

Competitiveness, Carbon Intensity, and Import Dependence in Spain

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Abstract

This paper assesses the economic weight, carbon profile, and import dependence of seventeen strategic industry groups in Spain using EXIOBASE 3.10.1, an environmentally extended multi-regional input-output database covering 49 regions and 163 industries, for the period 2019-2022. We map 127 out of 163 sectors from EXIOBASE into 17 broader sectors. Empirically, the seventeen groups account for roughly 27 percent of Spanish gross value added and 21 percent of employment. On an identical sector basket, Spain's carbon intensity of output (0.47 kg CO₂e per euro) exceeds that of Germany (0.34), France (0.30), and the EU-27 average (0.40), with the gap concentrated in electricity generation, cement, ceramics, and agri-food. Scope 3 emissions dominate in 13 of 16 measurable groups and carry 58 percent of the basket's footprint. Approximately 199 billion euro of the groups' value added is ultimately absorbed abroad, with revealed comparative advantage concentrated in construction, the automotive industry, and agri-food. Composite supply-risk rankings are shown to be highly sensitive to indicator weights, which cautions against point rankings in policy use.

Keywords: input-output analysis; carbon footprint; Scope 3 emissions; EXIOBASE; industrial policy; carbon border adjustment; trade in value added.

JEL codes: C67, F14, F18, L52, Q54.

1. Introduction

European industrial policy is being rebuilt around two constraints that used to be treated separately: the obligation to decarbonize and the desire to reduce exposure to concentrated foreign suppliers. The Carbon Border Adjustment Mechanism (CBAM) prices the carbon embodied in imports of energy-intensive goods at the European Union border with the purpose of addressing carbon leakages (European Union, 2023). In practice, this makes relative embodied-carbon intensity economically consequential for trade-exposed producers. At the same time, the policy discussion on open strategic autonomy has pushed governments to map where their industries depend on a small number of foreign suppliers for critical inputs. Any national industrial strategy therefore needs to answer three questions: (i) where a country creates value and employment, (ii) how carbon-intensive that activity is relative to competitors and where in the supply chain the emissions sit, and (iii) how exposed each industry is to import disruption.

Environmentally extended multi-regional input-output (EE-MRIO) analysis is the instrument used for this task, it embeds production, trade, emissions, and employment in one internally consistent framework (Leontief, 1970; Miller and Blair, 2009; Wiedmann et al., 2011; Tukker and Dietzenbacher, 2013). In practice, however, applied sector diagnostics built on MRIO data are vulnerable to a set of recurrent methodological failures: supply-chain footprints summed across sectors even though every intermediate transaction is embodied in both the buyer's and the seller's footprint; Scope 2 emissions computed by applying one country's average grid emission factor to every trading partner; sector concordances that quietly sweep large unrelated industries into a strategic group; and database vintages used beyond the years for which the underlying satellite accounts are actually populated. Each of these errors is individually capable of changing headline conclusions by a factor of two or more, as this paper documents.

This paper carries out an integrated assessment of seventeen strategic industry groups in Spain over 2019-2022, using EXIOBASE 3.10.1¹ in its industry-by-industry form, 49 regions by 163 industries (Stadler et al., 2018), benchmarked against Germany, France, Italy, Poland, the United States, and China, and complemented with the Spanish national input-output framework of the Instituto Nacional de Estadística (INE), Eurostat national-accounts employment, and World Bank development indicators.

First, the paper derives and applies an exact additive decomposition of each sector's gross-output carbon footprint into Scope 1, Scope 2, and Scope 3 components. The decomposition follows directly from the recursion satisfied by total emission intensities in the Leontief system and has three properties that the common practice of subtracting direct emissions and an electricity estimate from a total does not: it is exact by construction with no residual, it values each supplier at that supplier's own upstream

¹ Available at: <https://zenodo.org/records/20051562>

intensity so that electricity factors are region-specific automatically, and it charges purchases from electricity distribution at the generation carbon actually embodied in them rather than at a generation factor applied to a retail price.

Second, the paper treats the concordance between the analytical sector groups and the database's industry classification as an object of validation rather than an assumption. The Spanish automotive group contained the whole of wholesale and retail trade and consequently reported 15.9 percent of Spanish value added where vehicle and transport-equipment manufacturing accounts for 3.0 percent, an overstatement of 5.3 times. A defence and aerospace group defined as air transport plus public administration was, by value added, 95 percent civil government. The mapping is reported.

