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Working paper

Carbon bias in index investing

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Abstract

This paper presents evidence of a bias towards carbon-intensive companies in popular value-weighted stock market indices that are tracked by index funds and ETFs and serve as benchmark for active equity strategies. The average carbon bias in the U.S. Russell 1000 is close to 70% and the bias in the MSCI Europe index is about 90%. This means that the carbon intensity of the U.S. and European market indices is 70% and 90% higher than that of the U.S. and European economy, respectively. The carbon bias arises because firms operating in carbon-intensive sectors, such as mining, manufacturing, and electricity, tend to be more capital intensive and more likely to be publicly listed. These companies therefore issue more equity than firms in low-carbon sectors and receive a larger weight in the value-weighted stock market index than in the real economy. The carbon bias is problematic because it exposes institutional investors such as pension funds to carbon-transition risks and is at odds with their drive towards sustainability. We therefore explore several strategies for investors to mitigate the carbon bias in their equity allocation.

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1. Introduction

The value-weighted stock market index plays a prominent role in asset management, motivated by the modern portfolio theory of Markowitz (1952) that prescribes that investors should allocate their capital to the value-weighted market portfolio of risky assets and the risk-free asset. Due to this theoretical justification and its low costs, index investing has become an increasingly popular strategy among institutional investors, in particular pension funds and insurance companies. The value-weighted market index is also widely used as benchmark for active investment strategies.[1] An implicit assumption is that an investment in a broad value-weighted stock index reflects the "average" economy and is therefore a well-diversified investment. However, in practice the value-weighted index may not be an adequate representation of the overall economy because not all companies or institutions that contribute to GDP are publicly listed on the stock exchange.[2]

Because of this wedge between a sector's weight in financial markets and in the real economy, a carbon bias may occur when investing in a broad market index. This carbon bias is defined as the relative difference between the total carbon intensity of the index and the total carbon intensity of the aggregate economy. A positive carbon bias can arise because firms in carbon-intensive sectors, such as oil and gas companies and steel manufacturers, tend to be more capital intensive than companies in sectors that are less carbon intensive (Doda, 2018). These high-carbon sectors therefore issue more equity and debt than low-carbon sectors and receive a larger weight in a market-capitalization weighted stock market index than in the real economy.

The resulting carbon bias can be problematic for several reasons. First, an investment portfolio that is tilted towards high-carbon sectors is more exposed to transition risks. These are risks that arise when moving towards a low-carbon economy. For some sectors this transition may increase a company's cost of doing business or decrease its asset values. For instance, companies in the electricity and oil and gas sectors face the risk of stranded assets when known fossil fuel reserves cannot be burned due to changes in government policies (Welsby et al., 2021). Companies in the manufacturing sector that use a lot of energy such as steel companies may incur higher operating costs due to higher energy costs. As a result of this exposure to transition risk, investors' portfolios may incur losses. Second, the carbon bias is at odds with institutional investors' drive towards sustainable investing (Dyck et al., 2019), fueled by the preferences of (pension) fund investors (Bauer et al., 2021).

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[1] Bhattachary and Galpin (2011) present evidence that the popularity of value-weighting is growing around the globe.
[2] Some sectors are underrepresented in financial markets for several reasons. First, capital-intensive sectors, like mining and manufacturing typically consist of large companies because of economies of scale in their fixed capital. These large firms are often financed by stocks and bonds. Other sectors, like agriculture, consist of many small firms that are not listed on the exchange (e.g., farmers financed by bank loans). Second, in some sectors, companies tend to be organised as partnerships (e.g., professional services) or cooperatives (e.g., agriculture) that are not listed. Third, some sectors, such as education and health, are mostly (semi-)public and therefore not listed on the exchange.

In this paper, we investigate the existence of a carbon bias in two value-weighted equity indices over the period 2015-2019: the U.S. Russell 1000 index and the MSCI Europe. These indices are often used as benchmarks by institutional investors. In addition, many index funds and ETFs seek to track the performance of such broad equity market indices. We measure the carbon bias of these indices in three steps. We first compute the carbon intensity of each sector and multiply this intensity by the weight of that sector in the equity index and in the real economy. We compute index sector weights based on the market capitalization of the constituent companies. Economy sector weights are proxied by the share of each sector in the gross value added (GVA) of the economy. Subsequently, we calculate the total carbon intensity of the equity index and the real economy by aggregating these weighted intensities across sectors. Finally, we measure the carbon bias as the difference between the total carbon intensity of the index and the total carbon intensity of the aggregate economy, scaled by the carbon intensity of the economy.

We discover a large carbon bias in broad stock market indices both in the U.S. and in Europe. The average carbon bias of the Russell 1000 is close to 70% and the average carbon bias of the MSCI Europe is approximately 90%. This implies that the carbon intensity of the U.S. and European market indices is 70% and 90% higher than that of the U.S. and European economy, respectively. In the U.S., the carbon bias is mainly driven by the electricity and gas sector because the index weight of this carbon-intensive sector is much larger than its weight in the economy. In Europe, the mining sector (including petroleum extraction) is the largest contributor to the carbon bias, but the electricity and gas sector and the manufacturing sector also play an important role.

The difference in carbon bias across the two regions mainly reflects the fact that in the U.S., the low-carbon intensive technology sector has a relatively large weight in the index. In contrast, in Europe, traditional high-carbon sectors such as manufacturing and mining still have large weights in the index. Due to the growing importance of the tech sector in U.S. stock markets, we also observe a declining trend in the size of the carbon bias in the Russell 1000, from 71% in 2015 to 60% in 2019. We do not observe a clear time trend in the carbon bias of the MSCI Europe index.

After documenting the existence of a significant carbon bias in frequently used equity indices, we explore several methods for institutional investors to mitigate the carbon bias in their allocation. We evaluate these options based on criteria such as management and trading costs, risk, return, and ease of implementation. These approaches need not exclude each other, and their suitability can vary across investors depending on, among others, investors' sustainability preferences, risk aversion, beliefs about the value of active management, and assets under management.

Our paper is most closely related to existing work by Matikainen et al. (2017) that documents a carbon bias in the corporate bond purchases made by the ECB as part of its quantitative easing (QE) programs. These bond purchases are skewed towards high-carbon sectors that are capital intensive and therefore form a disproportionate share of the corporate bond market and of the universe of bonds eligible for the QE programs. We contribute to this work by quantifying the magnitude of the carbon bias in major European and U.S. stock market indices and by exploring several options for institutional investors to mitigate the carbon bias in their equity allocation.

