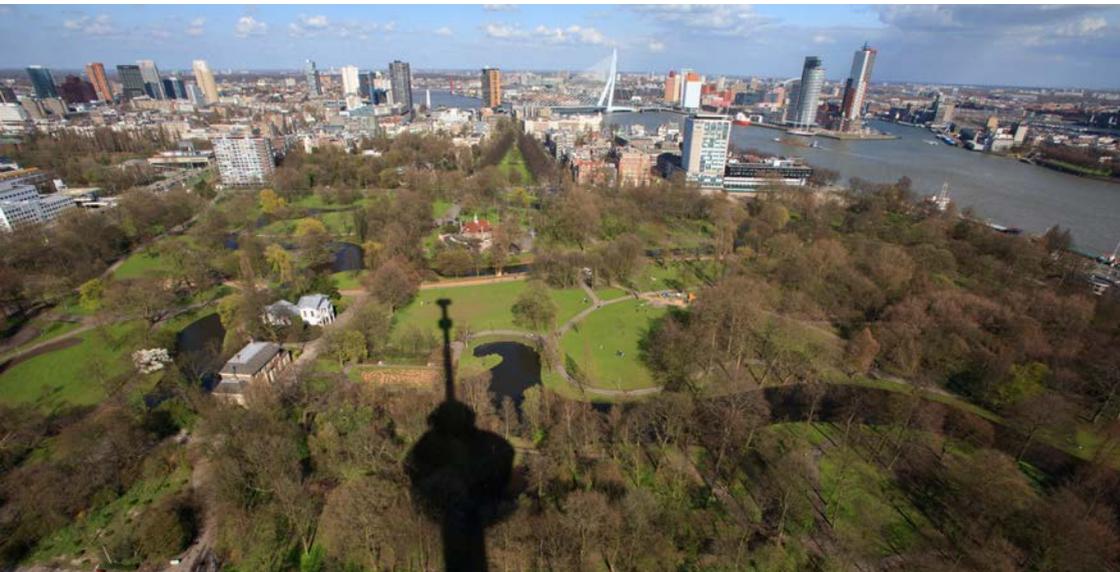


Rotterdam School of Management
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Erasmus Platform for Sustainable Value Creation

Climate change finance: Insights from research

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1 How climate change affects finance

This is an overview of the effects of knowledge about climate change in the financial sector. Research into climate change and finance is a growing field, and the findings of such research have increasingly important implications. Six key papers in different areas of finance that are affected by climate change are discussed in this booklet: banking, institutional investing, portfolio returns, real estate and long-term investments, and corporate finance.

Our reviews emphasise the essence of each investigation and bridge the gap between theoretical knowledge and practical action. We also provide indications for the future of finance-climate change research.

2 Introduction

Climate change is becoming important for society, government and business. But academics have been concerned with climate change for a longer time. They forecast it will bring many changes such as melting icecaps and rising sea levels – with increased flooding and destruction of coral reefs, more extreme weather including hurricanes and wildfires, increasingly frequent heatwaves and more severe droughts, increasing effects on health, and disruption to food chains. As the public becomes aware of the effects of climate change for humans, for ecosystems and the Earth, the call for climate change mitigation and adaptation programmes intensifies.

There are already many initiatives that tackle the problem of climate change across a broad front. One of the key breakthroughs was the ratification of the 2015 Paris Agreement by, at the time of publication, 184 countries, committing to efforts to keep temperature rises below 2°C. Intergovernmental panels have become more active in producing legislation and education on climate change, and the public is becoming more supportive of climate change mitigation. The international agreement has now been actioned at regional and country levels. New instruments, including carbon taxes, have been proposed to achieve the ambitious targets for reducing carbon emissions.

In the private sector, there is also an increasing need to adapt to this and adopt new instruments and mindsets. We present an overview of sophisticated climate finance topics that help to quantify the risk and the opportunities for businesses in the private sector, in particular for financing and investment activities. These topics cover: risk and returns; real estate investments; risk for banks; the impact of and for institutional investors; portfolio strategies and hedging; and corporate finance. The objective is to elaborate on the latest developments in climate finance and present them to the business world.

Climate change research was highlighted in business and economics academia in 2018 when the Nobel Prize for economics was awarded to William Nordhaus 'for integrating climate change into long-run macroeconomic analysis' and to Paul Romer 'for integrating technological innovations into long-run macroeconomic analysis'. The Nobel Laureates stress the importance of climate and technological change as drivers of endogenous growth, that is, economic growth that has as main ingredients human capital, innovation, and knowledge. The basic idea is that the human economy gets what it aims for. If we aim only for economic growth, then we get that – but with major effects on the climate. If we aim for carbon reductions instead, we may be able to mitigate climate change.

In 2018, the Erasmus Platform for Sustainable Value Creation opened its doors at RSM in Rotterdam. Its purpose is to create a place where business and academia can help each other

in formulating practical knowledge of sustainable finance. It's a place for generating meaningful insights and a forum for critical dialogues. Part of its mission is an annual review and forecast for climate finance. I would like to thank our fellow, Professor Gianfranco Gianfrate of EDHEC Business School, for leading this year's overview, which provides interesting but sobering reading.



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3 Implications for business

While the effects are so far largely invisible, the financial industry is already affected by climate change. The effects of climate run deep into many financial fields. Banks that ignore the call for sustainable investments will inevitably face severe losses in the future, and this is something that we will discuss later; banks should proactively integrate sustainability in their business model if they want to survive and thrive.

Key financial players are aware of the substantial risks associated with climatic changes and they are looking for ways to manage those risks. Institutional investors appear to be one of the driving forces behind the environmental and social performance of companies. Through active ownership institutional investors, in particular European investors, are able to drive the sustainability performance of invested companies all around the globe. Motivation for such calls are financial as well as social choices. While European investors expand their portfolios steadily in the United States, they are also 'greening' the U.S.

Particularly interesting to investors is the location of the company in relation to the Equator. The equity of companies close to the Equator is riskier than companies further away from it. The risk of rising temperature due to climate change, and the consequences, are greater for countries closer to the Equator for a range of reasons. Investors in companies located in these latitudes demand a risk premium. The demand for such premiums diminishes when investors look at companies located closer to the geographical poles.

The main contributor to climate change and rising temperature is CO₂ emissions. Rising temperatures have worldwide effects and investors should seek to limit investment in industries that release carbon dioxide into the atmosphere. Investing in industries listed in a decarbonised index is a way for investors to mitigate the effects of climate change through their investment decisions without sacrificing financial returns.

Another way that investors can mitigate their impact on the climate is to support long-term climate change abatement investments. But it's still unclear what an appropriate discount rate would be for investments with such a long horizon in which the principal return is the reduction of future CO₂ costs.

Companies must deal with growing pressures to consider their environmental impact. Moreover, companies must deal with potential pricing of carbon emissions and the future development of such prices as this can seriously affect operating cash flow. Companies should, therefore, adopt internal carbon pricing.

4 Climate and finance – useful knowledge

Economists around the world are busy investigating the relationship between climate and finance, and the amount of new knowledge from research in this field is growing steadily. Here are six important papers that provide useful knowledge that can be used by investors, financial professionals and corporate executives.

Themes and papers

1 Banking and sustainability risks

Battiston, S., Mandel, A., Monasterolo, I., Schütze, F., & Visentin, G. (2017). *A climate stress-test of the financial system*, *Nature Climate Change*, 7: 283–288.

