Juhász J. (ed) 2022: Proceedings of the European Union's Contention in the Reshaping Global Economy. University of Szeged, Doctoral School in Economics, Szeged, https://doi.org/10.14232/eucrge.2022.12

Corporate attitudes towards climate change and their implications for corporate governance

Péter Málits – Áron Drabancz – Nedim Márton El-Meouch

The position of science on climate change is quite consistent and grim, but humanity is currently not on the economic trajectory to avoid the most serious consequences. The aim of our research is to assess the financial implications of climate change based on the literature, as well as the attitudes of corporations towards the topic and the observable trends. Based on this review, we illustrate the relationships between climate risks (e.g. transitional and physical risks) and the corporate sector by building a model. According to the results of the modelling, the realization of climate change risks poses a real threat to the long-term operation of companies that are considered unsustainable by the markets.

Keywords: climate change, green transition, transitional and physical risks

1. Introduction

The activities of mankind cannot be separated from the natural environment, and its changes have an inevitable impact on social systems, including the economy. Climate change is therefore forcing economic actors to act.

There is no doubt that the world economy is facing a number of challenges nowadays, of which the most attention is currently being paid to the situation caused by the coronavirus. In the long run, however, based on the scientific consensus on the subject, the rising costs of climate change, and changing societal attitudes, tackling climate change could become the number one challenge of our time. So far, the adaptation steps and system-level changes have lagged behind the required level, as the related financial expenditures may result in a decrease in potential economic growth in the short run, which may also deter policy makers. However, due to increasing social pressures, this may change in the future, and it is even conceivable that fast and high-volume adaptation regulations could crack down on slow-responding companies. Thus, it is important to examine the challenges that corporate operations may face in relation to climate change. In our study, we approach the issue from a corporate perspective, within which we analyse the emerging transitional and physical risks. Using a general approach, the focus of our research is not on selected countries or regions, but on climate change issues affecting companies. We demonstrate our analysis using a model in which we incorporate different aspects of climate change, primarily transitional and physical risks, into a corporate project evaluation situation which is based on real-world data but is necessarily simplified.

Overall, the study pursues two goals: on the one hand, it systematizes the rapidly expanding literature, while it also presents the observable trends. On the other hand, in parallel, it highlights aspects of the realization of risks related to climate change that can influence corporate operations using a model. Based on all this, our research questions are the following:

- How can the direct financial risks of climate change be grouped and what characterizes them?
- Through what channels can observable trends appear in corporate operations?

In the next section of the study, we review the conceptual frameworks of climate change relevant to research. In the third section, we present the methodology used in the study, with special emphasis on the main features of the corporate model. Then, in the fourth part, we go through the financial risks and after that we summarize the main findings of the study.

2. The main features of climate change

In this section, we present the aspects of the phenomenon of climate change relevant to the study. To this end, we first consider it appropriate to have a precise definition of greenhouse gases. Natural science considers greenhouse gases to absorb some of the energy of the higher-wavelength radiation of the Sun reflected from the Earth's surface, thus warming the atmosphere as part of a fundamentally natural process (Civin 1998). Three-quarters of the greenhouse gases present in the Earth's atmosphere and specifically emitted by human activity are carbon dioxide (IPCC 2014), which is why the most attention is focused on this gas, all other greenhouse gases (such as methane) are also taken into account in terms of carbon dioxide. Two-thirds of carbon dioxide deriving from human activity comes from the combustion of fossil fuels, in descending order of quantity, coal, oil and natural gas. By sector, the three largest emitters are electricity and heat production, transport and transportation, and industrial production (IEA 2019).

It is important to mention the summary of the UN Intergovernmental Panel on Climate Change (IPCC) Comprehensive Report (IPCC 2018) published specifically for decision makers on the causes and consequences of climate change, as its findings provide conceptual frameworks for the whole study. The authors of the report have specifically sought to draw attention to the difference between making efforts to achieving a maximum increase in temperature of 1.5°C in 2015, instead of the 2°C maximum target adopted by the vast majority of the world’s countries in the Paris Convention on Climate Change. Relevant findings of the IPCC report (IPCC 2018) for the study:

- human activity has now raised the average temperature of the Earth's surface by 0.8–1.2°C compared to pre-industrial times;
- global warming is likely to stop if humanity were to stop emitting greenhouse gases, especially carbon dioxide;
- warming in the range above 1.5°C would be expected to cause extreme weather events not seen in today's climate, leading to significant damage to the built infrastructure in parallel with rising sea levels;
- the effects of climate change may have a direct impact on, inter alia, human health, food supply and agricultural activity which is ubiquitous, but to a varying degree according to geographic location, leading to a measurable decline in the performance of the world economy as a whole;

- assuming that the current rate of greenhouse gas emissions is maintained, a very limited time interval separates humanity from reaching the level of emission that will cause a warming of 1.5°C.