The paper proceeds as follows. Section 2 explains the approach we use to measure the carbon bias in stock market indices and presents our empirical results. Section 3 discusses options for institutional investors to mitigate the carbon bias in their equity allocation. Section 4 concludes.

2. Measuring the carbon bias

In this section we measure the size of the carbon bias in equity market indices. We focus on stock markets in the U.S. and Europe as these markets cover more than 80% of global stock market capitalization and have readily available data on scope 1 carbon emissions. For both regions, we first compute the carbon intensity per sector based on the NACE classification.[3] We then obtain the weight of each sector in the real economy and in the stock market index. The next step is to compute the carbon bias of the indices using the sectoral carbon intensity and sectoral weights. Finally, we analyse the source of the carbon bias, i.e., which sectors contribute most to the bias?

2.1 Sectoral carbon intensity

We take a sectoral approach towards measuring carbon intensity and quantifying the size of the carbon bias in well-known stock market indices. The main reason for performing a sector-level rather than a firm-level analysis is that data on the weight (importance) of each sector in the real economy and data on the carbon emissions of each sector are readily available. In addition, partitioning the investment universe into sectors is common practice in the investment industry.

We focus on direct (scope 1) carbon emissions to avoid double counting problems that arise when including scope 2 and 3 emissions. Double counting occurs because the economy and the broad market index include all (listed) companies within the same supply chain. For instance, the emissions due to burning gas for electricity production count as scope 1 emissions for the utility company and as scope 2 emissions for a manufacturer using that electricity in its production process. Data on scope 1 emissions are also more reliable than data on scope 2 and 3 emissions (Bolton et al., 2021).

We calculate a sector's carbon intensity as follows:

[3] NACE is the classification of economic activities in the European community, used for collecting and presenting data according to economic activity in the field of statistics (e.g., production, employment, and national accounts).

$$Carbon\ intensity_{j,t} = \frac{Carbon\ emissions_{j,t}}{Gross\ value\ added_{j,t}}, \quad (1)$$

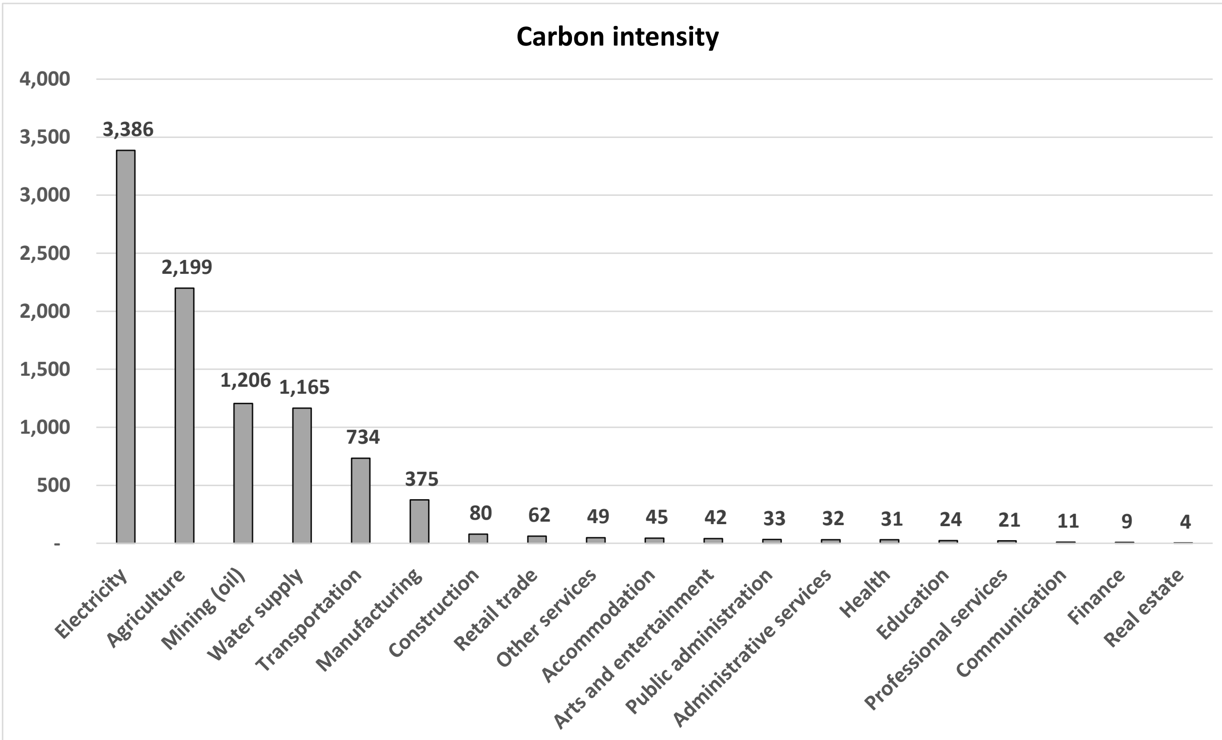
where $Carbon\ intensity_{j,t}$ represents the carbon intensity of sector j in year t, computed as a sector's carbon emissions divided by its gross value added (GVA). Throughout the paper we use carbon (CO_2) emissions as shorthand for greenhouse gas (GHG) emissions. Annual data on GHG emissions as well as the data on the economic contribution (GVA) per NACE sector are retrieved from Eurostat for Europe (EU 28 countries) and from the OECD for the United States.[4]

Tables A1 and A2 in Appendix A show the GVA, GHG emissions, and carbon intensity for the EU28 and U.S. industry for the period 2015 to 2019. At the aggregate level, the U.S. produces more GHG emissions than Europe (5.3 vs. 3.4 billion metric tons in 2019). The GVA of the U.S. economy is also larger than that of the EU28 area (20.7 trillion US dollars vs. 15.0 trillion Euros in 2019). Both areas show a declining trend in emissions, whereas GVA is steadily increasing. As a result, we observe a gradual decrease in carbon intensity over the five-year period: 16% for the EU28 to 17% for the U.S. The resulting carbon intensity is 228 metric tons of GHG emissions per million EUR GVA for the EU28 and 257 metric tons of GHG emissions per million USD GVA for the U.S. in 2019. After adjusting for exchange rates, the carbon intensity of the EU28 decreases to 204 (metric tons of emissions per million USD GVA) in comparison to 257 in the U.S. This reflects the lower carbon intensity of the EU28 economy compared to that of the U.S. economy.

