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CO_2 emissions in French international trade

The article presents an assessment of French CO_2 emissions linked to the production and distribution of imported and exported goods and services. It shows that France consumes more CO_2 than it produces, resulting in a balance of trade deficit of 122 million tonnes. This situation is due in particular to (i) a trade balance deficit in monetary value terms, (ii) CO_2-efficient production due to France's energy mix, and (iii) the sectoral structure of trade flows (with exports measured in value added mainly originating from services, which are low-polluting) and integration in global value chains. Thus, almost half of the CO_2 embodied in French exports is emitted abroad, mainly in China and Germany.

Note: Focusing on the case of France, this article illustrates the method developed in a previous article, "CO_2 emissions embodied in international trade", *Banque de France Bulletin* 228/1, March-April 2020.

Rafael Cezar and Tancrède Polge
Balance of Payments Directorate
Syntheses Division

JEL codes
F15, F18,
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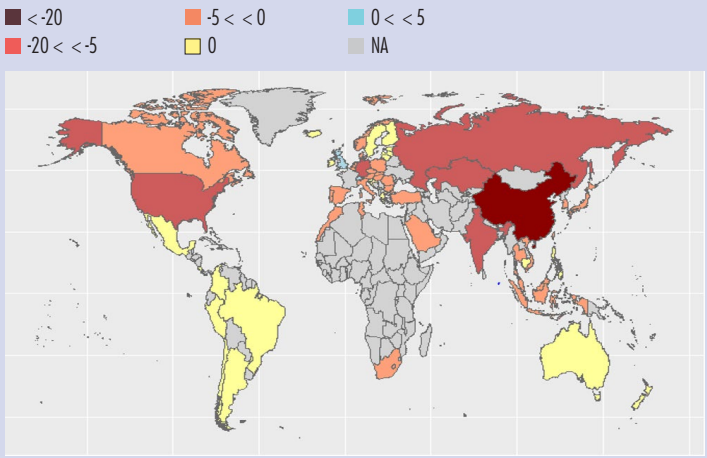
122 million tonnes of CO_2
2015 French trade deficit in terms of CO_2 emissions

–13%
decrease in the deficit measured in CO_2 emissions between 2005 and 2015, resulting from a reduction in imports exceeding that of exports

46%
proportion of foreign CO_2 emissions embodied in French exports due to the fragmentation of production across global value chains

French bilateral CO_2 trade balances in 2015
(millions of tonnes)



Source: OECD inter-country input/output (ICIO) database, 2018 edition, and trade in embodied CO_2 ($TECO_2$) database; authors' calculations.
Note: CO_2 emissions resulting from the burning of fossil fuels, excluding LULUCF (land use, land-use change and forestry), non-energy-related industrial processes and the other main greenhouse gases.

The article analyses the impact of international trade on French CO_2 emissions. It aims to measure all the CO_2 emitted along the entire chain of production and distribution of French exports and imports. It thus complements the article "CO_2 emissions embodied in international trade" (Cezar and Polge, 2020) with a country-specific focus.

The fight against global warming is based on carbon dioxide (CO_2) emissions as the main measurement tool. International agreements thus attempt to coordinate a collective effort to reduce these greenhouse gas emissions (United Nations, 2015). The objectives set out in such agreements target emissions within national borders (United Nations, 1992). However, this measurement does not take into account international trade and thus remains an incomplete indicator of countries' respective impact on global CO_2 emissions.

An alternative approach consists in attributing these emissions to the country in which they are consumed rather than produced. This method makes it possible to establish a country's "carbon footprint", i.e. the quantity of CO_2 emitted to produce the goods and services consumed in the country (Davis and Caldeira, 2010). International trade serves as a link between these two measurements. Indeed, part of a country's consumption may be imported, leading to "offshoring" of the associated emissions to their country of origin (Peters et al., 2011). Conversely, another proportion of the country's emissions may not be consumed locally, but rather exported.

France has a CO_2 trade deficit of 122 million tonnes. This means that the country consumes more CO_2 than it produces, its footprint exceeding national emissions by the amount of this deficit. France's carbon footprint was 445 million tonnes of CO_2 in 2015 (OECD, trade in embodied CO_2 [$TECO_2$] database). This corresponds to the emissions produced within its borders (323 million tonnes), plus imports (236 million tonnes of CO_2 emitted abroad), minus exports (115 million tonnes of CO_2 emitted on French territory but subsequently consumed abroad).

BOX 1

Details of the data used

The data used in this article cover all emissions stemming from the burning of fossil fuels in the production and distribution of traded goods and services. These data account for nearly all global CO_2 emissions and around two-thirds of global greenhouse gas emissions (in CO_2 equivalent). They do not include emissions from industrial processes other than energy production (e.g. manufacture of cement) and LULUCF (land use, land-use change and forestry), or emissions of other greenhouse gases such as methane (CH_4), nitrous oxide (N_2O), and fluorinated gases (HFC, PFC and SF_6).[1] Details regarding the data can be found in the methodology appendix.

Data are constructed from three sources published by the OECD: $TECO_2$, TiVA and ICIO (Wiebe and Yamano, 2016).[2] Our database breaks down the CO_2 emissions of each country-sector pair, making it possible to develop detailed insight into the main actors, as well as interactions among them.

1 Divergences between different sources with regard to CO_2 or CO_2 equivalent emissions are due to the inclusion or exclusion of some of these emissions (see for example INSEE, 2018).
2 $TECO_2$: trade in embodied CO_2; TiVA: trade in value added; ICIO: intercountry input-output.

This situation is due in particular to the trade balance in monetary terms, which is in deficit overall. In addition, France has a lower CO_2 emission intensity[1] compared to its partners, owing to the prevalence of CO_2-efficient nuclear power in the French energy mix (IPCC, 2018). Moreover, the trade structure also plays a role: value added from the service sector, which emits very little, accounts for nearly two-thirds of French exports (Cezar, 2016).

France thus maintains a "carbon" deficit with almost all of the countries in the sample studied here. China, Germany and the United States are the countries that contribute the most to foreign CO_2 emissions consumed

1 CO_2 emissions per unit of value added produced.

in France, accounting for 40, 24 and 15 million tonnes respectively. Conversely, Germany and the United States import the largest share of CO_2 emissions from French exports, amounting to 14 and 10 million tonnes respectively.

This assessment takes into account the internationalisation of the French economy resulting in the fragmentation of production, and thus of CO_2 emissions, along global value chains (Malliet et al., 2020).[2] Thus, almost half of the CO_2 embodied in French exports stems from emissions released abroad. The transport equipment sector serves as an illustration of this global integration. Exports associated with this industry include relatively few emissions originating from French territory, which predominantly accommodates low-emission activities, particularly services. The largest share of emissions is based on the use of foreign inputs and therefore involves third countries responsible for the emissions.

