International trade with China increases global CO₂ emissions

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International trade has become the fastest growing driver of global carbon emissions. In particular, Chinese trade represents 34% of all emissions embodied in trade, and these traded emissions are growing each year. International trade with China poses a dilemma for climate and trade policy: To the extent China and other emerging markets have comparative advantages in manufacturing, such trade is economically efficient and desirable. However, if carbon intensive manufacturing in China entails drastically more CO₂ emissions than making the same product elsewhere, then trade unnecessarily increases global CO₂ emissions. Here we show that the emissions embodied in Chinese exports, which are larger than the annual emissions of Japan or Germany, are primarily the result of China’s coal-based energy mix and very high emissions intensity in a few provinces and industry sectors. Exports from these province-sectors therefore represent targeted opportunities to solve the climate-trade dilemma by improving production technologies and decarbonizing the underlying energy systems or else reducing trade volumes. [157 words].
Despite international efforts to reduce CO₂ emissions, global emissions have increased by an average of 3.1% per year since 2000. Economic growth has been identified as the main driver for the sharp increase of CO₂ emissions in the 2000s, and in particular the rapid industrialization of China, which has contributed roughly 60% of global increase in CO₂ emissions since 2000 and became the world’s largest carbon emitter in 2004. However, China is also the world’s largest net exporter of CO₂ emissions embodied in goods and services: In 2007, emissions in China were 7.3 Gt CO₂ (production-based emissions), of which 1.7 Gt (23%) were related to goods exported and ultimately consumed in other countries. In contrast, only 0.2 Gt CO₂ emissions were embodied in products imported to China from other countries. As of 2008, Chinese trade accounts for a third of all emissions embodied in global trade, and these traded emissions have been growing faster than global emissions. The magnitude and growth of emissions embodied in Chinese trade pose a dilemma for trade and climate policy: To the extent China and other emerging markets have comparative advantages in manufacturing, international trade is economically efficient and desirable. However, if carbon intensive manufacturing in China entails drastically more carbon emissions than making the same production elsewhere, then trade unnecessarily increases global carbon emissions. Yet, although previous studies have quantified emissions embodied in China’s trade, none have quantified the underlying factors, leaving open the question of how to mitigate such embodied emissions.

Here, we decompose the key factors contributing to the prodigious imbalance of emissions embodied in China’s international trade: (1) the large trade surplus between China and its trading partners, (2) the structure of the Chinese economy (i.e. specialization in energy-intensive production) and (3) the emissions intensity of Chinese production (i.e. the emissions produced per unit of economic output). Because China is a country with substantial regional differences in technology, energy mix and economic development, as well as large volumes of interprovincial trade, our analysis is also more resolved than any previous study, assessing the magnitude and intensity of emissions from 46 industry sectors (Supplementary Table 1) traded among 30 Chinese provinces/cities (Supplementary Figure S1) and 129 other countries/regions (Supplementary Table 2 and Table 3).

Details of our analytic approach are presented in Methods. In summary, we track emissions embodied in trade among 159 regions using a global multiregional input–output (MRIO) model of emissions and trade as of the year 2007 (Supplementary Table 4). The trade and emissions data supporting the model are a combination of the most up-to-date version of the Global Trade Analysis Project (GTAPv8) and province-level input-output tables of China that we
We analyze the driving factors of emissions embodied in international trade using an index decomposition approach (IDA). The results presented below and in the figures reflect only international trade and not trade between Chinese provinces. Our model links physical production of emissions with the consumption of final goods without regard for the location of intermediate consumption. For example, emissions related to components manufactured in Inner Mongolia that become part of a product assembled in Beijing and exported to another country are assigned to Inner Mongolia. If the same final product were exported to another Chinese province, the embodied emissions are consumed domestically and are therefore excluded from our analyses.

Magnitude and intensity of emissions embodied in Chinese exports

Figure 1 shows the top 10 regions (including both countries and Chinese provinces) whose exports (first row), imports (second row) and net trade (third row) embody the greatest CO$_2$ emissions (first column), including the greatest emissions per unit of economic output (second column) and per capita (third column). China is the largest net exporter of embodied emissions, by a large margin (Fig. 1g) with 8 times more emissions embodied in its exports than its imports (Figs. 1a and 1d). In contrast, this ratio of emissions embodied in exports to imports is much less in other major exporting nations (e.g., 0.5 in the U.S., 0.5 in Japan, 1.3 in India, 1.2 in Canada, 0.5 in Germany and 1.5 in Australia).

