Credit risk sensitivity to carbon price

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CREDIT RISK SENSITIVITY TO CARBON PRICE

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Abstract. One way to reduce greenhouse gas (GHG) emissions is to find an efficient carbon price, which transfers the cost of the negative externalities of GHGs to the companies that are responsible for them and can avoid them through appropriate investments. However, a rising carbon price may financially weaken some of them, and by extension the banks they borrowed money from. In this context, the European Central Bank is organizing a *climate stress test*, part of which concerns the risk related to a rise in the price of carbon. In this paper, we present a practical method for assessing the sensitivity of credit risk to the carbon price.

KEYWORDS. Green house gas emissions, Transition risk, Credit risk, ECB climate stress test.

JEL CODES : G18, G24, E58, Q01.

1. INTRODUCTION

In a context of climate change due to human activities (Caldeira and Wickett, 2003), one of the major indicators of the ecological transition, which has also become a tool for steering the politics of change, is the quantity of greenhouse gases (GHGs) emitted by economic activities. Recent international agreements, such as the Paris Agreement, have set GHG emission targets for the international community, and in particular for countries through nationally determined contributions (NDCs). These NDCs are roadmaps that countries commit to follow in order to reduce their GHG emissions and to meet the objective of keeping global warming to below 2°C in 2100 compared to the pre-industrial level. They can be adjusted regularly to achieve *carbon neutrality* (i.e., equilibrium between anthropogenic emissions and natural or artificial absorptions) as quickly as possible: for instance, the European Union (EU) has increased its GHG reduction target compared to 1990 from 40% net (2015 NDC) to 55% net (2020 NDC).

In particular, two-thirds of the NDCs filed by countries with the UN include the implementation of a *carbon price* as a tool to control or offset GHG emissions. The objective of carbon pricing is to make emitters pay the cost of the externalities induced by GHGs. This idea existed prior to the Paris Agreement: since 2005 and the implementation of an emissions trading scheme (ETS) within the EU, carbon has a market price, determined by exchanges between companies belonging to particularly emitting sectors, taking into account a quantity distributed by the Member States through a national allocation plan (Zetterberg et al., 2004). Each year, the quantity of allowances available on the market decreases (e.g., France has reduced it by 1.74% per year over the period 2013-20, with the objective of reaching 0% of free allowances). This situation, in association with regulations, has recently created an inflation of the carbon price.

Certain studies have shown that the ETS has not specifically impacted on the competitiveness (Arlinghaus, 2015) or performance of companies (Dechezleprêtre et al., 2018), and by extension their creditworthiness. However, these results come from historical data recorded when the carbon price was low and free allowances were widely distributed. In an inflationary carbon market with more restrictive regulations, the impact of carbon on the performance and therefore the credit of companies raises the question of the market's resistance to a sharp rise in the carbon price.

For banks, credit risk exposure and capital values may be sensitive to increases in the carbon price, with risks ranging from *counterpart default* to *asset value impairment*. This risk is called *transition risk*.

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Like macro-financial risks, transition risk is of interest to banking regulators. The Basel Committee on Banking Supervision, for example, recently created a Task Force on Climate-Related Financial Risks (TFCR). The TFCR contributes to the Committee's objective of enhancing financial stability by taking initiatives on climate-related financial risks. Its economic research has, for example, mapped climate-related financial risks (Basel Committee on Banking Supervision, 2021b), surveyed Basel Committee members to learn about their various initiatives on this subject (Basel Committee on Banking Supervision, 2020), or identified their associated methodologies (Basel Committee on Banking Supervision, 2021a).

In this context, the European Central Bank (ECB) has decided to organise a climate risk stress test (CST), inspired by the stress tests of European Banking Authority's (STEBA) (European Banking Authority, 2021) for macro-financial risks. For this exercise, the ECB draws on the climate scenarios of the Network for Greening the Financial System (NGFS) (Bertram et al., 2020) and defines a set of macro-financial trajectories including the impacts of climate change. In these scenarios, the short-term transition risk (3 years) corresponds to a sudden and unexpected increase in the carbon price linked to a *disorderly transition* which assumes that climate policies are not introduced before 2030, implying a sudden and brutal increase in the carbon price (European Central Bank, 2021).