Tables A3 and A4 show that a few sectors drive most of the carbon intensity in each area. These carbon-intensive sectors are agriculture (NACE A), mining (B), which includes companies involved in oil exploration, manufacturing (C), utilities for electricity production (D) and water supply (E), and transportation (H). All other sectors have a relatively low carbon intensity. Figures 1 and 2 highlight the lopsided distribution of carbon intensity across sectors for the EU28 and for the U.S.

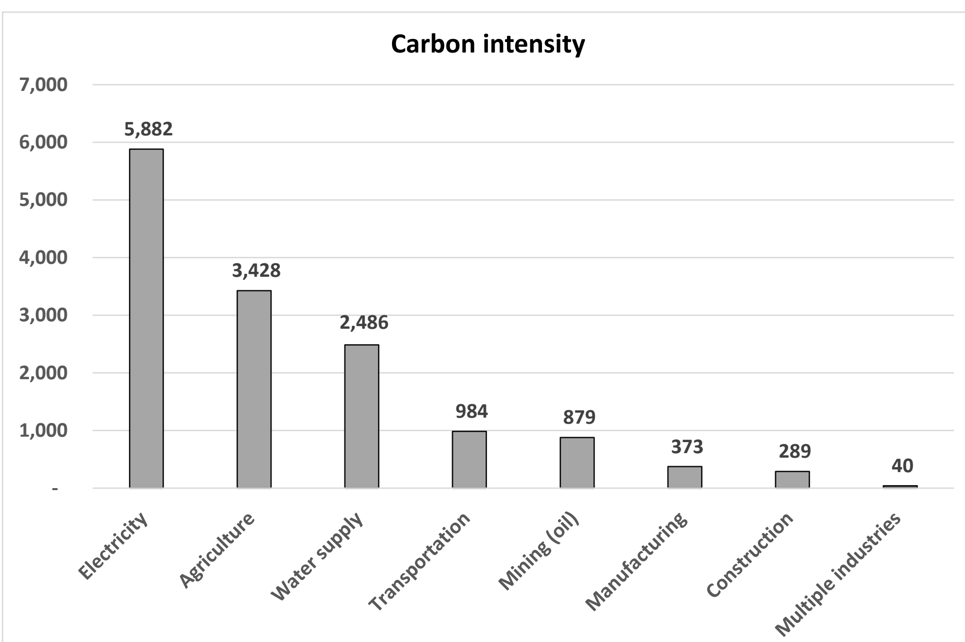
[4] Eurostat provides data for each NACE sector separately. The OECD aggregates data for some NACE sectors into one category (labeled "multiple industries" in our analyses). As discussed in Appendix A, these combined sectors comprise only sectors with low carbon intensity. Hence, no information is lost on carbon-intensive sectors in the U.S.

Figure 1. Carbon intensity by sector (EU28, 2019)



Note: This graph depicts the carbon intensity of sectors in the EU28 area, measured as emissions in millions metric ton CO_2 divided by GVA in trillions of euro. Source: Eurostat

Figure 2. Carbon intensity by sector (U.S., 2019)



Note: This graph depicts the carbon intensity of sectors in the United States, measured as emissions in millions metric ton CO_2 divided by GVA in trillions of dollar. Source: OECD

2.2 Carbon bias in equity indices

The next step is to compute the carbon bias in equity indices. We measure the bias for the Russell 1000 index and the MSCI Europe index because these indices are widely used as benchmarks by major asset managers in the U.S. and Europe for their all-equity funds (see Appendix B).[5] The carbon bias of each index is defined as the relative difference in the carbon intensity of the index in region *k* and the carbon intensity of the economy in region *k*:

$$Carbon\ bias_{k,t} = \frac{Carbon\ intensity\ index_{k,t} - Carbon\ intensity\ economy_{k,t}}{Carbon\ intensity\ economy_{k,t}}. \qquad (2)$$

To compute the carbon intensity of the equity index and the real economy we first multiply the carbon intensity of each sector by the weight of that sector in the index and in the economy. Index sector weights are based on the market capitalization of the constituent companies. Each constituent is assigned to a NACE sector based on the classification in Refinitiv.[6] We proxy sector weights in the economy by the share of each sector in the gross value added (GVA) of the economy. Subsequently, we calculate the total carbon intensity of the equity index and the real economy by aggregating the weighted carbon intensities over all NACE sectors.

Tables 1 and 2 show the results for Europe and the U.S., respectively, in the most recent year of our sample (2019). The carbon intensity of each sector in column 1 is computed as explained in Section 2.1. The sectoral composition in column 2 indicates that the sectoral weights are rather evenly spread, with some concentration in manufacturing (15% in EU28 and 11% in U.S.). The index weights in column 3 show a much larger concentration in manufacturing (49.2% in MSCI Europe and 36.4% in Russell 1000). We further observe that in Europe, the mining and financial sectors also have much larger weights in the index than in the economy.

The last two columns report the contribution of each sector to the total carbon intensity of the economy (column 4) and the market index (column 5), computed as the weighted average of the sector intensities. Note that although both value-weighted market indices overweight some high-carbon sectors (e.g., mining, manufacturing, and electricity), other high-carbon sectors such as agriculture are underweighted relative to their share in the real economy. We examine the contribution of each individual sector to the carbon bias of the index in detail in Section 2.3.

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[5] The MSCI Europe covers about 85% of the market capitalization across developed European equity markets. The Russell 1000 comprises more than 90% of the total market cap of all listed stocks in the U.S. equity market.

[6] Some companies are in more than one NACE sector. For example, oil and gas companies do upstream exploration (NACE B mining) and downstream refining (NACE C manufacturing). Companies are assigned to their dominant sector in terms of activities. In our example of oil and gas companies, this is NACE B. Note that the NACE classification differs from the industry classification used by MSCI. For example, pharmaceutical companies, which have a large weight in the MSCI Europe, are classified as “Manufacturing” according to NACE and as “Health Care” according to MSCI.