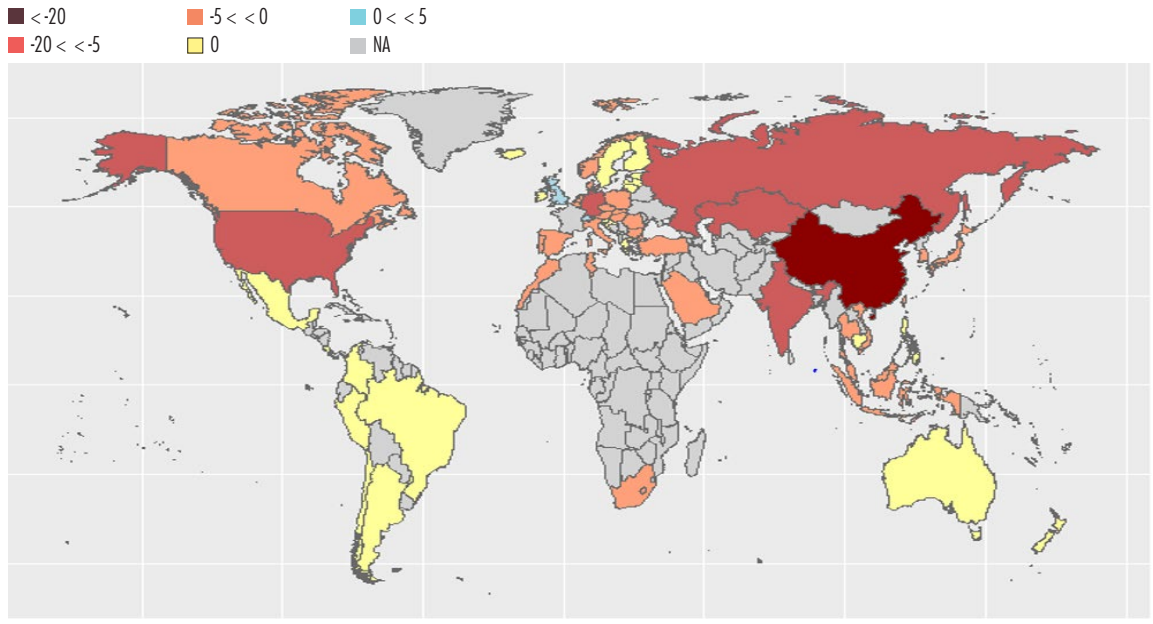
1 France consumes more CO_2 than it emits

France stands out as a major net CO_2 consumer centre. The country consumes more CO_2 than it produces, its deficit reaching 122 million tons in 2015. This balance corresponds to the emissions resulting from the production and distribution of French trade flows with the rest of the world. France's carbon footprint thus exceeds its national emissions by the amount of this deficit (Peters et al., 2011).

Nevertheless, this balance has been clearly decreasing since 2005. It peaked at 158 million tons in 2008. The decline stems from a more pronounced decrease in imports than in exports (see Chart 2 below). Despite this rather favourable trend, in 2015 France continued to maintain a deficit with almost all the countries in the sample.

C1 French bilateral CO_2 trade balances in 2015

(millions of tonnes)



Source: OECD inter-country input/output (ICIO) database, 2018 edition, and trade in embodied CO_2 ($TECO_2$) database; authors' calculations.
Note: CO_2 emissions resulting from the burning of fossil fuels, excluding LULUCF (land use, land-use change and forestry), non-energy-related industrial processes and the other main greenhouse gases.

2 According to Shapiro (2016), the benefits of this international structure of production exceed the costs, in particular those accounted for through impact in terms of CO_2 emissions.

France's position can be explained in particular by its trade deficit in monetary value terms vis-à-vis a considerable number of its partners. Moreover, the CO_2 intensity of French exports (i.e. emissions per unit of value added traded) is relatively lower than that of its imports. More specifically, the ratio between the CO_2 intensity of its exports and that of its imports is 51%, the lowest among the countries studied, with the exception of the United Kingdom (50%). Bilateral deficits measured in CO_2 emissions are thus more pronounced than those measured in monetary value (Cezar and Polge, 2020).

These low emissions are largely due to the energy sources used in France, principally nuclear power, which generates a very low level of emissions (IPCC, 2018). Yet, the energy sector is the sector with the highest emissions worldwide, responsible for 32% of global emissions embodied in international trade, while it accounts for 10% in French trade (see Section 4 below). In addition, the sectoral structure of trade flows also plays a role. The weight of the tertiary sector, which emits very little, is preponderant in the French economy: value added from services accounts for nearly two-thirds of total value added exported by the country (Cezar, 2016).

France's largest deficit in terms of CO_2 emissions is vis-à-vis China, which accounts for a quarter of the total balance. French imports from this country (40 million) exceed exports (8 million) by 32 million tonnes. This deficit nevertheless declined over the period, after peaking at close to 42 million in 2011.

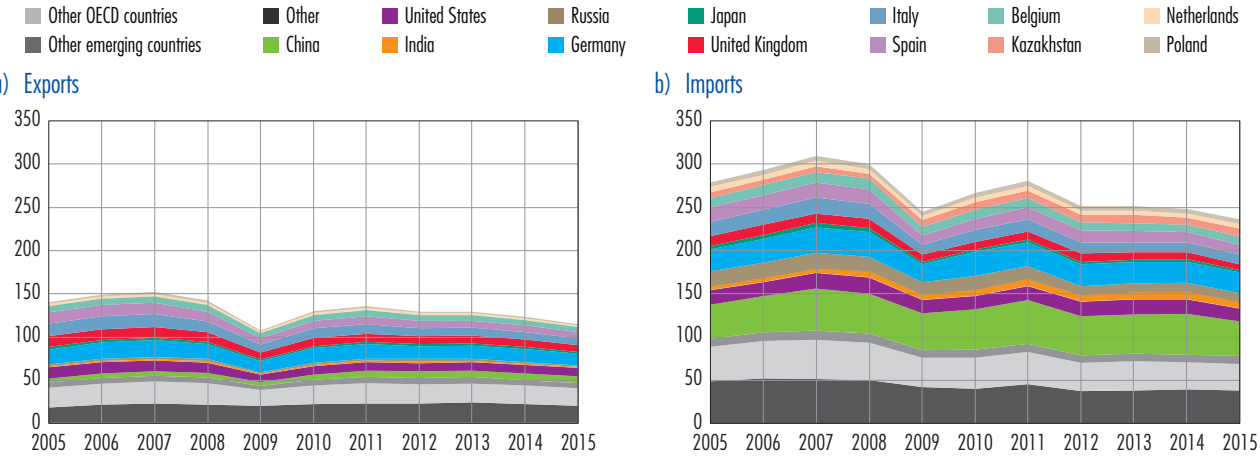
China is followed by Germany (–10 million tonnes), Kazakhstan (–10) and Russia (–9) in the rankings of the largest CO_2 trade deficits. These deficits stem either from the trade deficit in monetary value, as is the case for Germany, or from the sectoral structure of trade flows for the other two countries, where imports are dominated by raw materials and hydrocarbons.