Although climate change is indeed a complex process, its solution is, at least in theory, less complicated: in order to keep warming within the limits agreed in the Paris Convention on Climate Change, greenhouse gas emissions must be reduced in line with the IPCC's (2018) proposals. The ultimate manifestation of low carbon intensity is (net) carbon neutrality, meaning that a given economy emits less carbon dioxide than it can neutralize through natural methods or artificially produced technologies. McKinsey (2009) identifies 3 possible ways in which emission levels can be reduced. The most significant results can be achieved by increasing energy efficiency (for example by improving the fuel efficiency of transport vehicles or with better thermal insulation of buildings), followed by increasing the share of renewable (such as solar, wind, and hydroelectric power plants) and alternative energy sources (such as nuclear energy) in energy producing, and the third way is to achieve better management of agricultural land, in particular through greater protection of forests capable of binding carbon dioxide.

As Stern (2006) pointed out, climate change is an external phenomenon from a global economic point of view, in which the victims themselves are not always directly identifiable, as most of the negative effects will only be borne by future generations. Complemented by a significant uncertainty factor, these characteristics make climate change an extremely complex economic challenge. The effects of this adaptation on economic operators are presented in a way already mentioned, through the decision-making situation of a (oil) company.

3. Modeling methodology

The findings and trends of the literature in the following section will be incorporated into the model, adapted to the content of each sub-section in relation to the actual topic. This is why we consider it appropriate to review the methodology used for modelling at this point in the study.

3.1. The purpose of modelling and theoretical approach

The aim of the application of the model is to present a realistic example of the channels related to the studied phenomena that affect the operation of a company. Climate change considerations are rarely integrated into company decision-making mechanisms in current practice. However, it may be appropriate to present each scenario with its associated (estimated) probability of occurrence in relation to long-term investment decisions, as these may have an impact on the profitability of a given project and the profitability of the company. The constructed model, which necessarily simplifies reality, presents a methodology that can be potentially applied in real decision-making, when adapted to the characteristics of the given company.

In our example, a profit-maximizing company performing only one type of activity (oil refining) is facing a decision on a project. In the framework of the project the company envisages the commissioning of a high-carbon intensity *oil refinery unit* related to the traditional oil industry, which is expected to operate over a 10-year period and will be linearly depreciated over the period without residual value. The net present value (NPV) calculated by discounting the cash flows resulting from the project is used as a decision criterion.

It is important to mention that the model presented in the study differs from real corporate practice in several respects. On the one hand, the net present value calculation is not used as the sole decision criterion, positive NPV can only be referred to as a necessary but not sufficient condition. Another significant simplification in the methodology is that because company management gives a forecast for the future in investment decisions, it is not able to calculate changes that do not exist at the time of the decision. In the following, therefore, our goal is not strictly to model the decision, but to identify events that could potentially influence it. Hence the question asked is not the general "is the investment worthwhile for the company" but "how would the company decide on the investment if it knew these changes were happening"? In addition, we use the following assumptions:

1. The company is not environmentally sustainable and has a poor rating. Its capital structure is constant and does not change during the period under review. This means that there is no financing-related economic event, the value of financing cash flow is zero. In order to simplify the calculation, we did not account for changes in net working capital (inventories, current assets, etc.). The rationality of the company management can be assumed, which decides on its investments only on the basis of the NPV. It is also an important assumption that in the model environment, a universal tax rate that applies equally to all is applied. The financial expense of the company consists exclusively of the difference between the interest paid and received, no other factors are taken into account.

2. In connection with the project, it can be said that the data were based on industry foundations, but cannot correspond to reality. In this way, the 10-year duration of the project is also a simplification in order to maintain the transparency of the project. This, in turn, leads in each scenario to the effects occurring over a period of time that cannot be considered realistic, but the goal is not primarily this, but to map the channels of the phenomena that affect the company's operations. The new production unit to be commissioned is paid in full in year zero, but does not generate income or incur costs that year.

3. In connection with each effect, their occurrence is assumed ceteris paribus so that the individual channels can be well separated. However, it is important to emphasize that it may be logical to assume their co-occurrence, in which case the impact on the decision is even stronger, and a smaller shock can cause more significant changes. In the initial model, revenues and expenses are constant over time. This simplification serves to generalize the model, as oil refining activity is highly exposed to changes in oil prices. For the sake of simplification, changes in each scenario immediately affect the decision, there is no way to compensate, such as raising the price of the product and thus increasing revenue, given the price sensitivity of demand.

3.2. Calculation procedure and initial parameters

The net present value (NPV) on which the decision is based is derived from the following equation:

$$NPV = \sum_{t=0}^{10} FCFF_t \times \left(\frac{1}{1+WACC_{project}}\right)^t \quad (1)$$

in which $FCFF_t$ is the expected (free) cash flow generated by the project and $WACC_{project}$ is the weighted average cost of capital of the project.

To determine the expected (free) cash flow (FCFF) generated by the project, it is necessary to calculate its after-tax profit (NOPLAT):

$$NOPLAT_t = EBIT - Tax\ burden - Financial\ expense = [Revenue_t - (Raw\ material\ cost_t + Operating\ cost_t) - \delta_t] - [EBIT * T] - [Interest\ expense - Interest\ income] \quad (2)$$

where δ_t is the annual depreciation rate, T is the (universal) tax rate.