Table 1 Carbon intensity MSCI Europe index and EU economy (2019)

Industry	NACE	Industry carbon intensity (1)	Economy weights (2)	Index weights (3)	Economy weighted average (1)*(2)	Index weighted average (1)*(3)
Agriculture, forestry, and fishing	A	2,199.0	1.6%	0.0%	35.1	0.0
Mining and quarrying	B	1,206.3	0.4%	8.4%	5.1	101.2
Manufacturing	C	375.3	15.3%	49.2%	57.4	184.5
Electricity, steam, gas	D	3,385.5	1.8%	3.9%	60.5	131.3
Water supply	E	1,165.4	1.0%	0.8%	11.3	8.9
Construction	F	79.7	5.6%	2.2%	4.4	1.7
Wholesale and retail trade	G	62.0	11.0%	1.9%	6.8	1.2
Transportation	H	733.6	4.8%	1.7%	35.1	12.4
Accommodation and food	I	44.8	2.9%	1.0%	1.3	0.4
Communication and IT	J	11.1	5.3%	7.9%	0.6	0.9
Financial activities and insurance	K	9.2	4.7%	18.8%	0.4	1.7
Real estate	L	4.1	11.0%	1.1%	0.5	0.0
Professional activities	M	21.2	6.7%	1.3%	1.4	0.3
Administrative services	N	32.5	4.7%	1.0%	1.5	0.3
Public administration	O	33.4	6.1%	0.1%	2.0	0.0
Education	P	23.7	4.9%	0.1%	1.2	0.0
Human health activities	Q	30.7	7.3%	0.5%	2.2	0.2
Arts and entertainment	R	42.2	1.4%	0.2%	0.6	0.1
Other services	S	48.8	1.6%	0.0%	0.8	0.0
Activities of households	T	1.3	1.6%	0.0%	0.0	0.0
Extraterritorial activities	U	0.0	0.3%	0.0%	0.0	0.0
Total	**A-U**		**100%**	**100%**	**228.2**	**445.1**

Source: Authors' calculations based on Eurostat (GHG emissions and GVA) for columns 1 and 2 and on MSCI for column 3.

Table 2 Carbon intensity Russell 1000 index and U.S. economy (2019)

Industry	NACE	Industry carbon intensity (1)	Economy weights (2)	Index weights (3)	Economy weighted average (1)*(2)	Index weighted average (1)*(3)
Agriculture, forestry, and fishing	A	3,428.2	1.0%	0.0%	32.6	0.0
Mining and quarrying	B	879.4	1.4%	3.4%	12.5	30.0
Manufacturing	C	373.0	11.3%	36.4%	42.3	135.9
Electricity, steam, gas	D	5,881.6	1.4%	3.3%	84.0	191.3
Water supply	E	2,485.9	0.3%	0.4%	8.5	9.8
Construction	F	289.2	4.3%	0.5%	12.5	1.4
Multiple industries	G, I-U	40.3	76.7%	53.8%	30.9	21.7
Transportation	H	983.9	3.5%	2.2%	34.1	21.7
Total	**A-U**		**100%**	**100%**	**257.4**	**411.8**

Source: Authors' calculations based on OECD (GHG emissions and GVA) for columns 1 and 2 and on Russell for column 3.

Tables 3 and 4 report the carbon intensity of the economy and the index over the sample period for Europe and the U.S., respectively. Both indices are considerably more carbon intensive than the economy throughout the period, resulting in a large carbon bias computed according to eq. (2). The average bias ranges from approximately 70% for the Russell 1000 to 90% for the MSCI Europe. This means that the carbon intensity of the U.S. and European market indices is 70% and 90% higher than that of the U.S. and European economy, respectively.

The higher carbon bias for Europe can be explained by the composition of the index. Specifically, in Europe, traditional high-carbon sectors such as manufacturing and mining still have relatively large weights in the index. In contrast, in the U.S., the newer low-carbon technology sector plays an important role in the index. Due to the growing importance of the tech sector in U.S. stock markets, we observe a declining trend in the size of the carbon bias in the Russell 1000, from 71% in 2015 to 60% in 2019. We do not observe a clear trend in the carbon bias in the MSCI Europe.

Table 3 Carbon bias MSCI Europe index (2015-2019)

Carbon intensity	2015	2016	2017	2018	2019	Average	Annual decrease
EU economy	271.6	267.0	259.4	246.4	228.2	254.5	-3.2%
MSCI Europe index	475.2	516.3	495.9	453.6	445.1	477.2	-1.3%
Carbon bias	**74.9%**	**93.4%**	**91.2%**	**84.1%**	**95.0%**	**87.7%**	

Table 4 Carbon bias Russell 1000 index (2015-2019)

Carbon intensity	2015	2016	2017	2018	2019	Average	Annual decrease
U.S. economy	311.2	294.9	280.9	273.3	257.4	283.5	-3.5%
Russell 1000 index	533.5	531.3	467.5	450.1	411.8	478.8	-4.6%
Carbon bias	**71.4%**	**80.2%**	**66.4%**	**64.7%**	**60.0%**	**68.5%**	

Next, we measure the global carbon bias as a weighted average of the regional carbon biases:

$$Carbon\ bias\ global\ index_t = \sum_k S_{k,t}^{index} * carbon\ bias\ index_{k,t}, \tag{3}$$

where $S_{k,t}^{index}$ is the share of the index of region k in the global index in year t. The MSCI World index is dominated by U.S. companies (68%) followed by European companies (19%). Companies from the rest of the world have a minor share of only 13%. As an approximation, we assume that the carbon bias of the rest of the world is an average of the European and U.S. carbon bias. The carbon bias for the global index then becomes 69.0% in 2019.[7]