All of the 30 Chinese provinces assessed are net exporters of embodied emissions, meaning that in all cases the emissions embodied in exports exceed the emissions embodied in imports. Figure 1 also highlights the significance of particular Chinese provinces; 7 of the top 10 net exporting regions are Chinese provinces—larger than many large nations (Fig. 1g). Furthermore, the ratio of emissions embodied in exports to imports in these Chinese provinces is immense: 11 of China’s 30 provinces export more than 10 times as much emissions as they import, including Xinjiang, Shanxi, and Hebei, whose export-import ratios are the largest of any region in our model: 25, 19 and 16, respectively. Five provinces account for 46% of the 1,671 Mt CO$_2$ embodied in China’s exports in 2007: Shandong (178 Mt CO$_2$), Jiangsu (173 Mt CO$_2$), Guangdong (161 Mt CO$_2$), Hebei (139 Mt CO$_2$) and Zhejiang (111 Mt CO$_2$) (Fig. 1a).

China’s provinces are also the most carbon-intensive exporters in the world. The average emissions embodied per dollar of Chinese exports is 1,357 g CO$_2$/$, which is about 6 times the average emissions embodied per dollar of China’s international imports (230 g CO$_2$/$). This is reflected in the very high emissions embodied per dollar of exports from individual provinces, which comprise all of the top 10 regions in this category (Fig. 1b). The provinces with the
greatest emissions intensity of exports also tend to be less economically developed; provinces where GDP is less than $4,000 per capita show the largest difference in the emission intensity of exports and imports (Fig. 2). About 80% of China’s export-related emissions are produced by these poorer regions where the emissions intensity of exports is more than 5 times the emissions intensity of imports. For example, in Guizhou, where per capita GDP was $900 in 2007, the emissions intensity of international exports was almost 31 times the emissions intensity of imports (Fig. 2). Similarly high ratios exist in the also poor provinces of Inner Mongolia, Yunnan and Gansu. In the more affluent coastal provinces, ratios of emissions intensity of exports to imports are much smaller: ratios in Beijing, Zhejiang and Shanghai are 2.8, 3.0 and 4.1, respectively. But even these ratios are still much higher than those of other large trading nations such as U.S. (0.8), Germany (0.4), Japan (0.2), Canada (1.1), the UK (0.3), and India (1.7).

Although it is the most populous country in the world, since 2013 China’s per capita emissions have exceeded those in Europe when one ignores the fact that a large fraction of emissions are destined to exports\textsuperscript{16}. However, the per capita net export of embodied emissions from some Chinese provinces is also much larger than most developed countries, three Chinese provinces among the top 10 in this category (Fig. 1i), and 15 of China’s 30 provinces could listed as the world top 30 regions with higher net trade emission per-capita.

Figure 3 shows the destination of exports from the five provinces whose exports embody the greatest emissions (see also Fig. 1g). Just five provinces, Jiangsu, Shandong, Guangdong, Hebei and Zhejiang, represent 10.7%, 10.4%, 9.7%, 8.3% and 6.7% of all emissions embodied in China’s exports, respectively (Fig. 3). As previous studies have shown\textsuperscript{17,18}, developed countries are the primary importers of Chinese embodied emissions, foremost among them the U.S. (395 Mt CO\textsubscript{2}, 24% of China’s exported emissions and 44% of the U.S.’s imported emissions), the EU (422 Mt CO\textsubscript{2}, 25% and 42%) and Japan (149 Mt CO\textsubscript{2}, 9% and 48%). The international and domestic destination of China’s products are listed in Supplementary Figure 2 and Figure 3.

**Driving factors of China’s carbon intensive trade**

Several factors can contribute to the observed differences in the magnitude and intensity of emissions embodied in exports and imports. First, in recent years China has become a “factory for the world,” with high concentrations of heavy industry and manufacturing. For example, China produces 60%, 51% and 65% (by mass) of the world’s cement, steel and coke, respectively. Such large imbalances in the volume of traded products may correspond to similarly large imbalances
in the emissions embodied in traded products. Figure 4 compares the percentage of emissions related to consumed goods that are imported (y-axis) and the percentage of produced emissions that are embodied in exports for a number of industry sectors in China (Fig. 4a) and Europe (Fig. 4b). For example, 34% (26 Mt CO$_2$) of emissions produced by the European metal production industry are embodied in products exported from Europe in 2007, but emissions embodied in all metal products consumed in Europe were 140 Mt CO$_2$, 64% of which (90 Mt CO$_2$) were imported from outside Europe (Fig. 4a; red circle labeled “Metal”). In comparison, the share of emissions produced by China’s metal production sector that is exported is similar to Europe’s (33%; Fig. 4b), but the share of emissions related to Chinese consumption of metals that is imported is much lower: 11%.