Due to the indirect cash flow calculation approach, $NOPLAT_t + \delta_t = CFO$, where CFO is the value of operating cash flow if, according to the preliminary assumption, net working capital does not change. The sum of operating cash flow (CFO) and investment cash flow (CFI) in the model is equal to corporate free cash flow (FCFF) because we assume that there is no financing cash flow in the model. Free corporate cash flow is thus the result of the $FCFF = CFO + CFI$ relationship. The weighted average cost of capital for the project can be calculated based on the Modigliani–Miller (1958) methodology,

$$WACC_{project} = WACC_{company} + \alpha = \left[\frac{E}{V} * r_e + \frac{D}{V} * r_d * (1 - T)\right] + \alpha \quad (3)$$

where

- E is the market value of the company's equity stock;
- D is the market value of the company's liabilities;
- r_e is the company's return on equity under the CAPM (Sharpe 1964). $r_e = r_f + \beta \times (r_m - r_f)$, where r_f is the risk-free yield: the yield on the 10-year HUF government bond on 24 March 2021 (Trading Economics 2021), β is the beta corresponding to MOL Group's risk compared to S&P500 (Erste Market 2021), r_m is the market return, the expected average return of S&P500 between 2021-2030 (Scheid 2020);
- r_d is the return on the company's external liabilities (loans) (quotient of total interest expenses and total loans);
- T is the tax rate (the ratio of tax expense to pre-tax profit);
- α is the project-specific compensation term. The viability of this value is given by the goal of approximating the corporate WACC value calculated from the data in the report of MOL, which serves as a sample company, to the value typical of the oil refining projects mentioned in the report. It follows that the project under review is considered to be riskier than the operation of the company as a whole.

The company's financial data is therefore based on the 2019 financial statements of the MOL Group (MOL Group 2019). The initial values of each parameter recorded in the model can be read in Table 1.

Table 1 Parameters of the model company

	(HUF million)
E	2,451,369
D	2,680,918
V	5,132,287
E/V	47.76%
D/V	52.24%
Earnings before tax	275,699
Tax expense	47,318
T	17.16%
Total loans	909,039
Total interest expense	19,946
r_d	2.19%
r_f	2.71%
r_m	6%
B	1.23
r_e	6.76%
A	3%

Source: Own construction

The company therefore decides on an oil refinery as part of the investment decision. Its zero-year (one-time, immediate payment) investment cost (CAPEX) is 5.5 billion dollars. We assumed all this based on Tuttle (2019), who mentioned in his writing that the cost of building a plant capable of refining 100,000 barrels of oil per day is 6.9-8.6 billion dollars in Canada and 2.9-3.6 billion dollars in China. The capacity of the plant is accordingly 100 thousand barrels/day. We assume this is Brent oil, of which Fitch Ratings (2021) estimates a unit price of 53 dollars per barrel in the long run. Assuming 360 days of operation per year, this represents a total annual raw material cost of 1,908 million dollars. According to Robinson (2006), the cost distribution typical of oil refineries is that 85 percent is crude oil and 15 percent is other operating costs. Using this, the annual operating cost is 336.7 million dollars. Based on all this, the total annual cost is 1908 + 336.7 = 2,244.7 million dollars. Based on Avdeev&Co. (2021), we assume an average gross margin of 30 percent. Using the total cost calculated above, the annual revenue is 3,128.5 million dollars.

Based on all this, the initial parameters of the model (values in millions of dollars) can be read in Table 2. In the initial model, NPV = 445 million dollars, so rational corporate management would use its current knowledge to decide to implement the project. In this study, we use a sensitivity analysis approach for each scenario. This means that we show how much impact is required in a given factor to result in just zero net present value for the given company and project characteristics.

Table 2 Initial parameters of the model

	Year										
Name	0	1	2	3	4	5	6	7	8	9	10
(1) Revenue	0	3206.7	3206.7	3206.7	3206.7	3206.7	3206.7	3206.7	3206.7	3206.7	3206.7
(2) Raw material cost	0	1908	1908	1908	1908	1908	1908	1908	1908	1908	1908
(3) Operating cost	0	336.7	336.7	336.7	336.7	336.7	336.7	336.7	336.7	336.7	336.7
(4) EBITDA (1)-[(2)+(3)]	**0**	**962.0**	**962.0**	**962.0**	**962.0**	**962.0**	**962.0**	**962.0**	**962.0**	**962.0**	**962.0**
(5) Depreciation	0	550.0	550.0	550.0	550.0	550.0	550.0	550.0	550.0	550.0	550.0
(6) EBIT (4)-(5)	**0**	**412.0**	**412.0**	**412.0**	**412.0**	**412.0**	**412.0**	**412.0**	**412.0**	**412.0**	**412.0**
(7) Financial result	0	37.9	37.9	37.9	37.9	37.9	37.9	37.9	37.9	37.9	37.9
(8) Tax burden	0	70.7	70.7	70.7	70.7	70.7	70.7	70.7	70.7	70.7	70.7
(9) NOPLAT (6)-(7)-(8)	**0**	**303.4**	**303.4**	**303.4**	**303.4**	**303.4**	**303.4**	**303.4**	**303.4**	**303.4**	**303.4**
(5) Depreciation	0	550	550	550	550	550	550	550	550	550	550
(10) Operating CF (9)+(5)	**0**	**853.4**	**853.4**	**853.4**	**853.4**	**853.4**	**853.4**	**853.4**	**853.4**	**853.4**	**853.4**
(11) TE procurement (CAPEX)	5500	0	0	0	0	0	0	0	0	0	0
(12) Investment CF [-(11)]	**–5500**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
(13) FCFF (9)+(12)	**–5500**	**853.4**	**853.4**	**853.4**	**853.4**	**853.4**	**853.4**	**853.4**	**853.4**	**853.4**	**853.4**
(14) Discount rate	1	0.9330	0.8706	0.8123	0.7579	0.7071	0.6598	0.6156	0.5744	0.5359	0.5000
(15) PV (13)*(14)	–5500	796.24	742.92	693.18	646.76	603.45	563.04	525.34	490.16	457.34	426.72
NPV [(15) sum]	**445**										