2.3 Sectors contributing to carbon bias

The analysis in the previous section shows that there is a strong carbon bias in value-weighted equity indices in the U.S. and in Europe. In this section we examine which sectors contribute most to this carbon bias and dig deeper into the drivers of the difference between the carbon bias in the U.S. index and the European index. We do so by computing the carbon bias for each sector j:

$$Carbon\ bias_{j,k,t} = \frac{(CI_{j,k,t} - \overline{CI}_{k,t}) \times \left(W_{j,k,t}^{index} - W_{j,k,t}^{economy}\right)}{\overline{CI}_{k,t}}, \tag{4}$$

where $CI_{j,k,t}$ is the carbon intensity of sector j in region k in year t and $W_{j,k,t}^{index}$ and $W_{j,k,t}^{economy}$ the index weights and economy weights of sector j in region k in year t, respectively. $\overline{CI}_{k,t}$ is the weighted average carbon intensity of the economy of region k in year t, computed as:

$$\overline{CI}_{k,t} = \sum_j W_{j,k,t}^{economy} CI_{j,k,t}. \tag{5}$$

The product of the two terms in the numerator of Eq. (4) determines the sign of the carbon bias for each sector. An above-average carbon intensity ($CI_{j,k,t} > \overline{CI}_{k,t}$) combined with a larger index weight than the sectoral economy weight ($W_{j,k,t}^{index} > W_{j,k,t}^{economy}$) leads to a positive carbon bias.[8]

[7] This is calculated as follows: 67.8% * 60.0% + 19.0% * 95.0% + 13.2% * (60.0%+95.0%)/2 = 69.0%.

[8] Note that a sector with below-average carbon intensity ($CI_{j,k,t} < \overline{CI}_{k,t}$) and lower weight in the index than in the economy ($W_{j,k,t}^{index} > W_{j,k,t}^{economy}$) will also contribute positively to the carbon bias in the index.

Table 5 shows that the major contributors to the carbon bias of 95% in the European index in 2019 are the mining (34%), electricity (29%), and manufacturing (22%) sectors.[9] These sectors have a high carbon intensity and a larger weight in the index than in the economy. In contrast, the agriculture and financial sectors have a *negative* carbon bias (-14%). For the high-carbon agriculture sector, this negative bias arises because it is underweighted in the index. For the low-carbon financial sector, the negative bias is due to its overweighting in the index.[10]

Table 5 Sectoral analysis carbon bias MSCI Europe index (2019)

Industry	NACE	Industry carbon intensity	Industry weights	MSCI weights	Carbon bias MSCI
Agriculture, forestry and fishing	A	2,199.0	1.6%	0.0%	**-13.8%**
Mining and quarrying	B	1,206.3	0.4%	8.4%	**34.1%**
Manufacturing	C	375.3	15.3%	49.2%	**21.8%**
Electricity, steam, gas	D	3,385.5	1.8%	3.9%	**28.9%**
Water supply	E	1,165.4	1.0%	0.8%	**-0.8%**
Construction	F	79.7	5.6%	2.2%	**2.2%**
Wholesale and retail trade	G	62.0	11.0%	1.9%	**6.6%**
Transportation	H	733.6	4.8%	1.7%	**-6.8%**
Accommodation and food	I	44.8	2.9%	1.0%	**1.6%**
Communication and IT	J	11.1	5.3%	7.9%	**-2.5%**
Financial activities and insurance	K	9.2	4.7%	18.8%	**-13.6%**
Real estate	L	4.1	11.0%	1.1%	**9.8%**
Professional activities	M	21.2	6.7%	1.3%	**4.9%**
Administrative services	N	32.5	4.7%	1.0%	**3.2%**
Public administration	O	33.4	6.1%	0.1%	**5.1%**
Education	P	23.7	4.9%	0.1%	**4.4%**
Human health activities	Q	30.7	7.3%	0.5%	**5.8%**
Arts and entertainment	R	42.2	1.4%	0.2%	**0.9%**
Other services	S	48.8	1.6%	0.0%	**1.3%**
Activities of households	T	1.3	1.6%	0.0%	**1.6%**
Extraterritorial activities	U	0.0	0.3%	0.0%	**0.3%**
Total	**A-U**	**228.2**	**100%**	**100%**	**95.0%**

[9] Results for the other years in our sample are similar.

[10] Recall that the carbon emissions only include the direct (scope 1) emissions of each sector to avoid double counting at the level of the economy. Indirect emissions (e.g., caused by a bank's clients in its loan book) are not included.

Table 6 shows that the electricity sector is also a major determinant of the carbon bias in the U.S. index in 2019, contributing 40% to the total bias of 60%. However, the mining and manufacturing sectors contribute much less to the carbon bias in the U.S. than in Europe because these high-carbon sectors are not overweighted as much in the U.S. market index as in the European index. Whereas the largest companies in European stock markets belong to the traditional industries of mining (oil) and manufacturing, the largest U.S. companies are Big Tech active in other sectors: Alphabet, Facebook, and Microsoft (Communication and IT) and Amazon (Retail Trade).[11]

Table 6 Sectoral analysis carbon bias Russell 1000 index (2019)

Industry	NACE	Industry carbon intensity	Industry weights	Russell weights	Carbon bias Russell
Agriculture, forestry and fishing	A	3,428.2	1.0%	0.0%	**-11.7%**
Mining and quarrying	B	879.4	1.4%	3.4%	**4.8%**
Manufacturing	C	373.0	11.3%	36.4%	**11.3%**
Electricity, steam, gas	D	5,881.6	1.4%	3.3%	**39.9%**
Water supply	E	2,485.9	0.3%	0.4%	**0.4%**
Construction	F	289.2	4.3%	0.5%	**-0.5%**
Multiple industries	G, I-U	40.3	76.7%	53.8%	**19.3%**
Transportation	H	983.9	3.5%	2.2%	**-3.5%**
Total	**A-U**	**257.4**	**100%**	**100%**	**60.0%**

3. Carbon bias mitigation strategies

The carbon bias in equity indices documented in the previous section is problematic because a portfolio tilted towards high carbon-intensive sectors is more exposed to carbon-transition risks. Regulators and supervisors are also aware that environmental factors can pose large investment risks and encourage financial institutions such as pension funds to disclose the risks related to environmental factors. Survey evidence provided by Krueger, Sautner, and Starks (2020) shows that institutional investors themselves also believe that climate risks have financial implications for their investment portfolios. Institutions are increasingly incorporating sustainability issues in their investment decisions not only because of these financial motivations, but also because of social norms towards environmental issues (Dyck et al., 2019; Bauer et al., 2021). The carbon bias in index investing conflicts with this drive to sustainability.

In this section we explore several approaches for institutional investors to mitigate the carbon bias in their allocation. We evaluate the pros and cons of each option based on criteria such as

[11] The fourth Big Tech company, Apple, falls under manufacturing (NACE C) but has relatively low carbon intensity.

costs, return, risk, sustainability preferences, and ease of implementation. These approaches need not exclude each other, and their suitability can vary across different types of investors.

