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LETTER

Key drivers of the rebound trend of China’s CO₂ emissions

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Abstract

China’s CO₂ emissions declined by 5.1% in 2013–2016 as China steps into a new period of development, in which the economy shifts from the previous high-speed growth driven by input and investment to a medium-speed growth driven by innovation and consumption. However, the decline did not continue; the national CO₂ emissions rebounded since 2016, with the drivers of the rebound unclear. Here, we apply the input–output structure decomposition analysis to decompose emissions in 2002–2017 to reveal driving factors of the emission rebound trend. Results show that the input–output structure among sectors (partially reflecting production structure) and the demand pattern have contributed to emission reduction as China entering ‘the new normal’ pattern of development. However, the two factors reversed and therefore induced emissions, contributing to 5.2% and 0.1% of the increase in emissions since 2015. Such obvious contribution reversal can be explained as a new round of infrastructure stimulated substantial energy consumption and the electricity demand was mainly supported by coal-fired power (59.0%). Besides, the emission reduction effect of the energy mix has shrunk from −11.8% in 2012–2015 to −6.9% in 2015–2017, closely related to the slowing growth of renewable energy and the slight recovery of coal consumption. The findings can reasonably infer novel insights into curbing the potential reversal of China’s emission trend and aligning China’s CO₂ emission trend with the goal of achieving peak emissions before 2030.

1. Introduction

As an emerging economy, China has become the world’s leading CO₂ emitter and accounts for almost 30% of total global CO₂ emissions (Jackson et al 2017, Liu et al 2018, Cui et al 2019). To combat global climate change, China has committed to peak CO₂ emissions around 2030 and a series of policies have been proposed (China 2018, Pan et al 2018, Zhou et al 2019). The stabilization and decline of CO₂ emissions since 2013 have been generally regarded as an important sign that the 2030 emission peak target could be fulfilled. The decline is partially because China’s economy has stepped into the ‘new normal’ mode, a new phase where China’s economy shifts from the previous high-speed growth driven by input and investment to a medium-speed growth driven by innovation and consumption (Mi et al 2017a, Zheng et al 2020, Zheng et al 2019b). Given the long-term trend of low-carbon economy and industrial transitions, the structural decline of Chinese emissions is likely to continue (Guan et al 2018).

However, recent studies subsequently observe that China’s CO₂ emissions have recovered since 2015 or 2016 with the updated data (Jackson et al 2017, Liu et al 2018, Zheng et al 2018). Although the initial rebound year and growth rate are controversial due to the variances in emission accounting methods, the existence of emission rebound is a consensus (figure S1 (available online at stacks.iop.org/ERL/15/104049/mmedia)). For instance, Crippa et al (2019) shows that China’s
carbon emissions rebounded in 2015–2018, with an average annual growth rate of 1.34%. Shan et al (2018) and (2020) points out that the emission growth rate was about −1.9% yr$^{-1}$ in 2013 ~ 2016, however, it rebounded to 1.5% yr$^{-1}$ after 2016. Note that these datasets contain emissions from different scopes. While EDGAR calculates emissions from energy consumption and cement production, IEA only includes emissions from fossil fuel combustion (table S1 lists the detailed source and scope of these datasets). Although differences among datasets bring the uncertainty of assessing the degree of China's emission rebound, these estimates indicate that China's CO$_2$ was not yet peak in 2013.

The temporary dip rather than turning point ignited concerns about the weak decoupling between China's emissions and economic development (Le Quere et al 2018, Liu et al 2018, Zheng et al 2018). For example, Liu et al (2018) illustrated that the investment to mitigate the economic downturn stimulated CO$_2$ emission associated with growing coal and natural gas consumption. Given the ambitious emission peaking target, mitigation policies should further take the emission rebound trend into account and be aware of potential rebound drivers. As carbon emissions induced by energy consumption are closely intertwined with various socioeconomic factors, the underlying socioeconomic drivers associated with emission rebound will need to be carefully monitored.

