Carbon footprints of Chinese fund firms' equity portfolios

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Article

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Abstract

Under the dual carbon goals in China, the transition to a net-zero carbon economy demands massive amounts of capital, which must be provided and facilitated by financial institutions. Yet there are no accurate, annual, publicly available disclosures of the carbon emissions embodied in investments, leaving Chinese financial institutions facing significant carbon risks. To bridge this gap, this study looked at data from China's 105 fund firms to measure the CO_2 emissions embodied in their equity investments and carbon intensities from 2010 to 2020. The findings show that total financed emissions have been on a continuous upward trend since 2015, with large-sized fund firms contributing most. The overall trend for carbon intensity metrics shows a reduction in exposure to carbon-intensive assets and an increase in carbon efficiency. It is therefore crucial to identify the drivers of financed emissions and explore the potential for carbon reduction. Our findings suggest that some fund firms have already shifted their capital allocations to decarbonize their investment portfolios. Divesting from high-carbon assets and turning to high-tech sectors can help reduce carbon risk exposures and improve carbon efficiency, which is crucial if China's institutional investors are to achieve a low-carbon transition and long-term sustainable development.

Introduction

The current emission pledge to the Paris Agreement appears insufficient to hold the global average temperature increase below 2 °C [1,2]. Growing numbers of governments are thus introducing targets and plans to achieve net-zero goals [3]. The transition to net zero is a strategic imperative for the financial sector, with trillions in capital that are aligned towards meeting the Paris Agreement [4,5]. Under the commitment, some financial institutions are competing to showcase their green ambitions and committing to align their portfolios with 1.5°C consistent with decarbonization trajectory by 2050 [6]. However, the vast majority of asset managers didn't account for the carbon emissions embodied in their portfolios, which makes assessment of their portfolio risk inherently difficult [7]. As the world's largest CO_2 emitter [8], the Chinese government has committed to achieving peak carbon dioxide emissions by 2030 and carbon neutrality by 2060 [9]. Consequently, Chinese financial institutions are active participants in decarbonizing the global economy and avoiding the economic and environmental risks of climate change. However, there has been a lack of accounting regarding the carbon footprint of investment portfolios in China's financial institutions.

Given the importance of finance to the net-zero transition, it has become paramount to assess institutional investors' carbon emissions accurately [10]. Methods for assessing the climate impact of investments are also being developed and tested in open network initiatives such as Partnership for Carbon Accounting Financials (PCAF, an industry-led initiative to enable financial institutions to consistently measure and disclose greenhouse gas emissions financed by their loans and investments). The Financial Stability Board's Task Force on Climate-related Financial Disclosures [11] provided guidance on calculating GHG for certain financial products such as private equity investment funds and green

bonds. Several countries are already transitioning from encouraging the voluntary adoption of the recommendations to mandating TCFD-aligned disclosure [12]. China has also achieved significant decarbonization of its booming economy with a package of low-carbon development policies, including improved climate-related and environmental information disclosure [13,14]. In 2021, the People's Bank of China issued the document *Guidelines on Environmental Information Disclosure for Financial Institutions* [15], which was the first to put forward requirements on quantitative methodologies to be disclosed by financial institutions. As the largest institutional investors in the stock market, fund firms offer an important route towards investing in the equity markets to achieve carbon neutrality goals [16]. And some of these firms have started to pay attention to the CO_2 emissions associated with their investment portfolios, and have disclosed these carbon footprints voluntarily [17,18]. Despite the progress in climate disclosure systems for China's financial institutions, however, accounting for the carbon footprint of investment activities is still in its infancy. There may be large gaps in the financed emissions data, given the lack of annual, publicly financed emissions disclosures for China's financial institutions.

Accurate corporate carbon information is a key basis for measuring the carbon footprint of investment portfolios. Calculating for financed emissions is a complicated task because of the dearth of firm-level CO_2 emissions data [4]. Only a few listed firms in China voluntarily disclose CO_2 emissions, which renders data quality difficult to guarantee [19]. The corporate CO_2 emissions database is dominated by countries in Europe, North America and other developed economies [20,21], developing countries — including China — have yet to formulate such a database [22]. There is still a large gap in the level of carbon disclosure between Chinese firms and companies in other developed countries [23].

In this study, we used methodologies introduced by TCFD to study the equity portfolios of China's 105 public fund firms over the period from 2010 to 2020. We first account for and analyze the financed emissions and carbon intensities of the fund firms' investment portfolios, then use this to assess overall trends and heterogeneity of institutions. The study also reveals the drivers of financed emissions to help in identifying key carbon risk exposures and potential for emissions reductions. It can guide in designing efficient portfolio decarbonization strategies for different types of fund firms and provide compelling insights for policymakers and investors.

Results

Trends in the carbon footprints of 105 fund firms' equity portfolios.

The figure is divided into three categories by the size of equity AUM in 2020. The first (large-sized), second (medium-sized) and third line (small-sized) show financed emissions of top 10 fund firms in 2010, 2015 and 2020, respectively. See details of the left fund firms in Supplementary Table 3. The share in the bottom righthand corner represents the share of the top 10 fund firms' financed carbon emissions.

The total financed emissions embodied in the equity portfolios of China's 105 fund firms maintained an overall trend of decline from 2010 to 2015, falling from 57.03 Mt CO_2 in 2010 to 39.56 Mt CO_2 in 2015, while they rose sharply in 2012 with 96.16 Mt CO_2 and thereafter rebounded to 58.11 Mt CO_2 in 2020 **(Supplementary Fig. 1)**. We classified 105 fund firms into large-, medium- and small-sized, based on the size of their equity AUM **(Supplementary Table 2);** the financed emissions embodied in the equity portfolios of these firms are also illustrated in **Fig. S1**. Large-sized fund firms had the highest point in 2012 (79.98 Mt CO_2) and lowest in 2015 (30.56 Mt CO_2). Large-sized fund firms consistently account for over 70% of total financed emissions, and largely contributed to the peak of total financed emissions in 2012. Medium-sized firms followed the same trend before 2015, then reached stability. The financed emissions of small-sized fund firms were relatively low, accounting for less than 10% of the total, and fluctuated continuously, peaking at 3.29 Mt CO_2 and 6.07 Mt CO_2 in 2013 and 2017, respectively.