3.1 Strategy 1: Exclusion/Divesture

The most direct way for investors to reduce the carbon bias is to exclude firms in high carbon-intensive sectors from their portfolio. Although such exclusions are frequently used in practice, they have important downsides. First, excluding these sectors will lead to reduced diversification, particularly given their importance in stock markets, and thus increase portfolio risk. Second, Berk and Van Binsbergen (2021) show that current ESG divesture strategies have little impact on real investment decisions because they have little effect on a company's cost of capital. Hence, although exclusion reduces the carbon footprint of a portfolio, it is unlikely to change the actual carbon emissions of companies. They argue that instead of divesting, socially conscious investors should remain invested and exercise their rights of control to have meaningful impact on corporate policy.

3.2 Strategy 2: Engagement

A second carbon bias mitigation strategy is active engagement of investors with management of firms in high-carbon intensive sectors. Azar et al. (2021) find a strong negative relation between engagement efforts of large asset managers and the emissions of the firms in which they hold a large stake. A possible target for engagement and voting is a decline in a firm's carbon emissions in line with the European Green Deal, i.e., a 55% reduction in emissions by 2030. When investors can induce companies to speed up the transition from fossil fuels to renewables through engagement, the risk of climate change is mitigated (Quigley, 2021). In this way, investors internalise, at least partly, climate externalities and protect the long-term health of the economy.

Investors can periodically monitor a company's adherence to plans for reductions in emissions based on various firm-level metrics, such as capital expenditures on new CO_2-reducing technologies (including investment in renewables). When a company repeatedly undershoots the promised CO_2-reduction path in the engagement process, there may ultimately be no other choice for the institutional investor than to divest.

Effective engagement requires that the investor holds a sufficiently large stake in the company. It can also be a challenge for investors to engage with companies in emerging markets because of restricted access to management or a lack of knowledge of local conditions and regulations. In addition, active engagement requires some efforts, e.g., for obtaining the information necessary to make informed voting decisions. Coordinated engagement and voting with other institutions can help to strengthen the effectiveness of the engagement and to reduce costs by sharing information and knowledge (Dimson, Karakaş and Li, 2015; 2021).

3.3 Strategy 3: Low-carbon index investing

A third alternative to reduce the carbon bias are "semi-passive" investment strategies in low-carbon indices that can be implemented at low cost. These indices are designed to lower the exposure to high-carbon companies while retaining a risk-return profile similar to that of their parent index that serves as benchmark.[12] For example, Andersson et al. (2016) present a dynamic investment strategy that allows passive long-term investors to reduce the carbon footprint of their portfolio with 50% relative to its benchmark while virtually eliminating the tracking error. This objective is achieved by re-weighting the index constituents based on their carbon intensity while constraining the tracking error relative to the parent index to a target value such as 30 bps. Because the low-carbon index does not exclude any stocks or sectors from the parent index, it remains well diversified and allows for engagement with company management. Recent work by Bolton, Kacperczyk, and Samama (2022) generalizes this approach by dynamically constructing a low-carbon portfolio that gradually decarbonizes a market index to satisfy a carbon budget.

3.4 Strategy 4: Low-carbon active investing

Investors who believe in the value of active management can integrate climate-related risks and carbon emissions into the valuation models they use for stock selection. Such an active strategy incorporates information about a company's fundamentals, carbon intensity, and exposure to other climate risks. In addition to using information obtained from a company's annual reports, investors can use modern techniques such as machine learning and textual analysis to identify the companies that are transitioning towards a lower carbon footprint and a lower exposure to climate risks (see, e.g., Sautner et al., 2021). The low-carbon indices discussed in Strategy 3 can be used as benchmarks for these low-carbon active strategies instead of the traditional indices.

These active strategies offer the possibility of outperforming the low-carbon benchmarks but incur higher management and trading costs (French, 2008). One possibility to reduce the costs associated with an active sustainable investing is to reduce the number of investee companies (Schoenmaker and Schramade, 2019). The current practice among many pension funds and insurance companies of investing in nearly all companies included in broad market indices such as the Russell 1000 has several drawbacks. First, the small fractions held in many companies make it difficult to engage effectively with each of these firms. Second, performing a thorough sustainability analysis for a large stock universe can be very time consuming and costly.[13]

[12] Examples include the S&P Carbon Efficient Indices and the MSCI Low Carbon Target Indexes.

[13] The use of external ESG ratings does not solve this issue because these ratings diverge considerably across the major rating agencies due to differences in scope and measurement (Berg, Kölbel, and Rigobon, 2022).

A concentrated portfolio with larger stakes in fewer companies enables investors to focus their efforts and leverage their influence on corporate policy. As many companies are still in transition, high-carbon companies that are strongly committed to reduce their carbon intensity and making capital expenditures in line with this goal can still be included in the portfolio. This helps to ensure that the concentrated portfolio remains sufficiently diversified across sectors. Estimates of the number of stocks required for a well-diversified portfolio vary from 30 stocks (Statman, 1987; Chong and Phillips, 2013) to more than 300 stocks (Statman, 2004; Haensly, 2020), depending on the sample period studied and the method used to measure diversification benefits. The optimal number of stocks also varies across investors, depending on the investment universe and on investor characteristics such as assets under management (Zaimovic et al., 2021). Funds with large AUM for which investment capacity is important may choose to combine a concentrated active portfolio with a passive investment in a low-carbon index as discussed in Section 3.3.

3.5 Risk and return of low-carbon strategies

An important open question for investors is how carbon bias mitigation strategies affect the risk and return on their portfolios. Bolton and Kacperczyk (2021, 2022) find that stocks of firms with higher carbon emissions earn higher realized returns. They attribute this carbon premium to investors demanding compensation for the exposure of these stocks to carbon-transition risk. Ilhan, Sautner, and Vilkov (2021) document that carbon-intensive firms exhibit more tail risk. Lukomnik and Hawley (2021) consider climate risk a source of systematic risk.