Overall, Figure 4 highlights that, across many industry sectors, the share of European consumption that is imported is consistently greater that the share of produced emissions that are exported, and the opposite is true for China. These trade imbalances are evident for both primary and secondary industries (yellow, red and purple circles).

A second factor influencing emissions embodied in trade is economic structure. Figure 5 shows the industry categories that make up Chinese imports, exports and domestic consumption. Emissions embodied in heavy, energy-intensive products such as metal and non-metal products and equipment make up much larger shares of China’s exports (37% and 22%, respectively) than its imports (19% and 16%, respectively; light green and dark blue bars in Fig. 5). Meanwhile, mining products is the category with the greatest proportion of emissions embodied in Chinese imports (23%). The dominance of these industries in Chinese trade implies that China is not just the world’s workshop, but is engaged in the most emission-intensive stages of manufacturing: the smelting and processing of raw materials. This pattern is visible at the province level, as well; in Shandong, where emissions embodied in trade are largest, 8 Mt CO$_2$ are embodied in imports of mining products from other countries (42% of all emissions embodied in imports) and 60 Mt CO$_2$ are embodied in exported metal and non-metal products (34% of emissions embodied in the province’s exports).

The third major factor affecting emissions embodied in trade is emissions intensity, or CO$_2$ emissions per dollar of output in each particular industry. Such emissions intensity reflects both energy intensity (energy consumed per dollar of output) and carbon intensity of energy (CO$_2$ per unit of energy consumed). The combination of a carbon-intensive coal power supplying industry and of a relatively low value-added of industry thus translate into the consistently high emissions intensity of production and exports of China and its provinces (Figs. 1b, 1h, and 2). In 2007, 75%
of China’s primary energy was supplied by coal, the highest level among major energy-
consuming nations. As a result, the carbon intensity of energy consumption in China is extremely
high: Chinese exports entail 61 tCO$_2$/PJ on average, which is almost triple the carbon intensity of
imports to China, 24 tCO$_2$/PJ. The energy intensity of China’s exports is similarly high; in 2007,
China consumed 22 MJ per dollar of output, on average, or more than twice the energy intensity
of products imported to China (9 MJ/$). This high energy intensity implies low value-added and
less advanced technology of China’s production, as previously suggested by other
studies.$^{17,19}$ The sectoral emission intensity of China’s imports and exports are listed in
Supplementary Figure 4).

Supplementary Figure 5 shows the industry sectors with the greatest emissions intensity in each
of the six Chinese provinces with the greatest emissions intensity of exports (see also Fig. 1b).
Although there is some variation among the emissions intensity of sectors in these six provinces,
the manufacture of heavy industrial materials for export (e.g., mining products, chemical
products, metal/non-metal products, and energy) is many times higher than the emissions
intensity of similar products that are imported and consumed in China (Fig. 2; Supplementary
Figure 4).

Figure 6 shows the contribution of the different factors to the net emissions embodied in trade
of each Chinese province. Four factors are decomposed: (1) differences in the total economic
value of exports and imports (trade volume, black bars), where greater trade volumes correspond
to greater embodied emissions; (2) differences in sectors responsible for exports and imports
(economic structure, orange bars), where greater shares of heavy industry and manufacturing, for
example, correspond to greater embodied emissions; (3) differences in the carbon-intensity of
energy used to produce exports and imports, where a greater share of low-carbon energy sources
such as renewables and nuclear correspond to less embodied emissions; and (4) differences in the
sectoral energy intensity of exports and imports, where greater shares of low-energy, high value-
added products correspond to less embodied emissions (shown combined with (3) as emissions
intensity, purple bars).

On average, the high energy intensity of sectors and the coal-dominated energy mix accounted
for 43.3% and 43.0% of the net emissions embodied in exports, respectively (Fig. 5). In
comparison, the structural preference for manufacturing and heavy industry accounted for only
8% of the net emissions embodied in exports, and less than 6% of the net exports are related to
the larger volume of exports than imports. Emissions intensity, including both differences in
energy intensity and carbon intensity of sectoral energy use, is by far the most important factor
underlying the large net exports of embodied emissions, explaining 86% of the emissions embodied in exports, or 1,438 Mt CO$_2$ of emissions.