Source: Own construction

4. Financial risks

In the next section, we examine the direct financial risks of climate change. The findings reviewed at the beginning of each sub-section are incorporated into the corporate decision model presented in the previous section in the second half of the sub-sections. There is basically a consensus in the literature on the types of risks. To identify these, we use as a main starting point the recommendations of the TCFD[1] made to economic operators under the auspices of the Financial Stability Board (FSB), which is closely linked to the G20 (TCFD 2017). The body was set up to develop a methodology for publishing climate-relevant corporate information. In the report, the authors distinguish between transitional and physical risk and assign economic and financial consequences to these.

4.1. Transitional risks

TCFD (2017) classified transitional[2] risks as the first risk type, of which four subtypes can be distinguished.

One of these is the group of legal-political risks, such as a sudden increase in the cost of greenhouse gas emissions (for example, through the introduction of a tax), which from a financial point of view could lead to an increase in costs and an obligation to pay any emission penalties. Also included are costs incurred as a result of new regulations applying to a particular group of raw materials (in this case, coal or oil, for example), which thus becomes a stranded asset. Consistent with this, McGlade and Ekins (2015) concluded that, to achieve the maximum warming level of 2°C from the Paris Climate Convention, a third of the currently known oil reserves, half of all natural gas reserves, and 90% of the world's coal reserves would become such devices because they cannot be used.

Factors of technological origin were classified in the second subtype of transitional risks. Manifestations of this include the need to replace companies' current products and services with lower-emission alternatives in order to stay on the market, and the risk that the introduction of new technologies will lead to failure. From a financial point of view, the increased capital expenditures on research and development and the increased capital requirements following the implementation of new solutions are what can be a problem here.

The third subtype is the group of transitional risks of market origin. These include changes in consumer behaviour and increases in commodity prices linked to climate change, the negative financial impact of which is due to, among other things, declining demand for the products of a company operating in a carbon-intensive industry, rising raw material costs or a profound transformation of the company's cost structure.

The final transitional risk is the perception risk that the reputation of a company operating in "more polluting" industries will deteriorate in the eyes of consumers and

[1] Task Force on Climate-Related Financial Disclosures

[2] By transition the process itself is meant, during which an economic model is established in which the pursuit of economic activities involves the emission of less carbon dioxide (and its equivalent gases).

other stakeholders (including investors). This may be detrimental to economic operators in terms of declining demand and declining available capital.

Pointner et al. (2019) approach the question somewhat differently. In their research, 6 traditional banking risks (credit, market, liquidity, operational, reputational, systemic) were taken into account and the risks arising from the transition were assigned to them. For the groups formed in this way, the effects of risks on the financial system were named. In terms of types of risks, there is significant overlap with the recommendations of the TCFD (2017), the uncertainties concerning future regulations and uncertainties regarding the level of real interest rates resulting from the impact of a possible carbon tax on inflation are introduced as new elements. The most significant difference in their research is that the effects, introduced by the TCFD mainly from a corporate perspective, are passed on to the banking system. In several cases, it appears that the aforementioned challenges for companies result in higher loan loss rates, thus jeopardizing banks' profits, in response to which they may set higher levels of risk premiums. Also, relevant findings of the authors of the study is that the Paris Climate Convention sets clear limits on greenhouse gas emissions, so a transition is inevitable.

The aspect often appears as well (e.g. Bank of England 2018; Rudebusch 2019) that a sudden switch to renewable energy makes it inevitable for the market to reprice the shares of companies operating in carbon-intensive industries, which could significantly reduce the market value of these securities and thus the company. Considering Battiston et al.'s (2017) finding that 45 to 47 percent of all financial intermediaries' assets are exposed in industries that may be directly affected by environmental regulations, this can be assessed as a significant risk that could ultimately undermine the stability of the financial system.