However, Pastor, Stambaugh, and Taylor (2021a) argue that in equilibrium, green assets have lower expected returns because of investor preferences for sustainability and because green assets hedge climate risk. In a follow-up paper, Pastor, Stambaugh, and Taylor (2021b) attribute the high realized returns on green assets to unexpectedly strong increases in environmental concerns that led to increased demand by ESG investors. They conclude that the high green returns realized in recent years are likely poor predictors of future returns on these assets. The flip side of the coin is that greener firms will likely have lower costs of capital than their recent stock returns might suggest, whereas the future cost of capital for browner firms may increase. These higher costs of capital may incentivize brown firms to become greener.

In sum, this evidence suggests that expected returns for long-term investors such as pension funds may decrease when moving into green assets to reduce the carbon bias of their portfolio. At the same time, their exposure to climate risks is also expected to decrease. Investors should therefore evaluate their low-carbon strategies based on *risk-adjusted* returns.

4. Conclusion

This paper provides empirical evidence on the existence of a large carbon bias in popular stock market indices in the U.S. and in Europe. This carbon bias is defined as the relative difference between the total carbon intensity of the equity index and the carbon intensity of the underlying economy. We show that the carbon intensity of two major U.S. and European market indices is 70% to 90% higher than that of the U.S. and European economy, respectively. The bias arises because of a wedge between a sector's weight in the index and in the real economy. We show that carbon-intensive sectors such as mining, manufacturing, and electricity are strongly overweighted in value-weighted stock market indices relative to their share in the gross value added of the economy. Firms in high-carbon sectors form a disproportionate share of the index because they tend to be capital intensive and are more likely to be publicly listed than firms in low-carbon sectors such as education, health, and consultancy. As a result, the value-weighted stock market index is not an adequate representation of the overall economy.

The resulting carbon bias has important implications for investors following passive strategies that aim to track these equity indices and for investors following active strategies that are benchmarked to these indices. Due to the tilt towards high-carbon sectors, investors' portfolios are more exposed to carbon-transition risks. The carbon bias in index investing also goes against the commitment of many institutional investors to reduce the carbon footprint of their portfolio.

We explore various strategies for investors to reduce the carbon bias in their allocation. Although divestment from companies operating in high-carbon sectors is the most straightforward way to mitigate the bias, it reduces portfolio diversification and is unlikely to lower the carbon emissions of companies because it has little effect on their cost of capital. Engagement and voting can be more effective in reducing emissions by steering investment decisions of companies towards low-carbon technologies and products and away from high-carbon activities. Joint engagement with other institutions can help to further strengthen the effectiveness of the engagement efforts.

Because engagement does not lead to an immediate reduction in the emissions of companies, investors can complement engagement with active or passive low-carbon strategies. Passive managers can choose to track various low-carbon indices that reweight companies in the market index based on their carbon intensity while constraining the tracking error with respect to that reference index. Active managers can integrate carbon emissions and other ESG factors and climate risks in the company valuation models used for stock selection. They may choose to hold a concentrated portfolio with larger stakes in fewer companies to increase the effectiveness of their engagement efforts and to lower the costs associated with active sustainable investing.

Institutional investors such as pension funds that aim to reduce the carbon bias in their portfolios should adopt a low-carbon benchmark index that reflects this choice. Benchmarking a low-carbon strategy to a broad value-weighted market index may lead to a large tracking error and improper assessment of strategy performance, for instance in times when oil prices are going up.

Finally, institutional investors should openly communicate to clients and fund participants about the impact of adopting a low-carbon strategy on the expected risk-return profile of their portfolio. Although returns on green assets have been high in recent years due to increased demand from sustainable investors, expected future returns may be lower because green assets hedge against climate risk. On the positive side, lower expected returns imply that greener firms will have lower costs of capital than their recent returns may suggest, thereby accelerating the energy transition. In addition, moving into low-carbon assets is expected to lower the portfolio's exposure to climate-related risks. Investors should therefore evaluate the performance of low-carbon strategies based on *risk-adjusted* returns.

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Appendix A: Carbon intensity

The data on GHG emissions and on the economic performance in terms of GVA per NACE sector are retrieved from Eurostat for the EU 28 countries and from the OECD for the United States. Eurostat provides GHG emissions for each NACE industry separately. The OECD aggregates NACE sectors G and I to U into one category ("Multiple industries"). Tables A1 and A2 show the GVA, GHG emissions, and carbon intensity for the EU28 and U.S. industry for the period 2015 to 2019. The carbon intensity is expressed in metric tons of GHG emissions per million of GVA.

Table A1 Total carbon intensity of EU28 industry (2015-2019)

	2015	2016	2017	2018	2019
GVA (in EUR trillion)	13.5	13.6	14.0	14.5	15.0
GHG (in million tons of CO_2 equivalent)	3,672.3	3,637.6	3,636.4	3,566.6	3,418.4
Carbon intensity EU	**271.6**	**267.0**	**259.4**	**246.4**	**228.2**

Source: Eurostat

Table A2 Total carbon intensity of U.S. industry (2015-2019)

	2015	2016	2017	2018	2019
GVA (in USD trillion)	17.6	18.1	18.8	19.9	20.7
GHG (in million tons of CO_2 equivalent)	5,469.8	5,331.4	5,294.1	5,427.3	5,317.0
Carbon intensity U.S.	**311.2**	**294.9**	**280.9**	**273.3**	**257.4**

Source: OECD

Tables A3 and A4 show a decrease in the carbon intensity for all sectors over the sample period, in line with the aggregate results in Tables A1 and A2. Although most sectors experience a smooth decline in intensity over time, the mining sector stands out. The carbon intensity for mining and quarrying (NACE B), which comprises large oil companies such as British Petroleum, Exxon, Shell and Total, shows a large increase in 2016, particularly in Europe. A likely explanation for this finding is that the oil price reached a 13-year low in 2016. Although the GHG emissions decreased because of lower demand for oil, the GVA of the sector decreased by more. As a result, the carbon intensity of the mining sector spiked in 2016 and started to decline afterwards.

