CLIMATE

DANMARKS NATIONALBANK

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Investors pay a premium for green equities

Investors reward companies with low carbon emissions with higher equity prices

Companies with low carbon emissions have higher equity prices because they are perceived as less risky. However, it is unclear whether investors' pricing of carbon risks reflect the actual risk caused by a green transition.

Read more

Cheaper financing gives companies a higher incentive to make a green transition

A company can reduce its financing costs by around 3 per cent by reducing its carbon emissions by 1 per cent. The cost reduction is relatively modest, but it does provide an increased incentive for making green investments.

Read more

Clarity about a carbon tax will increase these incentives further

Danmarks Nationalbank supports transparent regulation with a high degree of certainty about the time and size of a future carbon tax. This will support the incentive for companies to make a timely green transition.

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Climate change

Climate change is impacting society already today and will have further consequences in the future. A successful green transition will require unprecedented efforts, both in Denmark and abroad.

As a case in point, climate change and the transition to a greener economy will impact corporate earnings and economic activity. This may compromise price and financial stability in Denmark, which it is Danmarks Nationalbank's objective to ensure. It is therefore essential that Danmarks Nationalbank increases its knowledge of how, and by how much, the climate challenges will impact various parts of the economy.

Against this backdrop, Danmarks Nationalbank will focus on climate challenges in a series of publications.

ABOUT THIS ANALYSIS

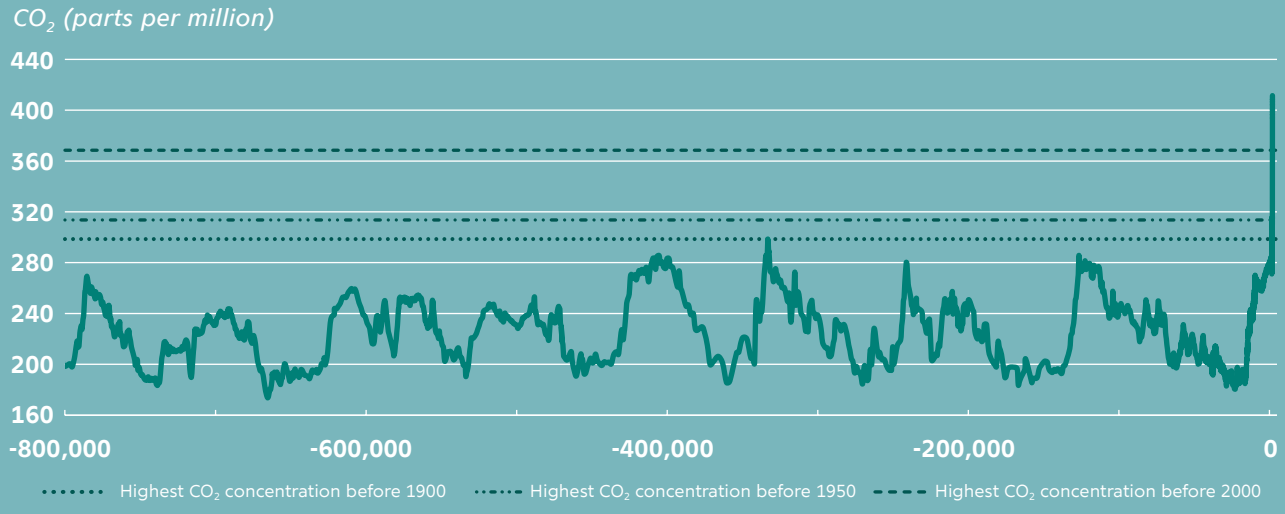
The prospect of a coming carbon tax has increased uncertainty about companies' future earnings and thus their value. Accordingly, investors are willing to pay a higher price for a company with low CO_2e emissions relative to a corresponding company with higher emissions.

Companies with low emissions can finance themselves at a lower cost than companies with higher emissions. Cheaper financing gives companies a higher incentive to invest in a green transition.

CO_2 concentration in the atmosphere

800,000 BCE to 2019 ACE

The chart shows the number of carbon dioxide molecules per million molecules of dry air.



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Source: National Oceanic and Atmospheric Administration (until 1957) and National Aeronautics and Space Administration (from 1958).

Projections of global greenhouse gas emissions show that the world is a long way from meeting the goal of climate neutrality by 2050 agreed under the Paris Agreement in 2015. One reason is that companies worldwide do not fully pay for the global costs of greenhouse gas emissions and the related climate change. Accordingly, the current financial incentives are insufficient to ensure a transition in accordance with the Paris Agreement. Further policy measures, such as a global tax on greenhouse gas emissions, may thus be necessary. The International Monetary Fund (IMF) has recommended the introduction of a global carbon tax of 75 dollars per emitted tonne of CO_2e in 2030. [1] [2] [3] According to the IMF, this could limit the long-term global temperature rise to 2°C. A carbon tax is the most cost efficient tool to reach the goals of climate neutrality.[4] A credible announcement of a future carbon tax will increase private incentives for green investments. At the same time, an announcement will reduce the uncertainty relating to the green transition, thereby supporting the pricing of climate-related risks in financial markets.

In 2020, the companies included in the analysis emitted a total of 1.8 billion tonnes of CO_2e, equal to 3 tonnes per million euro earned. If the IMF's proposal for a global carbon tax is implemented, these companies will be liable to pay around 120 billion euro in carbon tax, equal to approximately 20 per cent of their total profit. A global carbon tax will therefore have wide consequences for the future earnings of companies if they do not reduce their emissions before any tax is implemented.

The prospect of a future carbon tax results in increased uncertainty surrounding companies' future earnings and thus their valuation. These include uncertainties about the timing of the implementation of the tax, the size of the tax and the company's ability to adapt before the tax is implemented. A company's ability to adapt will depend on a number of factors, including technological limitations and whether the company can afford to make the necessary investments. Assumably the risks are greater, the higher a company's current CO_2e emissions are. Other things being equal, this should result in a lower equity price due to higher risks on the company's future earnings.

This analysis examines whether investors are willing to pay a higher price for a company with low CO_2e emissions relative to a corresponding company with higher emissions. The analysis is based on all non-financial corporations included in the leading European stock index, Eurostoxx 600. The analysis shows that, all else equal, companies with lower emissions have a higher equity price due to lower risks on future earnings than comparable companies with higher emissions. It is assessed that if an average company reduces its CO_2e emissions by 1 per cent, the value of the company's shares will increase by around 6 per cent. Although the price effect is not linear in the CO_2e reduction and is smaller for larger reductions, it gives a clear indication that prices increase if emissions are reduced. There are, however, large differences in how CO_2e risks are priced across industries.