Recent extensive studies have analyzed China's emission trends and identified driving factors from a socioeconomic perspective. Generally, there are two types of driving factors: production-based and consumption-based factors. Production-based factors, energy mix, carbon intensity, and production efficiency, contribute mainly to emission changes during the production process. Consumption-based factors are derived from the decomposition of the final demand, including demand pattern, the volume of per capita final demand, population, etc. It is widely acknowledged that the improvement of energy intensity and production efficiency generally contributes to emission mitigation, while economic growth and population drive the emission increment (Guan et al 2009, Minx et al 2011, Liu et al 2012, Li 2015, Mi et al 2017b). Previous studies also assessed the driving factors of China's emission decline trend. The key drivers recognized in their work is the increasing energy efficiency, the slowing economic growth, and the changing demand pattern. For example, Guan et al (2018) evaluated the drivers of the peak and decline of China's emission in 2007–2016 and demonstrated that the emission decline is primarily associated with changes in industrial structure and a reduction in the share of coal used for energy, which points to the potential decline trend of China's emissions. Zheng et al (2019b) decomposed the emission deceleration during the new normal (2012–2017) with the structure decomposition analysis (SDA) model and noted that gains in energy efficiency are the most significant cause while slowing GDP growth and changing demand patterns also make substantial contributions. Some papers explored drivers at the regional level. For example, Zheng et al (2019a) identified the significant mitigation effect of the regional structure in 2012–2016 with the LMDI model. They revealed that although industrial structure and energy mix resulted in emission reduction at the national level, these drivers led to emission growth in some regions. However, the impacts of these factors on the reversed CO$_2$ emissions trend remain unclear.

To fill this gap, this study aims to investigate key drivers of the emission rebound. It traces China's CO$_2$ emissions during 2002–2017 using the input–output structure decomposition analysis (IO-SDA) model and empirical data. Results show that the effect of input—output (IO) structure and demand pattern change from curbing carbon emission in 2012–2015 to driving the increase in 2015–2017, and the mitigation effect of the energy mix is shrinking. These findings provide new insight into optimizing the roadmap to align China's emission with the goal of achieving peak emissions before 2030.

2. Methodology and data

2.1. Structural decomposition of CO$_2$ emission changes

In this paper, we decompose China's CO$_2$ emission change to identify socioeconomic driving factors. Traditionally, the driving factors can be traced by index decomposition analysis (IDA) and SDA. While IDA is more flexible for choosing the driving factors and more suitable for studies with sufficient time-series data, SDA can reflect both direct and indirect sectoral linkage and the effects of driving factors with the IO model (Dietzenbacher and Los 1998). Here, the weighted average SDA decomposition method is used to analyze the emission change in 2002–2017 at the national level. It is worth noting that according to Shan et al (2018) and Shan et al (2020)'s work, CO$_2$ emissions have recovered since 2016, which cannot be captured by the SDA method directly due to the limitation of IO table availability. As an alternative, we investigate the drivers which have changed significantly before and after 2015 through SDA model, and provide additional empirical analysis to confirm their contribution to China's rebounding emission trend. Although this indirect way may underestimate the contribution of key drivers, it still enhances the understanding of the reasons for the emission rebound.

Before the weighted average SDA, we calculated the direct and indirect CO$_2$ emissions with the IO model:
Table 1. Definition of factors.

| Type               | Factor               | Symbol | Dimensions | Definition                                                                 | Calculation |
|--------------------|----------------------|--------|------------|----------------------------------------------------------------------------|-------------|
| Energy mix         | M                    | 1 × i  |            | CO₂ emitted per unit of energy consumption (tce) in each economic sector, reflecting the energy mix | \( M = \text{CO}_2/\text{En} \) |
| Production-based drivers | Energy intensity | C      | i × i      | Energy consumption per unit of economic output in each economic sector, reflecting the efficiency of energy consumption | \( c = \text{diag}(\text{En}/\text{VA}) \) |
|                    | Input–output structure | B      | i × i      | Leontief inverse matrix, which represents the industrial linkages as well as the production efficiency | \( B = \text{VA}/\text{X} \times (I - A)^{-1} \) |
|                    | Consumption pattern  | S      | i × j      | The proportion of each demand composition for each products in the final demand, reflecting the consumption pattern | \( S = F_{ij}/\sum_i \sum_j F_{ij} \) |
| Consumption-based drivers | Per capita final demand | G      | 1 × 1      | The final demand consumed by one person, reflecting the economic development | \( G = \sum_i \sum_j F_{ij}/P \) |
|                    | Population           | P      | 1 × 1      | The number of population in the certain period | \( P \) |
| Other              | Energy consumption   | En     | 1 × i      | The sectoral volume of energy consumption | \( \) |

\[
\text{CO}_2 = E \times B \times Y = E(I - A)^{-1}Y \tag{1}
\]

