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Analyse

Dynamics of the carbon footprint of financial institutions: a decomposition approach

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Dynamics of the carbon footprint of financial institutions: a decomposition approach

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Introduction

Introduction

A better understanding of the exposures of the financial sector to the risks associated with climate change, but also of the role of financial institutions in financing the transition, requires statistical indicators on, amongst others, the CO_2 emissions associated with their portfolios. The compilation of those indicators is however hampered by a lack of data and methodological challenges. In this paper we tackle one of those challenges, namely to better understand the mechanisms through which CO_2 emissions associated with asset portfolios may change over time. Such an understanding is relevant as society aims for 'net zero' in 2050, and the different mechanisms of change may be caused by, or result in, different policy measures. For example, changes in CO_2 emission indicators may be driven by choices of the financial institutions (for instance by divestment trades or exclusionary screening, or even by an engagement strategy) or more general 'greening' (reduction in CO_2 emissions) of the underlying assets.

At the core of our work is the notion that indicators of CO_2 emissions associated with the portfolios of financial institutions combine information on both the securities portfolios of financial institutions, *and* the carbon emissions of the issuers in these portfolios. Therefore, variation over time in either of these two - either on the holder (investor) side or on the issuer side (company in which the investment is made) - can cause changes in the final statistics. On the holder side, the (value of) assets in the portfolio will fluctuate over time due to portfolio rebalancing through transactions, as well as due to price mutations and exchange rate effects. Similarly, CO_2 emissions on the account of the issuers also vary over time, thus affecting all climate indicators.

In order to better understand the dynamics of the indicators it is necessary to disentangle the effects of investment choices by the holder from the effect of emissions reductions by the issuer. We therefore developed a decomposition methodology to disentangle the holder-side effects from issuer-side effects due to the greening of the underlying assets. We thereby provide not only new information for policy makers, but also build upon, and contribute to, the broader ESCB statistical work in this area that aims at the development of harmonized standards and calculation methods to improve the quality of financial statistics in the field of sustainability.

Scope of the analysis

Granular data of equity holdings by Dutch financial institutions (the securities holdings statistics (SHS) data collected by DNB) is enriched with the company-level carbon emissions (total of Scope 1 and Scope 2) and emission intensities. The focus is on the listed shares of pension funds and insurance companies, where data are aggregated to a sector level. Since a large part of the investments are carried out by specialised investment funds, also included are listed shares managed by investment funds coupled to their respective pension fund or insurance company via investment fund shares (i.e. a look-through approach is applied). For this analysis, annual frequency for the years 2017-2020 are used. Further information can be found in the Appendix.

Methodology

This section first presents two of the indicators; namely the Financed Emissions and the so-called Weighted Average Carbon Intensity. These indicators have been identified widely in the academic literature as well as by the ESCB statistical function as key to understanding the CO_2 emissions associated with the portfolios of financial institutions. These indicators are also part of the first release of ESCB indicators on climate change, which occurred simultaneous with the publication of this analysis. Next, the methodology used to decompose the dynamics of the indicators into their contributing factors is discussed. An Appendix delves into the methodology in more detail.

Indicators

A commonly used indicator to measure financing of the climate change transition is the so-called *Financed Emissions* indicator, measuring the total greenhouse gas (GHG) emissions of an issuer weighted by the share of the investment over total company value. This indicator reveals the financed emissions of a counterparty (either individually or at sector or country level) and as such can be used to understand how the debtors/issuers' emissions evolve over time in anticipation of the need to transition to a net-zero economy. This absolute indicator is the most indicative of the total emissions of the financial sector, but large differences in the size of portfolios make it unsuitable for comparing sectors or individual financial institutions.