Previous studies have found that companies with higher CO_2e emissions have lower equity prices relative to comparable companies with lower emissions, see Bolton and Kacperczyk (2020) and (2021).[5] This analysis goes one step further and investigates whether the fundamental cause of the lower price is a higher perceived carbon risk. It finds that companies with higher CO_2e emissions have higher equity risk premia, which is the underlying cause of the lower equity prices.

1 CO_2e indicates CO_2 equivalents, i.e. incl. emissions of other greenhouse gases than CO_2, which also lead to climate change.

2 The international action to mitigate greenhouse gas emissions is anchored in the Paris Agreement from 2015. The agreement aims to limit the long-term global temperature increase to below 1.5-2°C relative to pre-industrial levels. Meeting the 1.5-2°C goal requires a halt to global net emissions of CO_2e by 2050 at the latest.

3 IMF, Fiscal Monitor: How to Mitigate Climate Change, October 2019.

4 Ingholt, Jygert og Marcussen, Climate change and the role of central banks, *Danmarks Nationalbank Analysis*, No. 19, July 2021.

5 Patric Bolton and Marcin Kacperczyk, Carbon Premium around the World, CEPR Discussion Paper Series, May 2020. Patric Bolton and Marcin Kacperczyk, Do investors care about carbon risk, Journal of Financial Economics, Volume 142, November 2021.

The results of the analysis suggest that companies with low emissions can finance themselves at a lower cost than companies with higher emissions. By investing in a green transition now, a company can thus achieve lower financing costs going forward. Although the cost reductions are modest relative to the total financing costs, it nevertheless increases the incentive to invest green when assuming an unchanged capital structure. It is estimated that an average company can reduce its annual financing costs by just under 3 per cent by reducing its CO_2e emissions by 1 per cent. However, it is important that the compensation for risks reflects the actual risks. The willingness to make green investments has increased significantly in recent years. The high demand may have led to a lower required return on green equities, although the risk has remained unchanged.

The pricing of CO_2e risks in the equity market does not necessarily correspond to the actual risks. This may be due to several factors, including low transparency about how vulnerable business models are to a green transition. In addition, investors may have another perception of the political will to implement the necessary political actions, including a carbon tax. If the equity market underestimates risks of future losses, equities may end up in the hands of investors who do not have the necessary capacity to absorb losses. If the losses are sufficiently large, this may challenge the stability of the financial markets and the future financing of the green transition.

CO_2e risks and equity pricing

Shareholders has the right to the company's income, either in form of dividends or stock buybacks, once wages, other production inputs, taxes and interest on debt have been paid. In order to value an equity stock, an investor must form an expectation of the development in future earnings, the alternative return on a risk-free investment and how much compensation needed to undertake the risk of holding the equity instead of the risk-free investment. The risk compensation is referred to as the equity risk premium and reflects how much an investor requires in expected future additional return relative to a risk-free investment.

CO_2e risks may affect the equity risk premium
A carbon tax may affect the company's valuation in three ways:

1. If a carbon tax is implemented without uncertainty, it will result in a lower future return on capital and thus a lower equity price.
2. If there is uncertainty about the size and implementation time of the carbon tax, it will increase the risk on future capital returns. This leads to a higher equity risk premium and a lower equity price.
3. Uncertainty about a company's ability to adapt its business model increases the risk on future capital returns. Like in effect 2, the increased risk leads to a higher equity risk premium and a lower equity price.

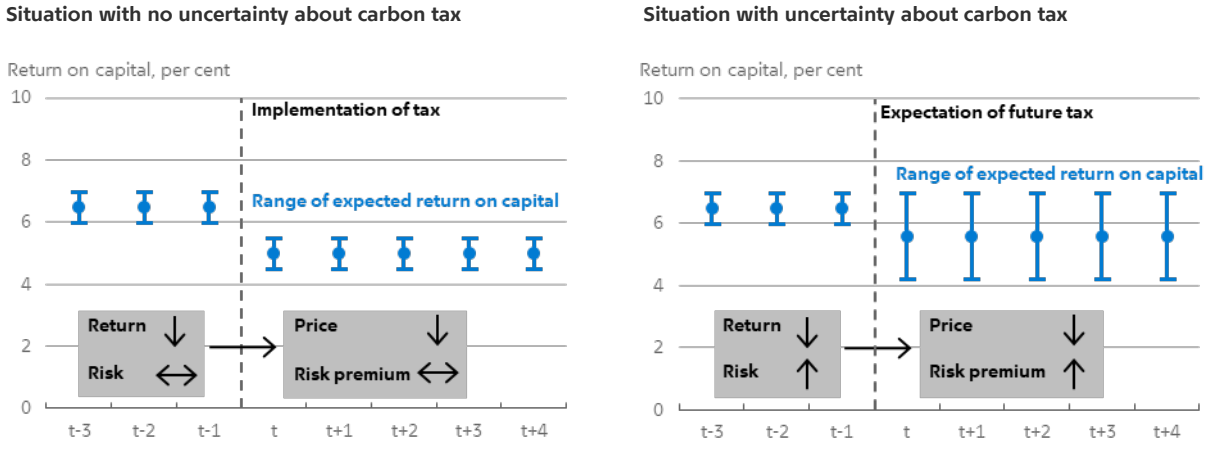
If a carbon tax is implemented immediately and with a high degree of transparency, corresponding to effect 1 above, this will affect a company's equity price via a decrease in expected earnings, see chart 1 (left). This reflects that, other things being equal, the carbon tax reduces the company's return on its capital stock, which will result in lower earnings without any further risk. The unchanged risk means that the equity risk premium remains unchanged, while the equity price decreases as a result of the decline in expected future earnings.

As different industries have different levels of emissions, the effect of a carbon tax will be highly industry-specific. Some industries will retain a much smaller share of their earnings relative to other industries if a carbon tax is introduced, see chart 2. For example, a materials company that extracts metals via mining operations will be much harder hit on its earnings than a technology company whose production is much more based on intangible assets that are not CO_2e intensive.