\( \text{CO}_2 \) refers to the \( \text{CO}_2 \) emissions caused by final demand \( Y \). \( E \) is \( \text{CO}_2 \) intensity. \((I - A)^{-1}\) is the Leontief inverse matrix, reflecting both direct and indirect consumption in the economic system. To clarify the production- and consumption-based effect, it is necessary to further decompose \( \text{CO}_2 \) intensity \( E \) and final demand \( Y \). Therefore, \( \text{CO}_2 \) emissions (equation 1) during period \( t \) can be further written as:

\[
\text{CO}_2 = M_t \times C_t \times B_t \times S_t \times G_t \times P_t \tag{2}
\]

\[
\Delta \text{CO}_2 = M_t C_t B_t S_t G_t P_t - M_{t-1} C_{t-1} B_{t-1} S_{t-1} G_{t-1} P_{t-1} = \Delta M \times C \times B + M \Delta C \times B + MC \Delta B \tag{3}
\]

\[
= \Delta \text{MCBSGP} + M \Delta \text{CBGP} + \text{MC} \Delta \text{BSGP} + \text{MCBS} \Delta \text{GP} + \text{MCBSGP} \Delta P \tag{4}
\]

\[
= C(\Delta M) + C(\Delta C) + C(\Delta B) + C(\Delta S) + C(\Delta G) + C(\Delta P) \tag{5}
\]

Definitions of the driving factors considered in equation 2 can be found in table 1, and equation 5 represents the contributions of these factors. Among various kinds of SDA, it has been proven that the weighted average SDA demonstrates robust performance in the decomposition of the interaction term (Li 2004).

Thus, we adopt the weighted average SDA proposed by Li (2004), with a weight of \( 6! = 720 \).

2.2. Data

We adopt China’s national \( \text{CO}_2 \) emission inventories of 2002–2017 from Shan et al (2018) and Shan et al (2020). This dataset is compiled based on detailed sectoral energy consumption and cement process data, which can present accurately China’s \( \text{CO}_2 \) emission trend. China IO tables of 2002, 2007, 2012, 2015 and 2017 are collected from the National Bureau of Statistics (NBS) of China (NBS 2018). To exclude the influence of price factors, this paper compiles the latest price index table based on the sectoral producer price index (table S2) and deflate the national IO tables in 2002–2017 to 2002 constant prices with the double deflation method (UNSD 1999). Further, we merge \( \text{CO}_2 \) emission inventories and IO tables to 42 sectors to simplify sector classification and extract more overall information (table S3). Then socioeconomic data were collected from NBS and converted into 2002 constant prices to accomplish the decomposition.

3. Results and discussion

3.1. Key drivers of \( \text{CO}_2 \) emission change identified in SDA analysis

To reveal the key factors of China’s \( \text{CO}_2 \) emission change, we trace the emissions in 2002–2017 at the national level (figure 2). The results show that the
changes in energy mix, energy intensity, IO structure, and demand pattern after 2015, underlie the recent trends of China’s emission rebound.

Energy intensity contributes positively to the emission reduction, even though in the period of emission rebound. During 2002–2012, energy intensity declined by 32.2% and offset 67.9% of the initial emission increment (figure 1). Its emission reduction effect reversed temporarily in 2012–2015, causing a 3.3% increase in emissions. Notably, the metal smelting sectors accounted for 97.5% of associated emissions. Since 2015, there has been a sharp drop in energy intensity (−18.8%), resulting in the reoccurrence of its role in mitigating emissions in 2015–2017 and contributing to an 18.1% decrease in emissions. 78.7% of the associated contributions are related to the efficiency gains in three heavy industrial sectors in energy efficiency: electricity (−705.6 MtCO₂), nonmetal mineral product (−505.0 MtCO₂), and metal smelting sectors (−344.3 MtCO₂).

The shrinking emission reduction effect of energy mix since 2015 partially explains the rebound in CO₂ emission trend. Due to China’s high reliance on coal consumption, energy mix pushed emissions up by 42.7% in 2002–2012 (figure 1). After 2012, the contribution of the energy mix stopped growing and shifted to reducing emissions by 11.8%, related to the rapid development of renewable energy and the declining proportion of coal consumption in China’s energy mix. Yet, the emission reduction effect showed a sharp drop after 2015, shrinking to 6.9%, which is roughly half of that in 2012–2015. In particular, the shifting energy mix in the electricity sector accounted for the shrinking emission mitigation effect, which contributes to 504.0 Mt CO₂ of emission reduction in 2012–2015 but only contributes to 252.7 MtCO₂ in 2015–2017.