**Discussion**

We show that the very large quantities of emissions embodied exported from China on net are due primarily to Chinese reliance on coal energy and the very high energy intensity of the exporting industries, which are in turn geographically concentrated in a small number of less-developed provinces.

Our analysis is based on aggregated sectors (e.g., “electronic equipment and machinery”) rather than the specific products (e.g., iPhones), such that we may underestimate the effect of economic structure on net trade of emissions if differences in production are too specialized to be reflected by the 46 sectors in our model (Supplementary Table 1). The comprehensive data necessary to support product-level analysis are not yet available. However, we also used up-to-date and independent life cycle analysis datasets (PRé SimaPro LCA 7.3 dataset$^{20}$ for Europe and RCEES 2012 database$^{21}$ for China) to investigate the carbon emission per unit product of the production process for a sample of 15 industrial products made in Europe and China. Doing so revealed that the emissions per unit mass of each product (kg CO$_2$/kg) for Chinese products was on average 4.4 times higher than the same products made in Europe, ranging from 1.4 times as high for copper production to 18.4 times as high for propylene production (Supplementary Table 5).

Product-level data are therefore entirely consistent with our more aggregate sector-level analysis showing that production in China is several times as carbon intensive as the same production in other countries, therefore supporting our conclusion that the emissions intensity of Chinese production is the main factor driving the country’s large net exports of embodied emissions. This suggests that, although international trade with China may be economically optimal given comparative advantages in labor costs, such trade is on average causing an increase in global CO$_2$ emissions relative to production that instead occurs in the countries which now import from China.

However, because Chinese emissions intensity is highest in a small number of provinces and sectors, targeted changes in energy and improvements in technology used by these sectors and provinces could drastically reduce the emissions embodied in Chinese exports and thereby global emissions. For example, if the emissions intensity of China’s international exports were equal to the intensity of its imports, total emissions embodied in exports as of 2007 would be reduced by 86%, from 1,671 Mt CO$_2$ to 233 Mt CO$_2$. In this hypothetical, the avoided emissions are roughly equivalent to the total CO$_2$ emissions of Japan. Even without improving the energy intensity of
its economy, decarbonizing China’s energy supply to the global average of emissions per $GDP would reduce the emissions embodied in Chinese exports by 43% (619 MtCO₂). Similarly, Chinese targets to increase the share of energy produced from renewable sources to 20% of the total by 2020 could reduce exported emissions by 5%.

National economic policy underlies China’s carbon-intensive exports. China has for many years prioritized economic growth over environmental management, maintaining 10% economic growth over the past decade, even as the world experienced a global economic crisis that slowed consumption in the major developed countries that consume most of China’s exports. The Chinese government has sustained such a high level of economic growth in part by large capital investments in energy-intensive infrastructure and by favoring industry sectors with high emissions intensity, which has caused China’s national carbon intensity to increase by 3% during 2002-2009.22

There is a now large opportunity to improve the emissions intensity of the Chinese economy by focusing on a small number of provinces and sectors where more energy-efficiency technologies can be installed and meanwhile shifting the Chinese energy systems away from coal towards lower-carbon energy sources. Such improvements can be supported by both domestic and international efforts to transfer best-available technologies into critical and still underdeveloped Chinese provinces. Until the vast difference between the emissions intensity of Chinese exports and domestic production in developed countries is reduced, international trade with China conflicts with efforts to reduce global CO₂ emissions.
Methods

Production-based accounting of emissions. Emissions resulting from combustion of fossil fuels or cement production within a territory, or production-based emissions, are the primary basis for national emission inventories. For example, the methodology prescribed in IPCC guidelines for greenhouse gas (GHG) emission inventories calculates production-based emissions based on activity data in the region (i.e. the amount of energy consumption) and the associated emission factors (i.e. GHG emissions per unit energy consumption).

\[
\text{Emission} = \sum \sum \sum (\text{Activity data}_{i,j,k} \times \text{Emission factor}_{i,j,k}) \tag{1}
\]

Notes: i: fuel types, j: sectors, k: technology type.

Emission factors can be further disaggregated into net heating value of certain fuel "V", carbon content "F" and oxidization rate "O".