Among large-sized fund firms, the top 10's share of the total financed emissions continued to decline. The highest share of 55.72% came in 2015, then fell to 50.41% in 2020. These top 10 firms showed a relatively stable trend, with some changes in the rankings. In particular, a trio of large-sized fund firms accounted for 23.14%, 22.57%, and 19.25% of total financed emissions. Of these, China Southern consistently ranked in the top three, while Bosera Asset, which ranked third in 2010, has seen its financed emissions fall steadily over the period: it ranked fifth in 2015 and fell to ninth in 2020. In addition, Shanghai Orient Securities overtook China Southern in second place, with 3.80 Mt CO_2 of financed emissions in 2020, while China Asset was again in first place with 3.96 Mt CO_2.

By contrast, the volume of financed emissions in medium- and small-sized fund firms was relatively small. The financed emissions of the top 10 in large-sized fund firms were 9.57 times and 30.07 times higher than those of medium- and small-sized fund firms, respectively. Compared to large-sized fund firms, there was a significant change in the places of the ranking in medium-sized and small-sized fund firms. For medium-sized fund firms, the financed emissions of Everbright Pramerica continued to decrease, ranking first with 0.97 Mt CO_2 in 2010, dropping to third with 0.42 Mt CO2 in 2015, and dropping out of the top 10 in 2020. In addition, China Life AMP and Manulife Teda Fund have grown significantly in recent years, ranking first and second, respectively, in 2020.

The portfolios of fund firms present divergence of carbon exposures and efficiency.

The metric Weighted Average Carbon Intensity (WACI) indicates the exposure of an equity portfolio to carbon-intensive assets [11]. Additionly, we computed the carbon risk exposure, which can be interpreted as the fraction of high-carbon investments of the total portfolio values, to measure the portfolio-related carbon risk. We divided the firms by portfolio into high-carbon companies and non-high-carbon companies according to their sectors **(Supplementary Table 1)**. A higher WACI value indicates greater exposure to carbon-intensive assets and a higher carbon risk exposure indicates a higher proportion of high-carbon companies. Although the average WACI for the three size-based categories of fund firms all showed a downward trend over the designated period, there were significant differences between fund firms and drivers **(**Fig. 2 **)**. Large-sized fund firms decreased most in average value, from 317.80 tonnes

CO_2/$ in 2010 to 114.38 tonnes CO_2/$ in 2020, with a decrease of 64.01%. Wanjia Asset, which was ranked first in 2010 with a WACI of 541.57 tonnes CO_2/$, dropped out of the top 10 in 2015, mainly due to a reduction in its holdings of electricity, gas and water (-61.38%) and coal mining (-97.50%). In a similar vein, the WACI of Baoying Fund and China Southern Asset declined by 48.48% and 45.31% over the period 2010–2015 and both of them exited the top 10 in 2020. At the same time, the investment portfolios of large-sized fund firms contained a large number of high-carbon sector targets; of these, the high-carbon investment in top 10 fund firms' portfolios all accounted for over 25% in 2010. Among the underperformers, Bank of China Investment (342.52 tonnes CO_2/$), which ranked first in 2020, held 34.29% of high-carbon investment, mainly in nonmetal products and electricity, gas and water. In contrast, PICC Asset performed well in climate risk governance, actively divesting from the carbon-intensive assets and reducing the proportion of high-carbon investments from 38.43% in 2010 to 1.18% in 2020.

Meanwhile, the WACI of medium- and small-sized fund firms declined by 51.99% and 16.25%, respectively. Regarding medium-sized firms, the institutional rankings have changed significantly. Specifically, Morgan Stanley Huaxin Fund (477.66 tonnes CO_2/$), which was ranked first in 2010, dropped significantly to 254.92 tonnes CO_2/$ in 2015, relegating it to ninth place. This was associated with a significant decline in metals and nonmetal mining (-81.47%) and coal mining (-76.16%). Similarly, Truvalue Asset, which was 564.21 tonnes CO_2/$ in terms of WACI, declined to 210.13 tonnes CO_2/$, which was mainly due to the reduction of its holdings of electricity, gas and water (-48.93%). Compared to large-sized fund firms, medium-sized firms have a relatively high proportion of high-carbon investments in their portfolios and have not made effective improvements, as shown by the fact that Beixin Ruifeng Fund, Truvalue Asset and Caitong Fund held 54.14%, 46.92% and 39.25% of high-carbon investments, respectively, in 2015. However, their asset allocation varied; for example, the Beixin Ruifeng Fund's high-carbon investments were concentrated in petroleum and natural gas extraction (19.95%) and raw chemical materials and chemical products (9.96%), while ferrous metals smelting (13.71%) and transportation and telecommunication (11.94%) were the main carbon risk exposures of Caitong Fund.

For small-sized fund firms, the average was relatively low and declined slowly, with clear differences seen in WACI among institutions. Soochow Asset was 3.91 times larger than ChangAn Fund in 2010. In 2020, ChangAn Fund was 9.43 times higher than Tebon Fund, which illustrated a significant imbalance among institutions, despite the lower average WACI compared to other sizes of firm. In terms of portfolio asset allocation, the small-sized fund firms had no significant decarbonization initiatives and their portfolios were dominated by high-carbon assets. Significantly, BOC International's portfolio in 2015 was entirely composed of high-carbon assets, with a concentration in transportation and telecommunication. The Founder Fubon Fund and Xinyuan Asset held 77.25% and 62.76% of high-carbon investments, respectively, with transport and telecommunication being their main sector at, respectively, 75.65% and 47.67%.