Modelling the impact of the realization of transitional risks on corporate project evaluation – tax shock

In the corporate decision situation depicted in the constructed model, we analyse the effect of a sudden tax on the transitional risks. Our assumption is that in a country relevant to the company, a government will come to power that seeks to achieve emission reductions by drastically taxing companies operating in carbon-intensive industries. The issue of carbon-dioxide tax has been raised at several points in the study, and real examples of this can be seen, so the assumption has a basis in reality. Table 3 illustrates the mechanism of action of this scenario.

In this scenario, we approach the question with a sensitivity test to examine what is the tax rate that leads to zero net present value if this tax is levied in the first year and remains unchanged thereafter, and if it is levied from year 6 and stabilizes thereafter. This seemingly arbitrary choice of years is justified by the fact that the primary aim is to demonstrate the mechanism of the effects and to illustrate the time differences observed in the occurrence of the effects, the examination of which these two dates thus allows. One of our basic assumptions was that all activities have the same T tax rate, so in the calculations this is reflected in the discount rate as part of the weighted average cost of capital and as a factor influencing corporate earnings. The results are summarized in Table 4.

Table 3 The mechanism of action of the realization of transitional risks

Event	Causes	Impact on corporate decision
Realization of transitional risks: tax shock	A change in public thinking due to extreme weather events or other reasons that puts pressure on policy makers to tax the most polluting companies	1) Increases the present value of cash flows by decreasing the discount rate 2) Reduces the present value of cash flows by reducing after-tax profit

Source: Own construction

Table 4 The sensitivity of the model firm's project appraisal to tax shock

Impact of the tax increase	Tax rate	Increase (percentage point)	Increase (%)
Base case	17.16%	–	–
Tax increase from year 1	34.4%	17.25%-points	100.50%
Tax increase from year 6	60.72%	43.56%-points	253.81%

Source: Own construction

As can be seen, in the first case, the tax rate resulting in the NPV = 0 level is 34.4%, which represents an increase of 17.25 percentage points, or 100.5 percent, compared to the initial value of 17.16 percent. In the second case (when the tax shock occurs in the sixth year), a tax rate of 60.72 percent of zero net present value can be achieved with an increase of 43.6 percentage points to 253.81 percent from the initial level. Although, among other things, the European Green Deal mentions the tightening of the carbon tax policy in the EU as an aim (European Commission, 2019), such an increase is not realistic in the current political climate in Europe in the period under review. The scenario is conceivable if extreme (e.g. weather) phenomena occur that fundamentally change the public mood, and much larger masses than at present demand more strong action from policy makers against climate change.

4.2. Physical risks

Another type of risk with financial consequences is the physical realization of hazards. We need to highlight, that this kind of risk poses a challenge for all companies, not just the ones operating in energy-intensive sectors, however, we continue our modelling with the same model company. One subcategory of this type includes acute risks, which can be seen in the increasing incidence of extreme weather events, the other subcategory includes chronic risks, such as changes in longer-term weather trends such as rainfall distribution, average temperature and sea level rise. There is basically a consensus in the literature that these two types of physical risk can be distinguished. However, it is typical to further expand and broaden them, and to take other aspects into account. In their study cited above, Pointner et al. (2019) also used physical risk sources to link them to traditional banking risks and examine their effects on the financial sector. According to their study, extraordinary weather events infiltrate the banking sector through the losses of their affected customers and the loss of their ability to repay their loans, but in the case of a more severely affected country, even increased capital withdrawals due to increased country risk can be considered as a likely consequence, which can increase exchange rate volatility. That increasing country risks is a truly relevant issue is well illustrated by Klusak et al. (2021) who found that assuming that the current rate of emissions is maintained, the credit ratings of 63 countries could deteriorate by 2030 solely because of climate change risks, which could increase interest rates on sovereign government bonds, placing a significant additional burden on public budgets around the world.

The negative impact of physical risk on economic performance realized in more frequent extreme weather events is often mentioned in the literature (Sterner 2015, TCFD 2017, DNB 2017, Olovsson, 2018, Pointner et al. 2019). This is done by the fact that these events have an impact on factors of production, leading to a reduction in economic output. Using a different approach, the same result is reached by Rudebusch (2019). He noted that the adverse effects of weather extremes on corporate creditworthiness would lead to increasing uncertainty in the entire financial sector. This uncertainty will ultimately lead to higher lending rates and higher consumer savings rates, and through this will lead to lower economic performance.