On the other hand, France has a surplus measured in CO_2 terms with the United Kingdom and Switzerland (1 million tonnes each). Positive balances – although close to zero – can also be observed for other countries, including Colombia, Sweden and Argentina.

2 China, Germany and the United States: France's main partners in trade-embodied CO_2 emissions

France exported the equivalent of 115 million tonnes of CO_2 in 2015. The country's imports represented 236 million tonnes. Between 2005 and 2015, French CO_2 exports fell by 18%, a reduction equivalent of 25 million tonnes. Imports followed a similar trajectory, declining by 15%, i.e. –43 million tonnes.

C2 Geographical breakdown of French trade-embodied CO_2 emissions
(millions of tonnes)



Source: OECD inter-country input-output (ICIO) database, 2018 edition, and trade in embodied CO_2 ($TECO_2$) database; authors' calculations.

These developments contrast with the overall upward trend in emissions in world trade, which came to +10% over the period. On the other hand, the reduction in France coincides with that observed in European countries such as Spain (–13 million for exports and –41 million for imports), Italy (–18 million and –43 million respectively) and the United Kingdom (–20 million and –57 million).

Germany and the United States are the main destinations for French exports in terms of CO_2. These two countries imported in 2015 14 and 10 million tonnes respectively, accounting for 12% and 9% of the total. The other main outlets are China, Italy and the United Kingdom (all three at 7%).

With regard to imports, China and Germany are the main suppliers of foreign CO_2 consumed in France. With 40 million tonnes for China and 24 million for Germany, these two countries alone accounted for a quarter of French imports in 2015. The other major contributors are the United States (6%), Italy (5%) and Spain (5%).

More generally, the major European countries (Germany, Italy, Spain, the United Kingdom, Belgium, the Netherlands and Poland) receive 40% of France's CO_2 exports, while the other advanced countries (United States, Japan and "Other OECD countries") account for 27%. The remaining flows are destined to emerging countries (15%) and other countries in the sample (18%). For imports, on the other hand, the share originating from emerging countries (29%) is almost equal to that of European countries (31%).

This difference is due in particular to a highly heterogeneity in the CO_2 efficiency of production between advanced countries on the one hand and emerging countries or producers of raw materials on the other. The former emit less per unit of value added traded than the latter (Cezar and Polge, 2020).

BOX 2

The global CO_2 emissions value chain

The fragmentation of production across global value chains (GVCs) increases the share of imported inputs in exports. French integration within these value chains increased between 1990 and 2011. As a result, the share of foreign value added in its exports rose from 20% to 30% over the same period (Cezar et al., 2017).

This international production structure impacts CO_2 emissions as well. A country's imports meet domestic demand, but also serve as inputs into the production of its exports. From this perspective, the emissions associated with the production and distribution of these foreign inputs are accounted for in the exports of the country using them.

The share of foreign CO_2 emissions in French exports remained relatively stable between 2005 and 2015, at around 46%, after peaking at 49% in 2008 and 2011. France thus ranks as the country with the second highest rate of imported CO_2 in exports, after Italy (47%). Generally speaking, European countries' trade structures include a significant proportion of imported CO_2, particularly due to their participation in the European value chain, as illustrated by Germany (38%) and the United Kingdom (33%). Conversely, commodity exporting countries or countries with relatively low levels of integration, such as Russia (5%) and South Africa (8%), incorporate a lower proportion of imported CO_2 in their exports (Cezar and Polge, 2020).

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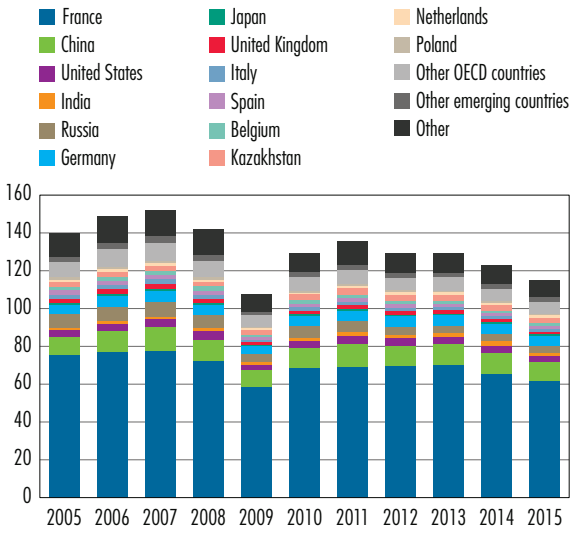
Nonetheless, foreign CO_2 emissions embodied in French exports have declined in absolute terms (from 64 million tonnes in 2005 to 53 million tonnes in 2015), which contributes to the overall decline in France's exported CO_2 emissions (see Section 1).

China is the main supplier of imported CO_2 in French exports with 9.8 million tonnes. This amount has remained practically stable since 2005 (9.5 million). However, China's share in French exports is on the rise (given the drop in total CO_2 exports), having increased from 6.8% to 8.5% over the ten years in question.

Germany, the second largest foreign contributor, accounts for 4.5% of the CO_2 emissions exported by France, i.e. 5 million tonnes. As in the case of China, German participation has been increasing proportionally since 2005 (when it accounted for 3.5%) despite a stable contribution in absolute terms over the period. The next largest contributors are Russia (3.4%), the United States (2.9%) and Kazakhstan (2.7%).

As with trade balances, the contribution of foreign countries to CO_2 exports depends on their share in export production, as well as the sectoral structure of their trade flows and their carbon intensity (Cezar and Polge, 2020).

Geographical origins of CO_2 emissions embodied in French exports
(millions of tonnes)



Source: OECD inter-country input-output (ICIO) database, 2018 edition, and trade in embodied CO_2 ($TECO_2$) database; authors' calculations.

3 France is primarily responsible for the reduction in CO_2 emissions associated with its exports

France's trade-embodied CO_2 emissions are made up of CO_2 emitted within its borders, but also of CO_2 emitted abroad in countries participating in its value chains (see Box 1). As such, reductions in emissions are dependent upon all the countries contributing to these flows. (see Figure 3 below and Appendix 1 for details on geographical areas).

French exports in terms of CO_2 emissions fell by a cumulative 18% over the period, from 140 million tonnes in 2005 to 115 million tonnes in 2015. This decrease is primarily due to France itself, which emissions embodied in its own exports fell from 76 to 62 million tonnes. This represents an aggregate downward contribution of nearly 10 percentage points (pp), i.e. more than half of the total.