2 Institutional investors and active ownership

Dyck, A., Lins, K., Roth, L., & Wagner, H. (2019). *Do Institutional Investors Drive Corporate Social Responsibility? International Evidence*, *Journal of Financial Economics*, 131(3): 693-714.

3 Risk and returns

Bansal, R., Ochoa, M. (November 2011), *Temperature, Aggregate Risk, and Expected Returns*, NBER Working Paper No. 17575

4 Portfolio strategies and climate risk hedging

Andersson, M., Bolton, P., Samama, F. (April 2016), *Hedging Climate Risk*, *Financial Analysts Journal* 72 (3): 1-20.

5 Real estate and long-term investments

Giglio, S., Maggiori, M., Stroebel, J., Weber, A. (November 2015), *Climate Change and Long-Run Discount Rates: Evidence from Real Estate*, NBER Working Paper No. 21767

6 Corporate finance and internal carbon pricing

Aldy, J., Gianfrate, G. (May-June 2019), *Future-Proof Your Climate Strategy*, *The Harvard Business Review*.

5 Banking and sustainability risks

A climate stress-test of the financial system

Business and business school relevance:

The financial industry is already feeling the effects of climate change (and when finance is affected, business is affected overall). This situation continues to intensify. In any case it is clear that human economic activity must shift drastically if the 2°C temperature rise limit, agreed to by 184 signatories of the Paris Agreement (2018), is to be met. Yet key players in the financial sector, including banks, investment funds, insurance and pension funds, individuals, governments, non-financial companies and other credit institutions, continue to have exposure to (or 'invest in') fossil fuels and other climate-policy-relevant sectors. This exposure may pose a huge risk to (European) financial institutions if new climate policies and regulations prevent them from going on with 'business as usual'. These players are therefore vulnerable to 'climate-policy shocks', in which invested equity capital in firms in climate-policy-relevant sectors will be lost. Estimated equity exposures enable us to approximate Value-at-Risk (VaR) for shocks to climate-policy-sectors, providing a picture of potential bank losses. Research indicates that 'green' banks, with equity holdings wholly in renewable-based utilities, are more resilient to shocks over time than are 'brown' banks (with equity holdings in fossil fuel-based utilities and who maintain equity holdings in the fossil fuel sector.)

Financial sector exposure to fossil fuels

Human economic activity has to change drastically if we are to meet the 2°C temperature rise limit in the Paris Agreement; in particular, this applies to the consumption of fossil fuels. Meeting the 2°C target and putting a limit on global warming means leaving reserves unused until at least 2050: leaving 82% of global coal reserves where they are, leaving 49% of global gas reserves in the ground, and leaving 33% of global oil reserves untapped. Yet, European financial institutions have exposure to (are invested in) fossil fuels, to around 1.3% for banks, 5% for pension funds and 4.4% for insurance companies, in relation to their total assets. This exposure may be a huge risk if additional policies and regulations prevent such companies from continuing their business.

Division of financial assets

Financial institutions' assets can generally be divided into three types:

- » equity holdings (both tradable and private shares)
- » bond holdings
- » loans

Each of these asset classes can mean the institution is exposed to investment in fossil fuels.

Reclassification of NACE Rev. 2

Industries are classified according to the statistical classification of economic activities in the European Community, abbreviated as NACE. 'Rev. 2' is a revised classification from 2007. However, the sectors in NACE Rev. 2 do not represent financial exposure to climate regulation. The authors propose a new definition of sectors based on the direct and indirect (through the supply chain) level of greenhouse gas emissions. The new sectors that originate from exposure to climate policy are:

1. fossil fuels
2. utilities
3. energy-intensive manufacturing
4. housing
5. transport

And two residual sectors:

6. finance
7. other

Categorisation of financial players

Key players in the financial sector that may have varying exposure to fossil fuels or other climate-policy-relevant sectors (via their financial assets) can be identified. Foremost amongst these investor types are:

- » banks
- » investment funds
- » insurance and pension funds
- » individuals
- » governments
- » non-financial companies
- » other credit institutions
- » other financial services that may provide credit

Equity exposure to climate-policy-relevant sectors per financial actor

In Table 1 below the individual and cumulative exposure to climate-policy-relevant sectors per financial actor is displayed. The relative equity portfolio exposure to the fossil fuel sector appears to be relatively low for all types of financial actors. However, the relative equity portfolio exposure of all financial actor types to all climate-policy-relevant sectors, in particular exposure to the energy-intensive sector, is extensive. Moreover, financial actors bear additional indirect exposure to climate-policy-relevant sectors, as the financial sector itself is also exposed to these sectors). At individual investment fund and banking level, BlackRock and JP Morgan Chase have the highest exposure to climate-policy-relevant sectors, respectively.

Table 1: Average equity portfolio exposures in percentages (%).

	IFs (5,124)	Banks (798)	IPFs (6,392)	NFCs (14,851)	OFSs (3,081)	GOV (125)	Indi- viduals (33,733)	OCIs (955)
Fossil fuel (767)	4.91	6.87	6.16	6.12	4.73	12.88	4.38	4.08
Utilities (216)	1.36	2.68	1.60	1.80	1.46	6.27	0.80	2.10
Energy-intensive (3956)	27.89	24.52	25.37	27.86	25.79	19.51	27.28	21.15
Housing (797)	5.03	5.84	4.68	7.52	4.06	7.69	5.21	7.13
Transport (224)	2.46	2.59	1.93	1.90	2.13	1.32	1.19	1.53
Finance (2659)	15.09	20.09	17.98	13.03	17.89	17.01	19.86	25.77
Other (6259)	43.27	37.43	42.29	41.75	43.93	35.32	41.27	38.25
Cumulative climate-policy- relevant sectors	41.65	42.50	39.73	45.22	38.18	47.67	38.87	35.98

How to read this table:

This table represents the mean of the relative exposure of individual financial actors of given type in each sector as a percentage of the financial actor's total portfolio of equity holdings. The last row represents the cumulative exposure of the average financial actor of each type over all climate-policy-relevant sectors (i.e. fossil fuel, utilities, energy-intensive, housing, and transport). The absolute numbers used in the data set are presented (in parentheses).

Potential bank losses due to climate-policy shocks

The above estimated equity exposures enable us to approximate Value-at-Risk (VaR) for shocks to climate-policy-sectors. The VaR is a measure of the risk of loss for investments, creating an estimate of how much a set of investments might lose. It can provide some confidence that losses will not exceed a certain amount over a specified time interval. The individual bank exposures also allow us to calculate individual VaR levels. Systematic losses due to climate-policy shocks occur in two ways: direct losses (losses in banks' equity due to direct exposure to shocks) and indirect losses (losses in banks' equity due to devaluation of counterparties' debt obligations). Indirect losses quantify the amplification of losses due to financial interconnectedness. The paper ('A climate stress-test of the financial system') estimates the potential losses for the 50 largest European banks.

100% Shock. In the worst-case scenario climate-policy shock leads to a total demolition of the equity of firms in the climate-policy-relevant sector. This is a 100% shock: all invested equity capital in firms in the climate-policy-relevant sector will be lost, providing an upper bound of losses (because losses of climate-policy shocks cannot get worse than this). Equity losses (relative to total equity) for a 100% shock in four different scenarios are presented in Table 2.