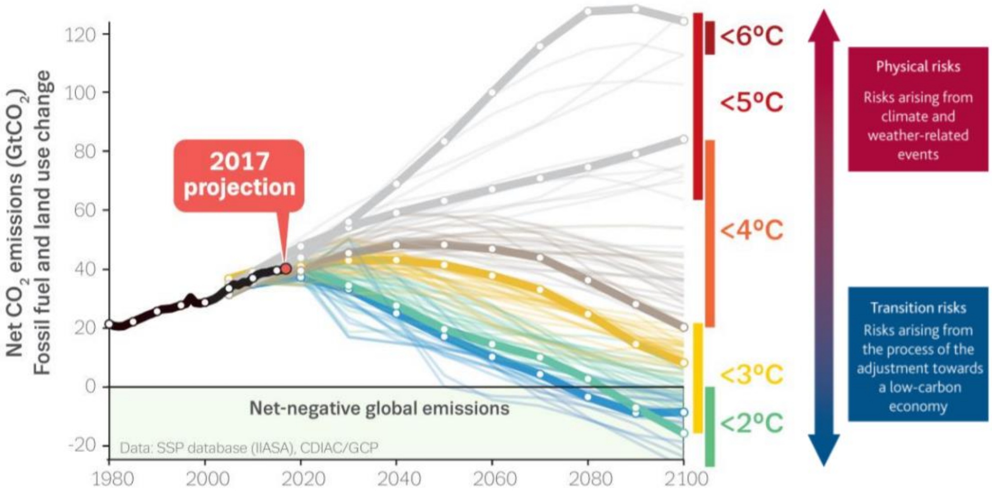
Related to the former is the content of The Economist Intelligence Unit's (2015) study on quantification (*Value at Risk*) and forecasting of financial risks. In this, the authors tried to predict what the cost might be if there was no reduction in greenhouse gas emissions. According to their findings, in an extreme case, assuming a warming of 6°C, nearly a third of the world’s total allocable assets will lose their value. According to the research, a small proportion of financial institutions have taken steps to estimate and manage the risks posed by climate change.

All in all, higher lending rates are a plausible consequence which could cause financial issues for companies, the most for which are operating in energy-intensive sectors. Aside from that, individual and institutional investors could also change their behaviour and climate-conscious investment thinking become more prominent, one good example being the ESG rating system that has appeared in recent years. The consequences of the realisation of transitional and physical risks concerning the credit and capital market are not examined in detail in this study.

The link between the increasing frequency of extreme weather events and climate change has already been pointed out in several studies (see, for example, Coumou and Rahmstorf 2012). The financial implications of extreme weather events are often the subject of research in the scientific sphere (e.g., Hsiang and Jina 2014, Schüwer et al. 2017). One of the findings of Klomp's (2014) research on the effects of natural disasters on financial stability, covering 160 countries and spanning 13 years, is that the realized effects depend significantly on the level of economic development of the affected country and the rigor of its financial regulation and supervision.

The opposite direction of the physical risk reviewed in this subsection and the transitional risk presented in section 4.1 was pointed out by a study by the Bank of England (2018) (Figure 1).

Figure 1 The opposite direction of the increase in physical and transitional risks.



Source: Bank of England (2018, 9)

Practically, this means that two scenarios can be imagined going forward in time. Assuming that the carbon-dioxide emissions continue at the current rate, the likelihood of physical risks occurring will increase due to the intensifying warming. If, on the other hand, emissions are successfully reduced to a lower level, the occurrence of physical risks are less likely due to the lower level of warming, but this will lead to an increase in transitional risks over time, since lower emissions presuppose the introduction of lower carbon practices in the economy. Thus, the later the transition begins, the greater the risk posed by one or the other risk, which is why timely action is critical.

Modelling the impact of the realization of physical risks on corporate project evaluation

With regard to physical risks, we basically present the impact of the increasing number of extreme weather events on corporate operations with the help of the model: first incorporating the realization of chronic risks and then the acute risks. There are also specific limitations to this scenario: much depends on where the company is geographically active and what such exposure other actors in the value chain have.

For simplification, we take the study of Cruz and Krausmann (2013) as a basis. In this, the authors examined the extent to which oil and gas infrastructure is exposed to physical risks. Among the chronic physical risks, the possible consequences of warming and among the acute risks, the possible consequences of storms and flash floods were listed in relation to the different stages of the oil industry value chain (extraction, transportation, refining). They illustrated the effects of these events with real examples and drew their conclusions from it. Based on these, warming appears in operating costs (e.g., heat reduces the capacity of machines, so more energy investment is required), and extreme events can cause huge one-time costs. They conclude that it is essential that industry players incorporate these risks into their operations and take adaptation steps.

We incorporate this into the model through an overview of two contingencies, the characteristics and effects of which are summarized in Table 5.

Table 5 The mechanism of action of the realization of physical risks

Event	Causes	Impact on corporate decision
Realization of chronic physical risks	As a result of warming, the efficiency of the company's means of production deteriorates	An increase in operating expenses that reduces profit and, through this, the present value of cash flows
Realization of acute physical risks	Extreme weather phenomenon that causes a significant deterioration of corporate infrastructure	Impact on CAPEX and through it on investment cash flow that reduces the present value of cash flows

Source: Own construction

In the first case, we model the increase in operating costs due to warming (chronic risk). Here, we examine the level of increase in operating costs that would result in a project being rejected if this cost increase occurred from the first year or only from the sixth year, assuming that the decision makers are aware of this at the time of the decision. The results are summarized in Table 6.