Third, the paper documents several properties of EXIOBASE 3.10.1 that materially affect applied work and are not, to our knowledge, systematically discussed in the applied literature. First, the 2023 and 2024 nowcast years ship with an air-emissions satellite that contains almost no combustion carbon dioxide, so that global greenhouse-gas emissions computed from the database collapse from 43.4 to 13.3 gigatonnes. Second, the EXIOBASE factor-inputs block should be treated as an EXIOBASE-side value-added measure rather than as a replica of official Spanish gross value added at basic prices, so reconciliation against national accounts is required before it is used for country-level interpretation. Third, the employment satellite should be used with caution at detailed industry level, because it is constructed through multiple imputations, source harmonisation, classification crosswalks, and wage-based sectoral splits rather than being a direct readout of official national employment by EXIOBASE industry. Fourth, direct final-demand emissions are recorded separately in the F_V satellite block and are therefore omitted if only the industry block is read.

Empirically, the seventeen groups concentrate roughly 27 percent of Spanish gross value added and 21 percent of employment. On an identical basket of industries, Spain's aggregate carbon intensity of output is 0.47 kilograms of carbon-dioxide equivalent per euro, against 0.34 for Germany, 0.30 for France, and approximately 0.40 for the EU-27, and the excess is concentrated in electricity generation, cement, ceramics, and agri-food. Scope 3 is the largest of the three scopes in 13 of the 16 groups measurable in EXIOBASE and carries 58 percent of the basket's total footprint, which places most of the abatement lever upstream of the final producers. About 199 billion euro of the groups' value added is ultimately absorbed by foreign final demand; revealed comparative advantage, measured on value added rather than gross exports, is concentrated in construction, the automotive industry, and agri-food. Import dependence is dominated by the EU-27 for most groups, with two exceptions that matter for policy: fossil fuels, where the Middle East and Africa supply more than two fifths of imports, and a set of electrical-machinery inputs where China holds around 70 percent of supply. Finally, a composite supply-risk index is shown

to reorder substantially under alternative indicator weights, which argues for presenting such rankings as ranges.

The remainder of the paper is organized as follows. Section 2 situates the approach in the literature. Section 3 describes the data and the evidence behind the year coverage. Section 4 sets out the methodology. Section 5 reports the results. Section 6 discusses policy implications, Section 7 states limitations, and Section 8 concludes.

2. Analytical framework and related literature

The analysis belongs to the tradition of environmentally extended input-output accounting initiated by Leontief (1970) and consolidated, in its multi-regional form, by the global MRIO databases built during the 2010s, of which EXIOBASE is among the most detailed in environmental extensions (Wiedmann et al., 2011; Tukker and Dietzenbacher, 2013; Stadler et al., 2018). The distinction between production-based and consumption-based emissions accounting follows Peters (2008), while Davis and Caldeira (2010) provide a leading empirical application to CO₂ emissions embodied in trade. Spain is a net importer of embodied carbon throughout the sample: its consumption footprint exceeds its production-based total by 17 to 26 percent in every year, so the distinction is quantitatively material for the country studied here.

The Scope 1, 2, and 3 terminology is taken from the Greenhouse Gas Protocol (WRI and WBCSD, 2004), and its implementation in MRIO settings follows the logic of Hertwich and Wood (2018), who show that Scope 3 dominates the footprint of specific sectors once upstream supply chains are traced through the full inter-industry system. Section 4.2 shows that the three scopes can be obtained as an exact additive split of the Leontief footprint, rather than estimated separately and reconciled by a residual.

On the competitiveness side, the paper measures export performance in value-added terms, following the trade-in-value-added literature (Johnson and Noguera, 2012; Koopman, Wang, and Wei, 2014; Timmer et al., 2014): domestic value added absorbed abroad is computed by tracing each sector's value added through the global Leontief inverse to foreign final demand, so that intermediates crossing borders repeatedly are not counted twice. Specialization is summarized by a Balassa-type revealed comparative advantage index computed on value-added exports rather than on gross exports. Supplier concentration is measured with the Herfindahl-Hirschman index (HHI).

3. Data

3.1 EXIOBASE 3.10.1

The core dataset is EXIOBASE 3.10.1 in its industry-by-industry configuration: 49 regions, comprising 44 individual countries and five rest-of-world aggregates defined at

continental level, by 163 industries, for a total of 7,987 (49x163) region-industry nodes. For each year the database provides the inter-industry transaction matrix Z , the final-demand matrix Y (343 final-demand columns, seven categories per region), the gross-output vector x , a factor-inputs block with nine primary-input rows, and satellite accounts for air emissions, employment, energy, materials, and water. Air emissions are split between an industry block F_i with one column per region-industry node, and a final-demand block F_y , with one column per final-demand category, which records emissions released directly by final users, principally household fuel combustion in private vehicles and dwellings. Greenhouse gases are aggregated to carbon-dioxide equivalents using 100-year global warming potentials from the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2021), applied as a single vintage across all gases; fluorinated gases are already expressed in carbon-dioxide equivalents in the source files. Biogenic carbon dioxide is excluded, while biogenic methane and nitrous oxide are included, as prescribed by national inventory practice.