Table 2: Different upper bound shock scenarios and effect of relative equity losses on 50 largest European banks (excluding subsidiaries).

	Sector shock (100%)	First Round Relative Equity Losses	Second Round Relative Equity Losses
	Fossil fuels	2.55%	(6.08±0.10)%
+	Fossil- fuels Utilities	3.79%	(9.75±0.15)%
+	Fossil fuels Utilities	13.18%	(27.91±0.45)%
+	Energy-Intensive		
	Fossil fuels	15.09%	(30.24±0.40)%
+	Utilities		
+	Energy-Intensive		
+	Housing		
+	Transport		

How to read this table:

A 100% sector shock to fossil fuels, utilities, and the energy-intensive sector will on average lead to a 13.18% loss in equity capital for the top 50 largest European banks in the first round, rising to an average of 27.91% in the second round.

Realistic Shocks. As the 100% shock scenario only provides an upper bound of losses, more realistic approximations can be determined by using a database that provides estimates of the impact and timing of climate mitigation policies on energy sectors. For example, auxiliary estimates for the renewable-energy-sector are provided because shocks to climate-policy-relevant sectors (that have negative impact) might enhance performance of the renewable-energy sector. Calculating the shock estimates of 5,421 different shock scenarios, from 2019 to 2050, led to the following effects:

Table 3: Summary statistics of shocks sample. Under assumptions specified in Battiston et al. (2017) these can be interpreted as equity effects.

Shocks on	Mean	Median	Max	Min
Fossil fuel	-2.40%	-1.75%	+91.23%	-87.96%
Utilities Fossil fuel	-6.25%	-4.90%	+81.22%	-89.17%
Utilities Renewa-bles	+10.38%	+8.14%	+88.47%	-39.69%

How to read this table:

An average shock leads to a 2.4% and 6.25% decrease to the fossil fuel sector and fossil fuel based utility sector, respectively. The renewable-based utility sector, however, experiences an increase of 10.38%.

Green versus brown banks

To estimate the VaR for realistic scenarios, the paper’s authors take two banking strategies into particular consideration: ‘green banks’ and ‘brown banks’. Green banks are classified as banks whose utilities equity holdings are wholly in renewable energy. Brown banks are banks whose utilities equity holdings are in fossil fuel-based utilities and who maintain equity holdings in the fossil fuel sector. Comparing green with brown can deliver valuable information on banking strategies.

In the first round of losses, brown banks incur heavier losses than green banks (Table 4). These losses are, however, small when compared to the average total assets of these banks (604 Billion USD). In comparing green banks to brown banks, one can see that green banks perform better in terms of potential losses from climate-policy shocks.

Table 4: Summary statistics of asset variations under shock distribution for the average green and brown bank. All values are in USD million.

Round	Investment strategy	Mean	Median	Standard deviation	VaR 5%
1st round	Green bank	+22.25	+17.46	30.50	18.07
	Brown bank	-33.10	-26.55	74.65	131.27
1st + 2nd round	Green bank	+18.47	+17.45	37.66	42.53
	Brown bank	-87.04	-62.67	153.62	309.92

Winners and losers

These results in Table 4 show how climate policies can generate volatility in asset prices and determine ‘winners and losers’ among financial actors. Indirect losses further polarise the distribution of losses between green and brown banks. Hence - relative to a baseline of no climate policy - banks that start divesting from climate-policy-relevant sectors and investing in the green energy sectors are expected to benefit from positive volatility. This is in contrast to (brown) banks that continue to do business-as-usual, and which could face losses in asset value.

Greater than calculated: exposure to climate-policy-relevant sectors

The apparently limited magnitude of banks' losses is due to the fact that European banks have limited direct investments in the equity firms mostly because of regulatory constraints (Basel framework). Due to a lack of data, exposure to climate-policy-relevant sectors via channels other than equity cannot be calculated on individual-bank level as yet. It is therefore likely that exposure to climate shocks is in reality much greater than in the above calculations.

Read more about the research underlying this chapter:

- Battiston, S., Mandel, A., Monasterolo, I., Schütze, F., & Visentin, G. (2017). A climate stress-test of the financial system, [Nature Climate Change, 7: 283–288](#)

Read related literature from RSM:

- Gianfrate, G., Schoenmaker, D., Wasama, S. (2018), Cost of Capital and Sustainability: A Literature Review, working paper series, [Erasmus Platform for Sustainable Value Creation](#)
- Schoenmaker, D. (2017), [From Risk to Opportunity: A Framework for Sustainable Finance](#)

6 Institutional investment and active ownership

Do institutional investors drive CSR?

Relevance for Business and Business Schools:

While the impact of ESG performance for the average shareholder remains controversial, we know that shareholders drive important decisions in firms, and have sought the link between shareholders and Environmental and Social (E&S) decisions. The finding is that greater institutional ownership is, indeed, associated with higher and better E&S performance. How can institutional investors drive E&S performance? The mechanism known as 'voice' or active ownership is the main tool institutional investors can use to drive E&S. Voice is categorised into either public or private engagement with the firm; private seems the most effective. In setting the level of E&S performance, institutional investors may be motivated by financial returns and/or 'social norms' – norms being defined as a shared view of how investment managers and others should (or should not) behave. The influence of high social norms can cross borders. Foreign institutional investors' influence, for example, has made its way into the U.S. – and although U.S. investors are not a source of E&S improvements, European investors clearly are. These investors have a strong and significant impact on E&S performance in the U.S. It can therefore be concluded that foreign investors can 'transplant' their higher social norms.

Corporate social responsibility (CSR) and shareholders

Corporate social responsibility has become a very important topic for managers as well as investors. Environmental, social, and governance performance (ESG), along with financial performance, are two main components of CSR. However, the impact of ESG performance for the average shareholder remains controversial. Research has delivered many different results, with various underlying reasons, about the costs and benefits of improving environmental and social performance (E&S). As shareholders drive important decisions in firms, the link between shareholders and E&S decisions has been explored.

Institutional ownership and E&S performance

In an international context the relationship between institutional ownership and a firm's environmental and social performance has been sought. The finding is that greater institutional ownership is, indeed, associated with higher and better E&S performance. As such, a one standard deviation increase in institutional ownership enhances environmental performance by 4.5% and social performance by 2.1%. Institutional investors may therefore be the driving force behind CSR.

Two situations in particular influence the relationship between institutional ownership and E&S performance. First, if the institutional investor is signatory to the United Nations Principles for Responsible Investing (UNPRI), E&S performance increases 13% and 4.6%, respectively. This

is a huge increase compared to UNPRI non-signatories. Second, when a firm currently has low E&S performance, there is greater room for improvement. The E&S performance of such firms, therefore, improves rapidly after investments of UNPRI-committed institutional investors. Both situations raise confidence that institutional investors are the driving force behind E&S performance.

Box 1: Example of institutional ownership and E&S performance

To provide real-world proof of the relationship between institutional ownership and E&S performance, it is worth considering the BP Deepwater Horizon oil spills in 2010. This event arguably amplified investors' attention about the risks of weak environmental policies, increasing the perceived value of environmental commitments. It is consequently expected that if institutional ownership drives changes in firms' environmental policies, firms with greater institutional ownership at the time of a shock will be more active and responsive in improving environmental performance in the years after the shock.