If there is uncertainty about the implementation of a carbon tax, either in the form of time or size, the tax will primarily affect a company's equity price via the equity risk premium, corresponding to effect 2 above. The uncertainty about the size and timing of a carbon tax will increase the risk on the company's future return on capital, see chart 1 (right). In such a situation, the investor will require an additional compensation for the higher risk, i.e. a larger equity risk premium. This will reduce the equity price.

The risk on a company's future earnings also depends on the company's ability to adapt, corresponding to

A carbon tax may mean lower expected profit or a larger risk on future expected profit Chart 1



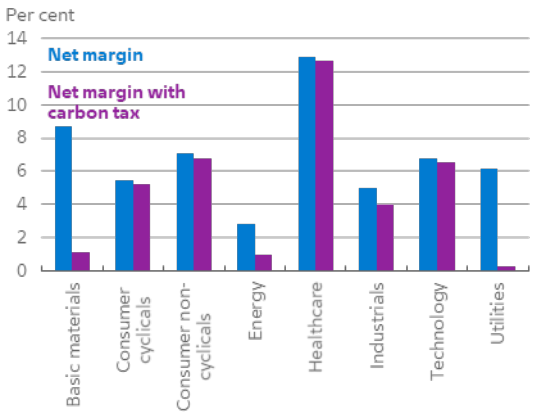
Note: Dot indicates the mean estimate of expected future earnings. The left-hand chart illustrates the effect of a carbon tax implemented at future time point t with certainty and transparency. The right-hand chart illustrates an uncertain implementation of a carbon tax where the time and size are uncertain. The profit in year t may thus be unchanged if the carbon tax has not been implemented, but it may also be lower if the carbon tax has been implemented.
Source: Own illustration.

effect 3 above. Transition risks reflect a company's ability to reduce its CO_2e emissions before the magnitude of carbon taxes have reached a level where it affects the company's earnings. Companies with large emissions, will typically have higher transition risks. This should be seen in the light of a number of factors, including that companies in industries with high competition cannot simply pass on the expense of a carbon tax to their customers via higher sales prices, as they will then lose market shares. Sharp competition will be particularly pronounced if a tax is only implemented regionally, whereas the competition is international. In addition, some companies will not have the technology to make a full transition, while others, for example coal producers, will end up with stranded assets in the long term. Higher transition risks thus increase the risk for the company's future return on capital. This increases the equity risk premium and results in a lower equity price.

Equity risk premia differ both within and across industries

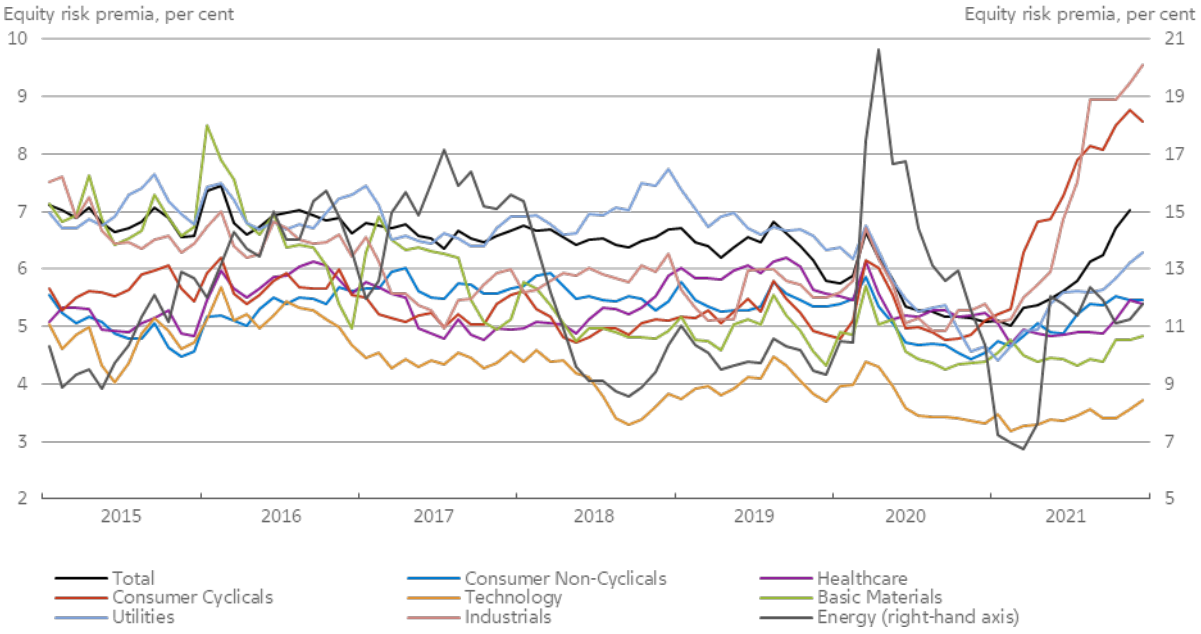
The equity risk premium in the euro area stands around the same level as at the beginning of 2015, after having increased during 2021, see chart 3. However, the development covers large differences across industries. Since 2015, the industry-specific equity risk premia have been around 3-21 percentage points, depending on industry and time, see chart 3.

Some industries are more exposed to a carbon tax than others Chart 2



Note: Net margin in 2020 with and without a carbon tax of 75 dollars per tonne. The chart is based on all non-financial corporations in Eurostoxx 600. Net margin has been calculated without behavioural effects such as higher prices or lower future CO_2e emissions. Net margin is the percentage of the company's total earnings that will ultimately remain after all expenses have been paid. Net margin is therefore an expression of a company's profitability.
Source: Refinitiv Eikon and own calculations.

Differences in equity risk premia across industries Chart 3



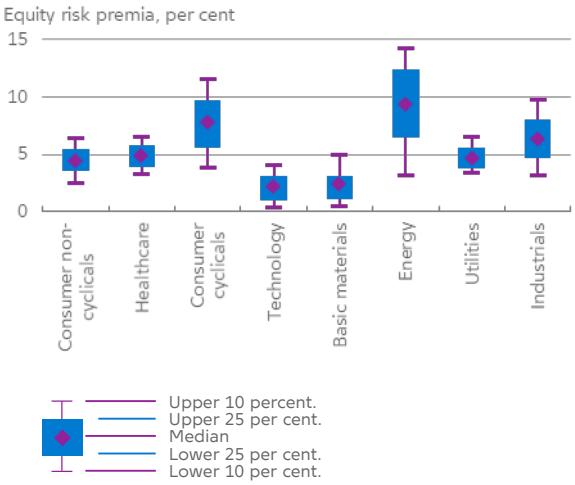
Note: Estimates of equity risk premia for companies in the leading European stock index, Eurostoxx 600. The equity risk premia have been calculated via a dividend discount model, DDM, see Appendix 1.
Source: Refinitiv Eikon and own calculations.