It is therefore necessary for banks to have new and clear methodologies to address this risk. In our paper, we propose a method that can be easily implemented, as it is inspired by *specific banking stress tests*, to compute the sensitivity of a portfolio's probability of default (PD) to an increase in the carbon price.

2. DEFINITIONS AND ASSUMPTIONS

2.1. *Greenhouse gas emissions*

GHG scopes. Greenhouse gas (GHG) emissions are divided into three scopes:

- Scope 1 (S1) covers GHG emissions from fixed and mobile installations within the organisational perimeter, emitted directly by the production activity
- Scope 2 (S2) includes indirect emissions associated with the production of electricity, heat or steam imported for the organisation's activities
- Scope (S3) includes all other emissions, indirectly related to the activity before or after production. In general, the majority of the emissions are in this scope

2.2. *Carbon pricing*

Definition. The *carbon pricing* is an instrument that takes into account the negative externalities of GHG emissions, i.e. the consequences of emissions paid for by people that are not directly responsible for them. These include crop damage, health care costs related to heat waves, droughts and pollution, and property losses due to flooding and sea level rise. GHG emitters must then decide whether it is more profitable to pay a carbon price or to reduce their emissions through appropriate investments and transformations.

Main carbon pricing schemes. There are several systems that use and value the carbon price, and make it usable by companies and investors.

The *Emissions Trading Scheme* (ETS) (Ellerman and Joskow, 2008) is a system by which emitters can trade emission credits. By creating supply and demand for emission units, an ETS establishes a market price for carbon. This system belongs to *cap-and-trade* schemes (Stavins, 2008), in which governments cap the total emissions level of one or more sectors of the economy and distribute it among the companies operating in these sectors in the form of emission units (also called allowances). These companies can receive, buy or trade allowances on the ETS.

A *voluntary offset mechanism* (Kollmuss et al., 2008) enables companies or States that wish or need to reduce their GHG emissions to do so by financing a carbon reduction or sequestration project. The carbon prices on the voluntary offset market are determined by various factors specific to the underlying projects: there is not one global unique carbon offset price with this mechanism (Conte and Kotchen, 2010).

Results-based climate financing (RBCF) is a financing mechanism in which an investor disburses funds to a recipient after a set of pre-agreed climate outcomes, such as GHG emission targets, have been achieved and verified. The RBCF can generate carbon credits, helping to provide liquidity to the carbon market.

The *internal carbon price* (Olivier, 2018) is a price integrated by companies into their economic model without waiting for it to be determined by the public authorities or the carbon market. This price can be set according to the ETS price, by taking into account the tutelary value of carbon or according to projective criteria, for example based on the carbon price scenarios provided by the regulators.

More generally, the explicit or implicit determinants of the carbon price have been studied, for example in (Chevallier, 2013). The authors categorize the main factors into *institutional decision*, *energy price and weather influence* and *macroeconomic and financial shocks*. Within these three categories, a large and sudden increase in the carbon price as incorporated into the ECB's short-term CST scenario is plausible.

2.3. *Transition risk and credit risk*

In the CST scenarios, a sharp and coercive increase in the carbon price occurs. It should be noted that this is a short-term *tail-risk* analysis and not a reference scenario. As this is a short-term risk, the banks' balance sheets can be considered static.