Two mechanisms to drive E&S

So, how can institutional investors drive E&S performance? Two main types of mechanisms exist. The first is known as 'exit and selection' referring to negative and positive screening of firms to include in an investment portfolio. However, the exit and selection mechanism does not seem to be an important driver of E&S performance. Given this result, it is expected that the other mechanism, known as 'voice' or active ownership, is the main tool institutional investors can use to drive E&S. Voice is categorised into public and private engagement with the firm. In reviewing the annual reports of major institutional owners, it is private, rather than public engagements that are preferred and are most effective.

Motivations for institutional investors to drive E&S

In setting the level of E&S performance, institutional investors may be motivated by financial returns, social norms, or both. Norms are defined as the overarching view of how investment managers should (or should not) behave. If for instance, an investment manager's social environment - their community - is strongly focused on achieving high levels of environmental and social performance, increasing the E&S performance of firms in his or her portfolio brings the investment manager social rewards, and averts social sanctions. In this setting, investment managers can potentially drive firms to overinvest in E&S performance in the sense that they exceed the level that maximises financial returns; this becomes acceptable because it moves firms' E&S performance closer to the community's E&S ideals.

Financial motivation

According to existing research¹ the global financial crisis increased the value of the E&S performance levels of firms because such firms potentially perform better during crisis periods. Thus, if the perceived value of E&S performance increases during financial crises, a financially-motivated investor is expected to increase E&S performance when a crisis is over. The results of various tests confirm this theory.² Therefore, financial gain might be one of the underlying reasons for institutional investors to stimulate E&S performance.

Social motivation

Using methods that differentiated high- and low-social-norm countries, the authors evaluated whether social norms in the country of domicile (or origin) of foreign institutional investors, influenced investors' E&S impact. For both environmental and social scores, foreign institutional ownership of the high-social-norm group is positively associated with E&S scores; whereas the ownership of the low-social-norm group is generally not significant, related to E&S scores. The analysis suggests that E&S performance would increase by 7.4% and 5.2%, respectively, if a firm's foreign institutional investor were to come from a country with strong (instead of weak) social norms.

Geographical Grouping. By placing high- and low-social-norm countries in geographical groups, it becomes clear that it is predominantly European investors that drive E&S performance. Dutch investors in particular seem to be leaders. By contrast U.S. investors do not play a significant role in driving firms' E&S performance.

Institutional Type Grouping. Moreover, investors were separated by institution type. Regardless of social norms, pension funds are found to have a positive influence on firms' E&S performance. Hedge funds are found to have no relationship with E&S performance. In both cases this is as expected. Independent individual investors, such as mutual funds, that belong to the high-social-norm group have large and significant influence on environmental performance as opposed to those in the low-social-norms group. For social performance similar results are found but are less pronounced. In summary, institutional investors around the world are motivated by financial as well as social returns while addressing firms' E&S performance.

European influence in the U.S.

Institutional investors' influence has also appeared to make its way into the U.S. Although U.S. investors are not a source of E&S improvements, European investors clearly are. By isolating foreign investors (i.e. non-U.S.), it was found that these investors have a strong and significant impact on E&S performance in the U.S. It can therefore be concluded that foreign investors 'transplant' their social norms when they invest in the U.S. The penetration of foreign institutional investors in the U.S. is still limited. Should the foreign IO increase, it is predicted to have a substantial impact on the E&S practices of US firms.

1 Karl Lins, Henri Servaes & Ane Tamayo (2017). Social Capital, Trust, and Firm Performance: The Value of Corporate Social Responsibility during the Financial Crisis. *Journal of Finance*.

2 Ibidem.

Table 5: Summary of findings by Dyck et al. (2019).

Investor	Focus	Effect on E&S performance
IO	Global effect	+
IO UN PRI	Global effect	++
IO weak E&S firm (greater scope)	Global effect	++
IO during BP disaster	Global effect	++
IO	Exit and select mechanism	+/- (no significant effect)
IO	Voice mechanism	++
IO during global fin. crisis	Financial motivations	+
IO strong norms	Social norms motivations	++
IO weak norms	Social norms motivations	+/- (no significant effect)
European IO	Social norms motivations	++
American IO	Social norms motivations	+/- (no significant effect)
Asian IO	Social norms motivations	+/- (no significant effect)
Australian IO	Social norms motivations	+/- (no significant effect)
African IO	Social norms motivations	+/- (no significant effect)
Pension plan IO	Type of investor norms	++
Hedge funds	Type of investor norms	+/- (no significant effect)
Individual investor strong-social-norm	Type of investor norms	++
Individual investor weak-social-norm	Type of investor norms	+/- (no significant effect)
Foreign (non-U.S.) IO	Effect on U.S. firms	++

Read more about the research underlying this chapter:

- Dyck, A., Lins, K., Roth, L., & Wagner, H. (2019), Do Institutional Investors Drive Corporate Social Responsibility? International Evidence, *Journal of Financial Economics*, 131(3): 693-714.

Read related literature from RSM:

- Tupitcyna, A. (2018) *Committed shareholders Institutional ownership report*
- Schoemaker, D., Schramde, W. (2018) *Investing for long term value creation*

7 Risk and returns

Temperature, aggregate risk, and expected returns

Relevance for Business and Business Schools:

It is important to understand the potential disruptive impact of rising global temperatures on the macro-economy and financial markets. Based on research and analysis by international research bodies, it can be concluded that climate change will negatively affect global GDP. How? Climate change affects labour productivity, labour supply, crime, human capital, and political stability amongst many other factors. Evidence indicates that increased temperature raises expected equity returns through advancing risk premia, with a consequent increase to the cost of borrowing in the aggregate economy. Using distance-to-the-Equator as a temperature measure, it was found that countries closer to the Equator have a higher exposure to temperature risk, and earn a higher risk premium than countries that are farther away. This can be partly explained by the exposure to climate-sensitive sectors in low-latitude countries. Countries closer to the Equator rely more on agriculture ($\pm 25\%$ of GDP) as opposed to high-latitude countries ($\pm 3\%$ of GDP). This implies that countries that are less dependent upon agriculture also have less temperature-related risk. Temperature is related to economic growth on both a domestic and global level. Globally, temperature is negatively related to economic growth (GDP as well as consumption growth).

Negative economic outlook

It is important to understand the potential disruptive impact of rising global temperatures on the macro-economy and financial markets. Based on research by the IPCC and analysis by other research bodies, it can be concluded that climate change will negatively affect global GDP, since it has effect on labour productivity, labour supply, crime, human capital, and political stability. There is also evidence that rising temperatures have an adverse effect on global equity markets.

Temperature as a source of risk

Temperature is indeed a source of economic risk in global equity markets. Evidence indicates that increased temperature raises expected equity returns through advancing risk premia. Consequently, the cost of borrowing increases in the aggregate economy.

A two-fold analysis

These results are based upon two types of tests. First, data on global capital markets were collected and the temperature was found to have significant influence on the expected returns of a country. Second, tests were performed that are related to the GDP growth of a country and its distance to the Equator.

Box 2: Temperature Beta

Beta (β) is a measure of risk. It indicates how much the returns of a certain security respond to swings in the underlying factor. The prominent "market-beta" reflects a security's response to movement in the overall stock market (i.e., is it more or less risky than the general market?). Similarly, the temperature beta reflects what happens to a security's returns in response to movements in temperature.

If a security appears to bear any kind of risk, investors want additional return. This additional return is also known as the risk premium. The risk premium can be captured in a number that reflects the premium per unit of beta and is indicated by lambda (λ).