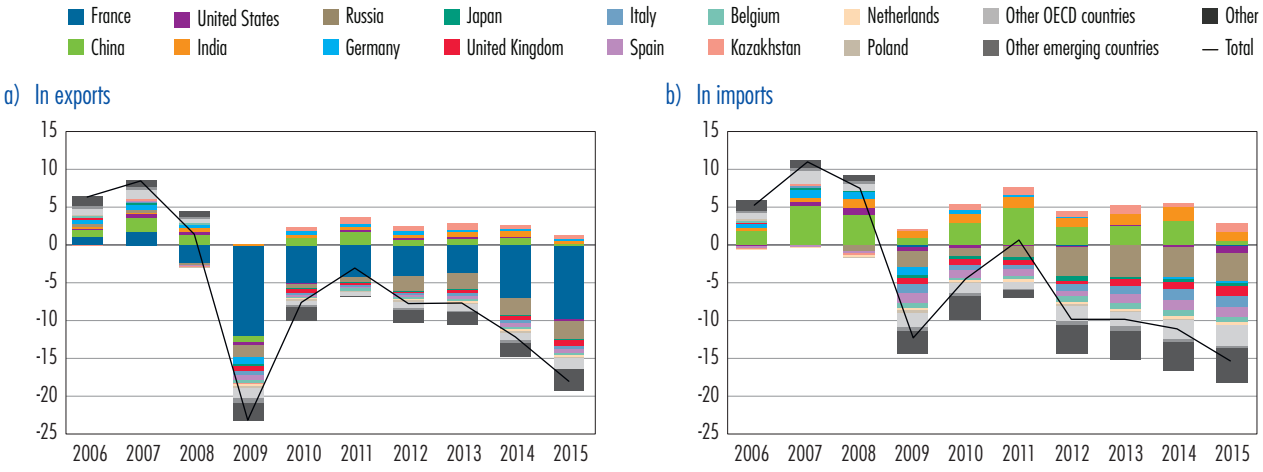
Other countries also contributed to the drop in CO_2 exports, albeit less significantly. In absolute terms, foreign CO_2 emissions fell from 64 million tonnes in 2005 to 53 million tonnes in 2015, i.e. –8 pp.

Russia contributed the most to this decrease, at –2.3 pp, followed by the United Kingdom (–0.7 pp), Italy (–0.5 pp) and Spain (–0.45 pp). In addition, the group of "Other" countries not covered in the sample (–2.8 pp) and "other OECD countries" (–1.4 pp) also contributed to the decline in French CO_2 exports.

In general, nearly all foreign countries follow this same trend. The exceptions are Kazakhstan (+0.5 pp), India (+0.5 pp), Germany (+0.15 pp) and China (+0.14 pp).

C3 Geographical breakdown of the change in CO_2 emissions

(% change, 2005 = 0)



Source: OECD inter-country input-output (ICIO) database, 2018 edition, and trade in embodied CO_2 ($TECO_2$) database; authors' calculations.

Imports in terms of CO_2 emissions decreased by –15%, from 279 million tonnes in 2005 to 236 million tonnes in 2015. The geographical structure of this decrease resembles that of exports, since emissions embodied in foreign exports were imported. Russia contributed –4.6 percentage points to the trend, followed by Spain (–1.4 pp), the United Kingdom (–1.4 pp) and Italy (–1.3 pp).

4 The transport equipment sector: main source of CO_2 emissions in French exports

The transport equipment, basic metals and transport-storage sectors are the main exporters of CO_2 emissions in France, accounting for 50 million of the 115 million tonnes of CO_2 embodied in French exports.[3] In the transport equipment sector, nearly three-quarters of exports in terms of CO_2 come from abroad, while in the other two sectors emissions originate mainly in France. France also exports CO_2 via the "chemicals and pharmaceuticals" sector (13 million tonnes) and the "agriculture and mining" sector (7 million tonnes).

Sectoral emissions can be analysed from the perspective of the direct exporting sector or the sector at the origin of the emissions. The first approach attributes to the exporting sector the CO_2 emitted throughout the production process and thus includes the emissions of all sectors upstream of export production chains. An alternative approach is to attribute the CO_2 to the sector at the origin of the emissions, whether it is itself an exporter or a supplier of inputs to an exporting sector. A further distinction is made within each sector between CO_2 emitted in France and abroad (see Annex 1 for sectoral aggregates).

In terms of the sector of origin of emissions, France's sectoral profile is characterised by a relatively small share of the energy sector in exports. Yet, this sector accounts for nearly one-third of global CO_2 exports, while constituting only 19% of French CO_2 exports. The disparity is even more pronounced when the data take into account only emissions within France: the sector is responsible for 6 million of the 62 million tonnes emitted in France and embodied in exports (see Chart 4 a below). It thus corresponds to less than 10% of total emissions exported. Moreover, the sector is "only" the

3 The transport equipment sector includes the automotive, aeronautics, maritime transport, rail and aerospace industries. The basic metals sector refers to production of metals. The transport and storage sector particularly includes international transport.