Table A3 Carbon intensity per NACE industry in EU28 (2015-2019)

Industry	NACE	2015	2016	2017	2018	2019
Agriculture, forestry and fishing	A	2,457.1	2,509.1	2,293.8	2,308.2	2,199.0
Mining and quarrying	B	1,319.9	1,522.5	1,320.4	1,168.8	1,206.3
Manufacturing	C	414.9	404.2	398.9	389.4	375.3
Electricity, steam, gas	D	4,513.3	4,415.9	4,275.6	3,920.6	3,385.5
Water supply	E	1,323.8	1,311.7	1,269.8	1,225.4	1,165.4
Construction	F	94.7	94.8	91.3	87.2	79.7
Wholesale and retail trade	G	75.1	72.9	68.9	64.5	62.0
Transportation	H	761.2	782.1	773.3	770.5	733.6
Accommodation and food	I	55.6	53.6	50.1	47.5	44.8
Communication and IT	J	16.9	16.5	13.0	12.0	11.1
Financial activities and insurance	K	9.4	9.8	9.8	9.3	9.2
Real estate	L	5.0	5.1	4.4	4.4	4.1
Professional activities	M	29.3	30.3	23.5	22.3	21.2
Administrative services	N	37.4	37.1	35.9	33.8	32.5
Public administration	O	39.0	39.3	36.8	34.9	33.4
Education	P	27.3	27.0	26.5	25.0	23.7
Human health activities	Q	34.4	34.3	32.9	32.0	30.7
Arts and entertainment	R	49.7	51.4	46.7	44.4	42.2
Other services	S	53.5	53.6	52.8	50.4	48.8
Activities of households	T	1.3	1.3	1.4	1.3	1.3
Extraterritorial activities	U	0.0	0.0	0.0	0.0	0.0

Source: Eurostat

Table A4 Carbon intensity per NACE industry in U.S. (2015-2019)

Industry	NACE	2015	2016	2017	2018	2019
Agriculture, forestry and fishing	A	3,466.4	3,666.8	3,502.6	3,511.4	3,428.2
Mining and quarrying	B	1,007.9	1,030.7	915.3	828.9	879.4
Manufacturing	C	408.3	407.3	388.4	377.8	373.0
Electricity, steam, gas	D	7,822.1	7,422.7	6,866.0	6,660.2	5,881.6
Water supply	E	3,123.8	3,030.8	2,787.6	2,581.9	2,485.9
Construction	F	331.0	336.2	314.4	297.9	289.2
Multiple industries	G, I-U	45.5	42.5	41.5	41.5	40.3
Transportation	H	1,077.4	1,074.1	1,068.1	1,030.5	983.9

Source: OECD

Appendix B: Benchmark indices

Table B1 provides an overview of the benchmark indices used by the largest asset managers in Europe and the U.S. for their all-equity funds. Funds with a blended benchmark of different equity indices are disregarded. Only funds that are managed by the asset manager and not by a third party are included. Within Europe, only countries with major asset managers are included. For each country at least the top three asset managers are included, based on the list of top-400 asset managers in the world provided by Investment & Pension Europe (www.ipe.com). Some managers use multiple benchmark providers depending on the nature of their funds.

We observe that for European-focused funds, MSCI is the most popular benchmark provider, used by 30 out of the 42 asset management firms in our sample. In our analysis we therefore use the constituents of the MSCI Europe index as reference for the overall European economy.

For U.S.-focused funds, the picture is less clear as Russell and S&P are both used by 17 managers. We pick the Russell 1000 as reference for the U.S. economy because it is broader than the S&P 500 and its sector composition seems a better representation of the U.S. market (Carty, 1999).

Finally, for global equities, the MSCI World is the most frequently used index: 35 out of 42 cases.

Table B1 Equity benchmark indices used by major asset managers (2021)

	Country	United States	Europe	World
ABN AMRO	Netherlands	MSCI	MSCI	MSCI
ABP	Netherlands	*#NA*	*#NA*	MSCI
Aberdeen Standard	UK	Russell	FTSE	MSCI
Actiam	Netherlands	MSCI	MSCI	MSCI
Aegon	Netherlands	*#NA*	MSCI	MSCI
Allianz	Germany	S&P	MSCI	MSCI
Amundi	France	S&P	MSCI	MSCI
Anima SGR	Italy	MSCI	MSCI	MSCI
Aviva	UK	Russell	MSCI/FTSE	MSCI
AXA	France	S&P	FTSE	FTSE
Banco Santander	Spain	S&P	MSCI/STOXX	*#NA*
BBVA	Spain	S&P	MSCI/STOXX	MSCI
BlackRock	USA	Russell/S&P	MSCI	MSCI
BNP Paribas	France	Russell	MSCI	MSCI
BNY Mellon	USA	Russell	*#NA*	MSCI
Candriam	Belgium	Own index	MSCI	MSCI
Caixa Bank	Spain	S&P	MSCI	MSCI
Credit Suisse	Switzerland	*#NA*	MSCI	MSCI
Degroof Petercam	Belgium	MSCI	MSCI	MSCI
DWS	Germany	Russell	*#NA*	S&P
Eurizon	Italy	Russell	MSCI/STOXX	MSCI
Fidelity Funds	USA	S&P	MSCI/EMIX	MSCI
Generali	Italy	*#NA*	MSCI	MSCI
Goldman Sachs	USA	Russell/S&P	MSCI	MSCI
J.P Morgan	USA	Russell/S&P	MSCI	MSCI
KBC	Belgium	MSCI	MSCI	MSCI
Legal and General	UK	FTSE	FTSE	S&P
Morgan Stanley	USA	Russell/S&P	MSCI	MSCI
M&G	UK	S&P	MSCI/FTSE	MSCI
Natixis	France	Russell	MSCI	MSCI
NN Investm. Partners	Netherlands	Russell	MSCI	MSCI
Norges Bank	Norway	*#NA*	*#NA*	FTSE
PGGM	Netherlands	*#NA*	*#NA*	FTSE
PICTET	Switzerland	S&P	MSCI	*#NA*
PIMCO	USA	S&P/Russell	*#NA*	MSCI
Robeco	Netherlands	Russell	MSCI	MSCI
Schroders	UK	S&P/Russell	MSCI	MSCI
Skagen funds	Norway	*#NA*	*#NA*	MSCI
State Street	USA	Russell/MSCI/S&P	STOXX	S&P/MSCI
UBS	Switzerland	Russell/MSCI	MSCI	MSCI
Union Investment	Germany	MSCI	MSCI	MSCI
Vanguard	USA	S&P	FTSE	MSCI

Note: #NA means that the asset management company does not use a benchmark index with an exposure to that geographic area or that such benchmark is not found in publicly available sources.