Let $H_{i,j,t}$ be the (end-of-period) value of equity holdings of securities issued by issuer i, held by sector j in year t; $V_{i,t}$ the company value represented by its market capitalisation, and $E_{i,t}$ the carbon-emissions (Scope 1 plus Scope 2) of the issuer of i. Then the financed emissions at the sector-issuer level are calculated as

$$FE_{i,j,t} = \frac{H_{i,j,t}}{V_{i,t}} E_{i,t}$$

As can be seen the expression, the value of holdings divided by market capitalisation, is in fact the proportion of the company value supported by the equity holdings of the sector. For example, if the pension funds sector owns 50% of the equity of a company, 50% of the emissions of this company are attributed to the pension funds sector. From the expression it is clear that both increases in the (value of the) holdings of asset i and the emissions of the issuer lead to an increase in financed emissions. The financed emissions on a sector-level are calculated by taking the sum over all issuers

$$FE_{j,t} = \sum_i \frac{H_{i,j,t}}{V_{i,t}} E_{i,t}$$

Another set of indicators measure relative CO_2 emissions. One of these relative carbon indicators, the so-called Weighted Average Carbon Intensity (WACI), measures CO_2 emissions per million euros of revenue, weighted according to the investor's portfolio weight. This indicator is relative in two ways: the carbon intensity reflects an issuer's emissions relative to its revenue, and the portfolio weight the value of an investment relative to the investor's entire investment portfolio. This indicator makes it possible to compare sectors or individual financial institutions. If the revenue of firm i is denoted $R_{j,t}$, the WACI can be written as

$$WACI_{j,t} = \sum_i \frac{H_{i,j,t}}{\sum_k (H_{k,j,t})} \frac{E_{i,t}}{R_{i,t}} = \sum_i w_{i,j,t} \frac{E_{i,t}}{R_{i,t}}$$

where $w_{i,j,t}$ represents the portfolio weight of asset i. From this expression it is clear that both an increase in portfolio weight and an increase in carbon intensity lead to an increase in the WACI, and also that an increase in the firm revenue leads to a reduction in the WACI. As such, the WACI is prone to changes in macroeconomic conditions such as fluctuations in inflation and exchange rates (Janssen et al., 2022).

Decomposition methodology

As is obvious from the expressions above, the change over time of the indicator (left-hand side) can be attributed to change of any or several of the components on the right-hand side. For example, the financed emissions may decrease due to emissions reduction among issuers of equity, but also due to reductions in market cap share. In order to understand the dynamics, allowing for a sharper interpretation of the indicator, it is useful to analyse the contributing factors.

However, since the indicators are calculated by first multiplying and then taking a sum, an analysis of the underlying dynamics is not straightforward. One possibility is to keep one of the components fixed at the value in the previous period, calculating a counterfactual value of the indicator (see e.g. Rohleder et al., 2022). Another possibility, which is chosen here, is to apply standard techniques from growth accounting (see e.g. Crafts and Woltjer, 2021), isolating the changes due to one component of the indicator from the changes due to another simultaneously. The literature of growth accounting initially sought to investigate the importance of capital stock growth, and hence investment, on economic growth (Solow, 1957). Today, methods of growth accounting belong to the standard toolbox of many statistical agencies and are frequently used to decompose changes in GDP into changes of its constituent factors such as capital, labour and total factor productivity.

Inspired by the literature on growth accounting, this study proposes an intuitive method aimed at decomposing the change in the indicators described above. Let $\Delta_{j,t}^{FE} = FE_{j,t} - FE_{j,t-1}$ be defined as the (absolute) change in financed emissions at a sector level, and $\Delta_{j,t}^{H/V}$ and $\Delta_{j,t}^{E}$ the contribution from changes in its components (see the Appendix for their definition). Then the financed emissions indicator is decomposed as follows:

$$\Delta_{j,t}^{FE} = \Delta_{j,t}^{H/V} + \Delta_{j,t}^{E}$$

This expression states that the changes in financed emissions, in units (ton) CO_2, can be decomposed into changes due to share of market capitalisation and changes due to emissions (both in terms of ton CO_2). The WACI can be decomposed in a similar way. However, as will be shown, it is useful to decompose the WACI into three components, namely portfolio weight, emissions and firm revenue:

$$\Delta_{j,t}^{WACI} = \Delta_{j,t}^{w} + \Delta_{j,t}^{E/R} = \Delta_{j,t}^{w} + \Delta_{j,t}^{E} - \Delta_{j,t}^{R}$$

In this expression, the terms on the right-hand side are all measured in the same unit as the WACI. Note that the method applies equally well to other linear indicators and also allows for the possibility of including more components.