Financial performance and risk related to carbon price. Several studies have examined the impact of carbon pricing on financial performance and risk. For example, Oestreich and Tsiakas (2015) empirically investigated the effect of the ETS on German stock market returns. They showed that companies that received EU allowances were on average better than others. This result confirms the conclusions of Oberndorfer (2009), which proposed a similar study carried out on electricity companies in several European countries, and of Scholtens and van der Goot (2014), which analyzed the positive effects of the EU-ETS system on stock market returns in four industries responsible for a majority of EU GHG emissions. Other studies have shown the extent to which market prices have already incorporated carbon risks. For example Andersson et al. (2016) showed that as long as climate change mitigation politics are pending, the low-carbon index performs in line with the benchmark; once GHG emissions are priced, the low-carbon index should start to outperform the benchmark. Görgen et al. (2020) developed a measure of carbon risk and observe two opposite effects: brown companies have higher average returns, but when firms become relatively browner their returns are lower. They also showed that carbon risk premium is insignificant, suggesting that investors may not require compensation for bearing carbon risk.

Credit risk and the carbon price. Credit risk is defined as the risk that a borrower will not be able to meet its financial obligations on time. When the carbon price rises, the revenues of emitting companies decline, and so does their credit worthiness. Two recent studies have examined the impact of carbon price change PD. A study by the United Nations Environment Programme Finance Initiative (UNEPFI, 2018) used the Merton model (Merton, 1974) to estimate the PD of a counterparty including a carbon price. The Merton model describes the value of a company as the price of a call option on its assets with an exercise price equal to the company's liabilities. With this model, we can estimate the probability that a firm's assets will no longer offset its liabilities, and by extension estimate its PD. Capasso et al. (2020) showed that Merton's PD is negatively associated with the amount of carbon emissions of a company and its carbon intensity. Bouchet and Le Guenedal (2020) analyzed the impact of variations in the carbon price at the sectoral level, for a variation in the carbon price of up to \$20 for short-term risks, and up to \$780 for long-term risks.

A more practical example is Axylia's Carbon Score[1], which tells investors and individuals whether a company is *creditworthy* and *responsible* after subtracting from its revenues the cost of the carbon it emits. For banks, this Carbon Score is an indicator of the creditworthiness of the companies in their portfolios with regard to climate issues.

2.4. *Methodology for assessing credit sensitivity to carbon price*

As in the studies presented above (Capasso et al., 2020, Bouchet and Le Guenedal, 2020), we determine the relationship between an increase in the carbon price and the subsequent increase in the credit risk of a portfolio by using the change in the PDs. However, both papers have two practical limitations for banks. First, the assumptions of Merton's model are particularly restrictive: perfect frictionless markets, each firm's liabilities are zero-coupon bonds, the value of the firm does not depend on its financial structure, the value of the firm is a stochastic process with constant volatility. Second, the authors use only Scope 1 GHG emissions, which is not in line with the ECB's CST requirements.

In our paper, we use the following approach: the carbon cost computed on the three scopes is subtracted from the financial results of the companies, and then a financial rating model (based on credit ratios) is used to obtain the PDs before and after carbon impact. From the carbon-related PD changes, we can compute:

- PD changes of a portfolio
- PD changes of an economic sector
- and PD sensitivity matrices by sector/initial rating pair, allowing the PD of any counterparty to be downgraded as soon as its initial rating (before carbon effect) and its sector of activity are known.

With methodological elements similar to those of bank-specific stress tests, we enrich the literature on the sensitivity of credit risk to the carbon price with a practical method that can be implemented by banks and that meets the requirements of the ECB's CST.

3. PRESENTATION OF THE METHOD

An illustration of the method is shown in Figure 1.

3.1. *Data related to GHG emissions*

Data. We use EthiFinance's proprietary database, which includes the following variables: the GHG emissions Scopes 1, 2, and 3 (in tons of CO2 equivalent, tCO2), 3 years of financial statements (for this paper, 2018-20), the GICS sector and the number of employees. For this paper, we select 1,200 European companies with a turnover (in €m) above €10m and complete balance sheet data, giving a sector distribution similar to that of the Stoxx600.