Equity risk premia depend on a number of conditions, including CO_2e risks, the competitive situation, regulation, liquidity risk and credit risk. These conditions vary from company to company. This means that equity risk premia differ from company to company, both for companies within the same industry and from other industries, see chart 4. In addition, equity risk premia are affected by other conditions that are not company-specific, for example the price of risk and financial behaviour, see Autrup and Hensch (2020).[6]

Investors price carbon risks

An econometric model, see Appendix 2, is used to identify whether companies with higher CO_2e emissions have higher equity risk premia as a result of

Equity risk premia vary within industries Chart 4



Note: 10th percentile, 25th percentile, median, 75th percentile and 90th percentile of equity risk premia in each industry in 2021. Equity risk premia have been estimated based on a DDM model and a Capital Asset Price Model, CAPM, see Appendix 1.
Source: Refinitiv Eikon and own calculations.

6 See Søren Lejsgaard Autrup and Jonas Ladegaard Hensch, Do equity prices reflect the ultra-low interest rate environment?, *Danmarks Nationalbank Economic Memo*, No. 1, February 2020.

higher carbon risk (via effects 2 and 3). The model is based on equity risk premia, CO_2e emissions[7] and accounting data for all non-financial corporations in the leading European stock index, Eurostoxx 600, in the period 2015-2020.

According to the model, the average carbon premium over the period 2015-2020 is approximately 25 basis points, see chart 5. However, it covers large fluctuations over the period. For example, the premium increased significantly in 2016. This likely reflects the conclusion of the Paris Agreement in autumn 2015, which formed the basis for expectations of political action, including a future carbon tax. However, uncertainty remained high. The carbon premium decreased slightly in the subsequent years, but it is still positive and significantly different from zero.

A carbon premium of an average of 25 basis points is relatively modest compared to the overall equity risk premium, averaging around 6 percentage points in the period 2015-2020. This means that the carbon premium has constituted around 4 per cent of the total equity risk premium in the period.

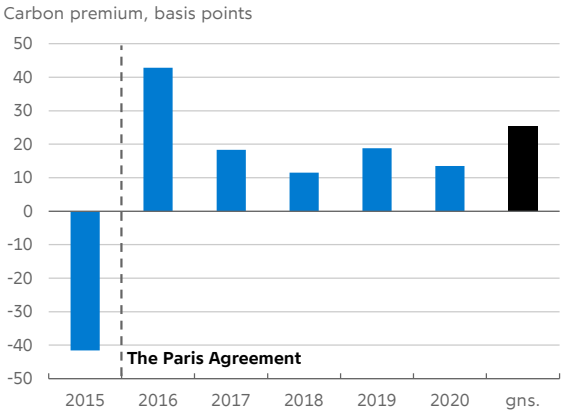
A positive carbon premium means that investors are willing to price a company higher if it reduces its emissions as it thereby lowers the risk on future earnings. According to the model, investors price an average company's equity approximately 6 per cent higher if the company is able to lower its CO_2e emissions by 1 per cent.

The results are robust to a number of changes in the specification of the model, including alternative definitions of CO_2e emissions, see Appendices 3-4. In addition, our results are not driven by CO_2e emissions in individual industries, such as energy companies, but apply across all industries.

Carbon premia are higher in CO_2e-intensive industries

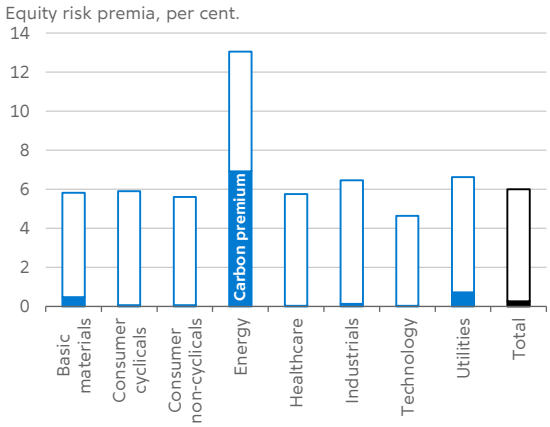
Carbon premia are very different across industries, see chart 6. This reflects that carbon risks are far lower for industries that are already less CO_2e-intensive.

Investors price a small, but significant, carbon premium Chart 5



Note: The chart shows the average carbon premia for non-financial corporations in the leading European stock index, Eurostoxx 600. The carbon premium has been calculated by multiplying estimated coefficient of CO_2e emissions with an average of the company-specific CO_2e emissions in a given year. The carbon premium is therefore a measure of the investors' assessment of the average company's carbon premium.
Source: Refinitiv Eikon, Sustainalytics and own calculations.

Some industries have higher carbon premia than others Chart 6



Note: The chart shows the average industry-specific carbon premia for companies in the leading European stock index, Eurostoxx 600, in the period 2015-2020. The carbon premium has been calculated by multiplying the industry-specific estimated coefficient of CO_2e emissions with an average of the company-specific CO_2e emissions in a given industry over the whole period. The carbon premium is therefore a measure of the investors' assessment of the average company's carbon premium in a given industry.
Source: Refinitiv Eikon, Sustainalytics and own calculations.

7 The companies' CO_2e emissions cover both their direct CO_2e emissions from their own production and their indirect CO_2e emissions from purchases of energy produced by other companies. These do consequently not take the use of materials into account. For details on CO_2e emissions, see Appendices 2-3.

For example, the prospect of a carbon tax creates greater uncertainty about a company's future earnings if its concentrated in the production of equipment or other material assets that are CO_2e-intensive in the production process. This includes companies in industries such as materials production, energy, manufacturing industry and supply.

In addition, companies in these industries may also have greater transition risks, as they cannot simply change their business models or production equipment from one day to the next. This requires that there exist new profitable business models or new production equipment that pollutes less.

Pricing of carbon risk does not necessarily reflect the actual risk

It is important to stress that the equity market does not necessarily price the risk for carbon-intensive business models correctly. If the equity markets underestimate the risk of future losses in case of increased carbon taxation, equities may end up with investors who do not have the capacity to absorb any losses. Very large losses may challenge the stability of the financial markets. This emphasizes the necessity of having good data and transparency about how vulnerable companies' business models are to a green transition. It also stresses the importance of a specific and credible announcement of the future carbon taxation, as this creates clarity about regulation of the corporate sector.