Carbon Emissions to Revenue intensity (CTEV) measures total financed emissions divided by total economic activity, where higher values indicate more efficiency. Although the average CTEV of the three categories of fund firms by size all showed a decreasing and then an increasing trend (Fig. 3), there is wide variation among institutions. Specifically, large-sized fund firms experienced a significant decrease, from 327.49 tonnes CO_2/$ to 191.13 tonnes CO_2/$, and then a slight increase to 201.02 tons CO_2/$ in 2020. In 2010, China International Fund and Penghua Fund were in the top two with 706.20 tonnes CO_2/$ and 563.84 tonnes CO_2/$, respectively; most of the carbon was concentrated in the electricity, gas and water sector. The fund firms overall maintained a downward trend over the period 2010 to 2015. For example, Baoying Fund, Huatai PineBridge Fund and Bosera Asset declined from 455.23 tonnes CO_2/$, 496.17 tonnes CO_2/$ and 362.11 tonnes CO_2/$ to 411.45 tonnes CO_2/$, 288.49 tonnes CO_2/$ and 220.14 tonnes CO_2/$, respectively. The difference was more pronounced among institutions in 2020, with Bank of China Investment and Shanghai Orient Securities revealing a CTEV of 631.59 tonnes CO_2/$ and 496.63 tonnes CO_2/$, respectively; the figures are 3.14 times and 2.47 times the average value. In contrast, Fullgoal Fund had a CTEV of just 235.84 tonnes CO_2/$.

For medium-sized fund firms, the average CTEV fell by 25.73% from 2010 to 2015, and then increased by 17.20%. The rankings changed significantly: for example, Morgan Stanley Huaxin Fund, Golden Eagle Asset and Great Wall Fund, which ranked in the top three in 2010, showed similar declines and dropped out of the top ten in 2015. However, the CTEVs of First State Cinda Fund, Truvalue Asset, Caitong Fund and Tianhong Asset bucked the trend, and ranked in the top four in 2015. In particular, the CTEV of First State Cinda Fund increased significantly from 345.46 tonnes CO_2/$ to 556.01 tonnes CO_2/$; this was mainly caused by the firm's heavy investment in several ferrous metals smelting and energy companies such as Shenzhen Energy Group and Shandong Gold Mining Corporation, which formed its main source of carbon emissions. In 2020, the CTEV of Beixin Ruifeng Fund, Huatai Securities, China Life AMP and Manulife Teda Fund were 1378.51 tonnes CO_2/$, 857.56 tonnes CO_2/$, 721.31 tonnes CO_2/$ and 702.12 tonnes CO_2/$, respectively, which are 5.50 times, 3.42 times, 2.88 times and 2.80 times higher than the average value.

The average TREV of small-sized fund firms declined from 187.61 tonnes CO_2/$ to 173.60 tonnes CO_2/$, and then increased to 200.78 tonnes CO_2/$ in 2020. While the CREV was relatively low, the disparities between institutions stand out. For example, the first-ranked Soochow Asset (448.76 tonnes CO_2/$) was 11.28 times higher than the tenth-ranked Changjiang Securities (39.77 tonnes CO_2/$) in 2010, and the CTEV of Hafor Fund reached 750.62 tonnes CO_2/$, 4.32 times higher than the average, in 2015. In addition, the two funds, ChangAn Fund and ZhongRong Fund, had quite high CTEVs of 1389.96 tonnes CO_2/$ and 917.85 tonnes CO_2/$ in 2020, respectively, while Hotland Innovation Asset, ranked tenth, was below average at 196.11 tons CO_2/$.

Trends and drivers of financed emissions for fund firms.

The bar chart represents the financed emissions of the equity portfolio of the fund firms. The two lines in the line chart represent the two carbon intensity indicators of the fund firms, namely the Weighted Average Carbon Intensity (red line) and the Carbon Emissions to Revenue intensity (blue line). Each row of the graph represents a category of fund firms with the same characteristics, with the first row of fund firms showing an increasing trend in financed emissions, the second row showing a decreasing trend, and the third row showing fluctuations over the period.

The Chinese equity market experienced significant shocks in 2015. Afterwards, equity market volatility was relatively subdued, and fund firms' portfolio allocation was based more on their own judgment of market expectations and investment preferences. In this study, as we have seen, there is significant heterogeneity among size-based categories of fund firms, therefore, we further focused on observing the changing trend from 2016 to 2020. By revealing the dynamic trend of financed emissions and carbon intensities of investment portfolios, it can effectively identify the driving factors and future carbon reduction potential of different fund firms.

We classified fund firms into three categories based on the trend of financed emissions, which were consistently rising, falling and fluctuating. However, due to the continuous volatility of the stock market, the trend of financed emissions didn’t show a perfect continuous increase or decrease; so we consider small fluctuations as a normal situation in line with stock market fluctuations, with the overall trend as the main.

Figure 4 shows the trend of financed emissions of equity investments and the corresponding carbon intensities for the three types of fund firms. Typically, Bank of China Investment, HFT Investment and GF Fund have maintained a consistent upward trend in financed emissions over this period, at an annual growth of 28.39%, 14.14% and 12.81%, respectively. It can also be observed that two high-carbon sectors — ferrous metals smelting, and metals and nonmetal mining — account for a significant share of their financed emissions.

In terms of carbon intensities, these three funds follow different patterns, with Bank of China Investment's WACI and CTEV both showing a consistent upward trend over the period. Sector allocations within investment portfolios are an important driver of financed emissions, and around 40% of Bank of China Investment's financed emissions were concentrated in ferrous metals smelting. The share of this sector in its financed emissions increased significantly in 2020, reaching 74.16%; meanwhile, CTEV also increased significantly. Compared to the other two funds, the investment structure of Bank of China Investment reflected greater allocation to assets based in high-carbon sectors, resulting in relatively inefficient investments and a continued increase in financed emissions.