The reversed contributions of the IO structure and the demand pattern are two main reasons for the emission rebound. As for the IO structure, it contributed to retarding 45.9% of emissions during
2002–2012 (figure 1(a)). In 2012–2015, the changing production structure induced 11.9% of the initial emission downtrend, becoming the most significant factor behind the observed emission decline (figure 1(b)). The decline is owing to the gains of production efficiency with technical advance as well as outsourcing of emission-intensive sectors (Meng et al 2018). However, after 2015, the IO structure yielded the reversed contributions, causing a 5.2% increase in emissions (figure 1(b)). Notably, 50.4% of associated emissions related to investment and were mainly concentrated in high-energy intensive sectors: non-metallic products sectors (+294.3 MtCO₂), electricity sector (+203.1 MtCO₂) and metal smelting sectors (+23.2 MtCO₂).

The contribution of the demand pattern was relatively minor before 2012. As China entering the ‘new normal,’ the changing demand pattern exerted the downward influences on emissions, accounting for 0.7% of the initial emission downtrend (figure 1(b)). However, demand patterns became another reversal factor and increased emissions by 0.1% after 2015. Despite its relatively minor effect in inducing emission, the reversal of its contribution is still visible.

3.2. The recovering contribution of energy intensity to emission reduction
As has been warned in previous researches (Mi et al 2017a), the benefit of energy intensity to emission reduction was gradually absent in 2002–2012. Using the latest data, our decomposition analysis shows that its contribution was even reversal in 2012–2015, mainly related to metal smelting and nonmetal manufacturing sectors. During this period, the overcapacity of these sectors deteriorated, resulting from the contradiction between lower demand under the economic downturn and the excessive investment supported by local governments. In 2015, the capacity utilization rate of steel and cement sectors dropped to 67.2% and 67.0%, respectively (figure 2), far below the average level (NBS 2018). The overcapacity resulted in excessive consumption of energy and induced CO₂ emission growth during this period.

Under the pressure of industrial restructuring, resolving the overcapacity problem of steel, coal, and cement sectors has become a primary task of China’s supply-side reform since 2015. The steel sector has cut 100 ~ 150 million tons of capacity, increasing the capacity utilization rate to 80%. Similarly, the cement sector also improved capacity utilization to about 70% (NBS 2018). This remarkable achievement in cutting overcapacity and industrial restructuring resulted in a sharp decline in energy intensity, contributing significantly to reducing emissions under the emission rebounding trend.

3.3. The reversed contributions of demand pattern
Final demand consists of consumption, investment, and export, the proportions of which reflect the GDP structure from the demand side. Consistent with previous research, demand pattern has exerted a downward influence on emissions in 2012–2015, which means that the economic structure under the ‘new normal’ enables economic development aligned with emission mitigation (Zheng et al 2019b). However, our analysis points out that the demand pattern has become a small but non-negligible reversal factor after 2015. As shown in table 2, the proportion of investment in the demand pattern decreased in 2015–2016, which means that the change of demand structure in 2015–2017 we observed indeed occurred after 2016 and is the key driver contributing to the emission rebounding trend. The reversal of contribution during this period can be attributed to the increasing investment (+0.2%), more than half (53.9%) of which were related to infrastructure investment, including environmental infrastructure (+33.0%), transportation infrastructure (+15.2%),

![Figure 2. The rate of capacity utilization of the steel and cement sector.](image-url)
energy infrastructure (+3.9%) and communication infrastructure (+1.8%) (figure 3). This means a new round of infrastructure investment was supported and financed by local governments in the endeavor to stimulate the economy (Hao and Baxter 2019). While the economic growth rate remains around 6.7%, the annual credit increment increased by 26.2% in 2015–2017 (NBS 2018) (figure 4), which implies that support for infrastructure investment from government stimulus packages. Since infrastructure investment generates a strong reliance on high-energy intensity sectors through intermediate input, such as raw coal, steel, cement, electricity and so on, the unit investment will bring more energy consumption and CO₂ emissions than other demand composition. According to our calculation, emissions per unit investment in China are 1.2 ~ 3.2 times for consumption and export. Therefore, the increasing infrastructure investment has led to the recovering dominance of investment in economic structure, resulting in the reversal contribution of demand structure to emissions under the emission rebound trend.

3.4. The reversed contributions of input–output structure

The IO structure can reflect the change of production structure. Before 2015, the continuously optimized IO structure played a significant role in reducing emissions, due to the upgrading of the manufacturing industry and the outsourcing of high-energy intensity manufacturing sectors in recent years (Meng et al 2018).