Increased incentive for green investments

Corporates can generally finance investment through bank and mortgage loans, issuance of bonds or equity. A corporate's average financing costs can be calculated as the costs of these individual sources of financing weighted by the share of funding from these sources.

The cost of equity depends on equity market developments. The reason for this is that the cost of equity reflects the investors' requirements for the return on the company's shares. The higher the return investors' require for the corporate's shares, the higher the costs of equity. The equity risk premium is therefore of great importance to corporates' financing costs. A decrease in the risk compensation required by shareholders (i.e. a decrease in the equity risk premium) will, other things being equal, lead to a lower cost of equity.

Corporates can reduce their financing costs by lowering their CO_2e emissions

A positive carbon premium means that corporates that reduce their emissions will be able to achieve a lower cost on their equity and thus lower financing costs. The reason being that the issuance of new shares will be at a higher price. Other things being equal, lower financing costs will make it more attractive to make investments.

Our results show that an average corporate can reduce its cost of equity by around 3-4 per cent if the company manages to reduce its CO_2e emissions by 1 per cent. The cost reduction applies to the whole equity and not just the financing of new projects, as existing shares also become less risky when the company's emissions are reduced.

Lower financing costs make green investments more profitable

Equity financing plays a major role in the overall financing of European companies. It has constituted just below half of their total liabilities in recent decades, see chart 7 (left). This means that a change in the cost of equity has major implications for the total financing costs.

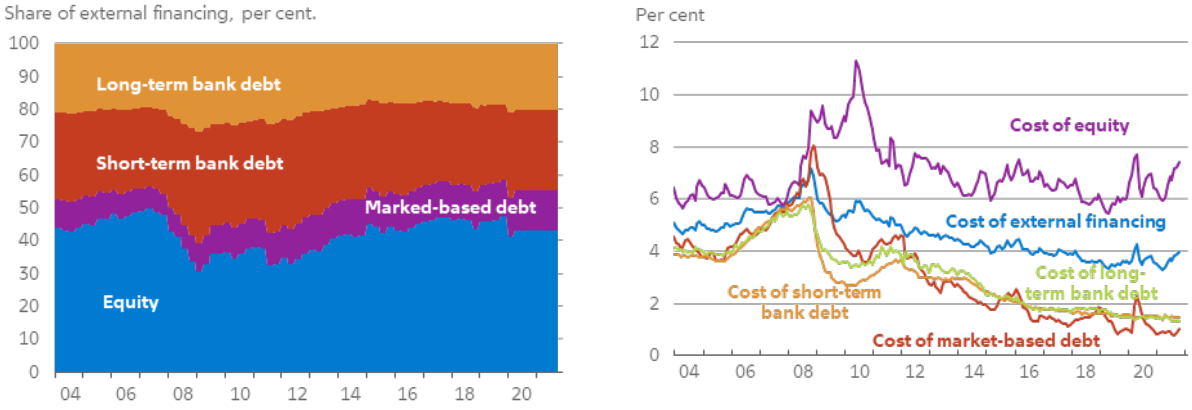
Assuming that the cost of debt financing, i.e. bank and bond debt, remains unchanged, an average corporate will be able to reduce its financing costs by just under 3 per cent if the corporate can reduce its CO_2e emissions by 1 per cent. The cost reduction is obviously higher in some industries and lower in others.

Lower financing costs mean that green investments become more profitable as they can be financed at a lower cost. The equity market thus rewards companies with low emissions, which is likely to lead more companies into making a green transition.

Low cost of green investments may change

The lower equity risk premia for corporates that are less CO_2e-intensive may either be due to investors

Equity is an important component of corporate financing Chart 7

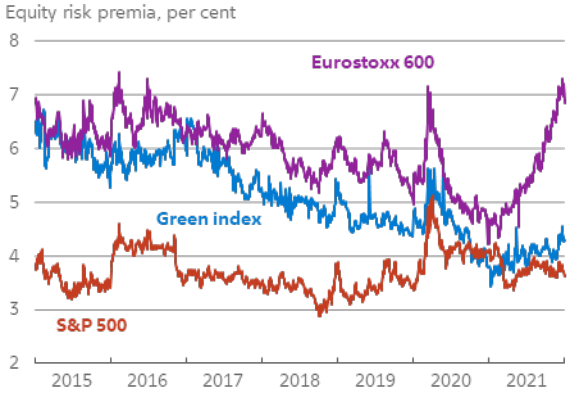


Note: Composition of financing (left-hand chart) and financing costs (right-hand chart) for non-financial corporations in the euro area, distributed on short-term and long-term bank loans, debt issuance and equity. Weighted by total outstanding amounts for non-financial corporations in the euro area.
Source: ECB and own calculations.

seeing the risk as lower or that they simply require lower compensation for the same amount of risk. If the risk is perceived as lower, it may be sensible to accept a higher price, i.e. a lower equity risk premium. This must be seen in the light of the lower risks including lower uncertainty about future taxation of CO_2e emissions and lower transition risks.

Lower equity risk premia for corporates with lower CO_2e emissions may also be a result of the investors demanding lower compensation for the same amount of risks for these companies. More and more investment funds and pension funds have implemented a green mandate. The green mandate is typically a benchmark for how much they want to allocate to green investments. For example, the Danish pension sector expects to have invested kr. 500 billion to support the green transition by the end of 2030.[8]

The equity risk premium for green business' has fallen sharply Chart 8



Note: Green index shows the equity risk premium for shares in iShares Global Clean Energy UCITS ETF. Equity risk premia have been estimated based on a DDM, see Appendix 1.
Source: Refinitiv Eikon and own calculations.

Increased interest in green investments may have led to lower equity risk premia for green business

The increased focus on green investments may have contributed to reducing equity risk premia for green companies, despite the underlying risk having

8 See Insuance & Pension Denmark (2019): The Danish Pension Industry Announces Green Investments Worth Billions (*link*).

remained unchanged. For example, the equity risk premium on the passive investment fund, which contains the 30 largest and most liquid listed companies globally in technological solutions for renewable energy, has fallen significantly since 2016, see chart 8. The decrease is noticeable in relation to the development in equity risk premia on global stock indices, such as Eurostoxx 600 and S&P 500, which have had a relatively stable development in the period.