Imagine that in Kenya there is a negative beta for temperature (meaning that security returns go down when temperature goes up) of -20 . Also imagine a negative risk premium for temperature risk of -1% . A negative risk premium implies that the risk compensation in countries where beta is more negative, is higher. Thus Kenyan securities would receive a risk premium of 20% ($= -1\% * -20$).

What does this mean on global scale?

The authors use distance to the Equator as a measure for its temperature. Countries have been placed in four groups based on distance to the Equator. The Netherlands, for example, was placed in Group 4, the group farthest away from the Equator. Indonesia, Mexico and Kenya were placed in Group 1, and so on. It was found that countries closer to the Equator earn a higher risk premium than countries that are farther away. In Table 6 below the average latitude (distance to the Equator), the average real return, and the temperature beta per group are presented.

Table 6: Latitude, Real equity return (R), Temperature beta and Risk premium.

Country	Latitude	R	Temperature beta	Risk premium
Group 1	0.10	19.74	-28.28	2.35%
Group 2	0.30	16.56	-21.28	1.77%
Group 3	0.45	15.11	-0.45	0.04%
Group 4	0.62	12.44	37.53	-3.11%
Market price temperature risk			-0.083% per annum	

How to read this table:

You can see that countries closest to the Equator (Group 1) have the most negative temperature beta. Consequently, considering the market price of temperature risk of -0.083% it can be argued that countries closest to the Equator earn the highest risk premium which decreases the farther from the Equator a country is located.

Distance to Equator and temperature-sensitive sectors

Countries closer to the Equator have a higher exposure to temperature risk. This can be partly explained by the exposure to climate-sensitive sectors in low-latitude countries. Countries closer to the Equator rely more on agriculture ($\pm 25\%$ of GDP) as opposed to high-latitude

countries ($\pm 3\%$ of GDP). The correlation between a country's temperature beta and the share of agriculture (as percentage of GDP) is about -0.46 . This implies that countries that are less dependent upon agriculture, also have less temperature-related risk. Agriculture represents a higher portion of the economy in countries closer to the Equator, making them more vulnerable to fluctuations in temperature. An explanation for this higher vulnerability may be that countries close to the Equator start with a relatively high temperature; so that small increases in temperature might bring the temperature to levels detrimental to agriculture.

Temperature and economic growth

Temperature is related to economic growth on both a domestic and global level. Globally, temperature is negatively related to economic growth (GDP as well as consumption growth). Especially in the long term, rising temperatures seem to have a strong negative effect on GDP and consumption growth (Table 7). As it is scientifically unlikely that an increase in economic growth lowers temperature, it seems that rising temperature does lower economic growth.

To quantify the effect of temperature changes on regional economies the effect of global temperature changes on GDP growth was further inspected (Table 8). Temperature and temperature shocks were both found to have negative impact on economic growth.

By including distance to the Equator in the model, it was found that countries closer to the Equator experience larger negative effects of temperature shocks than countries further away. Moreover, low-latitude countries also face aggregate growth risk (dependence on global economic growth). So, if global economic growth slows due to temperature increase, economies close to the Equator are hurt most.

The various risks with regard to economic growth and temperature are reflected in temperature betas. Thus, countries exposed to such risks have higher risk premia.

Table 7: Correlation matrix between temperature and growth rates.

Horizon	World	
	GDP growth	Consumption growth
1-year	0.02	0.12
5-year	-0.13	-0.15
10-year	-0.63	-0.65

Table 8: Temperature, GDP Growth, and Distance to the Equator

Coefficient	Dependent variable: GDP growth			
	(1)	(2)	(3)	(4)
Lagged GDP growth	0.08 (0.04)	0.40 (0.12)	0.08 (0.04)	0.08 (0.04)
Temperature (std.)	-0.18 (0.09)	-0.25 (0.18)	-0.18 (0.09)	-0.18 (0.09)
Temperature shock (std.)	-0.24 (0.10)	-0.04 (0.24)	-0.43 (0.16)	-0.43 (0.13)
Temperature shock effect of distance to Equator			0.73 (0.44)	
Temperature shock effect of Group 2				0.27 (0.25)
Temperature shock effect of Group 3				0.57 (0.27)
Temperature shock effect of Group 4				0.17 (0.17)

How to read this table:

The estimates in (1) suggest a one standard deviation shock to temperature lowers country GDP growth by 0.24%. Moreover, an increase in global temperature of one standard deviation (0.2°C) reduces country GDP growth by 0.18%. On a global level (2) these estimates are -0.25% and -0.04%, respectively. A one standard deviation shock to temperature will lower GDP growth of countries closest to the Equator by 0.4%, while having an effect close to zero for countries farther away (4).

Read more about the research underlying this chapter:

- Bansal, R., Ochoa, M. (November 2011), Temperature, Aggregate Risk, and Expected Returns, [NBER Working Paper No. 17575](#)

Read related literature from RSM:

- Ferwerda, W.H. (2015), 4 returns, 3 zones, 20 years: A Holistic Framework for Ecological Restoration by People and Business for Next Generations.

8 Portfolio strategies and climate risk hedging

Hedging climate risk

Relevance for Business and Business Schools:

While the scientific evidence for the link between CO2 emissions and the greenhouse effect/climate change is overwhelming, much uncertainty exists. The uncertainty about the tipping point of climate change is an increasingly important risk factor for investors. And beside the risk of catastrophic changes to the climate, there is also risk deriving from the timing of the introduction of climate policies. How can investors apply portfolio strategies that help to hedge climate risks in this uncertain and evolving scenario? Investing in 'green' indices may be such a strategy. There are different types of 'green' indices. **Pure play indices** focus fully on renewable energy, clean technology, and/or environmental services but do not protect against timing risk from climate change mitigation policies. **Decarbonised indices** do protect against the timing of climate change mitigation policies. They take a standard benchmark such as the S&P 500 or NASDAQ 100, and remove or underweight companies with relatively high carbon footprints. These indices are aimed at retaining a low tracking error with the benchmark, leading to similar risk-return characteristics. In practice, it is found that decarbonised indices outperform the original benchmark, and can mobilise financial markets to support the common good.

Considerations for the climate finance

Three important considerations fuel the discussion of the implications of climate change on the financial sector. First of all, countries and industries are not equally affected by climate change. Hence the question arises: who should bear the costs? Secondly, in politics climate mitigation is often postponed, as it is unpopular to introduce policies that may be very costly in the short run with direct benefits that are opaque and undefined. Thirdly, while the scientific evidence for the link between CO2 emissions and the greenhouse effect is overwhelming, much uncertainty exists about the rate of temperature increase over the coming 20 to 30 years. This third argument is magnified by the uncertainty with regards to the 'tipping point' at which catastrophic climate dynamics are set in motion. Similar to financial crises, observations of growing imbalances may alert analysts to the inevitability of a crash (or climate shock) but still leave them in the dark as to when a crisis is likely to occur.

Climate risk factors for investors

The uncertainty about the tipping point of climate change should be understood as an increasingly important risk factor for investors, particularly for long-term investors. Beside the risk of catastrophic climate change (think about the effect of temperature on rising sea levels), there is also a risk deriving from the timing of climate policies' introduction. For instance, an asset manager looking to hedge climate risk by divesting from stocks with a high carbon

footprint must risk underperforming against his or her benchmark for as long as climate mitigation policies are postponed and market expectations about their introduction are low. These risk factors should be accounted for in the investment strategies of long-term (passive) investors. Investing in 'green' indices may be such a strategy, without the need to sacrifice financial returns.