Results

In this section the calculated change over time in the two indicators and the results of the decomposition analysis are presented. The change over time is calculated using an index, where the value of each indicator for each sector in 2017 takes the value 1. Subsequently, the cumulative changes in the indices between 2017 and 2020 are calculated and reported in terms of percentage change. The decomposition method is applied to that percentage change, isolating the changes due to underlying factors.

Decomposition applied to Financed Emissions

Figure 1 shows the decomposition of the change in Financed Emissions over a three-year period. For pension funds, FE have decreased by 36% over this period, of which 23 percentage points can be attributed to a decrease in emissions on the issuer side (i.e. by CO_2 emission reductions of the enterprises in which pension funds have invested), and an additional 13 percentage points to a decrease in marketcap share (i.e. due to changes in the composition of the portfolio of the financial institutions concerned). On the insurers side, FE have decreased by 40% in the same period, 17 percentage points of which due to emission reductions and 23 percentage points due to a decrease in marketcap share.

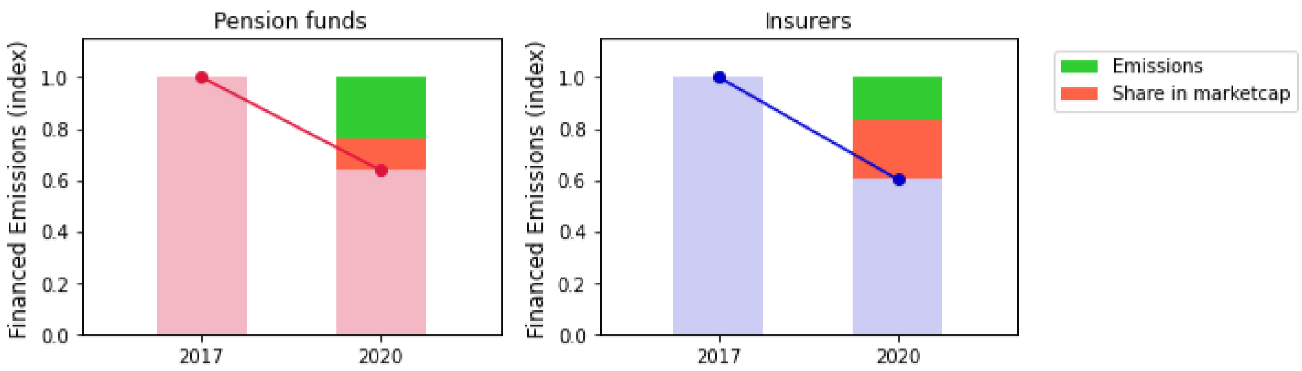

Figure 1: Financed Emissions (FE) index (2017 = 1). The change in FE in 2020 with respect to 2017 is decomposed into contributions from changes in emissions and changes in the share in marketcap. For both pension funds and insurers, the decrease in FE is a shared effect of reduced emissions and reduced market cap share.

Decomposition applied to Weighted Average Carbon Intensity

Since the Financed Emissions indicator only reports the absolute value of the CO_2 emissions financed by the financial sectors, comparison between sectors is not straightforward. Imagine sector A having a larger FE than sector B, this could be due to sector A having invested in carbon-richer assets, but it is also possible that sector A is simply larger than sector B. To be able to compare investment portfolios between holders, or compare sectors amongst each other, relative indicators such as the WACI are more useful.