There is no clear trend in the carbon intensities for HFT Fund, with the WACI remaining relatively stable while the CTEV fluctuated over the designated period. Nor is there a clear roadmap towards decarbonizing portfolios, and the continued growth in financed emissions and large exposure to carbon-intensive assets demand further attention. In addition, both the WACI and CTEV of the GF Fund were

relatively low and declining, from 208.00 tonnes CO_2/$ and 154.77 tonnes CO_2/$ to 128.25 tonnes CO_2/$ and 110.12 tonnes CO_2/$, respectively. GF Fund made a significant reduction in investments in major high-carbon sectors such as ferrous metals smelting (-1.51%) and coal mining (-1.05%), and shifted extensively to electronic and telecommunications equipment (+ 8.26%) and electric equipment and machinery (+ 0.06%). Electronic and telecommunications equipment, as a representative of the high-tech sector, is characterized by low carbon intensity and high energy efficiency [24], and increasing holdings in this sector plays a critical role in achieving investment portfolio decarbonization. While ferrous metals smelting and metals and nonmetal mining remained the two main contributors to the GF Fund's financed emissions, accounting for 21.10%, the firm's potential for emissions reductions and carbon efficiency gains is greater.

In the second category, as represented by Lion Fund, Caitong Fund and Donghai Fund, financed emissions and the carbon intensities of fund companies were all on a downward trend. More specifically, the sectors transportation and telecommunication, and raw chemical materials and chemical products, showed different degrees of decline during the period and were the main factors contributing to the decline in financed emissions. Looking at the Lion Fund, both the WACI and TREV declined from 369.59 tonnes CO_2/$ to 60.22 tonnes CO_2/$, and 280.26 tonnes CO_2/$ to 130.88 tonnes CO_2/$, respectively. On the one hand, high-carbon sectors also continued to decline significantly, such as the share of investments in the electricity, gas and water sector, which declined from 2.92–0.05%, while large amounts of capital flowed into the electronic and telecommunications equipment sector, with an increase of 38.38%. On the other hand, profits from high-carbon sectors were relatively low in contrast with high-tech sectors, so the reduction in holdings in these sectors led to an increase in carbon efficiency.

Similarly, the Caitong Fund's financed emissions also fell considerably over the designated period. This was associated with a significant reduction in holdings in the raw chemical materials and chemical products and coal mining sectors; meanwhile, electronic and telecommunications equipment became a major component of its capital pool, accounting for around 20% of equity AUM. The Donghai Fund shares the same investment profile, with a gradual reduction in investments in high-carbon sectors, particularly ferrous metals smelting and electricity, gas and water, which declined to zero by 2020. The shift from traditional high-emitting sectors to high-tech sectors has not only resulted in effectively reducing financed emissions, but also in restructuring investments in a way that has reduced carbon intensity and increased carbon efficiency. Against the backdrop of the global trend of decarbonizing asset portfolios of fund firms, Chinese fund firms whose investments are characterized by high-carbon assets, should adjust their portfolio structure. Capital should gradually move towards high-tech and service industries, focusing on efficiency and investment quality, while balancing capital gains and carbon reduction.

The financed emissions for the third category of fund firms continued to fluctuate, but the drivers were different. The UBS SDIC Fund's financed emissions experienced a downward and then an upward trend, mainly reflecting the contribution of the ferrous metals smelting sector. A significant investment reduction

in position of the sector caused financed emissions to reach a low point of 0.095 Mt CO_2 in 2018; the firm then increased holdings in the sector, and financed emissions rebounded to 0.19 Mt CO_2 in 2020. From 2016 to 2020, the share of UBS SDIC Fund's investments in ferrous metals smelting, the main sector exposed to carbon risk, increased by 0.72%. Meanwhile, the share of investments in other high-carbon sectors was also increasing, including electricity, gas and water (+ 0.14%), transportation equipment (+ 4.5%) and coal mining (+ 0.26%). The concentration of investments in high-carbon sectors will not only lead to a continued increase in financed emissions, but also to inefficiencies in the overall portfolio, leading to a possible lack of decarbonization potential in the future.

The fluctuating trend in financed emissions was consistent with the two carbon intensities for Gfund. From the two inflection points in 2018 and 2019, it was clear that the two high-emitting sectors, ferrous metals smelting and metals and nonmetal mining, were its main carbon exposures, affecting not only the movement of financed emissions, but also the improvement of carbon efficiency. Therefore, adjusting the weighting of key carbon exposures is key to decarbonizing the portfolio, and its carbon reduction potential depends on how much high-carbon sectors are restructured. In addition, Changxin Asset saw a significant decline in its financed emissions starting in 2018, which benefited from the firm’s ongoing reduction in two sectors, electricity, gas and water and ferrous metals smelting. In contrast to the second category, the less pronounced reduction trend was mainly due to the continued reduction in the size of its equity AUM, which decreased by 27.63%, and the lack of a significant downward trend in carbon intensities. In the longer term, fund firms in this category that maintain a lower carbon intensity, reduce highly carbon risk exposure of investment portfolios, and continue both rigorously into the future will reduce financed emissions.

Discussion

Climate change has become an important concern for financial institutions and a new challenge for their portfolio construction.

Many world's leading financial institutions have already undertaken a full-scope carbon accounting exercise, and 273 signatories have joined the Net Zero Asset Managers Initiative and committed to get their portfolios on track for net zero by 2050. However, no Chinese asset manager has signed this initiative to date, and as a whole they remain slow to act [25]. This study accounts for the financed emissions and carbon intensities of China’s fund firms, and explores the drivers of these emissions, and potential carbon reduction potential, from a dynamic perspective.