Yet, after 2015, the IO structure has become another reversal factor behind the emission rebound trend, mainly driven by investment (50.4%). One of the main reasons resulting in the reversed contribution is that another round of infrastructure investment has boosted the production of coal mining and dressing, metal smelting, and electricity sector. This is evidenced by the rising growth rate of production of coal, steel, and electricity, which reached 4.2%, 6.1% and 7.7% yr⁻¹ after 2016, respectively, corresponding to the sharp increase in financial support for infrastructure (figure 4). In particular, as the demand for electricity inclined rapidly, the contribution of the electricity sector accounted for 36.2% of associated emissions, mainly related to the increase in intermediate input of coal to the electricity sector (+4%). Thereby, the reversed contribution of IO structure can be attributed to the stimulation of infrastructure to the intermedium of high-energy intensity sectors.

3.5. Shrinking contribution of the energy mix

With the development of renewable energy, China’s energy mix has contributed to emission reduction since 2012. However, it is necessary to acknowledge its obvious declining contribution to emission reduction after 2015. As shown in figure 5, the growth rate of renewable energy decreased sharply from 22.3% to 15.6% in 2016–2018, while coal consumption recovered at an average annual rate of 0.8% after 2016. Thus, these two possible trends limited the emission reduction effect of energy mix and might contribute partially to emission rebound since 2016.

Renewable energy grew rapidly with early investment and subsidy, of which the installed capacity accounts for more than 35% in China’s energy mix since 2016 (NBS 2018). However, the lack of renewable energy consumption mechanism and supporting transmission infrastructure makes it difficult to improve its utilization and transmission across provinces. In 2016–2017, wind and solar curtailment reached about 12% and 7% (Shi and Zhao 2018). Moreover, natural gas has been highly valued since 2016 due to the ‘coal to gas’ policy, which keeps its annual growth rate at about 12%. This is in sharp contrast to the obvious slowdown of renewable energy growth and implies that natural gas may compete with renewable energy in development priority with the price advantage subsidized by the government (Shearer et al 2014, Feng et al 2015). These factors compressed the development space of renewable energy, leading to its declining growth and relatively low share in China’s energy mix (13 ~ 14%).

Meanwhile, coal consumption recovered at an average annual rate of 0.8% after 2016. This is because renewable power cannot fully meet the surging electricity demand stimulated by the new round of infrastructure investment with its relatively low share (as mentioned above). The gap between the two urged the recovery of coal-fired power (figure 6(a)), despite that the restrictions on coal-fired power has been implemented recently to clamp down on overcapacity. As is shown in figure 6(b), the proportion of coal-fired power has rebounded more significantly after 2016, accounting for more than 50% of newly generated electricity every year.

Thus, under the influence of these factors, the emission reduction effect of energy mix shrank significantly after 2016, thus partially contributing to the emission rebound after 2016.

Table 2. The proportion of components in the demand pattern (%).

| Year | Consumption | Investment | Net export |
|------|-------------|------------|------------|
| 2010 | 49.3        | 47.0       | 3.7        |
| 2011 | 50.6        | 47.0       | 2.4        |
| 2012 | 51.1        | 46.2       | 2.7        |
| 2013 | 51.4        | 46.1       | 2.5        |
| 2014 | 52.3        | 45.6       | 2.1        |
| 2015 | 53.7        | 43.0       | 3.3        |
| 2016 | 55.1        | 42.7       | 2.2        |
| 2017 | 55.1        | 43.2       | 1.7        |
| 2018 | 55.3        | 44.0       | 0.7        |
4. Policy implications

The role of infrastructure in the social benefit and emission target should be considered integrally. Although energy intensity plays an important role under overcapacity cutting policy, infrastructure investment still dominates China's recent emission rebound trend through demand pattern and IO structure. Given that infrastructure is a new driving force of social development, and there exists a large infrastructure gap in China (Hub 2018), the stable and even rising proportion of infrastructure investment in economic structure will be a long-term trend. This means that the combined consideration of emission reduction and infrastructure deployment is essential for China's low-carbon development and the effect of infrastructure on emissions should be valued integrally. As environmental infrastructure can contribute to pollution control and bring huge environmental benefits (Koppenjan and Enserink 2009), transportation infrastructure will yield climate as well as economic benefits with the deployment of electric vehicles and renewable energy (Eberle and von Helmolt 2010, Kennedy and Corfee-Morlot 2013, Zhang and Fujimori 2020). As for communication infrastructure, its role in greatly improving social productivity will provide a promising future for energy conservation and emission reduction (Despins et al 2011, Elkhorchani and Grayaa 2016, Bi et al 2019).