It is hard to tell if the decline in the equity risk premium reflects lower risk or increased investor interest. However, the decline indicates that some green equities may have a relatively high valuation in relation to the equity market as a whole. It is therefore important that investors can absorb any losses if the risk turns out to be higher than expected. Alternatively, heavy losses may force investors to sell other investments. This may lead to further market turbulence – to the detriment of financial markets and financing of the green transition.

Yields on corporate bonds are low in an historic context, and at the same time the cost of equity is reduced as emissions are cut. European companies are thus in a favourable position to finance green investments. However, this may quickly change if the perception of risk changes or if less money chases green investments.

Appendix 1: Calculation of equity risk premia

Investors require compensation in the form of a higher expected return for holding equites rather than a risk-free asset in their portfolio. The implied required return is called an equity risk premium. Equity risk premia cannot be directly observed and must therefore be estimated based on equity prices, expected return on a risk-free investment and expectations to earnings growth. Equity risk premia can be estimated in several ways. This analysis uses a Dividend Discount Model, DDM, developed by Danmarks Nationalbank. Similar models are used by other central banks, including the ECB.[9]

The risk premium for each equity is calculated in two steps: First, equity risk premia are estimated for different industries in the Eurostoxx 600 index via a DDM. Individual equity risk premia are then found using a Capital Asset Pricing Model, CAPM.

Industry-specific equity risk premia

Theoretically, the fundamental value of a share is calculated as the present value of the expected future dividends discounted by the required return:

$$P_t = \frac{D_{t,1}}{\left(1 + r^f_{t,1} + \varepsilon_t\right)^1} + \frac{D_{t,2}}{\left(1 + r^f_{t,2} + \varepsilon_t\right)^2} + \cdots + \frac{D_{t,\infty}}{\left(1+r^f_{t,\infty}+\varepsilon_t\right)^\infty},$$

where P_t is the equity price at time t, D_t is the expected dividend per share, $r^f_{t,i}$ is the i-year risk-free interest and ε_t is the risk premium. The equity risk premium is implicitly estimated to be precisely the value that will apply for the equity price to be equal to the present value of future dividends. In practice, however, it is necessary to make assumptions about the expected path of future dividends, as they are generally unknown.

At time t, the price is assumed to be given by

$$P_t = \underbrace{\sum_{h=1}^{15} \frac{D_{t,h}}{\left(1 + r^f_{t,h} + \varepsilon_t\right)^h}}_{Short\ and\ medium\ run} + \underbrace{\frac{D_{t,15} \cdot (1 + g^n_t)}{\left(1 + r^f_{t,20} + \varepsilon_t\right)^{15}\left(r^f_{t,20} + \varepsilon_t - g^n_t\right)}}_{Long\ run}$$

This is based on expected dividends for the present year and one year into the future, $D_{t,1}$ respectively $D_{t,2}$. $D_{t,3} = D_{t,2}(1 + g_{t,2})$ is used for expected dividends in year 3, where $g_{t,2}$ is the expected growth in earnings in an industry from two to three years into the future, $D_{t,4} = D_{t,3}(1 + g_{t,3})$ and $D_{t,5} = D_{t,4}(1 + g_{t,3})$, where $g_{t,3}$ is the expected average earnings growth in the industry from three to five years into the future, and

$$D_{t,h} = D_{t,h-1} \cdot \left(1 + g^a_t - (g^a_t - g^n_t)\frac{h-5}{10}\right)$$

for $h = 6, 7, \ldots, 15$, where g^a_t is the expected medium-term earnings growth rate and g^n_t is the expected long-term growth rate for the industry. An underlying assumption is that future dividends grow at the same rate as earnings, i.e. a constant payout ratio.

The model is an extension of the H model, which has previously been used by Danmarks Nationalbank, see Autrup and Hensch (2020). Compared to the H model, this model allows for variation in short-term and medium-term growth rates and discounts future dividends with an entire yield curve rather than just a single risk-free interest rate. One effect of this is the inclusion of short-term and medium-term earnings expectations. Therefore, the DDM has an advantage when estimating equity risk premia on smaller portfolios, such as industries within an index, as the model takes into account that some industries grow at higher rates than others in the short term and medium term.

9 See Geis, Kapp and Kristiansen (2018), Measuring and interpreting the cost of equity in the euro area, ECB, *Economic Bulletin*, Issue 4.

Data

Industry-specific equity risk premia are estimated using data for earnings per share, expected earnings, dividends per share and market value. Expected earnings and dividends are weighted averages of equity analysts' expectations. Yields on German government bonds with maturities that match the times of the future dividends are used as risk-free interest. The expected long-term growth rate is approximated by the sum of long-term inflation expectations in the euro area (5y-5y inflation swaps) and a 20-year historical average of real GDP growth in the euro area.

All variables are aggregated at industry level by a weighted sum, where each individual corporate is weighted by its share of the industry's total market value. Data is from Refinitiv Eikon.

The level of estimated equity risk premia is generally subject to considerable uncertainty, as the estimates are very model-specific. One should be careful when making level-based interpretations. However, the dynamics of risk premia as well as the relative size of the risk premium between different groupings are more robust and thus interpretable.

Individual equity risk premia

Equity risk premia on specific equities in a given industry can be estimated using the classic Capital Asset Pricing Model, CAPM. If an equity is riskier than the industry as a whole, shareholders will require a higher return on this equity relative to the industry as a whole. In CAPM, it is assumed that the systematic risk which cannot be eliminated by diversification is what shareholders require compensation for.

The risk premium for an individual equity is thus determined by:

$$E(R_{i,t}) = r_t^f + \beta_{i,t} \cdot \varepsilon_{m,t},$$

where $E(R_{i,t})$ is the expected return by holding equity i, r_t^f is the risk-free interest, $\varepsilon_{m,t}$ is the industry's risk premium, and $\beta_{i,t}$ is the co-variation of the returns between the equity and the industry:

$$\beta_{i,t} = \frac{Covariance(R_{i,t}, R_{m,t})}{Variance(R_{m,t})}.$$

If beta is greater than one, it means that when the equity price in a given industry increases, the price of the individual equity increases by more than the industry as a whole. The equity is therefore riskier than the industry as a whole, and the equity risk premium is higher. As both volatility and correlation change over time, a time-varying $\beta_{i,t}$ is estimated based on equity prices from 100 trading days.