We found that the total financed emissions were relatively small, but showed a year-on-year increase from 2015 onwards, which may cause huge potential climate risks to China’s financial system in the future. Due to more active investment activities, large-sized fund firms were the main contributors, responsible for about 70% of total financed emissions. Therefore, the focus should be on the top fund firms, which need to follow the lead of their international counterparts in setting specific phased carbon neutrality targets to decarbonize their portfolios as soon as possible. We further measured WACIs and

found that while the exposure to carbon-intensive assets had remained on a declining trend, portfolios still remained dominated by high-carbon investments: over 70% of fund firms held more than 10% high-carbon investments of their portfolios in 2020, with high-carbon investments in Donghai Fund accounting for more than 50%. In addition, the average CTEV continued to rise starting in 2015, a trend which may be responsible for the increase in financed emissions. The rise in variability can be clearly seen within institutions, indicating significant differences in carbon efficiency across institutions.

Taking into account the significant heterogeneity among fund firms, this paper explores the main drivers in their portfolios by looking at them in terms of trends of financed emissions, with a view to improving their investment portfolios to achieve long-term decarbonization goals. Firstly, fund firms that have seen a consistent increase in both financed emissions and carbon intensities are likely to face greater carbon risk and pressure to reduce emissions in the future, associated with their large holdings of assets in high-carbon sectors. Therefore, these firms should pull out of an ever-wider range of carbon-intensive asset and tilt their portfolios towards the investment universe of companies flagged as environmentally friendly.

Fund firms with rising financed emissions but declining carbon intensities indicate a trend towards decarbonization of their portfolios; but their expanding asset size is to some extent undermining their ability to reduce financed emissions. Such firms need to balance the relationship between continued expansion of asset size and the implied carbon emissions of their portfolios by optimizing portfolios via constraints on the carbon-intensive assets. In contrast, funds characterized by rising financed emissions but fluctuating carbon intensities do not follow a clear trend for reducing emissions, and their investments follow market fluctuations and are dominated by carbon-intensive assets, making them more vulnerable to carbon risk.

The optimal state for fund firms is to follow a continuous decreasing trend in both financed emissions and carbon intensities, which shows that their investment pattern is consistent with decarbonizing investment portfolios on the journey to net zero. The outflow of capital from high-carbon sectors and inflow into high-tech sectors will have a significant impact on decreasing carbon risk and increasing carbon efficiency. Such fund firms should therefore play a leading role in decarbonizing their portfolios by further increasing the rigor and transparency of carbon disclosure, in order to benefit from a progressive decarbonization process as the sustainable investment universe grows. Another manifestation is the fluctuating trend in financed emissions and carbon intensity metrics, where fund firms are constrained by multiple objectives — return, risk and climate mitigation — that may not be aligned on the same timescale. Such funds therefore achieve incremental decarbonization by setting up their portfolios to adjust to lower carbon assets.

Methods

Investment Carbon Metrics

To account for corporate CO_2 emissions, we introduced average-data method to calculate, shown in [26]. The estimation model that using environmentally-extended input output data acknowledged region-or sector-specific average emission factor expressed per economic activity, which is specifically for firm-level CO_2 emissions unavailable [27].

We then applied the TCFD framework to account for financed emissions and related carbon intensity indicators of equity portfolios; the equations can be expressed as (2) to (4).

$$E_{it} = R_{it} * C_{jt}/O_{jt}$$

1

Where E_{it} is the CO_2 emissions of company *i* in year *t*. R_{it} is total revenue of a company *i* in year *t*. C_{jt} indicates the sector *j*'s carbon emissions in year *t*. O_{jt} represents total output of sector *j* in year *t*.

$$F_t = \sum_i^n I_{it}/M_t * E_{it} \quad (2)$$

Where F_t is the financed emissions of the portfolio in year *t*. I_{it} is the market value of the invested company *i* where bank holds the equity holdings in year *t*. M_t indicates the total market value held by the banks in year *t*. Under this approach, if an investor owns 1% of a company's market capitalization, then the investor owns 1% of the company as well as 1% of the company's carbon emissions. The metric can clearly show the financed emissions and changing trends intuitively, but can't be used to compare with other portfolios.

$$WACI_t = \sum_i^n (I_{it}/M_t) * (E_{it}/R_{it})$$

3

Where $WACI_t$ refers to the metric Weighted Average Carbon Intensity of portfolios in year *t*, expressed in tonnes CO_2/$M sales. By normalizing financed emissions, it can compare portfolios of different sizes, in addition to being simple to calculate and easy to understand.

$$TREV_t = \frac{\sum_i^n I_{it}/M_t * E_{it}}{\sum_i^n I_{it}/M_t * R_{it}}$$

4

Where $TREV_t$ refers to the metric Carbon Emissions to Revenue Intensity and can be used to measure the productivity of the investee company, expressed in tonnes CO_2/$M revenue. It is used for comparison

between portfolios of different sizes. The disadvantage of this equation is that it is relatively complex and difficult to understand.

Data collection and processing

The primary data used in this study were from S&P Capital IQ Pro database [29] spanning the period from 2010 to 2020, and offering equity portfolio data on banks, insurance companies, private equity firms and other similar companies worldwide. We focused on this period because during it, China had support for a series of incentives to encourage green financing activities and back green financial development [30]. There were 153 public fund management firms released by China Securities Regulatory Commission [31], which collectively accounted for 7.51% of China's capital market. That profound market power meant that they could have signigicant influence with some high-emitting firms and improve corporate emissions management [32]. From this list, we eliminated fund firms established after 2015, whose equity portfolios did not figure in S&P Capital IQ Pro database. Our final sample was 105 fund firms, studied over the period from 2010 to 2020. In addition, we divided the firms into three sizes: large-, medium- and small-sized, based on the size of equity asset under management (equity AUM), detailed in Supplementary Table 2.