Collectively, although infrastructure investment has generated large short-term emissions and resulted in emission rebound, it will continually serve as the basis for...
of sustainable development and meet economic, climate as well as environmental targets in the long run.

China’s ‘new infrastructure’ strategy may promote ‘cleaner’ and more sustainable economic development pattern. Recently, China’s government has proposed the ‘new infrastructure’ strategy, arousing widespread concern in society (Huaxia 2020). New infrastructure mainly involves transportation and communication facilities, including the 5 G infrastructure, ultra-high voltage, the high-speed intercity railway and urban rail transit, the charging pile for new energy vehicles, the big data center, artificial intelligence and industrial Internet. In light of the role of these infrastructures mentioned above, it is reasonable to infer that the deployment of new infrastructure will align with the long-term roadmap for low-carbon development and emission reduction. However, there exist risks of rebound effects and induced energy demand, as the new infrastructure may trigger new products and applications leading to unintended emissions. The outcome of ‘new infrastructure’ investment in reducing emissions and promoting the economy should be tracked continually, so as to form effectively gain domestic experience of sustainable development and possibly extend to the rest of world.

Yet, under the pressure of 2030 emission peak target, carbon emissions during the construction phase should be paid more attention to. To curb the potential increment of emissions, radical decarbonization of energy system should be put as the first priority. This depends upon the early elimination of coal-fired power as well as the establishment of renewable energy consumption mechanism. Moreover, policies to cut overcapacity should continue to avoid the re-stimulation of infrastructure investment on capacity.
expansion. Finally, the decomposition of emission reduction targets can be taken into account, which means decomposing the target into sub-goals that can be added including technical level, production structure, demand pattern, etc. Assessing the emission reduction effect through several sub-goals will effectively achieve emission reduction targets.

Moreover, as driving factors may correlate with each other, emission reduction policies need to take the correlation into account. For instance, changes in demand pattern are probably correlated with economic development, since components in demand pattern (including consumption, investment and export) exert the significant influence on economic growth (Solow 1962, Podrecca and Carmeci 2001, Qin et al 2006). A panel data analysis (see more details in section 1 in supplementary Information) confirms this conjecture and finds that a 1% increase of per capita GDP is associated with 0.22% increase of GDP share of capital formation (reflecting demand pattern)(table S5). From the perspective of production side, changes in IO structure may also explain additional variance in energy intensity (Fisher-Vanden et al 2004, Feng et al 2009, Tianli et al 2011, Li and Lin 2014, Cheng et al 2018) Additionally, this can also be confirmed by China’s remarkable achievement in the decline of energy intensity due to industrial restructuring since 2016 (figure 2; table S4).

Additionally, there is a certain gap in regional rebound effects of CO$_2$ emission, due to the complex geographical location and economic development of China. Given emission mitigation actions are always taken by local governments, it is also necessary to further identify different emission trends and mitigation challenges from a regional perspective, which will put forward more suggestions of regional emission reduction for policymakers.

5. Conclusion

In order to explore the universally recognized reversals of China’s carbon emissions, this paper traces the changes of China’s CO$_2$ emissions in 2002–2017 using the IO-SDA method and empirical data to fully explore key drivers in emission rebound. Results show that due to cutting overcapacity policies since 2015, the contribution of energy intensity to emission reduction reappears (−17.0%). However, the emission reduction effect of the energy mix has shrunk by around half, closely related to the slowing growth of renewable energy and recovery of coal consumption. Besides, stimulated by a new round of infrastructure investment, the IO structure (partially reflecting the production structure) and demand pattern has reversed to induce emissions under the emission rebound trend, accounting for 5.2% and 0.1% of emission changes, respectively. Since ‘new infrastructure’ mainly focuses on communication and transportation infrastructure, China’s strong deployment of new infrastructure may still align with the long-term roadmap for low-carbon development and emission reduction in the long run. Meanwhile, large short-term emissions generated during the construction phase need more attention to ensure the achievement of the 2030 emission peak target. This requires radical decarbonization of the energy system, supported by the early elimination of coal-fired power and more development priority shifted to renewable energy.

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Declarations of interest

none

Data availability statement

The data that support the findings of this study are available upon reasonable request from the authors.

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