The data is preprocessed to impute missing or extreme values (e.g., carbon intensities outside the distribution indicating a reporting problem). For missing GHG, we assume that the larger the company, the more GHGs it emits. This assumption is in line with the proxies of the CST methodological guide (European Central Bank, 2021), is recommended by Carbon4 (Carbon Impact Analytics, 2015) and by the GHG Protocol (Standard, 2011), and is reviewed in (Gerardi et al., 2015). Two standard indicators of the size of the company are its turnover and number of employees. We also know that the sector of activity is an important variable in determining the relationship between company size and GHG emissions. By separating by sector of activity, and after passing through the log (the size variables being power-law distributed), we obtain the correlation Table I.

[1]https://www.axylia.com/score-carbone-axylia

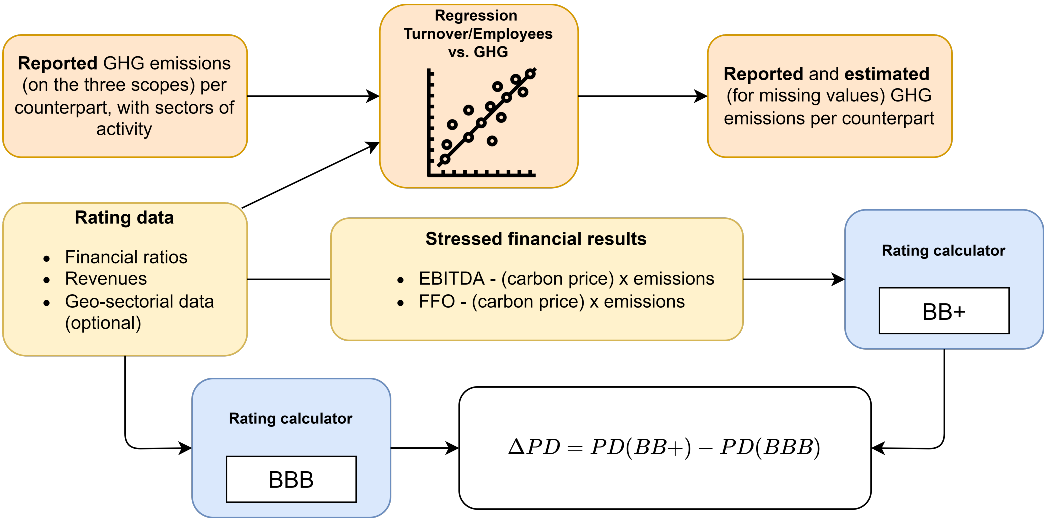


FIGURE 1.—Diagram of the complete methodology for assessing the sensitivity of PDs to the carbon price. Orange boxes are for GHG emissions data. The yellow boxes refer to the rating data. The blue boxes correspond to the rating before and after carbon stress. The white box quantifies the stress applied to PDs.

	Employees			Turnover		
Sectors \ GHG scopes	S1	S2	S3	S1	S2	S3
Industrials	0.75	0.74	0.84	0.69	0.65	0.87
Materials	0.83	0.72	0.84	0.73	0.79	0.94
Communication Services	0.96	0.96	0.97	0.95	0.92	0.99
Utilities	0.82	0.83	0.86	0.75	0.72	0.93
Energy	0.91	0.81	0.93	0.94	0.76	0.97
Consumer Discretionary	0.88	0.94	0.95	0.86	0.87	0.96
Information Technology	0.79	0.81	0.80	0.84	0.85	0.9
Consumer Staples	0.94	0.96	0.90	0.87	0.86	0.89
Health Care	0.84	0.92	0.91	0.82	0.82	0.98
All sectors	0.48	0.66	0.76	0.65	0.70	0.89

TABLE I

CORRELATION BETWEEN EACH GHG EMISSION SCOPE AND NUMBER OF EMPLOYEES/REVENUES, FOR EACH GICS SECTOR.