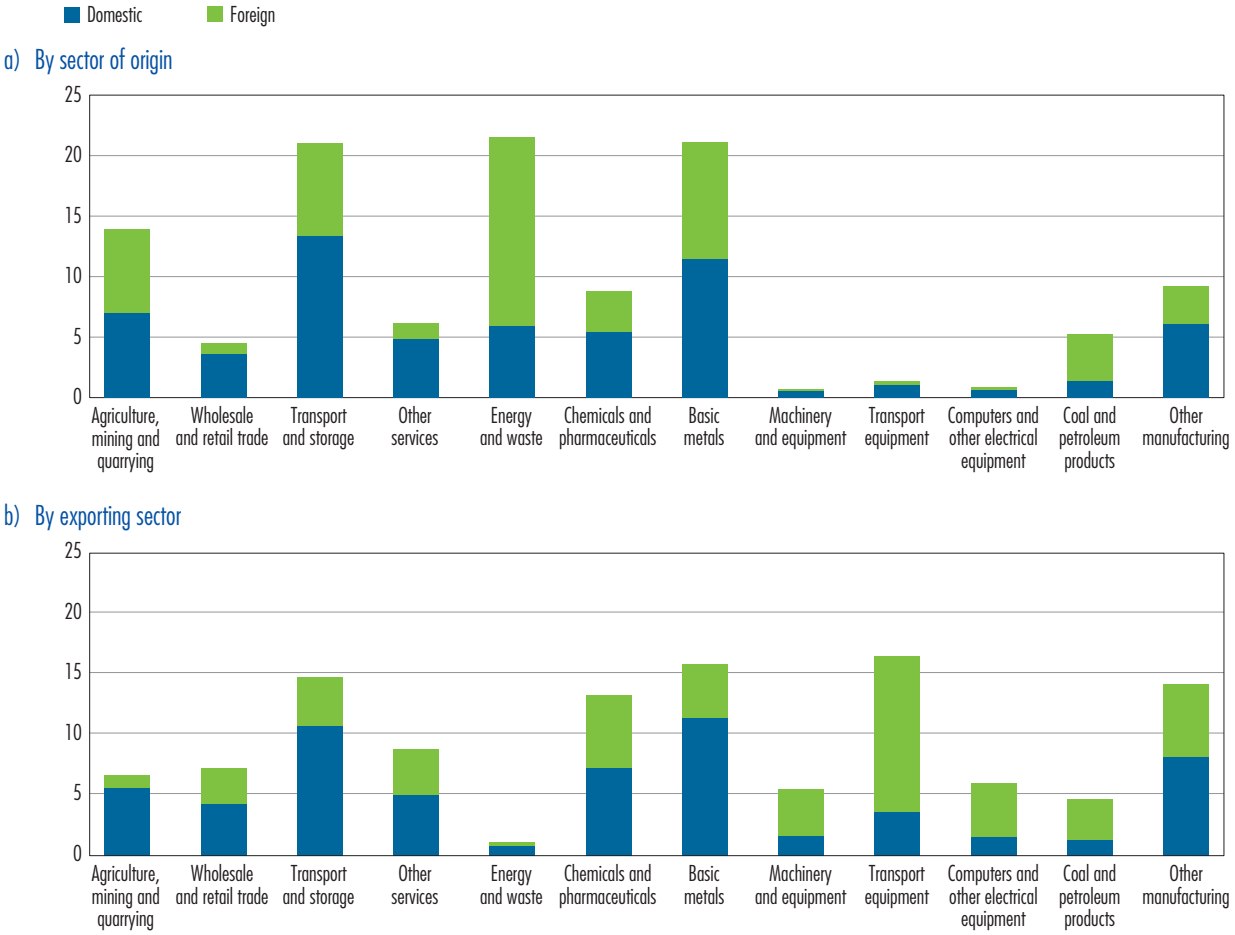
fifth largest emitting sector in France while it is the largest from a global standpoint.

This distinctive feature can be explained by energy production sources. While on a global scale energy is produced mainly from fossil fuels, France's energy mix is heavily dependent on nuclear power, which emits very little CO_2.

Still in terms of the origin of emissions, the basic metals and transport-storage sectors are the largest contributors to emissions in French exports. The breakdown between domestic and foreign emissions is fairly balanced for the first sector, while for the second emissions are more concentrated in France.

C4 Sectoral breakdown of CO_2 emissions

(millions of tonnes)



Source: OECD inter-country input-output (ICIO) database, 2018 edition, and trade in embodied CO_2 ($TECO_2$) database; authors' calculations.

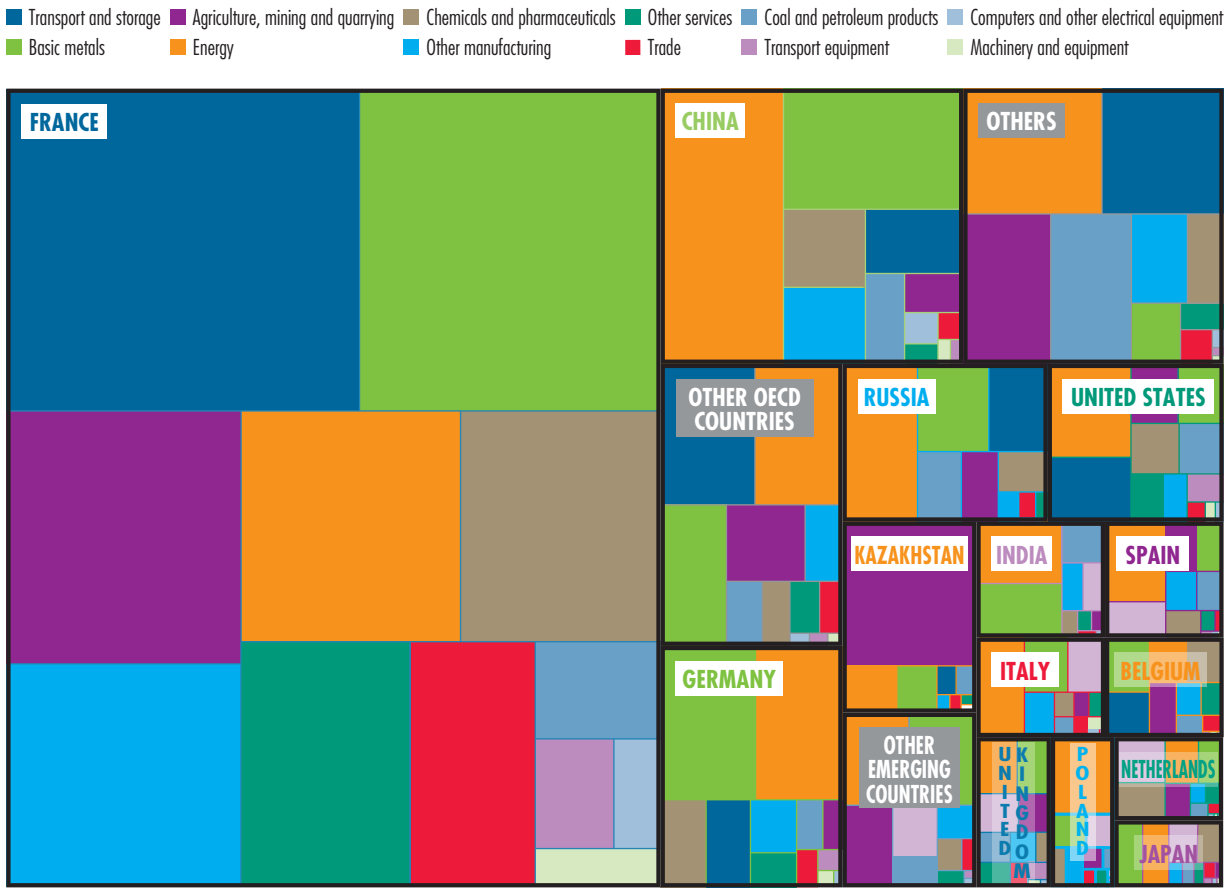
BOX 3

Two-dimensional analysis of emissions in global value chains

The CO_2 emissions embodied in French exports are incorporated into global value chains. This integration is achieved first by taking into account all countries participating in export production chains. The sectoral dimension is important as well: countries contribute to these chains according to their specialisations. As a result, CO_2 emissions vary according to the participation of different countries in various production or distribution tasks, such as assembly and international transport, as well as the supply of inputs, e.g. spare parts and raw materials.