Consumption-based accounting of emissions. An alternative to production-based accounting of CO₂ emissions is to compile inventories according to where related goods and services are ultimately consumed. Such a consumption-based method accounts for inter-regional exchange of energy supply, goods and materials by adding emissions embodied in imports to the production-based total and subtracting emissions embodied in exports.

The emissions embodied in a region’s imports and exports can be calculated using environmentally-extended input-output analysis (EIO). Environmentally-extended multi-regional input-output (MRIO) analysis has been widely developed for calculating the embodied carbon emission, virtual water, material use, biodiversity loss, and land use associated with international trade.

In MRIO framework, different regions are connected through inter-regional trade, \(Z\). The technical coefficient sub-matrix \(A\) consists of \([a_{ij}^r]\) is derived from \(a_{ij}^r = z_{ij}^r / x_j \), where \(z_{ij}^r\) is the inter-sector monetary flow from sector \(i\) in region \(r\) to sector \(j\) in region \(s\), \(x_j^r\) is the total output of sector \(j\) in region \(s\).

The final demand matrix is \(Y\) consist of \([y_{ij}^r]\), where \(y_{ij}^r\) is the region’s final demand for goods of sector \(i\) from region \(r\). Therefore, MRIO analysis can be shown as:

\[
\begin{bmatrix}
    x^1 \\
    x^2 \\
    \vdots \\
    x^n
\end{bmatrix} =
\begin{bmatrix}
    A_{11} & A_{12} & \cdots & A_{1n} \\
    A_{21} & A_{22} & \cdots & A_{2n} \\
    \vdots & \vdots & \ddots & \vdots \\
    A_{n1} & A_{n2} & \cdots & A_{nn}
\end{bmatrix}
\begin{bmatrix}
    x^1 \\
    x^2 \\
    \vdots \\
    x^n
\end{bmatrix} +
\begin{bmatrix}
    \sum x_{1r} \\
    \sum x_{2r} \\
    \vdots \\
    \sum x_{nr}
\end{bmatrix}
\tag{3}
\]

Using familiar matrix notation and dropping the subscripts, Equation 3 can be written as: \(x = Ax + y\) or \(x = (I - A)^{-1}y\), where \((I - A)^{-1}\) is the Leontief inverse matrix that captures both direct and indirect inputs.
required to satisfy one unit of final demand in monetary value; \( I \) is the identity matrix. To calculate the consumption-based CO\(_2\) emissions, we then extend the MRIO table with sector-specific CO\(_2\) emissions: 
\[
E = k(I - A)^{-1}y
\]
where \( E \) is the total CO\(_2\) emissions embodied in goods and services used for final demand and \( k \) is a vector of CO\(_2\) emissions per unit of economic output for all economic sectors in all regions.

**Index decomposition analysis of emissions embodied in trade.** The index decomposition of trade embodied CO\(_2\) emissions is presented by equation: 
\[
E = \sum_i E_i = \sum_i Q \frac{q_i v_i}{q_i v_i} = \sum_i Qs_i I_i F_i
\]
(4)
where \( E \) describes CO\(_2\) emissions embodied in imports or exports, \( Q \) is the economic value of imports or exports, \( S_i \) refers to the share of the economic value for sector \( i \), \( I_i \) to energy intensity of sector \( i \) and \( F_i \) refers to the emission per unit of energy consumption of sector \( i \) (\( i \) for 46 sectors). Thus, the factors contributing to a net trade in embodied emissions can be expressed based on the logarithmic mean divisia index (LMDI) approach (additive form) (25) as:

\[
\Delta E = E^{export} - E^{import} = \Delta E_{act} + \Delta E_{str} + \Delta E_{int} + \Delta E_{mix} \tag{5}
\]

Where \( \Delta E \) is the difference between the CO\(_2\) emissions embodied in exports (\( E^{export} \)) and the CO\(_2\) emissions embodied in imports (\( E^{import} \)); \( \Delta E_{act}, \Delta E_{str}, \Delta E_{int} \) and \( \Delta E_{mix} \) refer to economic scale effect, economic structure effect, sector intensity effect and energy mix effect, respectively. Where \( \Delta E_{act}, \Delta E_{str}, \Delta E_{int} \) and \( \Delta E_{mix} \) are expressed as:

\[
\Delta E_{act} = \sum_i w_i \ln \left( \frac{Q_i^e}{Q_i^0} \right) \tag{6}
\]
\[
\Delta E_{str} = \sum_i w_i \ln \left( \frac{S_i}{S_i^0} \right) \tag{7}
\]
\[
\Delta E_{int} = \sum_i w_i \ln \left( \frac{I_i}{I_i^0} \right) \tag{8}
\]
\[
\Delta E_{mix} = \sum_i w_i \ln \left( \frac{F_i}{F_i^0} \right) \tag{9}
\]
\[
w_i = \frac{E_i^e - E_i^0}{\ln E_i^e - \ln E_i^0} \tag{10}
\]