Appendix 2: Econometric method

Three different panel data models are used:

1) $\varepsilon_{i,t} = \alpha \cdot CO_2e_{i,t} + \psi \cdot Controls_{i.t} + e_{i,t}$,

2) $\varepsilon_{i,t} = \beta \cdot \log(CO_2e)_{i,t} + \delta \cdot Controls_{i.t} + u_{i,t}$,

3) $\varepsilon_{i,t} = \gamma \cdot \frac{CO_2e_{i,t}}{revenue_{i,t}} + \varphi \cdot Controls_{i.t} + \eta_{i,t}$,

where $\varepsilon_{i,t}$ is the equity risk premium for company *i* at time t, $CO_2e_{i,t}$ is firm-specific CO_2e emissions, $\log(CO_2e)_{i,t}$ is the logarithm of firm-specific CO_2e emissions, $\frac{CO_2e_{i,t}}{revenue_{i,t}}$ is firm-specific CO_2e emissions in million tonnes as a ratio of the revenue in billion euro. $Controls_{i.t}$ covers variables that capture industry-specific and firm-specific factors which may have an influence on the risk premium.[10] $e_{i,t}, u_{i,t}$ and $\eta_{i,t}$ are error terms. 'Clustered' standard errors allow the error terms to be heteroscedastic and autocorrelated over time. The models are estimated via fixed effects. This means that we examine whether there may be firm-specific factors that affect both CO_2e emissions and risk premia. The results are robust to OLS estimation of the models, where a dummy variable is included to check that there may be factors in individual industries that affect both CO_2e emissions and the risk premium. However, the robustness of the results indicates that there are no factors at the firm level that explain both CO_2e emissions and risk premia.

It is assumed in the models that the correlation between the equity risk premium and the different measures of CO_2e emissions are linear in the parameters. To ensure a causal interpretation of α, β and γ it is assumed that

$Cov(CO_2e_{i,t}, e_{i,t}) = 0$, $Cov(\log(CO_2e)_{i,t}, u_{i,t}) = 0$ and $Cov(\frac{CO_2e_{i,t}}{Revenue_{i,t}}, \eta_{i,t}) = 0$.

Significant effect on equity risk premia from CO_2e emissions Table 1

	(1)	(2)	(3)
CO_2e	0.067*** (0.008)		
log(CO_2e)		0.240*** (0.044)	
CO_2e/revenue			0.741** (0.088)
Control variables	Yes	Yes	Yes
Time dummies	Yes	Yes	Yes
Estimator	FE	FE	FE
Std. error	Clustered	Clustered	Clustered
Observations	23,435	23,435	23,435

Note: * p value <0.10, ** p value <0.05, *** p value <0.01. The standard error in the estimate is stated in brackets. The results are based on the models described in Appendix 2.
Source: Refinitiv Eikon and own calculations.

This means that the equity risk premium does not affect the CO_2e emissions and the factors that do affect the equity risk premia do not affect the CO_2e emissions. If these assumptions are met, causal interpretations can be applied to the estimates for α, β and γ. This means that α indicates the average change in equity risk premium in percentage points when CO_2e emissions increase by 1 million tonne. β indicates by how much the risk premium is changed in percentage points when the CO_2e emission increase by 1 per cent. Finally, "gamma" indicates changes in the risk premium in relation to a change of a unit in the CO_2e revenue ratio.

10 The control variables consist of: equity, return on capital, debt-to-assets, current ratio, revenue, debt-to-EBITDA, total assets, market value, net revenue, investments-to-equity, value of machinery, buildings and production plant as well as several different dummy variables for industries. Current ratio is a measure of a company's short-term liquidity, and is calculated as the ratio of liquid assets to short-term obligations. In specification (2), where log transformation for CO_2e emissions is used, log of the revenue is used instead of the revenue. In addition, the revenue is not checked in specification (3). The regressions include a constant term and time trend.

Appendix 3: Source of CO_2e emissions

The model uses different measures for firm-specific CO_2e emissions:

- Scope 1: Direct CO_2e emissions from the corporate's own production, emitted by the corporate itself. This covers both stationary emissions (such as production facilities and area use) and mobile emissions (such as transport of products).
- Scope 2: Indirect CO_2e emissions from the corporate's purchases of energy, produced by other corporates. These emissions come primarily from purchases of electricity, steam, heating or cooling.

The sum of Scope 1 and Scope 2 is used as the primary measure of CO_2e emissions. As a robustness check, the models are also estimated for Scope 1 and Scope 2 separately (see Appendix 4). The primary source of data for CO_2e emissions is Refinitiv Eikon, which gets data through Sustainalytics. As a robustness, CO_2e emissions from MSCI are also used to check that the results are not driven by the method of accounting (see Appendix 4).

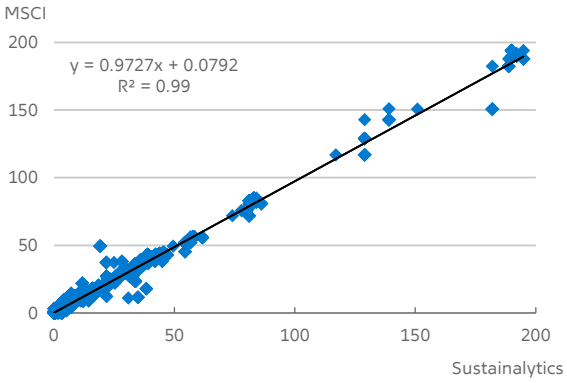
Two recognized data sources for CO_2e emissions

CO_2e emissions for Scopes 1 and 2, respectively, can be calculated in different ways. This can affect the results. There are two widely recognised data sources for CO_2e emissions: MSCI and Sustainalytics. Data from MCSI has been collected via Bloomberg. There is a high degree of co-variation between the two statistics, despite different calculation methods, see chart 9.

The variation in CO_2e emissions over time is also close across the two data sources. The average company's CO_2e emissions follow each other relatively closely in the two data sources, see chart 10. This underlines that the two data sources are relatively identical when comparing CO_2e emissions for large European companies. The results of the analysis are unchanged when using emissions reported by MSCI, see Appendix 4.