From each sector/scope pair, we apply a robust linear regression (Mangasarian and Musicant, 2000) to link (log) turnover or (log) number of employees (depending on the strongest correlation in the Table I) to each carbon scope. We impute the missing or extreme GHG data in each sector with these regressions. The average R2 of the regressions by sector is 0.81 ± 0.2.

We note that there are other methods for assessing the carbon footprint of a portfolio of credits, such as the PX9CA methodology developed within the framework of the Finance and Sustainable Development Chair at Dauphine (supported by CACIB) and published in a guide by the ADEME (2014).

3.2. *Stress of PDs by the carbon price*

We use a financial rating calculator to compute the PD before and after the carbon price shock.

Financial rating model. Rating models are tools used to assess the PD of a counterparty based on several financial and non-financial (e.g., sector, management, etc.) factors. We use a *financial* rating model based on the following credit ratios:

- **Net debt-to-EBITDA ratio**, which shows the years of revenue a company would need to pay off its debt if net debt and EBITDA are held constant. We add a conservative penalty: we downgrade to CCC when EBITDA is negative with a positive net debt.
- **EBITDA interest coverage ratio**, which assesses the financial sustainability of a company by examining whether it is at least profitable enough to pay its interest expenses with its EBITDA. We downgrade to CCC when EBITDA does not cover the interests.
- **EBIT interest coverage ratio**, which assesses the financial sustainability of a company by examining whether it is at least profitable enough to pay its interest expenses with its EBIT. We downgrade to CCC when EBIT does not cover the interests.
- **Funds from operations (FFO) to net debt ratio** is a leverage ratio assessing the liquidity solvency. We downgrade to CCC when FFO is negative with positive net debt.

From these ratios, we use EthiFinance's *financial rating calculator* specially adapted for the direct carbon impact exercise. For this article, we obtain the PD associated with each credit rating from the *default rates* table in the *Standard & Poor's (S&P) Annual Global Corporate Default and Rating Transition Study*[2]. We use the *Average PD* from the *One-year Global Corporate Default Rates by Rating Modifier* table, as allowed in banks for large corporate portfolios, which is:

	AAA	AA+	AA	AA-	A+	A	A-	BBB+	BBB	BBB-	BB+	BB	BB-	B+	B	B-	CCC
PD moyenne	0.00	0.00	0.01	0.02	0.04	0.05	0.07	0.12	0.21	0.24	0.49	0.68	1.21	2.07	5.76	8.73	24.92

TABLE II

DEFAULT RATES GIVEN BY S& P IN ITS *Annual Global Corporate Default and Rating Transition Study*, USED IN PARTICULAR BY BANKS TO EVALUATE THE SOLVENCY OF LARGE COMPANIES.

REMARK 3.1: It is important to note that for this exercise and following the example of Bouchet and Le Guenedal (2020), we only take into account the financial part of the rating. Nevertheless, it is possible to add sectoral and geographical adjustments, or additional relevant information.

In order to use the default rates of S&P, we must check that the distribution of the ratings of our study portfolio is similar to that of the S&P ratings. We retrieve the S&P rating from as many rows of our study portfolio as possible and perform a two-sample Kolgomorov-Smirnov test (KS test) (Massey Jr, 1951), the null hypothesis being "same distribution". We obtain a large p value (0.65), which indicates that we cannot reject the null hypothesis.

Stressed PDs. In order to obtain a GHG-based stressed PD, we impact the four credit ratios with an amount equal to the carbon price multiplied by the GHG emissions for each firm. As with the ECB's CST short-term transition risk, we have the following assumptions:

- The balance sheet is static
- There is no passing on of the carbon price to customers or suppliers
- There is no sectoral collusion to reduce or share the impact of a high carbon price