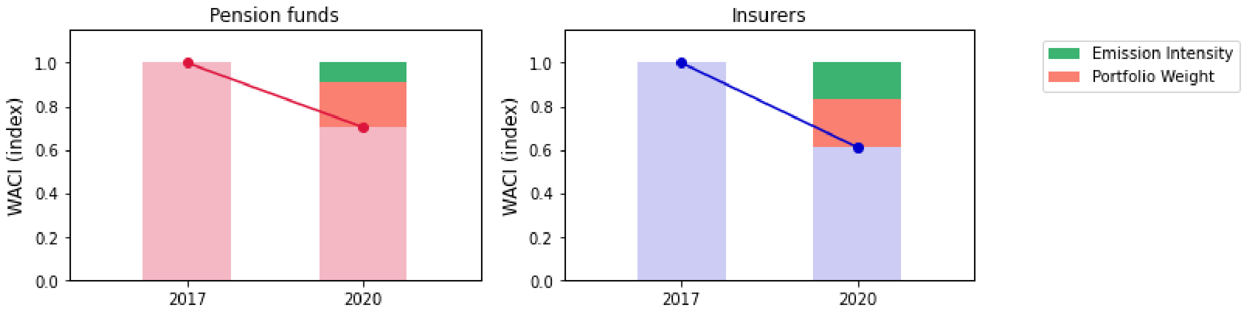

Figure 2 Weighted Average Carbon Intensity (WACI) index (2017 = 1). The change in WACI in 2020 with respect to 2017 is decomposed into contributions from changes in emission intensity and changes in portfolio weight. Dutch pension funds and insurance companies experienced a decrease in WACI.

The WACI for Dutch pension funds decreased by 30% in the period 2017-2020. For Dutch insurers this number is 39% (see Figure 2). The decline in WACI may be due to a decrease in portfolio weights, or a decrease in emission intensities, or both. The results of the decomposition of the WACI into these two components show that for both sectors the decrease in WACI is mainly due to changes in portfolio weights, and to a lesser extent due to changes in the emission intensities. However, because emission intensities are calculated as a companies' total emissions divided by revenue, this decomposition does not account for the fact that variation in emission intensity can be caused by both changes in emissions and changes in revenues.

As such, for the WACI it is useful to carry out the decomposition for three components: portfolio weight, emissions and revenue. Figure 3 shows that reductions in absolute emissions have a relatively larger effect on the WACI than the reduction in revenue for the 2017-2020 period. Note that revenues decline over the time period, thereby partially cancelling out the reduction in the carbon intensity due to emissions reductions. For insurance companies, the WACI is primarily falling due to emission reductions, while for pension funds portfolio weight and emission reductions contribute about equally.

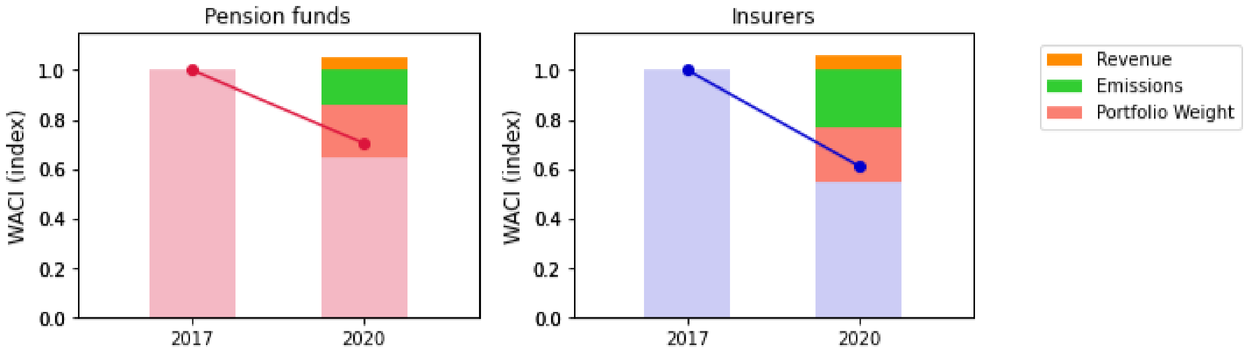

Figure 3 Weighted Average Carbon Intensity (WACI) as an index relative to the WACI in 2017. The change in WACI is decomposed into three contributions: changes from revenue (orange), changes in emissions (green) and changes in portfolio weight (pink). Note that revenue is inversely proportional to the WACI, such that the decrease in revenue over time partially cancels out the decrease in WACI caused by lower emissions and portfolio weight.

Discussion and Conclusion

Harmonized sustainability indicators are important tools to quantify the transition of the Dutch and European financial system. It is important to find out which factors play a role in the observed dynamics. DNB has developed a decomposition method and applied it to time series of two important CO_2 indicators. The application shows that for the 2017-2020 period the emission reductions of companies make a larger contribution to the greening of the portfolios than the investment choices made by the financial institutions.