The sectoral CO_2 emissions we used are from China Emission Accounts and Datasets (CEADs) [33], whose database covers 42 socioeconomic sectors and is updated annually. The input-output data are sourced from the Global Trade Analysis Project database (GTAP) [34], which is updated at four-year intervals and is available for 2011 (GTAP9), 2014 (GTAP10) and 2017 (GTAP11). Based on these tables, we calculated the direct carbon emission coefficient. To fill the data gap in intervening years, we used data from the neighbouring year to replace it. For example, 2011 data is used for the years 2010, 2012 and 2013. As indicated above, all equity portfolios and related financial data are collected from S&P Capital IQ Pro database. (The equity portfolio of financial institution refers to the shareholdings of listed companies, and the data is updated quarterly.) The S&P database also provides detailed financial information on listed companies, including details such as total revenue, market value, Standard Industrial Classification codes (SIC codes) and headquarters location.

At the industry scale, to maintain consistency we matched industry classifications of GTAP with CEADs, and we ended up with 32 sectors (shown in Supplementary Table 1). Each firm was assigned a SIC four-digit code to determine which industry sector it belonged to. For the regional scale, we distinguished the headquarters of invested companies based on their country-level distribution. The majority of the investment objects of Chinese fund firms are Chinese listed companies, so the study only focuses on the invested companies that are headquartered in China of the investment portfolio.

Declarations

Data availability

The datasets generated and analysed in this study are further elaborated in the supplementary information. The publicly accessible databases on equity portfolio, total revenue, market capitalization, sectoral carbon emissions and total output value can be downloaded at: (1) S&P Capital IQ Pro database (Capital iq): https://www.capitaliq.spglobal.cn/web/client?auth=inherit&overridecdc=1&#dashboard; (2) China Emission Accounts and Datasets (CEADs): https://www.ceads.net/data/nation/; (3) Global Trade Analysis Project database (GTAP): https://www.gtap.agecon.purdue.edu/.

Code availability

The Python script used for this analysis is available from the corresponding author upon reasonable request.

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Contributions

D.B.G. and J.L.W. conceived the original idea and designed the research. J.L.W. wrote the relevant procecing codes and drafted the initial manuscrift. X.Y. was responsible for writing methods and collecting the raw data. Z.K.Z. and J.L.W. analyzed the results and created the figures. Z.K.Z. and D.B.C. commented the discussion. All the authors contributed to writing the manuscript and discussed the results at all stage.

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Ethics declarations

Competing interests

The authors declare no competing interests.

Additional Information

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Figures

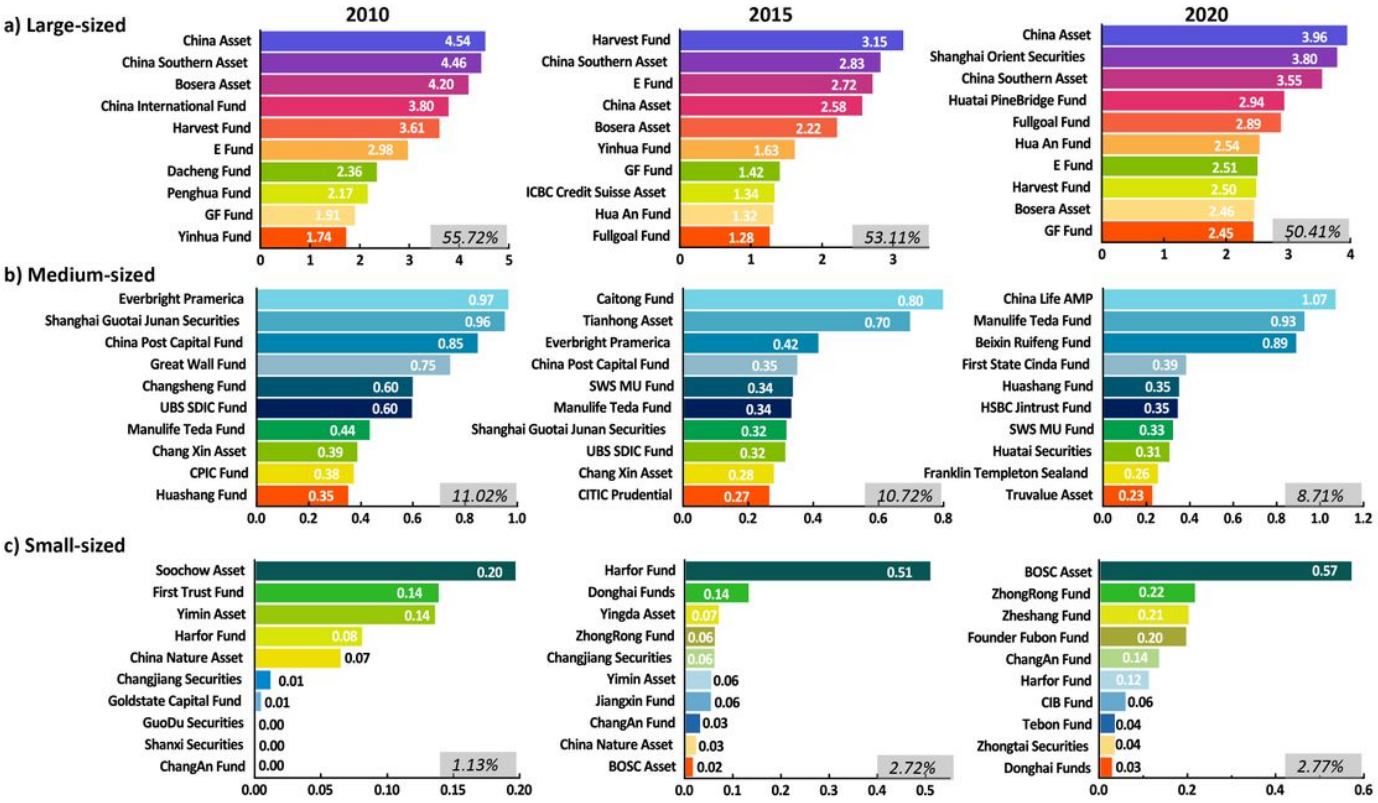

Figure 1

Trends in the carbon footprints of large-, middle- and small-sized fund firms' equity portfolios (units: Mt CO_2).