Different types of 'green' indices

Pure play indices

Pure play indices focus fully on renewable energy, clean technology, and/or environmental services. Thus investors in such indices invest exclusively in a group consisting of green components. The use and success of pure play indices, however, remains limited. First of all, such indices do not protect against timing risk from climate change mitigation policies. This means an investment potentially underperforms until certain climate policies are set. There are additional factors that contribute to the limited success of pure play indices: clean-tech has been over-hyped, and many climate mitigation policies in that were in place were scaled back after the financial crisis. Financial markets also deemed postponement of climate mitigation policies very likely after the financial crisis. Finally, as pure play indices lack diversification - consisting mainly of a few clean sectors - they are unsuitable as the foundation of a core equity portfolio for institutional investors. Many investors may interpret pure play indices more as a bet on clean-tech than a hedge for carbon risk.

Decarbonised indices

Decarbonised indices take a standard benchmark such as the S&P 500 or NASDAQ 100, and remove or underweight companies with relatively high carbon footprints. Unlike pure play indices, decarbonised indices do protect against the timing of climate change mitigation policies, as they seek to retain a low tracking error with the benchmark, leading to similar risk-return characteristics. Decarbonised indices thus seem superior to pure play indices.

Decarbonised indices keep aggregate risk exposure similar to the benchmark (e.g. S&P 500). Divestment of high-carbon-footprint stocks is the first step in designing such a portfolio. The second step consists of optimising the composition and weighting, such that the tracking error is minimised; the tracking error can be virtually eliminated while having much lower carbon exposure. Ideally, the only difference between the decarbonised index and the benchmark is exposure to the carbon risk factor while having similar exposure to other priced risk factors. As carbon risk remains unpriced, investors in decarbonised indices hold 'free options on carbon': as long as climate mitigation policies are postponed, this index offers similar returns as the benchmark; but when such policies are implemented (e.g. limit of carbon emission) the decarbonised index will outperform its benchmark.

Essentially, the underlying premise of this strategy is that financial markets currently underprice carbon risk. The fundamental belief is that eventually financial markets will begin to price carbon risk. This inevitably leads to the conclusion that a decarbonised index is bound to provide higher financial returns than the benchmark index. Scenarios in which this is not the case seem very

implausible; however, the worst-case scenario of this strategy is earning similar financial returns as its benchmarks.

Implications of decarbonised indices

Besides outperforming non-decarbonised indices, decarbonised indices potentially foster climate change mitigation activities via other channels. To begin with, inclusion or exclusion in an index is an important, newsworthy event for a firm. Hence, inclusion in a decarbonised index ought to have similar impact and value. Clearly communicating which constituent stocks are in the decarbonised index would not only reward the included companies for their efforts in reducing their carbon footprint, but also help induce excluded companies to take steps to reduce their carbon exposure. Moreover, clear communication with regards to exclusion criteria may stimulate discussion on whether greenhouse gas emissions are properly measured and could lead to improvements in the methodology for determining the carbon footprint of firms.

Considerations when picking or creating decarbonised indices

To construct an index, one could simply pick the procedure that yields the lowest tracking error - but other elements should also be considered. One example is the decision of whether to filter companies sector-by-sector, or across the entire benchmark portfolio. Using a sector-by-sector filter enables companies within a sector to determine their carbon footprint ranking, and how much reduction is necessary to gain inclusion in the index. This may foster carbon reduction competition within an industry. Furthermore, companies' carbon footprints should be reconsidered. First, carbon footprints should be normalised, as absolute carbon figures will tend to be biased against the largest firms. Therefore, a normalisation metric should be used, for instance dividing carbon footprint by sales. Another consideration is whether companies' carbon footprints are correctly measured. There is divergence in a firm's estimated carbon footprint between different organisations that seek to measure it. However, by drawing a parallel between carbon footprint measurers and credit-rating agencies you can argue that biased and noisy measurement of credit risk by credit-rating agencies has never been a decisive reason to abolish credit ratings altogether. Methodologies of measurement of firms' carbon footprints will improve over time, similar to those used for credit ratings. However, the use of decarbonised indices also provides a hedge against carbon footprint measurement risk if there is little or no tracking error.

Performance of decarbonised indices

In practice, it is found that decarbonised indices outperform the original benchmark. And besides offering investors a hedging tool against the rising risks associated with climate change, a decarbonised index investment strategy can mobilise financial markets to support the common good. As a larger and larger fraction of the index-investing market is devoted to decarbonised indices, a virtuous circle will be activated and enhanced. In this virtuous circle the greater awareness of carbon footprints and greenhouse gas (GHG) emissions will exert a disciplining pressure to reduce CO₂ emissions, and will gradually build an investor constituency

that supports climate change mitigation policies. Governments, businesses, technology innovators, and society will thus be encouraged to implement changes that accelerate the transition to a renewable energy economy.

Read more about the research underlying this chapter:

- Andersson, M., Bolton, P., Samama, F. (April 2016), Hedging Climate Risk, *Financial Analysts Journal* 72 (3): 1-20.

Read related literature from RSM:

- C.K.W. Dreu & M.A. van Dijk (2018). Climatic Shocks Associate with Innovation in Science and Technology. *PLoS One* (online), 13 (1). doi: [10.1371/journal.pone.0190122](https://doi.org/10.1371/journal.pone.0190122)

9 Real estate and long-term investments

Climate change and long-run discount rates

Relevance for Business and Business Schools:

Why is real estate important for climate finance? Over the past decade, there has been lively debate about anti-climate-change investments. One topic is whether today's investments aimed at reducing carbon emissions - and representing immediate costs - are worth the potentially uncertain long-run benefits. Discount rates play a central role; a small change to the discount rate can dramatically alter the present value of investments with very long horizons. Because there is no widespread agreement concerning discount rates to be used over the long horizon, we can use real estate investment (which has a long-term nature) as a proxy, giving us information relevant to climate change abatement investments and determining long-term discount rates. On the other hand, the real estate market is risky business considering its volatility during crisis periods, disasters and wars. Given this, mean reversion must be taken into consideration: it is the key mechanism that causes longer-term assets to provide a lower risk premium. Mean reversion is based upon the idea that when a negative shock hits the economy, the economy is expected to grow faster after the shock. Short run cash flows do not benefit from recovery; long-run cash flows do. Therefore, short-term cash flows are riskier, creating a negative-sloped term-structure.

Debate about anti-climate change investments

Over the past decade, there has been lively debate about anti-climate-change investments. One topic that is part of this debate is whether today's investments aimed at reducing carbon emissions, representing immediate costs, are worth the potentially uncertain long-run benefits. Discount rates play a central role within this discussion because a small change to the discount rate can dramatically alter the present value of investments with very long horizons. Discount rates determine the current value of a future benefit.

Box 3: Example discount rate

Assume that an investment to reduce carbon emissions costs \$3 billion and is expected to avert environmental damages worth \$100 billion in 100 years. At a discount rate of 3%, the present value of those damages is \$5.2 billion, and the project should be implemented. At an only slightly higher discount rate, 5% for instance, the present value of the investment drops to \$760 million, an order of magnitude smaller, and the investment no longer appears attractive.