This box provides a two-dimensional representation that takes into account both the geographical and sectoral components of the emissions embodied in French exports. These two components are situated upstream and thus indicate the country and the sector that actually emitted the CO_2. For example, energy is the main emitting source through its use as a production input for other sectors (countries) participating in the French production chain.

Diagram A Geographical and sectoral origin of CO_2 emissions embodied in French exports in 2015



Source: OECD inter-country input-output (ICIO) database, 2018 edition, and trade in embodied CO_2 ($TECO_2$) database; authors' calculations.
Note: The total area of the graph is equivalent to the 115 million tonnes of CO_2 exported by France in 2015. It is broken down by country and then by sector of activity, according to the CO_2 contribution of each in French exports.

.../...

China is the main foreign contributor to CO_2 emissions in French exports, particularly via the "energy" and "basic metals" sectors, the former being used in the production of Chinese exports, while the latter is exported directly. The "chemicals and pharmaceuticals" and "other manufacturing" sectors, as well as "transport-storage" are also major emitters in the production-sharing relationship between the two countries.

More generally, the "energy", "basic metals" and "transport and storage" sectors stand out as the main CO_2 emitters in the value chain linking France to the rest of the world. This is the case for Germany, Russia and the United States. One exception is Kazakhstan, with almost all of its emissions concentrated in extractive sectors.

These data provide a macroscopic portrait of French exports. Nevertheless, the global value chains (GVCs) in which France participates are made up of several value chains across sectors, and even at the level of individual companies.

The transport equipment sector, for instance, is the most integrated sector in France's CO_2 trade, with less than a quarter of the emissions embodied in its exports emitted within French borders. The remainder is emitted abroad. This allocation is due chiefly to the sector's pronounced international nature: value added produced abroad accounts for almost half of its exports (Cezar, 2017). Moreover, France's relatively low emissions compared to its partners also contribute to this phenomenon (see Box 1).

The example of coordinated manufacturing at Airbus is a good illustration of this strong internationalisation. Head office activities are based in France, with commercial activities shared with Germany (the aircraft are, however, invoiced in France and therefore accounted for as French exports). Upstream of manufacturing, design and engineering sites are divided between Europe (France, Germany, Spain and Russia through a joint venture), North America and two sites in India and China. Production plants specialise in the manufacture of aircraft components and are spread throughout four European countries: France (general design, flight testing, materials design and testing, aircraft assembly and flight preparation); Germany (manufacture and assembly of fuselage parts, painting, cabin equipment and vertical empennages); England (wing production and surfacing); and Spain (testing of complete fuselages, assembly, horizontal stabiliser production). In addition, the company sources engines from three countries: the United Kingdom, France and the United States.

The international character of this production network, in addition to the supply of raw materials and other inputs, explains why CO_2 emissions throughout the production process are scattered around the world. China, Germany, the United States and other member countries of the Organisation for Economic Co-operation and Development (OECD) are thus the main CO_2 emitters for French exports in the transport equipment sector.

The chemicals and pharmaceuticals sector offers another example of the internationalisation of production and thus of CO_2 emissions. France emits more than 50% of the 13 million tonnes of CO_2 embodied in its exports, the rest being emitted abroad. This sector thus appears to be highly integrated, but less so than the transport equipment sector. China, Germany and Russia are the main partners in the sector. In these three countries, emissions are primarily attributable to the energy sector and the chemicals and pharmaceuticals sector itself. "Agriculture and mining" is also an important sector in this production chain.

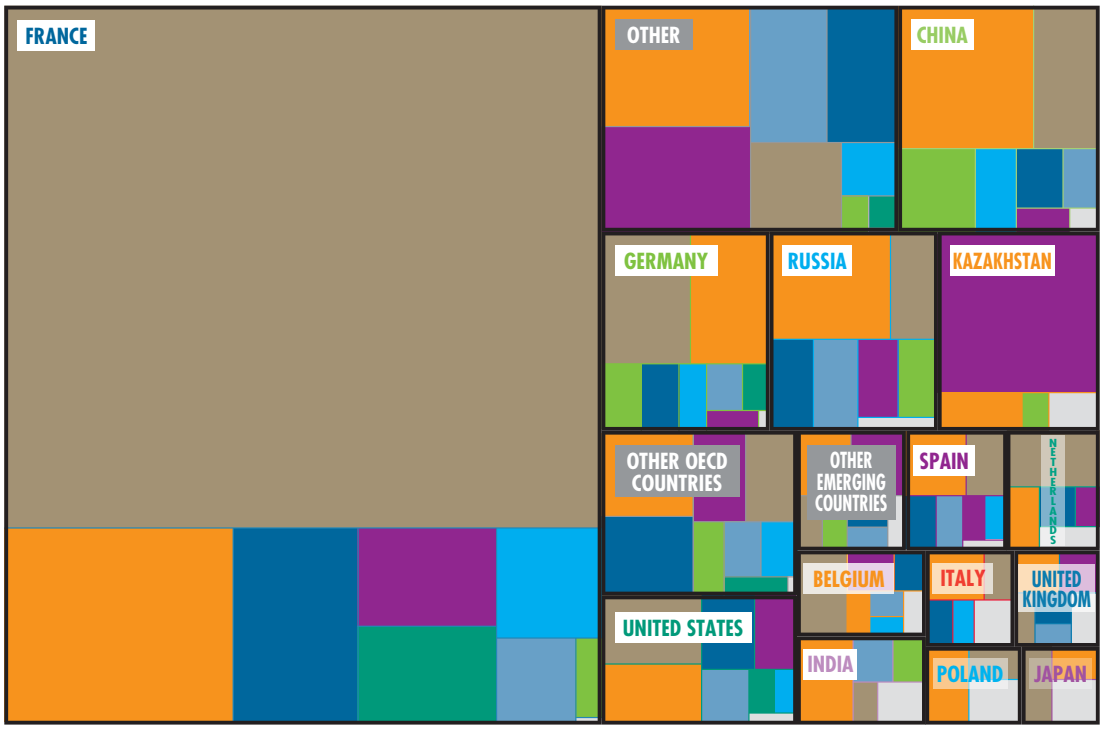
.../...

Diagram B Geographical and sectoral origin of CO_2 emissions embodied in French sectoral exports in 2015

Transport and storage
Basic metals
Agriculture, mining and quarrying
Energy
Chemicals and pharmaceuticals
Other manufacturing
Other services
Trade
Coal and petroleum products
Transport equipment
Computers and other electrical equipment
Machinery and equipment
Miscellaneous sectors of activity with non-significant impact

a) Transport equipment

b) Chemicals and pharmaceuticals



Source: OECD inter-country input-output (ICIO) database, 2018 edition, and trade in embodied CO_2 ($TECO_2$) database; authors' calculations.