The main contribution of this analysis is to provide a first version of a tool to analyse the dynamics of the harmonized sustainability indicators developed by the ECB. The indicators themselves are experimental, and results will change as methodology and data are refined. This means that results found in this analysis should be interpreted with utmost caution, and will most likely change as the decomposition method is applied to the harmonised sustainability indicators developed by the ESCB.

It should be noted that this study may illustrate the overall results, but does not as such investigate the effect(iveness) of any "strategic intent" that financial institutions may or may not have towards active divestment from specific high-carbon stocks within a portfolio, nor investigates the results of engagement or other investment strategies; other reasons or motivations may underpin the change in portfolio weights we have observed.

Other limitations include, as Janssen et al. (2022) argue, the fact that revenue is prone to inflation and exchange rate effects. Calculating revenue in terms of fixed prices would most likely lead to a smaller reduction in the WACI than observed in this study. Furthermore, the portfolio weight calculated using the value of equity positions can be affected by stock market fluctuations. The decomposition analysis could also be performed using fully constant prices (also excluding other/market price fluctuations) as a robustness check. These issues will be taken up in our future research.

Appendix

Data and variables used

Symbol	Explanation	Unit	Source
i	Identifier of issuer of security	RIAD/LEI	
j	Sector of holder of security	ESA sector classification	
t	Time period	Year	
H_i, j, t	Value of equity holdings at the end of the year	EUR (mln)	Internal data set on securities reporting statistics
$V_{i,t}$	Company value (market capitalisation)	EUR (mln)	ISS carbon core
$E_{i,t}$	Annual emissions (Scope 1 + Scope 2)	Ton CO_2 eq	ISS carbon core
$R_{i,t}$	Annual company revenues	EUR (mln)	ISS carbon core

Decomposing the financed emissions: an elaborate example

In this appendix the derivation of the decomposition for the financed emissions is shown. The derivation for the WACI follows a similar logic. As noted in the main text, the main interest is the value of the indicators at the sector level, i.e. summed over all issuers. This appendix shows how to first implement the decomposition at the sector-issuer level, and then how aggregate to the sector level. Let $H_{i,j,t}$be the (end-of-period) equity holdings of issuer i of institution j in year t, $V_{i,t}$ the company value and $E_{i,t}$ the carbon emissions (Scope 1 plus Scope 2) of the issuer of i. Then the financed emissions on a sector-issuer level are calculated as

$$FE_{i,j,t} = \frac{H_{i,jt}}{V_{i,t}} E_{i,t}$$

The relative growth of financed emissions can then be written as

$$\frac{FE_{i,j,t}}{FE_{i,j,t-1}} = \frac{(H_{i,j,t}/V_{i,t})E_{i,t}}{(H_{i,j,t-1}/V_{i,t-1})E_{i,t-1}}$$

By taking (the natural) logs on both sides and using the product rule for logarithms this expression can be rewritten in terms of log growth rates

$$\ln\left(\frac{FE_{i,j,t}}{FE_{i,j,t-1}}\right) = \ln\left(\frac{H_{i,j,t}/V_{i,t}}{H_{i,j,t-1}/V_{i,t-1}}\right) + \ln\left(\frac{E_{i,t}}{E_{i,t-1}}\right)$$

Again using the product rule for logarithms, and following the literature of growth accounting, the expression can be written more compactly as:

$$\Delta \ln F\,E_{i,j,t} = \Delta \ln\left(H_{i,j,t}/V_{i,t}\right) + \Delta \ln \mathrm{E_{i,t}}$$

The expression shows that the (approximately[1]) percentual change in financed emissions – over the course of a single year – for issuer i and sector j is equal to the sum of the percentual change in the share of market capitalisation and the percentual change in emissions. If the goal is to decompose the change in any indicator at the sector-issuer level this expression is in principle sufficient.