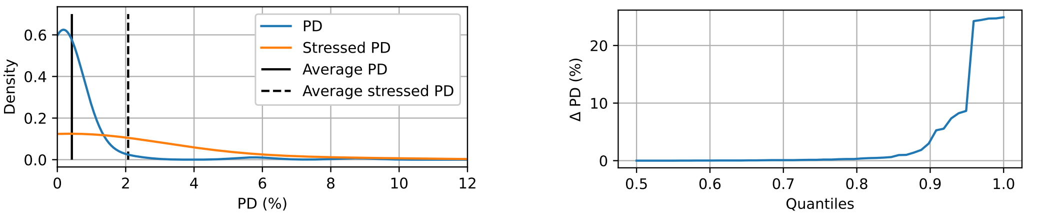
[2] https://www.spglobal.com/ratings/en/research/articles/210407-default-transition-and-recovery-2020-annual-global-corporate-default-and-rating-transition-study-11900573

Under these assumptions, we can directly alter each company's revenue as a function of the price of carbon times GHG emissions; in particular, we impact EBIT/EBITDA and FFO. In addition, for profitable companies with revenues cropped by carbon costs, the taxes paid are lowered. Therefore, we reduce the tax of each profitable company using the tax rate of its country of head office, which is has a positive impact on FFO.

We use the rating calculator with the stressed ratios and obtain a *stressed rating* for each company. As for the initial ratings, we use the Table II and obtain the *stressed PDs*. From the PDs and stressed PDs, we can also build a matrix of sensitivity of the PDs to the carbon price, for each initial sector/rating pair.

4. RESULTS OF THE STRESS TEST

Portfolio-level analysis. We show in Figure 2 the distribution of the density of the PDs before and after the carbon price rise. We see that the density of PDs essentially extends over the range 0-8% after the carbon price shock, as opposed to 0-2% before. The evolution of the quantiles of the difference between stressed and unstressed PDs (noted ΔPD) shows that $\sim 10\%$ of the companies have a degradation of their PDs higher than 5%; $\sim 5\%$ have a degradation higher than 10%.



(a) Distribution of PDs before and after stress

(b) Quantiles of ΔPD

FIGURE 2.—Elements of the PD distribution before and after carbon stress. In Figure 2a, the respective pre- and post-stress averages are 0.43 and 2.07.

Sector-level analysis. We analyze by sector the deterioration in creditworthiness due to carbon price rise. In (Bouchet and Le Guenedal, 2020), where the analysis was carried out only on Scope 1 and using the Merton model for PDs, the most affected sectors are *Materials* and *Utilities*, followed by *Energy*. In Figure 3, we observe the same two most affected sectors; however, the third most affected sector is *Consumer Staples*, then *Energy* in forth position.

We can explain the high impact on companies classified as *Consumer Staples* by looking at Figure 4. If we consider only Scope 1 of GHG, the sectors most affected in terms of EBITDA are indeed *Materials*, *Utilities* and *Energy*. However, the *Consumer Staples* sector has a relatively high Scope 3 ; since the ECB's methodology recommends to take all three scopes into account for the STC, as we do here, *Consumer Staples*' PDs becomes highly sensitive to carbon price variations.

As with the aggregate results, we can break down the analysis by looking at the quantiles of the ΔPD in figure 5. We see that the creditworthiness of the *Materials* sector deteriorates the fastest, with $\sim 35\%$ of companies having a ΔPD greater than 5%. For *Utilities*, the average degradation of 5% concerns $\sim 20\%$ of the companies. It is directly followed by *Consumer Staples*. Next, 15% of the companies in the Energy sector have a ΔPD of over 5%.