Because of scientific, economic, philosophical, and legal issues, there is no widespread agreement concerning discount rates that should be used in the long run. The authors researched the long-run characteristics of real estate with regards to discount rates. The long-

term nature of real estate assets can provide us with valuable insights about climate change abatement investments.

Today's problem

Current practices in using discount rates do not represent reality. On the one hand there are researchers who use returns averages of certain assets; on the other hand, there are researchers who use a standard discount rate. Both approaches ignore important considerations regarding the maturity and risk properties of such investments.

Risk and horizon of assets

The risk and maturity of the assets has important considerations for the discount rates. Therefore, in choosing discount rates the asset specifics should be considered. Determining the term-structure, where maturity is drafted against the appropriate rate, helps in identifying the appropriate rate.

Term-structure in the real estate market

By using data of the real estate returns in both the U.K. and Singapore, the overall trend of the real estate term structure can be determined. The U.K. and Singapore have different regulations with regards to ownership contracts (freehold vs. leasehold). The discount at which leasehold contracts (generally varying between 99 and 1,000 years) trade, compared to freehold contracts, functions as a proxy for long-term discount rates. In general, leasehold discounts are strongly associated with maturity, with shorter leaseholds trading at bigger discounts. Discount rates of around 2.6% for cash flows more than 100 years in the future have been found to be fitting.

On the other hand, the real estate market is risky business considering its volatility during crisis periods, disasters and wars. Hence, it is a relatively high expected annual return - between 6.4 and 8.0%. Only one type of term structure is conceivable, taking into consideration the bigger discounts for shorter leaseholds and concurrently the high annual returns (i.e. riskiness): a downward sloping term structure.

Mean reversion

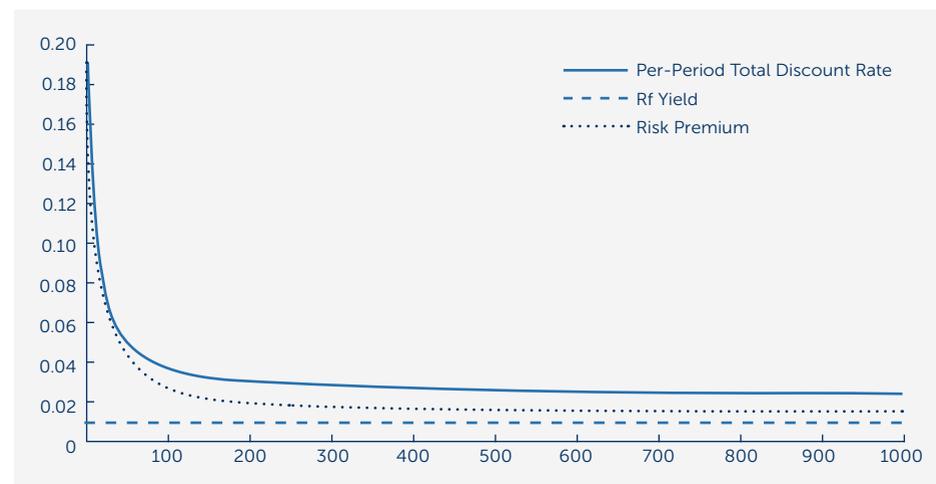
The key mechanism that causes longer-term assets to provide lower-risk premium is mean reversion. The rationale behind mean reversion is that whenever a negative shock hits the economy - for instance, the financial crisis - the economy is expected to recover and grow faster afterwards. Short-run cash flows do not benefit from this recovery while long-run cash flows do. Therefore, short-term cash flows are riskier, creating a negative sloped term structure.

Implications for climate change abatement investments

First, the common practice of using observed average rate of return of traded assets to discount investments in climate change abatement (even if the traded asset has the same riskiness as the investment in climate change abatement at all horizons), is misleading. This is because the benefits of climate change abatement investments are likely to materialise over several centuries (less carbon emission may lead to future benefits, such as preventing global warming); while average return of traded assets are largely driven by results of much shorter horizons. The appropriate discount rate should be the one that applies to the long-term cash-flow only.

Second, as real estate cash flows are considered risky, the risk premium should be larger than zero. The long-run discount rate of 2.6% is a combination of the risk-free discount rate, and the risk premium for the risky real estate. However, climate change abatement is generally considered as risk reducing - it hedges climate risk. It will therefore contain a negative risk premium. Hence, the discount rate for climate abatement (as long as it is seen as risk reducing) will always be smaller than for real estate, where the 2.6% acts as an upper bound for the long-run climate change abatement discount rates (see Figure 1).

Figure 1: The term structure of discount rates for real estate. Source: Giglio et al. 2015, p. 49.



Read more about the research underlying this chapter:

- Giglio, S., Maggiori, M., Stroebel, J., Weber, A. (November 2015), Climate Change and Long-Run Discount Rates: Evidence from Real Estate, [NBER Working Paper No. 21767](#)

Read related literature from RSM:

- Schoenmaker, D., Schramade, W. (2019), Principles for Sustainable Finance, [Oxford University Press](#)
- Schoenmaker, D., Schramade, W. (2018), Investing for Long-Term Value Creation, working paper series, [Erasmus Platform for Sustainable Value Creation](#)

10 Corporate finance

Internal carbon pricing

Relevance for Business and Business Schools:

From a company's perspective, it's important to take both climate risks and carbon risks into account. As climate change and its risks become increasingly prominent for the public, key stakeholders and policymakers, it is likely that policy responses that increase carbon risk will follow. Currently there are two main types of carbon policies in place around the world: carbon tax and carbon cap-and-trade systems. Carbon tax refers to the situation in which CO2 emissions are taxed by the (local) government. Carbon cap-and-trade systems put a limit on the total amount of CO2 emissions. Each emitting firm can buy, or receive, a certain amount of CO2 allowances and can buy/sell additional allowances. The carbon price here is set by market forces here (supply and demand of CO2 contracts). One increasingly-popular strategy to counter carbon risk and account for future pricing of carbon is internal carbon pricing. It entails putting a monetary value on a company's greenhouse gas (GHG) emissions. This internal price is not an actual fee or payment, but rather a theoretical price per ton of CO2 that helps companies evaluate carbon-related risks, investments, and strategic opportunities. To establish an internal carbon price, there is a five-step model companies can follow.

Carbon risk from a company's perspective

Companies should consider both climate risks (referring to the prospect that climate change could damage company assets, disrupt supply chains, or weaken consumer demands), and carbon risks (where new climate change/mitigation policies may affect a company's decisions and returns). As climate change and its risks become more prominent in the eyes of the public, to key stakeholders, and to policymakers, it is likely that policy responses that increase carbon risk will follow.

Carbon policies

Currently there are two main types of carbon policies in place around the world: carbon tax and carbon cap-and-trade systems. Carbon tax refers to the situation in which CO2 emissions are taxed by the (local) government. This tax should act as an incentive to lower carbon emissions, while its proceeds can be used for climate mitigation projects. The carbon price is set by taxation here.

Carbon cap-and-trade systems put a limit on the total amount of CO2 emissions. Each emitting firm can buy, or receive, a certain amount of CO2 allowances and can buy/sell additional allowances. The carbon price is set by market forces (demand and supply of CO2 contracts), within boundaries fixed by regulators who are in charge of deciding the total amount of carbon allowances traded in the market.