However, since the indicators at the sector-level (i.e., summed over all issuers) are of most interest, some further steps are needed. The terms on the right-hand side are first normalised by dividing on both sides with $\Delta \ln F\,E_{i,j,t}$ and rewritten as

$$1 = \widetilde{\Delta} \ln\left(H_{i,j,t}/V_{i,t}\right) + \widetilde{\Delta} \ln E_{i,t}$$

Here $\widetilde{\Delta} \ln$ denotes a normalised (log) growth rate. The two elements on the right-hand side can be interpreted as the relative contribution to the change in financed emissions of the two components. Note here that it is entirely possible (and observed in the data) that the elements on the right-hand-side take on negative values or become larger than 1.

In order to aggregate to the sector level it is preferable to transform the expression back to units of CO_2 emissions. Let $\Delta FE_{i,j,t} = FE_{i,j,t} - FE_{i,j,t-1}$ represent the (absolute) change in financed emissions. If one first multiplies both sides with $\Delta FE_{i,j,t}$ and then takes the sum over issuers, the expression used for the decomposition is written as

$$\sum_i \Delta FE_{i,j,t} = \sum_i \left(\Delta FE_{i,j,t} \widetilde{\Delta} \ln\left(H_{i,j,t}/V_{i,t}\right)\right) + \sum_i \left(\Delta FE_{i,j,t} \widetilde{\Delta} \ln E_{i,t}\right)$$

[1] Use approximation $\Delta \ln(x) \approx \Delta\%\, x$, for $x \approx 1$. For x close to 1, the percentual change in x is equal to the change in the logarithm of x. Although the values in this study occasionally deviate substantially from 1, it should be noted that this primarily affect the interpretation. Furthermore, the normalization also has the effect of smoothing out large deviations.

In order to facilitate notation, we write $\Delta_{j,t}^{FE} = FE_{j,t} - FE_{j,t-1}$ as the (absolute) change in financed emissions at the sector level, and $\Delta_{j,t}^{H/V}$ and $\Delta_{j,t}^{E}$ the contribution from changes in its components as shown on the right-hand side. Then the decomposition of the financed emissions indicator can be written as follows:

$$\Delta_{j,t}^{FE} = \Delta_{j,t}^{H/V} + \Delta_{j,t}^{E}$$

This expression states that the changes in financed emissions, in units (ton) CO_2, is the sum of changes due to investment (ton CO_2) and changes due to emissions (ton CO_2). Note that the method applies equally well to other linear indicators and also allows for the possibility of including more than two components.

This simple decomposition of changes in financed emissions over time is useful in that it, in a clear manner, allows the separation of the contribution of holder-side effects from those caused by emission reductions of the issuer. However, the simplicity comes at the cost of ignoring certain elements. Specifically, from the expression above it is not clear whether changes in holdings are due to active choices of the financial institution aimed at reducing the carbon footprint of their portfolio.

An alternative decomposition method, described in Rohleder et al. (2022), involves keeping one of the terms of the indicator at its value the previous period (a counterfactual) and calculate the difference between the actual financed emissions and the counterfactual. For example, the change in financed emissions from a counterfactual where emissions are kept constant can be calculated as:

$$\delta_{j,t}^{E} = \sum_{i} \frac{H_{i,j,t}}{V_{i,t}} \Delta E_{i,t}$$

If a similar calculation is carried out for marketcap share, it is straight forward to show that

$$\Delta_{j,t}^{FE} = \delta_{j,t}^{H/V} + \delta_{j,t}^{E}$$

An empirical comparison of the two methods will be picked up in future research.

Securities data

Information on pension funds and insurance companies holdings and transactions of assets is obtained from a confidential dataset provided by DNB, consisting of enriched monthly securities reporting statistics data. The dataset contains security-by-security portfolio investment positions and transactions, of individual holders and issuers, on a monthly frequency. The time period used for the analysis is 2017 to 2020. Individual securities are identified by their International Securities Identification Number (ISIN), while holders and issuers are identified by the Register of Institutions and Affiliates Database (RIAD) number or Legal Entity Identifier (LEI). Holders, issuers and instrument are classified according to their respective European Systems of Accounts (ESA) institutional sector code. The primary variable of interest is the value of the end-of period holdings, and the data is analysed at an annual frequency, meaning end-period holdings on 31 December represent year. Furthermore, the holdings from specialised investment funds that act on behalf of pension funds and insurance companies are extracted. The security holdings of each relevant investment funds are distributed in proportion to the ownership shares of each pension fund and insurance company in the each mutual fund (i.e. employing a 'look through' approach). Finally, all holdings are aggregated to the sector level.