5. CONCLUSION AND OUTLOOK

In this article, we have proposed a practical methodology for banks to assess the resilience of their counterparts to a sudden and sharp increase in the carbon price. The proposed methodology responds

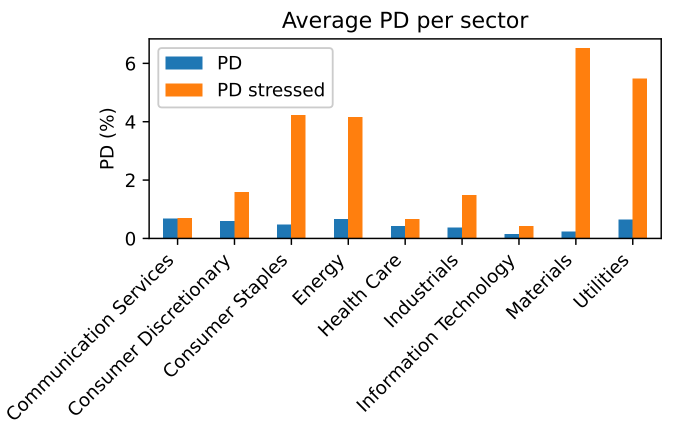


FIGURE 3.—Mean PD (%) before and after stress related to carbon price rise.

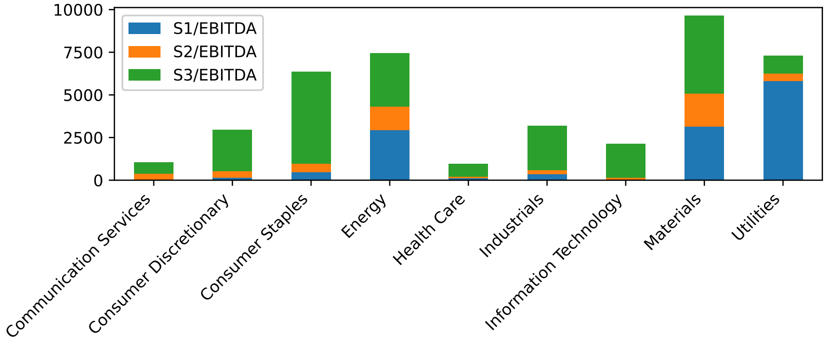


FIGURE 4.—Average GHG emissions on EBITDA (tons/M€), for each sector.

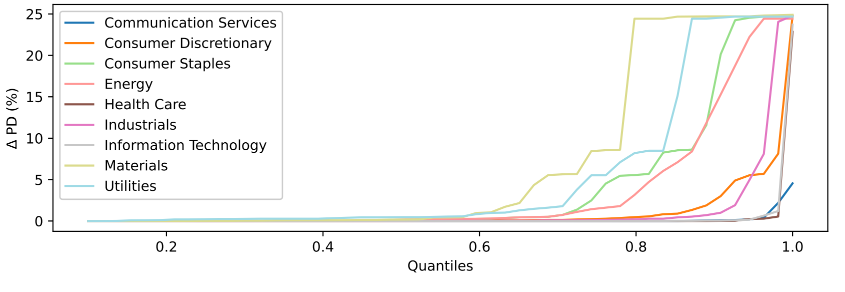


FIGURE 5.—Quantiles of ΔPD by GICS sector.

to the direct effects part of module 3 of the ECB's climate stress test, in which a sudden increase in the price of carbon in the short term is assumed. Compared to the existing methods proposed in recent literature, which are based on the Merton model and only take into account the first scope of greenhouse gas emissions, we have developed an approach similar to the methodologies already implemented in banks for their specific stress tests.

We proposed a series of illustrative experiments to better understand the results of a short-term carbon stress test. In particular, we have analyzed the sectoral effects of a suddenly and sharply rising carbon price, and determined that the *Materials*, *Utilities*, *Consumer Staples* and *Energy* sectors are the most affected with respect to their financial solvency.

In further work, we will formalize and implement the methodology for the long-term part of the stress test, with dynamic balance sheets and macro-financial scenarios applied to sectors and countries.

BIBLIOGRAPHY

ADEME, F. (2014). Réalisation d'un bilan des émissions de gaz à effet de serre.

Andersson, M., Bolton, P., and Samama, F. (2016). Hedging climate risk. *Financial Analysts Journal*, 72(3):13–32.

Arlinghaus, J. (2015). Impacts of carbon prices on indicators of competitiveness: A review of empirical findings.