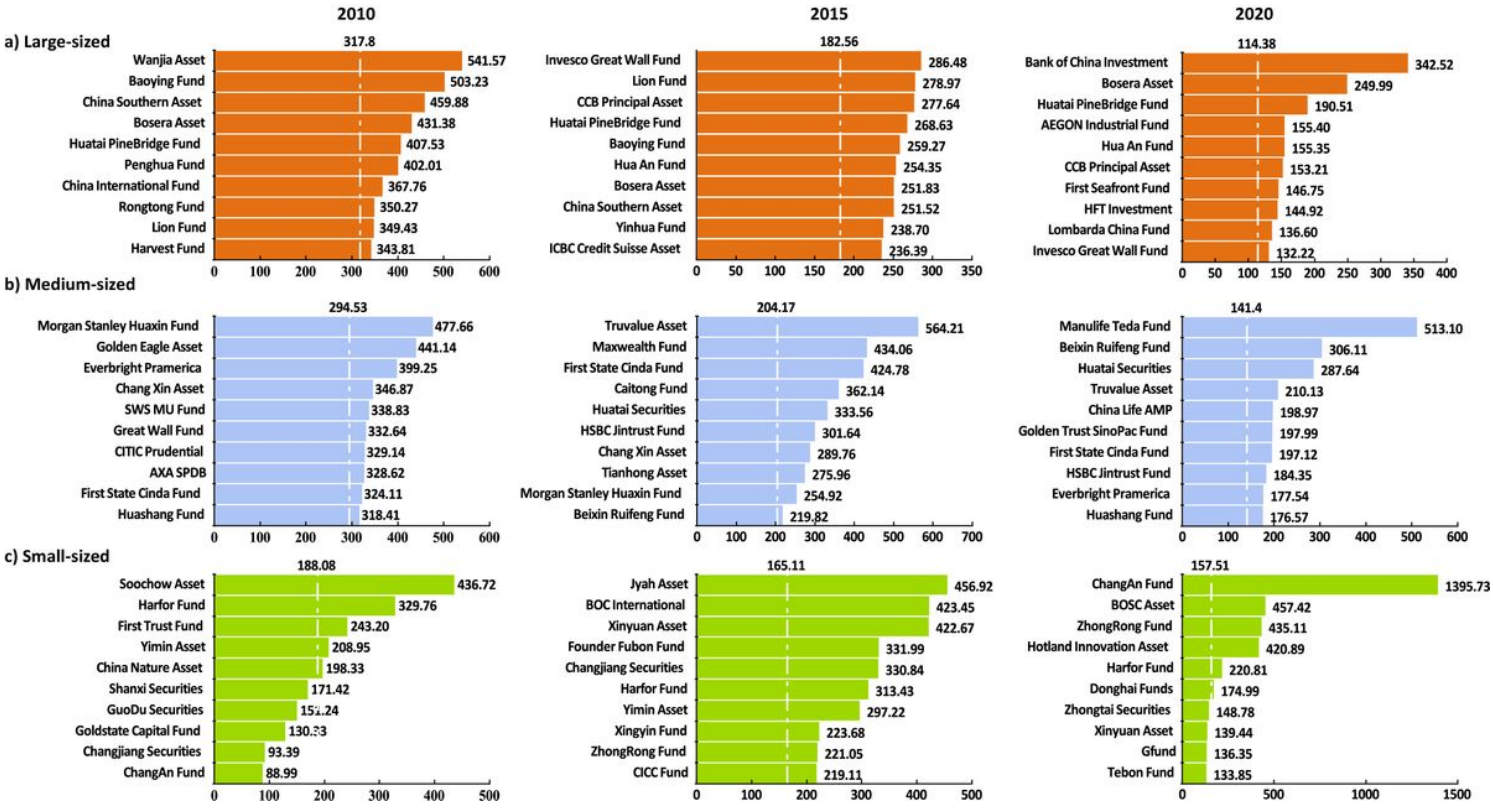

Figure 2

Weighted Average Carbon Intensity (WACI) of the top 10 in large-, medium- and small-sized fund firms' equity portfolios (units: tonnes CO_2/$).