Box 4: Example carbon pricing

To dive into the complexities of pricing carbon, you can consider the volatility of carbon prices in the EU emission trading scheme. In 2017 cap-and-trade allowances were trading at €5 per ton of carbon dioxide but jumped to €20 per ton in 2018. Simultaneously, prices in California's emission allowances trade system were sometimes quoted three times higher than those in other such systems active in the United States. The huge difference depends on how aggressive the climate policy approach of the regulator is.

A solution to carbon uncertainty: internal carbon pricing

One strategy to counter carbon risk and account for the future pricing of carbon is internal carbon pricing. This strategy is rising in popularity around the globe. It entails putting a monetary value on a company's greenhouse gas (GHG) emissions.

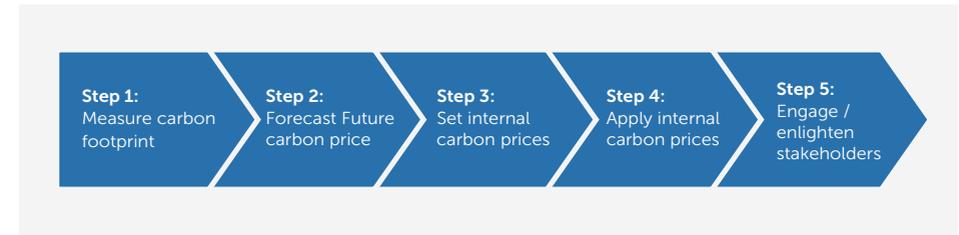
This internal price is not an actual fee or payment, but rather a theoretical price per ton of CO₂ that helps companies evaluate carbon-related risks, investments, and strategic opportunities. For some companies the price that is adopted internally reflects the actual carbon price imposed by the local jurisdiction; while other companies seek to formulate their own price. This may lead to huge differences in price, varying from \$0.1 per ton to well above \$100 per ton.

Purpose of internal carbon pricing

Internal carbon pricing serves three purposes. First, it provides information for decisions with regard to capital investments (especially when projects directly affect emissions, energy efficiency improvements, or changes in the portfolio of energy sources). Second, it helps to measure, model, and manage financial and regulatory risk associated with existing and potential government pricing regimes. Thirdly, internal carbon pricing integrates strategic planning activities to identify new risks and opportunities and enable a company to adjust its business model accordingly. Furthermore, a company's internal carbon price allows investors to assess the company's vulnerability to increasing carbon costs.

How to determine the internal carbon price

To establish an internal carbon price, companies should follow five steps. First, they should measure their carbon footprint and climate exposure. Next, they should forecast future carbon prices. Then, they should set internal carbon prices. And finally, they should apply these prices and model uncertainty. Afterwards, companies should engage with stakeholders.



Step 1: Measure carbon footprint and climate exposure

A company should get a detailed overview of its exposure to carbon policies. In doing so, the company should consider the amount of direct and indirect carbon emissions as well as the geographical location where CO₂ is emitted, because different prices are applied in various jurisdictions. Thus, a firm should map its carbon emissions and locations for each of the following three scopes to get a realistic overview of its exposure to this risk. Scope 1 refers to direct emissions, whereas Scope 2 (consumption of heat, electricity, steam and cooling) and Scope 3 (down the supply chain) refer to indirect emissions.

Step 2: Forecast future carbon prices

In the second step the company should examine its exposure, mapped in Step 1, with current and future carbon prices. In locations where carbon policies are in place - e.g. cap-and-trade system or carbon tax - current prices can be observed in the market. Where these policies are not in place, companies can review reports from the Organisation for Economic Co-operation and Development (OECD) that describe certain carbon prices under existing government policies. Consequently, the company should forecast how these current prices will develop in the future. This may be a time-consuming process that requires data reviews and analyses by climate experts, research institutions, peer companies, and environmental agencies. Companies should develop in-house expertise, or rely on external experts, to identify the likely evolution path of public policies and associated carbon prices.

Step 3: Set internal carbon prices

At this point, the company should understand its carbon exposure and the likely trajectory of carbon prices under public policy. The company can now set its own internal carbon price. This might be the most complex step, as it requires deep understanding of carbon economics and of the operations and strategy of the company. In setting the price, companies should first recognise the types of business decisions informed by the internal carbon price. For short- to medium-term decisions, this price is likely to be near the level of carbon prices under public policies. For long-term decisions, however, this makes less sense as more opportunities and threats from carbon emissions are likely to arise.

Step 4: Apply prices (and model uncertainty)

After internal carbon prices are set, the company should factor them into various business decisions and towards various goals. The areas in which the carbon prices can be applied are:

when deciding about new investments; in risk management; and in developing a long-term strategy. Managers should consider enhancing their valuation approaches through scenario- or simulation-based valuation when dealing with carbon risks and prices, enabling them to deal with the possibility of 'extreme' prices.

Step 5: Engage the stakeholders

If companies have worked through Steps 1 to 4, they may have reduced risk or seized new opportunities by accounting for carbon risk. Although the internal carbon prices should be re-assessed occasionally, the process of carbon pricing offers both an internal learning opportunity and an opportunity to improve collaboration among all the stakeholders (customers, supply chain partners, investors, etc.). If so, this may lead to progressive reduction of joint carbon exposure.

Why isn't every firm pricing carbon?

As yet, not every company is pricing carbon in this manner. A number of factors may explain this. For example, if a company has low carbon exposure, it may expect that carbon policy changes have limited impact on its operations. However, this is often a false assumption when all three scopes of emissions are considered.

Another reason: companies may not have the capabilities to understand potential future climate-related regulations and policies, and therefore do not see how carbon regulation may be a threat to their business.

Still there has been a tremendous growth in the use of internal carbon prices. This reflects the fact that more and more businesses see carbon pricing as an important tool to map carbon risks. Only companies that fully understand and proactively manage their carbon risks, however, will sustain their competitive advantage in the long-term.

Read more about the research underlying this chapter:

- Aldy, J., Gianfrate, G. (May-June 2019), Future-Proof Your Climate Strategy, *The Harvard Business Review*

Read related literature from RSM:

- Schoenmaker, D., Schramade W., (2019), Principles of Sustainable Finance, [Oxford University Press](#)
- Gianfrate, G., Peri, M. The green advantage: Exploring the convenience of issuing green bonds, [Journal of Cleaner Production, 2019, Vol. 219: 127-135.](#)

11 Current trends

There is rapidly escalation in the output and themes of research on climate finance-related topics. Some research themes dominate the current field. However, this is a swiftly-moving area in which essential themes keep arising and developing. To quickly delineate where the world of sustainable finance research is going, some key aspects (and discussion points) of recent global conferences can be found below.

Scaling up green finance: the role of Central Banks

Berlin, November 2018

- » Greening the activities of central banks
- » Understanding and monitoring the market dynamics of sustainable finance
- » Central banks as catalysts to make the financial system sustainable

Review of Financial Studies Climate Finance Conference

New York, November 2017

- » Investor attitude towards climate change
- » Belief and expectation errors
- » Pricing climate change uncertainty

Principles of Responsible Investment Network Conference

San Francisco, September 2018

- » Identifying low-carbon opportunities
- » ESG in private equity
- » Obstacles to responsible investing

Dynamics of Inclusive Prosperity Conference

Rotterdam, November 2018

- » Regulating responsibility
- » Responsible financial markets
- » Coordinated engagement

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