Table 6 The sensitivity of the model firm's project evaluation to the realization of chronic physical risks

Operating costs	Cost (USD million)	Increase (%)
Base case	336.71	–
Increase from year 1	413.85	22.91%
Increase from year 6	522.93	55.31%

Source: Own construction

Such an increase in operating costs is undoubtedly drastic. However, the example also illustrates that, depending on the cost structure, this factor may have a real impact on the project appraisal decision.

In the second case, we examine the effect of the realization of the acute physical risk, in the framework of which the plant suffers severe storm damage (flash flood). Cruz and Krausmann (2013) recall the flooding of the El Maleh River in Morocco in 2002 following a storm that destroyed seventy percent of the thermal power plant at the adjacent oil refinery complex. This is represented in the model as an impact affecting

CAPEX (and thus investment cash flow). Due to the nature of the net present value calculation, the later such an effect occurs during the period under review, the smaller the effect it has on the present value and thus on the decision. We assume that the extent of the destruction (expressed in percentages) the event causes will require the same amount of material expenditure for restoration. We examine the amount of damage in each year (expressed as a percentage of the investment amount in year zero) that, if it had been known at the time of planning, would have encouraged management to reject the project. The results of the calculation are summarized in Table 7.

Table 7 Sensitivity of the model firm's project evaluation to the realization of acute physical risks

Year	1	2	3	4	5	6	7	8	9	10
Cost* (%)	8.67	9.30	9.96	10.68	11.45	12.27	13.15	14.09	15.10	16.19

*The rate of loss of events resulting in zero net present value as a percentage of the initial investment amount
Source: Own construction

Table 7 shows that in the first year, the loss of only 8.67 per cent of the initial investment amount would have led to a net present value of zero, this value increased to 16.19 per cent over time. Although it is not justified to present such events as real decision criteria in the absence of information on the likelihood of their occurrence, depending on the geographical location of the entity and the characteristics of the industry, this perspective may appear in the design – for example, in the case of an agricultural enterprise, it is worth presenting this aspect even more strongly.

As the preliminary results of the European Central Bank's economy-wide climate risk modelling show, both physical and transitional risks pose a real threat to the functioning of the economy as a whole. The results also show that an unscheduled transition is also a threat to financial stability (De Guindos 2021).

4. Conclusion

In this study, we examined the financial and economic risks of climate change and their aspects affecting corporate operations through a review of the relevant literature and through the investment decision of an oil company based on this.

There is an extremely broad scientific consensus behind the fact of the threat of climate change. The two types of financial risks are transitional and physical risks, which are also potential threats to overall financial stability. The same factors can also affect the actors of the real economy through the interconnection of economic sectors. In a corporate decision model constructed with the necessary simplistic assumptions, the firm's sensitivity to the realization of transitional risks were presented through a tax shock, while its exposure to the emergence of physical risks were demonstrated through an increase in operating costs in the wake of warming, and for the acute physical risks, through the negative impact of a storm on production infrastructure.

It was also clearly observed in the models that the later an impact takes effect, the greater it must be to change the sign of the net present value of the cash flows generated by the project (provided that decision makers have prior information about it). However, this is a real possibility in each of the examined scenarios, as one of the most important lessons of the study is that the sooner the adaptation begins, the less drastic steps need to be taken to avoid the most adverse consequences. The results also point out that companies in industries with a traditionally high environmental impact will be more exposed to the risks of economic transition if they do not diversify their portfolios in time.

Developing tools similar to the model outlined in the study and adapting them to real corporate conditions can help integrate climate change considerations into decision-making, a practice that is not yet widespread, but can be an important tool for assessing and quantifying firms' climate-related operational risks.

References

Avdeev&Co. (2021): Oil And Gas Extraction: average industry financial ratios for U.S. listed companies. Avdeev&Co. https://www.readyratios.com/sec/industry/13/ Accessed: April 8, 2021.

Bank of England (2018): *Transition in thinking: The impact of climate change on the UK banking sector.* London: Bank of England.

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 (2017). https://doi.org/10.1038/nclimate3255 Accessed: June, 3, 2020.

Civin, V. (1998): Az üvegházhatású gázok kibocsátásainak csökkentése. *Iskolakultúra*, 1998, 12, 115–120.

Coumou, D. – Rahmstorf, S. (2012): *A decade of weather extremes.* Nature Climate Change 2, 491–496 (2012). https://doi.org/10.1038/nclimate1452 Accessed: March 6, 2021.

Cruz, A. M. – Krausmann, E. (2013): *Vulnerability of the oil and gas sector to climate change and extreme weather events.* Climatic Change 121, 41–53.

De Guindos, L. (2021): *Shining a light on climate risks: the ECB's economy-wide climate stress test.* European Central Bank. https://www.ecb.europa.eu/press/blog/date/2021/html/ecb.blog210318~3bbc68ffc5.en.html Accessed: April 8, 2021.

Erste Market (2021): *MOL – Piaci információk.* https://www.erstemarket.hu/termek/98/MOL Accessed: April 1, 2021.

European Commission (2019): *Az Európai Zöld Megállapodás.* https://eur-lex.europa.eu/legal-content/HU/TXT/?qid=1576150542719&uri=COM%3A2019%3A640%3AFIN Accessed: April 8, 2021.