Close correlation between CO_2e emissions from MSCI and Refinitiv Eikon (Sustainalytics)

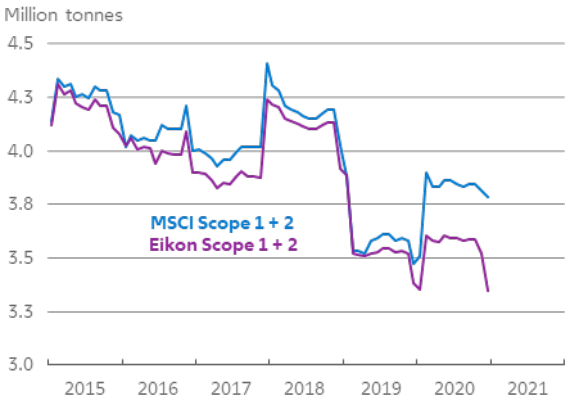
Chart 9



Note: Scatter diagram based on companies in Eurostoxx 600, CO_2e emissions from MSCI and Sustainalytics. CO_2e emissions include both Scope 1 and Scope 2. Data from 2015-2020.
Source: Bloomberg, Refinitiv Eikon and own calculations.

The variation over time is close in the two statistics

Chart 10



Note: CO_2e emissions from an average company in Eurostoxx 600. Data includes both Scope 1 and Scope 2.
Source: Bloomberg, Refinitiv Eikon and own calculations.

Appendix 4: Robustness checks

In this section, it is examined whether the results are robust to different data sources and models. The below estimations suggest that the positive correlation between equity risk premia and CO_2e emissions is quite robust to various choices of data and model specifications.

The first robustness checks consider the baseline model with OLS instead of fixed effects, see specifications (2), (9) and (16) in table 2. These regressions also include additional industry dummies that control for industry-specific effects. The coefficient of the estimates as well as the significance level are unchanged.

Subsequently, it is examined whether the results are robust to alternative specifications of the equity risk premia. It was assumed in our baseline model that the expected long-term earnings growth was the same across industries. As a robustness check, we used equity risk premia estimated via industry-specific long-term growth rates. These long-term growth rates have been calculated for industry b as follows:

$$g_{b,t}^{n} = \frac{g_{b,t}^{a}}{\sum_{b=1}^{B} \omega_{b,t} \cdot g_{b,t}^{a}} \cdot g_{t}^{n},$$

where $\omega_{b,t}$ is industry b's aggregated market value as a share of the total market value of all B industries, $g_{b,t}^{a}$ is the medium-term earnings growth and g_{t}^{n} is the long-term nominal GDP growth of the economy as a whole. The results are also robust to this change, see specifications (3), (10), (17).

Macroeconomic and financial data do often suffer from autocorrelation. This may cause incorrect estimates and/or significance levels. Therefore, a robustness check is performed where 1) autocorrelation is allowed for up to 12 months and 2) heteroscedasticity in the error terms by using the Newey-West estimator for the standard errors. Overall, the sign and the significance of the estimates are unchanged, see specifications (4), (11) and (18). However, the estimate in the model for the CO_2e revenue ratio is not significant. Overall, the results are robust to this change.

As previously mentioned, CO_2e emissions can be divided into Scope 1, Scope 2 and Scope 3 emissions. As corporates more actively influence their Scope 1 emissions than on Scope 2 emissions, the results could be expected to be driven by Scope 1 alone. However, the sign and significance level of the results are robust to the model based on Scope 1 and Scope 2, see specifications (5)-(6), (12)-(13) and (19)-(20). Both types of emissions are thus important to pricing of carbon risk.

Finally, a robustness check is performed of the data source for CO_2e emissions. As mentioned above, our main results are based on Sustainalytics. As an alternative, MSCI is used as a data source for CO_2e emissions. The coefficients of the estimates are robust to this change in all three specifications, see (7), (14) and (21). However, the estimate in the model for CO_2e at level is non-significant, see specification (21).

Robustness checks

Table 2

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
CO_2e/revenue	0.741***	0.663***	1.201***	0.158	2.721***	8.520***	0.438***
CO_2e source	Eikon	Eikon	Eikon	Eikon	Eikon	Eikon	MSCI
CO_2e scope	Scope 1 + 2	Scope 1 + 2	Scope 1 + 2	Scope 1 + 2	Scope 1	Scope 2	Scope 1 + 2
Estimator	Fixed effects	OLS	Fixed effects	OLS	Fixed effects	Fixed effects	Fixed effects
Standard error	Clustered	Clustered	Clustered	Newey-West	Clustered	Clustered	Clustered
ERP	ERP 1	ERP 1	ERP 2	ERP 1	ERP 1	ERP 1	ERP 1
Observations	23,435	23,435	23,435	23,435	21,645	21,553	19,077

	(8)	(9)	(10)	(11)	(12)	(13)	(14)
log(CO_2e)	0.240***	0.141***	0.345***	0.139***	0.212***	0.179***	0.247***
CO_2e source	Eikon	Eikon	Eikon	Eikon	Eikon	Eikon	MSCI
CO_2e scope	Scope 1 + 2	Scope 1 + 2	Scope 1 + 2	Scope 1 + 2	Scope 1	Scope 2	Scope 1 + 2
Estimator	Fixed effects	OLS	Fixed effects	OLS	Fixed effects	Fixed effects	Fixed effects
Standard error	Clustered	Clustered	Clustered	Newey-West	Clustered	Clustered	Clustered
ERP	ERP 1	ERP 1	ERP 2	ERP 1	ERP 1	ERP 1	ERP 1
Observations	23,435	23,435	23,435	23,435	21,645	21,553	19,077

	(15)	(16)	(17)	(18)	(19)	(20)	(21)
CO_2e	0.067***	0.039***	0.088***	0.011***	0.053***	0.279***	0.008
CO_2e source	Eikon	Eikon	Eikon	Eikon	Eikon	Eikon	MSCI
CO_2e scope	Scope 1 + 2	Scope 1 + 2	Scope 1 + 2	Scope 1 + 2	Scope 1	Scope 2	Scope 1 + 2
Estimator	Fixed effects	OLS	Fixed effects	OLS	Fixed effects	Fixed effects	Fixed effects
Standard error	Clustered	Clustered	Clustered	Newey-West	Clustered	Clustered	Clustered
ERP	ERP 1	ERP 1	ERP 2	ERP 1	ERP 1	ERP 1	ERP 1
Observations	23,435	23,435	23,435	23,435	21,645	21,553	19,077

Note: * p value <0.10, ** p value <0.05, *** p value <0.01. The results are based on the models described in Appendix 2.
Source: Bloomberg, Refinitiv Eikon and own calculations.

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