Basel Committee on Banking Supervision, . (2020). Climate-related financial risks: a survey on current initiatives.

Basel Committee on Banking Supervision, . (2021a). Climate-related financial risks – measurement methodologies.

Basel Committee on Banking Supervision, . (2021b). Climate-related risk drivers and their transmission channels.

Bertram, C., Hilaire, J., Kriegler, E., Beck, T., Bresch, D., Clarke, L., Cui, R., Edmonds, J., Min, J., Piontek, F., et al. (2020). Ngfs climate scenarios database: Technical documentation.

Bouchet, V. and Le Guenedal, T. (2020). Credit risk sensitivity to carbon price. *Available at SSRN 3574486*.

Caldeira, K. and Wickett, M. E. (2003). Anthropogenic carbon and ocean ph. *Nature*, 425(6956):365–365.

Capasso, G., Gianfrate, G., and Spinelli, M. (2020). Climate change and credit risk. *Journal of Cleaner Production*, 266:121634.

Carbon Impact Analytics, C. . (2015). How to measure the contribution of a portfolio to the energy and climate transition.

Chevallier, J. (2013). Carbon price drivers: an updated literature review. *International Journal of Applied Logistics (IJAL)*, 4(4):1–7.

Conte, M. N. and Kotchen, M. J. (2010). Explaining the price of voluntary carbon offsets. *Climate Change Economics*, 1(02):93–111.

Dechezleprêtre, A., Nachtigall, D., and Venmans, F. (2018). The joint impact of the european union emissions trading system on carbon emissions and economic performance.

Ellerman, A. D. and Joskow, P. L. (2008). *The European Union's emissions trading system in perspective*. Pew Center on Global Climate Change Arlington, VA.

European Banking Authority, U. (2021). 2021 eu-wide stress test.

European Central Bank, U. (2021). Climate risk stress test.

Gerardi, A., Grandjean, A., and Martinez, E. (2015). La quantification des émissions de gaz à effet de serre des institutions financières. *Revue d'économie financière*, (1):189–204.

Görgen, M., Jacob, A., Nerlinger, M., Riordan, R., Rohleder, M., and Wilkens, M. (2020). Carbon risk. *Available at SSRN 2930897*.

Kollmuss, A., Zink, H., and Polycarp, C. (2008). Making sense of the voluntary carbon market: A comparison of carbon offset standards. *WWF Germany*, pages 1–23.

Mangasarian, O. L. and Musicant, D. R. (2000). Robust linear and support vector regression. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 22(9):950–955.

Massey Jr, F. J. (1951). The kolmogorov-smirnov test for goodness of fit. *Journal of the American statistical Association*, 46(253):68–78.

Merton, R. C. (1974). On the pricing of corporate debt: The risk structure of interest rates. *The Journal of finance*, 29(2):449–470.

Oberndorfer, U. (2009). Eu emission allowances and the stock market: evidence from the electricity industry. *Ecological Economics*, 68(4):1116–1126.

Oestreich, A. M. and Tsiakas, I. (2015). Carbon emissions and stock returns: Evidence from the eu emissions trading scheme. *Journal of Banking & Finance*, 58:294–308.

Olivier, R. (2018). Internal carbon price: why and how?

Scholtens, B. and van der Goot, F. (2014). Carbon prices and firms' financial performance: an industry perspective. *Carbon Management*, 5(5-6):491–505.

Standard, G. P. (2011). The greenhouse gas protocol.

Stavins, R. N. (2008). Addressing climate change with a comprehensive us cap-and-trade system. *Oxford Review of Economic Policy*, pages 298–321.

UNEPFI (2018). Extending our horizons: Assessing credit risk and opportunity in a changing climate. outputs of a working group of 16 banks piloting the tcfd recommendations.

Zetterberg, L., Nilsson, K., Åhman, M., Kumlin, A.-S., and Birgersdotter, L. (2004). Analysis of national allocation plans for the eu ets.