5 The "energy", "coal and petroleum products" and "basic metals" sectors are the main contributors to the decrease in CO_2 emissions in French exports

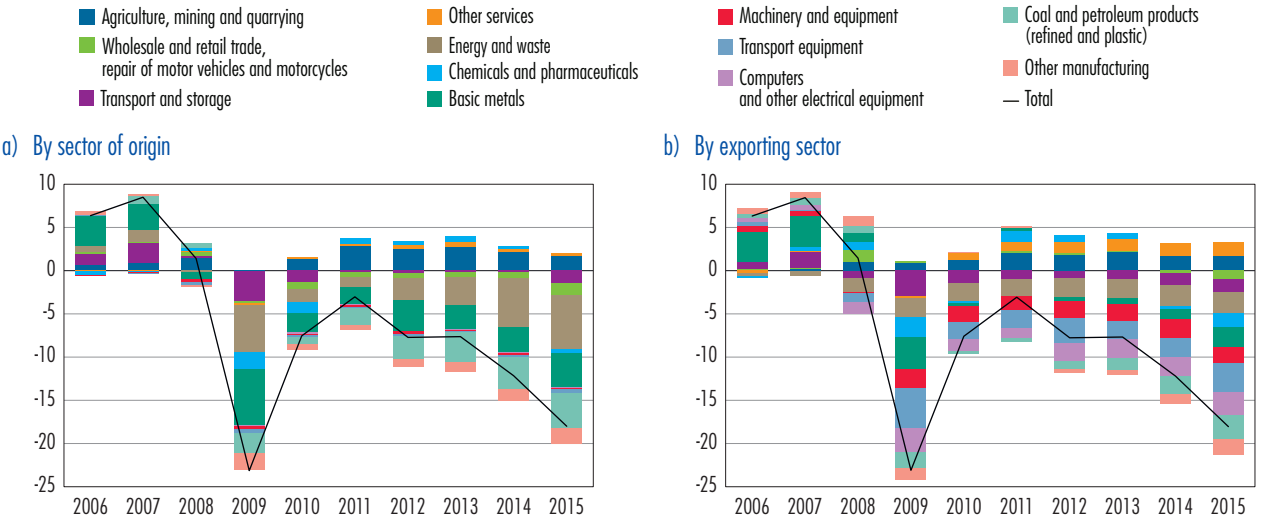
The breakdown applied in Section 3 can also be used to show the sectoral contribution to changes in CO_2 emissions in exports. The sectoral aggregates considered here include both resident and non-resident sectors involved in the production of French exports.

Measured by origin, the main sectors contributing to the overall decrease of 18 pp in CO_2 emissions in French exports between 2005 and 2015 are "energy" (–6.4 percentage points), "coal and petroleum products" (–4.1 pp), "basic metals" (–3.9 pp) and the "transport and storage" sector (–1.4 pp). Conversely, the only sector with a positive and significant contribution was "agriculture and mining" (+1.7 pp).

In terms of direct exporting sectors, the decrease in emissions embodied in French exports has primarily been driven by manufacturing and energy. The transport equipment (–3.3 pp), coal and petroleum products (–2.9 pp), computers and electrical equipment (–2.6 pp) and energy (–2.4 pp) sectors are the main vectors of the aggregate trend. Conversely, emissions are on the rise in the other services (+1.5 pp) and agriculture and mining (+1.8 pp) sectors.

C5 Breakdown by sector of the cumulative variation in exports of CO_2 emissions

(% change, 2005 = 0)



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"Estimating CO_2 Emissions Embodied in Final Demand and Trade Using the OECD ICIO 2015: Methodology and Results, *OECD Science, Technology and Industry Working Papers*, No. 2016/5.

Appendix I
Geographical and sectoral aggregates

CO_2 emissions intensity by sector of origin

(tonnes/USD million)

Code	Sector	Aggregate	2005	2010	2015
01T03	Agriculture	Agriculture, mining and quarrying	412	273	245
05T06	Mining and quarrying of energy producing materials	Agriculture, mining and quarrying	408	282	357
07T08	Mining and quarrying except energy producing materials	Agriculture, mining and quarrying	500	256	341
9	Mining support service activities	Agriculture, mining and quarrying	205	114	142
10T12	Food products, beverages and tobacco	Other manufacturing	259	194	165
13T15	Textiles, wearing apparel, leather and related products	Other manufacturing	376	248	156
16	Wood and products of wood and cork, except furniture	Other manufacturing	289	251	196
17T18	Paper products and printing	Other manufacturing	508	420	352
19	Coke and refined petroleum products	Coal and petroleum products	1,953	1,416	1,236
20T21	Chemicals and pharmaceutical products	Chemicals and pharmaceuticals	756	586	525
22	Rubber and plastics products	Coal and petroleum products	1,654	1,251	951
23	Manufacture of other non-metallic mineral products	Other manufacturing	3,061	2,478	2,248
24	Basic metals	Basic metals	3,889	3,335	3,294
25	Fabricated metal products	Other manufacturing	92	74	64
26	Computer, electronic and optical products	Computers and other electrical equipment	83	72	46
27	Electrical equipment	Computers and other electrical equipment	101	82	61
28	Machinery and equipment n.e.c.	Machinery and equipment	84	67	55
29	Motor vehicles, trailers and semi-trailers	Transport equipment	58	44	33
30	Other transport equipment	Transport equipment	71	63	49
31T33	Furniture; other manufacturing; repair and installation of machinery and equipment	Other manufacturing	1,268	930	750
35T39	Electricity, gas and water supply; sewerage, waste management and remediation activities	Energy and waste	9,395	7,206	6,876
41T43	Construction	Other services	102	78	80
45T47	Wholesale and retail trade, repair of motor vehicles and motorcycles	Wholesale and retail trade	71	53	49
49T53	Transport and storage	Transport and storage	1,293	1,023	983
55T56	Accommodation and food service activities	Other services	50	38	33
58T60	Publishing, audiovisual and broadcasting activities	Other services	44	33	27
61	Telecommunications	Other services	55	41	39
62T63	IT and other information services	Other services	47	38	34
64T66	Financial and insurance activities	Other services	40	31	26
68	Real estate activities	Other services	31	23	20
69T82	Professional, scientific and technical activities; administrative and support service activities	Other services	60	44	42
84	Public administration and defence; compulsory social security	Other services	109	81	63
85	Education	Other services	33	26	22
86T88	Human health and social work activities	Other services	36	26	27
90T96	Arts	Other services	61	43	39

CO_2 emissions intensity by country of origin

(tonnes/USD million)

