the Thomson Reuters – Asset4 database, we created the Mitigation Score. We summed the Resource Use Score and the Emission Score and divided by 2. Then, we replaced our variable Environmental Damages by Mitigation Score. *Appendix 3* presents the results of our robustness test. Mitigation Score is significant and positively related to the Return-on-Assets and Tobin's q ($p < 0.01$). A 1% increase in Mitigation Score by firm will result in an increase of 0.244 of the Tobin' s q. Our findings remain unaffected by the change of our Mitigation proxy by firm. Hypothesis 2b is supported. The result is robust in that the relationship persists regardless the proxy. Moreover, all the other coefficients remain essentially the same as the baseline model.

V. Conclusion

Despite a wide literature background dealing with the relationship between environmental performance and financial value, the debate is still on going. In this paper, we examined the relationship between mitigation and adaptation and financial value. We assess in two concepts the environmental performance, distinguishing mitigation and adaptation.

To summarize the empirical results, mitigate its environmental damages will have a positive and significant effect on financial value (in a short- and long-term perspective). However, environmental policy stringency by country will generate an economic loss for firms. Corporate managers will have to deal with a negative environmental policy pressure. Regarding adaptation effect, climate change innovation of countries will benefit for firms. Investors will reward firms located in an eco-innovative macroeconomic framework. At micro-economic level, time horizon conditioned the impact of firm adaptation on financial value. Examining impacts on short and long-term perspectives, we show that firm environmental innovation has a significant and positive effect in a long-term perspective. Investors will take green investment costs into consideration and only enhance climate change adaptation in the long term. They will consider that a firm that is more robust to climate change is also probably better in adaptation to economic change, making the firm more robust and flexible (Tol, 2005).

This study is the first to directly investigate the effect of both mitigation and adaptation on the firms' financial value. We show that mitigation and adaptation have different impact on a firm's financial value. This research paper raises the issue of economic spinoffs between reduce its environmental damages and adjust to the impacts of environmental change. Beyond the academic contribution, our findings have multi-level implications: for corporate managers, policymakers and investors. We demonstrate strong evidence of mitigation and adaptation effect on a firm's financial value that can inform all the stakeholders involved.

This study opens future paths of research. As previously studied (Hsiang and Jina, 2014, Huang, 2017), some industries are more vulnerable to climate change. One might ask about the effect of mitigation and adaptation strategies on financial value for vulnerable firms. On the other hand, Linnenluecke and al. (2016) underline the negative consequences of climate change, especially in less developed countries. Countries have a variable adaptive capacity that could moderate our results.

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Appendix 1 Variable Definition and Measurement

Variable	**Description**	**Source**
Tobin's Q	(Market value of equity + book value of assets - book value of equity - balance sheet deferred taxes)/book value of assets	Worldscope
Market-to-book	Market value of equity / book value of equity	Worldscope
Firm size	Ln(book value of total assets)	Worldscope
Return on assets	EBITDA/book value of assets	Worldscope
Sales growth	(Sales in year t / sales in year (t-1))	Worldscope
R&D expenses	R&D expenditures / sales	Worldscope
R&D dummy	Equals 1 if rd is non-available, zero otherwise	Worldscope
Leverage	Book value of debt / book value of assets	Worldscope
Return on equity	Net Income / Average Shareholders' Equity	Worldscope
Total environmental damages	The natural log of the total environmental damages by firm (direct and indirect).	Trucost
Environmental Policy Stringency Index	The OECD Environmental Policy Stringency Index (EPS) is a country-specific and measures the stringency of environmental policy. The index covers 28 OECD and 6 BRIICS countries for the period 1990-2015. The index is based on the degree of stringency of 14 environmental policy instruments.	OECD (Botta, and Kozluk (2014))
Environmental Innovation Score	Environmental innovation category score reflects a company's capacity to reduce the environmental costs and burdens for its customers, and thereby creating new market opportunities through new environmental technologies and processes or eco-designed products.	Asset4
CCPI	Climate Change Performance Index gives scores of environmental innovations of countries.	Germanwatch
Mitigation Score	(Emission Score + Resource Use Score)/ 2	Asset4
GDP per capita	Natural log of GDP per capita	WorldBank
GDP growth	GDP growth	WorldBank

Appendix 2 Correlation table

Total Damages	Mitigation Score	EPSI	Innovation Score	CCPI	Leverage
1					
0.0563***	1				
-0.0744***	0.0868***	1			
0.0333**	0.390***	0.0947***	1		
-0.0418***	0.213***	-0.0483***	0.0585***	1	
0.156***	0.0215*	-0.0420***	0.0426***	0.0219*	1
-0.112***	0.368***	0.0140	0.315***	0.00361	0.144***
0.00915	-0.0955***	0.0221*	-0.0764***	-0.0362***	-0.0272*
-0.0651***	0.0182	0.0845***	0.0273*	0.0128	-0.154***
-0.0429***	-0.0675***	0.200***	0.00331	-0.224***	0.0566***
0.0637***	-0.160***	-0.365***	-0.109***	-0.0986***	0.00601

Appendix 2 Regression analysis of mitigation and adaptation on ROE and MB

VARIABLES	(5) Past	(6) Future
Total Damages	-13.465***	-1.845***
	(2.741)	(0.331)
EPSI	-7.106***	-0.845*
	(2.572)	(0.433)
Innovation Score	1.951	0.564***
	(1.271)	(0.204)
CCPI	11.297***	2.383***
	(3.496)	(0.624)
ROA		0.132***
		(0.011)
Leverage	-0.057**	0.019***
	(0.025)	(0.004)
Firm Size	-0.938***	-0.304***
	(0.276)	(0.040)
Sales Growth	4.290***	0.088
	(1.153)	(0.131)
R&D	-0.472***	0.058***
	(0.087)	(0.017)
R&D dummy	-4.011***	-0.168
	(0.793)	(0.105)
GDP per capita	1.905***	0.051
	(0.441)	(0.068)

GDP Growth	0.743***	0.070***
	(0.173)	(0.019)
Industry/ Year/ Region	Yes	Yes
Cluster by firm	Yes	Yes
Constant	-27.947**	3.813*
	(13.059)	(2.033)
R-squared	0.095	0.262
Observations	8,581	8,581

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Appendix 3 Robustness test with Mitigation Score by firm

VARIABLES	(1) Past	(2) Future
Mitigation Score	2.841***	0.244***
	(0.470)	(0.062)
EPSI	-5.227***	-0.481***
	(0.971)	(0.163)
Innovation Score	-0.289	0.191***
	(0.421)	(0.070)
CCPI	3.233**	0.591***
	(1.341)	(0.227)
ROA		0.072***
		(0.004)
Leverage	-0.034***	-0.001
	(0.007)	(0.001)
Firm Size	-1.130***	-0.194***
	(0.110)	(0.015)
Sales Growth	2.007***	0.056
	(0.538)	(0.056)
R&D	-0.180***	0.038***
	(0.043)	(0.008)
R&D dummy	-1.385***	-0.001
	(0.269)	(0.036)
GDP per capita	0.584***	0.013
	(0.170)	(0.026)

GDP Growth	0.221***	0.012
	(0.060)	(0.008)
Industry/ Year/ Region	Yes	Yes
Cluster by firm	Yes	Yes
Constant	6.769	3.498***
	(5.043)	(0.782)
R-squared	0.151	0.433
Observations	8,581	8,581

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1