\( Q^e, S^e, I^e \) and \( F^e \) is the GDP, GDP share, energy intensity and the emission coefficient of export, respectively. \( Q^0, S^0, I^0 \) and \( F^0 \) is GDP, GDP share, energy intensity and the emission coefficient of imports, respectively.
Emissions and trade data. In this study we estimate emissions from fossil fuel energy combustion and cement production, which together account for about 90% of GHG emissions produced in China. Our calculations include 20 different types of fuel and 44 energy consumption sectors. Further details of data sources and processing methods are available in Liu et al. (2012)\textsuperscript{13} and Guan et al. (2012)\textsuperscript{31}.

Our multi-regional input-output (MRIO) relies on data from the Global Trade Analysis Project (GTAP)\textsuperscript{32}, which includes 129 regions (mostly countries, but some aggregated regions). Although GTAP data covers 57 industry sectors, we aggregate to 30 sectors in order to match input-output tables of interprovincial trade compiled by Liu et al. at the Chinese Academy of Sciences\textsuperscript{33}. In turn, we use Liu et al.’s tables to disaggregate the Chinese region in GTAP into 30 sub-regions (26 provinces and 4 cities). Thus, we have a global MRIO comprised of the latest available economic data that allows us to assess consumption-based CO₂ emissions in each Chinese sub-region as well as emissions embodied in trade among these sub-regions and all 129 other GTAP regions around the world. Technical details of how the Chinese IO tables are nested with the GTAP MRIO are available in Feng et al. (2013)\textsuperscript{8}. 

[799 of 800 words]
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Figure 1 | Emissions embodied in trade. Top ten regions (including both countries and Chinese cities/provinces) by emissions embodied in exports (a–c), imports (d–f) and net trade (g–i), shown in absolute numbers (a, d, g), per dollar of output (b, e, h) and per capita (c, f, i). Data is in year 2007.
Figure 2 | Emissions intensity of trade and GDP per capita of Chinese provinces in 2007. Kilograms of CO\(_2\) per dollar of output in each of 30 Chinese cities/provinces for international export (red bars) and domestic consumption in China (gray bars), as well as the emissions intensity of goods imported to the city/province from outside China (green bars). The blue curve shows GDP per capita in each city/province according to the top axis.
Figure 3 | Top exporting provinces. The emissions embodied in goods exported from China to the US, EU and Japan represented 58% of all emissions embodied in trade in 2007 (a). Five Chinese provinces account for 46% of these exports (b).
Figure 4 | Differences in share of embodied emissions traded by industry categories. Circles indicate the share of consumed emissions that are imported (y-axis) and the share of produced emissions that are exported (x-axis) for a range of industry categories in Europe (a) and China (b). The size of each circle denotes the sector’s total production emissions, providing an indicator of the relative importance of different sectors. The colours of the circles indicate whether the industries are primary (yellow), secondary and energy-intensive (red), secondary and non-energy intensive (purple) or tertiary (green). It should be noted that while the marker area scale is common across both charts (to aid comparison); the x- and y-axis scales differ. A line representing equal import and export share is shown in each chart. Data is in year 2007.
Figure 5 | Sectoral share of China’s embodied emissions.
Figure 6 | Factors contributing to emissions embodied in provincial trade. Decomposition of factors underlying emissions embodied in trade for each of 30 Chinese cities/provinces. Net emissions embodied in trade (red circles) are equal to emissions embodied in exports minus emissions embodied in imports. Black bars show the effect of unbalanced trade volume; orange bars show the effect of differences in the industry sectors involved in trade (i.e. trade structure, for example, the proportion of heavy industries); and purple bars show the effect of differences in the emissions intensity of imported and exported goods. Green circles show what net emissions embodied in trade would be if there was no difference in the emissions intensity of imported and exported goods—i.e. if trade volume and economic structure were the only factors affecting embodied emissions. In reality, all 30 regions are net exporters of emissions, but only 11 of the 30 would remain net exporters of emissions if differences in emissions intensity were eliminated.