Country	Geographical aggregate	2005	2010	2015
Argentina	Other emerging	880	436	308
Australia	Other OECD	612	417	454
Austria	Other OECD	336	294	261
Belgium	Other OECD	367	282	254
Bulgaria	Other OECD	1,619	936	827
Brazil	Other emerging	620	299	434
Brunei Darussalam	Other	451	465	389
Canada	Other OECD	590	502	474
Switzerland	Other OECD	199	154	119
Chile	Other OECD	619	432	491
China	China	2,336	1,413	981
Colombia	Other	579	328	476
Costa Rica	Other	374	266	187
Cyprus	Other OECD	525	416	411
Czech Republic	Other OECD	799	505	470
Germany	Germany	318	271	246
Denmark	Other OECD	535	424	381
Spain	Other OECD	421	272	269
Estonia	Other OECD	1,021	831	595
Finland	Other OECD	479	405	304
France	France	277	217	189
United Kingdom	United Kingdom	269	229	178
Greece	Other OECD	714	456	536
Hong Kong	China	652	552	449
Croatia	Other OECD	440	321	303
Hungary	Other OECD	530	418	391
Indonesia	Other emerging	1,183	560	615
India	India	1,403	1,072	999
Ireland	Other OECD	262	183	147
Iceland	Other OECD	602	485	417
Israel	Other OECD	413	283	231
Italy	Italy	328	272	249
Japan	Japan	367	300	352
Kazakhstan	Other	2,839	1,697	1,562
Cambodia	Other	503	452	444
South Korea	Other OECD	757	638	554
Lithuania	Other OECD	660	422	353
Luxembourg	Other OECD	167	115	88
Latvia	Other OECD	647	470	349
Morocco	Other	592	455	462
Mexico	Other emerging	527	488	423
Malta	Other OECD	417	237	205
Malaysia	Other	932	663	675
Netherlands	Other OECD	353	251	250
Norway	Other OECD	281	215	239
New Zealand	Other OECD	422	321	281
Peru	Other	509	366	287
Philippines	Other	748	414	361
Poland	Other OECD	961	523	492
Portugal	Other OECD	388	280	324
Romania	Other OECD	1,111	480	417
Rest of the world	Other	942	560	522
Russia	Russia	1,992	1,151	1,121
Saudi Arabia	Other	405	263	361
Singapore	Other	643	526	471
Slovakia	Other OECD	896	533	453
Slovenia	Other OECD	524	384	341
Sweden	Other OECD	259	199	153
Thailand	Other	1,041	661	654
Tunisia	Other	611	539	508
Turkey	Other emerging	592	509	500
Taiwan	China	900	689	590
United States	United States	436	351	270
Vietnam	Other	1,356	1,009	859
South Africa	Other emerging	1,837	1,470	1,692

Appendix 2
Methodology

The database used in this bulletin was constructed using three main sources, all compiled by the OECD. First, the trade in embodied CO_2 ($TECO_2$) and trade in value added (TiVA) databases were used to calculate CO_2 emissions intensities by sector (i.e. CO_2 per unit of value added). Second, the inter-country input/output tables (ICIO) were used to break down trade flows by country-sector pair participating in the production of those flows. Combining these two indicators allowed us to calculate the CO_2 emissions embodied in trade flows, taking into account the structure of their production and the degree of integration of each country into global value chains.

The $TECO_2$ database shows the emissions produced by the burning of fossil fuels.[1] These emissions are calculated using International Energy Agency (IEA) data on the CO_2 emissions produced by fossil fuels (coal, hydrocarbons). IEA data cover nearly all CO_2 emissions. The remainder stem from LULUCF (land use, land-use change and forestry) and industrial processes other than energy production. Note that IEA data do not cover all greenhouse gas emissions –some 20% of emissions by volume are excluded (Ahmad and Wyckoff, 2003). The other main greenhouse gases are methane (CH_4), nitrous oxide (N_2O) and fluorine gases (HFC, PFC and SF_6). These gases account for a third of global emissions in CO_2 equivalent (INSEE, 2018).

The $TECO_2$ database provides a geographical and sectoral breakdown of CO_2 emissions (Wiebe and Yamano, 2016). It is compiled using statistics on the CO_2 produced to meet countries' final demand (demand-based approach). However, it does not take into account emissions from international aviation and maritime transport (3.5% of the total). To get around this problem, we assumed that the structure of domestic transport also applies to international transport. This assumption probably led us to underestimate the emissions in question, especially those related to aviation.

The TiVA database provides a geographical and sectoral breakdown of international trade in value added (domestic or foreign). In this article, we used statistics on the value added produced to satisfy countries' final demand.

The ICIO database consists of international tables of annual inputs and outputs that break down bilateral trade flows in intermediate and final goods by sector and country. This makes it possible to trace the total value added produced globally each year back to its original source.

The breakdown into sixty-five countries and thirty-six sectors of origin (according to the International Standard Industrial Classification or ISIC Rev. 4) is the same for all three databases.

Emissions intensity of each country-sector pair

As a first step, we constructed the CO_2 emissions intensity for each country-sector pair, in other words the quantity of CO_2 emitted for each unit of value added. The intensity of sector *k* in country *i*($Int_{i,k}$) was calculated by dividing the CO_2 emissions produced by the sector ($EM_{i,k}$), as listed in the $TECO_2$ database, by the value added produced by that sector ($VA_{i,k}$), as indicated in the TiVA database. This calculation can be written as follows:

$$I_{i,k} = \frac{EM_{i,k}}{VA_{i,k}}$$

The CO_2 emissions and value added for each sector are measured according to the principle of the output necessary to satisfy domestic final demand. The calculated intensities thus show the emissions associated with the production of one unit of value added by each country-sector pair. In other words, they show the quantity of CO_2 emitted for each dollar of output.

1 IEA (2015), CO_2 Emissions from Fuel Combustion 2015, OECD Editions.

The contribution of each country-sector pair to global trade

As a second step, we calculated the total emissions produced throughout the production chain of international trade. This chain is defined as all intermediate and final activities carried out by businesses in order to produce an exported good or service. The CO_2 emissions embodied in trade were calculated by combining the value added embodied in global trade flows that was produced by each country-sector pair with the respective emissions intensity of each pair. These emissions may be produced within the country or abroad. By combining the two variables, we arrived at the geographical and sectoral distribution of the emissions produced throughout global value chains, and their respective contributions to exports and imports. This provided a picture of global trade flows in CO_2 emissions.

$$EMX_i = \sum_{jk=1}^{36*65} VAX_{ijk} * I_{jk}$$

Where EMX_i is the emissions embedded in the exports of country *i* (France for the purposes of this article); VAX_{ijk} is the value added produced by country-sector pair *jk* (domestic or foreign) that is embodied in the exports of country *i* (France), and I_{jk} is the CO_2 emissions intensity per unit of value added produced by country-sector pair *jk*. The breakdown of the contribution of each country-sector pair *jk* to the exports of country *i* (VAX_{ijk}) is calculated using the ICIO tables (see Cezar, 2017, for more details). Imports were calculated using mirror data (i.e. the exports of country *i* to country *j* are deemed to be equivalent to *j*'s imports from *i*).

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