The monetary tables are expressed in current basic prices in millions of euro. No constant-price version of EXIOBASE 3 has been released; the release notes state that a constant-price estimate exists internally but is not considered robust enough to publish. This property was verified empirically: Spain's total primary inputs equal Spain's current-price gross domestic product in both 2019 and 2022, which can only occur in a nominal series. All monetary aggregates used in time comparisons are therefore deflated with World Bank gross-domestic-product deflators rebased to 2019, as discussed in Section 4.9.

3.2 Year coverage: 2023 and 2024 are excluded from the emissions analysis

EXIOBASE 3.10.1 ships tables through 2024, with the most recent years produced by a nowcasting procedure. For 2023 and 2024 the air-emissions satellite is structurally incomplete. Recomputing Spain's direct industrial emissions for 2024 from the raw satellite file yields 104.5 megatonnes of carbon-dioxide equivalent, of which the carbon dioxide rows contribute only 16.6 megatonnes, against an official national total of 225 megatonnes: the nowcast carries almost no combustion carbon dioxide. At world level, total greenhouse-gas emissions computed from the database fall from 43.4 gigatonnes in 2022 to 13.3 gigatonnes in 2023, which signals data inconsistencies. Further, the employment, energy, and water satellites are entirely absent for those two years. Accordingly, all emissions, employment, and derived indicators in this paper use the native years 2019-2022, with 2022 as the reference cross-section; 2023 and 2024 are retained only for monetary aggregates.

3.3 Complementary sources

Three complementary sources are used. First, the Spanish national input-output framework published by INE (65 branches) provides the official value-added and employment weights of each sector group within the Spanish economy, and the split key

with which a pharmaceutical group is carved out of the chemical industry, since the EXIOBASE industry classification contains no separate pharmaceutical industry. Second, employment by industry for Spain and the European peers is taken from the Eurostat national-accounts employment domain, as the EXIOBASE employment satellite shows employment inconsistencies at industry level for several large economies. Third, official national greenhouse-gas totals (total emissions excluding land use, land-use change and forestry, on Fifth Assessment Report global warming potentials) and gross-domestic-product deflators are taken from the World Bank's World Development Indicators and are used solely as reconciliation benchmarks and for deflation.

3.4 Sector definition

The unit of analysis is a set of seventeen strategic industry groups: agri-food; automotive; cement; ceramics; chemicals; construction; data centres and telecommunications; defense and aerospace (other transport equipment); three energy groups covering fuels, electricity generation, and electricity transmission and distribution; mining; paper and board; pharmaceuticals; plastics; steel; and textiles. The groups are unions of EXIOBASE industries: 125 of the 163 industries enter exactly one core group, and the remaining 38 (largely services and residual activities) stay outside the mapping. Plastics is a strict subset of chemicals in the underlying classification and is therefore reported but never added to chemicals in any aggregate. Pharmaceuticals cannot be resolved within EXIOBASE and is reported exclusively from the INE layer. The mapping is described in Section 4.5 and Appendix A.

4. Methodology

4.1 Leontief framework and notation

Let Z denote the 7,987 by 7,987 inter-industry transaction matrix, x the gross-output vector, and $A = Z\hat{x}^{-1}$ the technical-coefficient matrix, where $\hat{x}$ is the diagonalized output vector. With f the vector of total final demand, gross output satisfies $x = (I - A)^{-1}f = Lf$, with L the Leontief inverse. Let e be the vector of direct emission intensities, $e_j = F_j/x_j$, in kilograms of carbon-dioxide equivalent per euro of gross output. The vector of total (direct plus indirect) intensities is

$$\psi' = e'L, \text{ equivalently } \psi = e + A'\psi. \quad (1)$$

The cradle-to-gate footprint of node j 's gross output is $x_j\psi_j$. Because EXIOBASE 3 is roughly 46 to 55 percent dense, the Leontief system is solved by dense lower-upper factorization of $(I - A)'$ rather than by sparse methods.