CO_2 emissions data

Data on company-level (scope 1 and 2) carbon emissions, market capitalisation and firm revenue are obtained from the ISS Climate Core dataset. This commercial dataset contains information on a company's carbon footprint, including absolute emissions and carbon intensity metrics representing the GHG emissions per million USD/EUR of revenue as a proxy of the carbon efficiency per unit of output. The information is available on 25,000+ companies and issuers of corporate debt, with a yearly frequency dating back to 2012. ISS applies their own industry classification system that allows for benchmarking of non-reporting companies against their reporting peers with approximations applied for non-reporting companies. The variables for each company are reported by the company's ISIN codes. The company-level data from ISS Climate Core data is merged with the granular data on stock holdings using the ISIN codes and year.

Although the ISS Climate Core provides information about Scope 3 emissions, these are not included in the analysis. This is of course a potential drawback, since a firm could reduce their Scope 1 and 2 emissions by outsourcing parts of its supply chain, meaning some of the observed emissions reductions could be reductions only on paper. Although the most recent recommendation of the Task Force for Climate-related financial Disclosures (TFCD) is to encourage the reporting of Scope 3 emissions, there are still substantial concerns over the quality of the data. Therefore Scope 3 emissions is left out of this analysis.

Merging strategy and data issues

The climate and the investment data are merged using ISIN-number and year, resulting initially in an unbalanced data set on a sector-security-year dimension. However, since indicators are aggregated to the sector level, there is potential of double counting emissions, market capitalisation and revenue. Although filtering on equity positions should minimise this problem, further analysis reveals that some issuers emit more than one type of equity as identified by the ISIN-number. The solution for these 'multiple emitters' is in first instance to remove any modelled data points, which leaves only a very small amount of issuers with several ISIN numbers for which the duplicates are removed. Finally, the data set is aggregated to the sector-issuer level, resulting in an unbalanced data set with sector-issuer-year dimension. Since the modelled emissions from the ISS Climate Core data are included, the coverage, in terms of frequencies, where both emissions and investment data are observed is very high – mostly above 95%.

However, the financial data (market capitalisation and revenue) necessary for the calculation of the indicators, does contain missing values. Since the decomposition methodology is sensitive to missing data, it is necessary to create a balanced data set at the sector-issuer-year level. In essence, this entails first calculating each the indicator and then filter out all observations where the indicator takes an unknown value. Next, the data set is balanced by, for each sector, including only the issuers for which a complete time series is available – i.e. where observations for all years 2017-2020 are available. Since market capitalisation and revenue may not be missing simultaneously, the number of observations in the balanced data set differ between each indicator. The data used for the financed emissions contains 40605 observations, meaning that there are more than 10000 (not necessarily unique) issuers yearly, spread over two sectors. The data used for the WACI contains 51675 observations (almost 13000 issuers yearly), meaning the number of missing values for market capitalisation is larger than for revenue. After balancing the data, the coverage – in terms of value of holdings – is generally above 80%.

Literature

Bolton, Patrick, and Marcin Kacperczyk. "Do investors care about carbon risk?." Journal of financial economics 142.2 (2021): 517-549.

Crafts, Nicholas, and Pieter Woltjer. "Growth accounting in economic history: findings, lessons and new directions." Journal of Economic Surveys 35.3 (2021): 670-696.

Janssen, A., Botzen, W., Dijk, J., & Duijm, P. "Overcoming misleading carbon footprints in the financial sector." Climate Policy 22.6 (2022): 817-822.

Rohleder, Martin, Marco Wilkens, and Jonas Zink. "The effects of mutual fund decarbonization on stock prices and carbon emissions." Journal of Banking & Finance 134 (2022): 106352.

Solow, Robert M. "Technical change and the aggregate production function." The review of Economics and Statistics (1957): 312-320.

Task Force for Climate-related financial Disclosures. “Annex: Implementing the Recommendations of the TCFD” (2021).