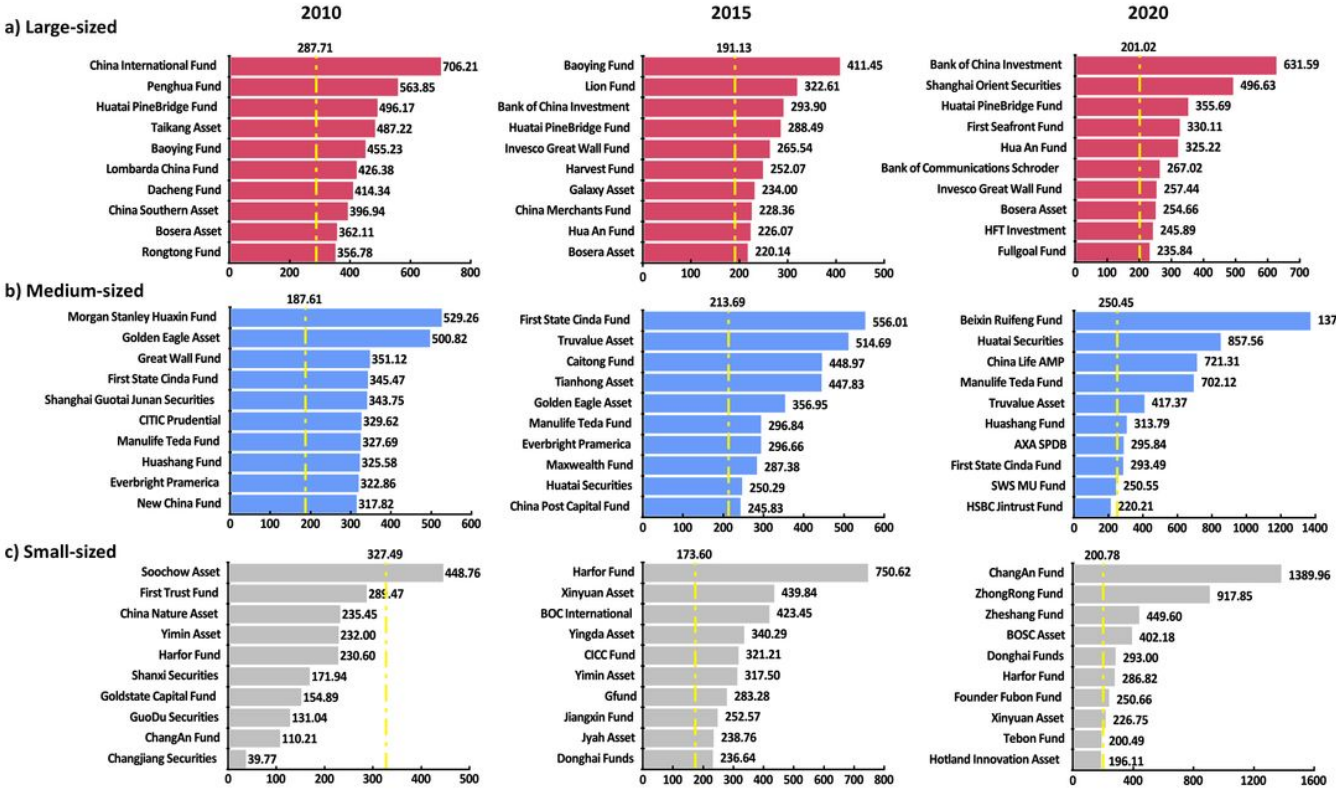

Figure 3

Carbon Emissions to Revenue Intensity (CTEV) of the top 10 in large-, medium- and small-sized fund firms' equity portfolios (units: tonnes CO_2/$).

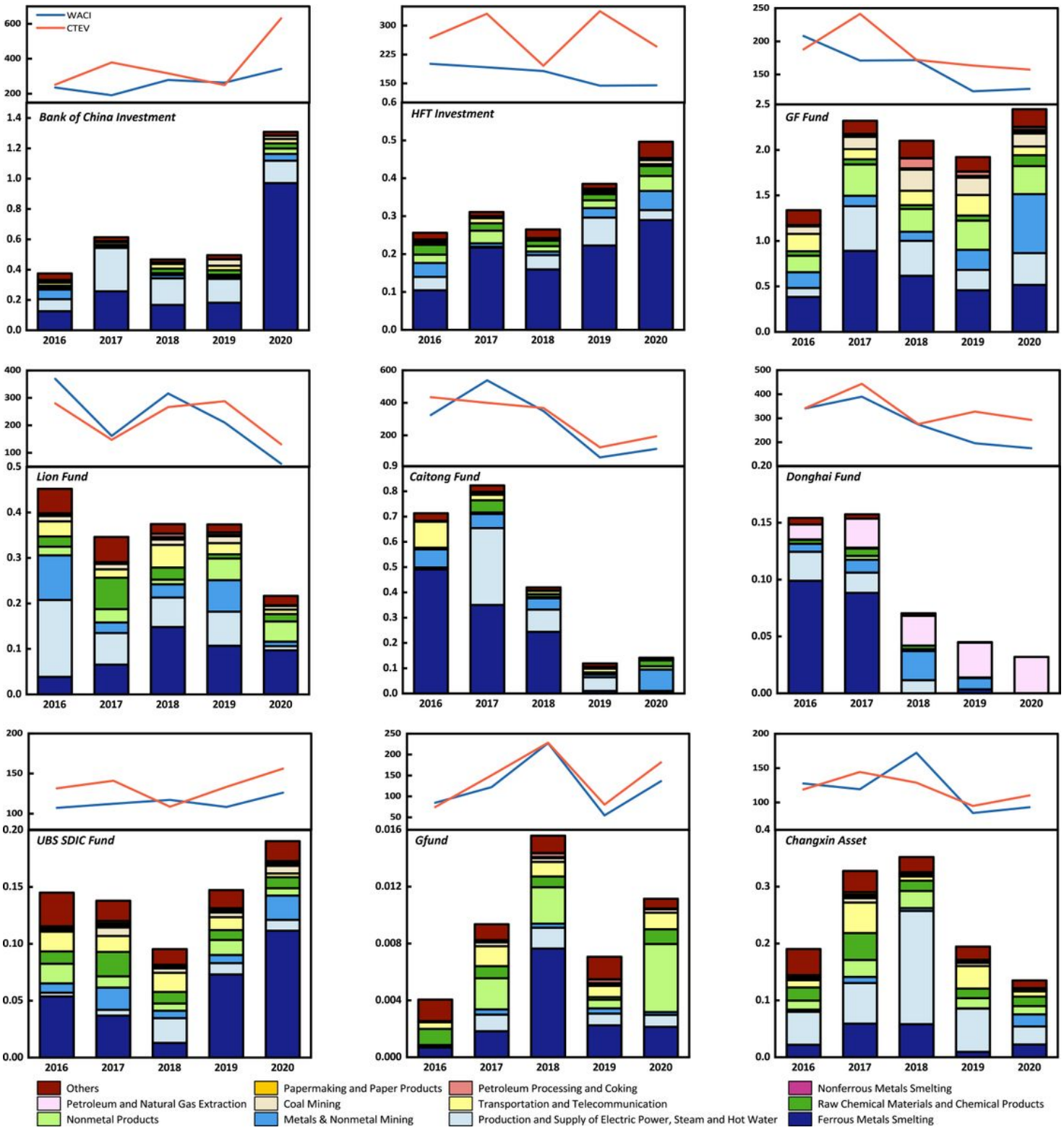

Figure 4

Trends of financed emissions and carbon intensities for three categories of fund firms studied (units: Mt CO_2).

Supplementary Files

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- SupplementaryMaterial.docx