Fitch Ratings (2021). *Fitch Ratings Raises Short-Term Oil and Gas Price Assumptions.* Fitch Ratings. https://www.fitchratings.com/research/corporate-finance/fitch-ratings-raises-short-term-oil-gas-price-assumptions-17-03-2021 Accessed: April 8, 2021.

Harvey, F. (2012). *Sir David King: quantitative easing should be aimed at green economy*. https://www.theguardian.com/environment/2012/jun/26/david-king-quantitative-easing-green Accessed: March 2, 2021.

Hsiang, S. M. – Jina, A. S. (2014): *The Causal Effect of Environmental Catastrophe on Long-Run Economic Growth: Evidence From 6,700 Cyclones*. NBER Working Paper No. 20352. Cambridge, MA: The National Bureau of Economic Research.

IEA (2019): *CO_2 emissions from fuel combustion*. Paris: International Energy Agency.

IPCC (2014): *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge: Cambridge University Press.

IPCC (2018): Summary for Policymakers. In: *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty*. IPCC.

Klomp, J. (2014): Financial fragility and natural disasters: An empirical analysis. *Journal of Financial Stability* 13, 180–192. https://doi.org/10.1016/j.jfs.2014.06.001 Accessed: June, 6, 2020.

Klusak, P. – Agarwala, M. – Burke, M. – Kraemer, M. – Mohaddes K. (2021): *Rising Temperatures, Falling Ratings: The Effect of Climate Change on Sovereign Creditworthiness*. Cambridge: Bennett Institute for Public Policy, University of Cambridge, UK.

McGlade, C. – Ekins, P. (2015): *The geographical distribution of fossil fuels unused when limiting global warming to 2°C*. Nature, 517, 7533, 187–190. https://doi.org/10.1038/nature14016 Accessed: April 2, 2021.

McKinsey (2009): *Pathways to a Low-Carbon Economy. Version 2 of the Global Greenhouse Gas Abatement Curve*. New York: McKinsey&Company.

Modigliani, F. – Miller, M. H. (1958): The Cost of Capital, Corporation Finance and the Theory of Investment. *American Economic Review* 48, 261–297.

MOL Group (2019): *Konszolidált éves jelentés*. MOL Magyar Olaj- és Gázipari Nyrt. https://molgroup.info/storage/documents/publikaciok/eves_jelentesek/2019/mol_group_annual_report_2019_hun.pdf Accessed: April 8, 2021.

Olovsson, C. (2018): Is climate change relevant for central banks? *Economic Commentaries*, 13, 1–8.

Pointner W. – Ritzberger-Grünwald, D. (2019): *Climate change as a risk to financial stability*. Financial Stability Report 38 – December 2019, 30–45. Österreische Nationalbank, Vienna, Austria.

DNB (2017): *Waterproof? An exploration of climate-related risks for the Dutch financial sector*. Amsterdam: De Nederlandsche Bank.

Robinson P.R. (2006): *Petroleum Processing Overview*. In: Hsu C.S. – Robinson P.R. (eds.) Practical Advances in Petroleum Processing. New York: Springer.

Rudebusch, G. D. (2019): *Climate Change and the Federal Reserve*. FRBSF Economic Letter, 2019-09. San Fransisco, USA.

Scheid, B. (2020): *S&P 500 returns to halve in coming decade – Goldman Sachs.* S&P Global Market Intelligence. https://www.spglobal.com/marketintelligence/en/news-insights/latest-news-headlines/s-p-500-returns-to-halve-in-coming-decade-8211-goldman-sachs-59439981 Accessed: April 8, 2021.

Schüwer, U. – Lambert, C. – Noth, F. (2017): How do banks react to catastrophic events? Evidence from Hurricane Katrina. *SAFE Working Paper* No. 94. Goethe University Frankfurt, Frankfurt am Main, Germany. http://dx.doi.org/10.2139/ssrn.2585521 Accessed: March 6, 2021.

Sharpe, W. F. (1964): Capital Asset Prices: A Theory of Market Equilibrium Under Conditions of Risk. *The Journal of Finance,* 19, 3, 425–442.

Stern, N. (2006): What is the Economics of Climate Change? *World Economics,* 7, 2, 1–10.

Sterner, T. (2015): Higher costs of climate change. *Nature*, 527, 177–178.

TCFD (2017): *Recommendations of the Task Force on Climate-related Financial Disclosures. Final Report.* Basel, Switzerland.

The Economist Intelligence Unit (2015): *The cost of inaction: Recognising the value at risk from climate change.* The Economist Intelligence Unit, London, UK.

Trading Economics (2021): *Hungary Government Bond 10Y*. https://tradingeconomics.com/hungary/government-bond-yield Accessed: March 24, 2021.

Tuttle, R. (2019): *Alberta's potential new refinery to reduce oil glut may only end up giving it a gasoline glut instead*. Financial Post. https://financialpost.com/commodities/energy/if-you-cant-pipe-it-refine-it-alberta-seeks-oil-glut-solution Accessed: April 8, 2021.