4.2 An exact additive Scope 1-2-3 decomposition

The Greenhouse Gas Protocol distinguishes emissions released by a producer's own activities (Scope 1), emissions embodied in its purchased electricity (Scope 2), and all other upstream emissions (Scope 3). In MRIO applications these are commonly estimated separately: Scope 1 from the satellite, Scope 2 by multiplying electricity purchases by an average grid emission factor, and Scope 3 as the residual of the total, truncated at zero where the pieces overshoot. This paper instead obtains the three scopes as an exact partition of the footprint. Substituting the recursion in equation (1) into the footprint of node j gives

$$x_j \psi_j = x_j e_j + \sum_i a_{ij} x_i \psi_i \quad (2)$$

The first term is Scope 1. The sum runs over all direct suppliers i of node j , each purchase $a_{ij} x_j$ valued at the supplier's own total intensity ψ_i . Splitting the sum between suppliers that are electricity industries and all others yields Scope 2 and Scope 3 respectively. The decomposition is additive by construction: the three components sum to the footprint identically, with no residual and no clipping. Two further properties follow. Because each supplier carries its own ψ_i , the electricity factor applied to a German plant's purchases is the German one and the factor applied to a Spanish plant's is the Spanish one, without any additional modelling. And purchases from electricity distribution and trade are charged the generation carbon actually embodied in the distributor's supply chain, rather than a generation emission factor applied to a retail transaction.

The practical difference is large. On a synthetic MRIO constructed for unit testing, the decomposition reproduces a fourfold difference in Scope 2 between a high-carbon and a low-carbon grid where the average-grid-factor approach reports a ratio of exactly one, and the average-factor approach overstates the footprint of electricity purchased through distributors by 67 percent. Additivity holds to a relative error of 8×10^{-7} in the tests and the components reconcile against the full panel in production runs.

One qualification is required. Equation (2) presumes $x_j > 0$. EXIOBASE contains between 1,586 and 1,888 nodes per year with zero recorded output that nevertheless carry direct emissions, between 62 and 105 megatonnes globally per year. For these nodes the footprint is undefined; their direct emissions are kept in production-based totals, where they belong, but they cannot propagate into any purchaser's footprint because they have no recorded sales. The affected total is reported by the pipeline.

4.3 Aggregation without double counting

Per-node footprints must not be summed across sectors: every intermediate transaction is embodied in both the buyer's and the seller's footprint, so $\sum_j x_j \psi_j$ equals $d'L^2 y$ over final demand y . For Spain in 2019 the erroneous sum yields 724 megatonnes against a production-based national total of 323: an overstatement of 2.2 times. National aggregates in this paper are therefore computed only two ways: the production-based

total, as the column sums of the industry satellite plus the direct final-demand block, and the consumption footprint eLy_{fd} over Spanish final demand plus direct household emissions. Per-node footprints are used for ranking and intensity comparisons only.

4.4 Sector concordance as a validated object

The mapping from 163 industries to seventeen groups is treated carefully. Three classes of error were found in an earlier vintage of the mapping and corrected, and they are reported here because the pattern generalizes.

First, semantic drift: the automotive group contained wholesale trade and retail trade, industries whose own names state that they exclude motor vehicles. As mapped, the group reported 15.9 percent of Spanish value added; vehicle and other transport-equipment manufacturing account for 3.0 percent. Every derived statistic inherited the error, and it produced a striking artifact in cross-country comparison: because the employment satellite populates retail employment for Spain but not for Germany, Spain appeared to hold 18.3 percent of its employment in the automotive group against Germany's 1.5 percent under an identical mapping. Second, category capture: a defence and aerospace group defined as air transport plus public administration and defence was 95 percent civil government by value added, while aerospace manufacturing itself sat in the automotive group under other transport equipment. The two groups exchanged the industry, and the defence group is now defined as other transport equipment, which covers aerospace, shipbuilding, and rail, the closest defensible approximation available in either classification, and is labelled as such. Third, resolution failure: the EXIOBASE classification has no pharmaceutical industry, so a pharmaceutical group mapped onto medical instruments reported identically zero for Spain; pharmaceuticals are instead reported from the INE branch that carries them.

4.5 Employment

Employment by industry is taken from Eurostat national accounts rather than from the EXIOBASE employment satellite. The satellite was checked directly against Eurostat on 85 overlapping industry cells for the five European economies: the median absolute deviation is 39 percent in the satellite's best year and 53 percent in 2022, and the satellite exhibits discontinuities, for example German motor-vehicle employment of 1.45 million (2019), zero (2020), 1.62 million (2021), and zero (2022). EXIOBASE value added and emissions do not share this defect; they reconcile against the factor-inputs block and the official inventories to within fractions of a percent. Where the satellite is used, we used data in persons instead of in hours.

4.6 Value added

Value added is computed from the nine-row factor-inputs block by exact row labels. First, one row is labelled "Operating surplus: Consumption of fixed capital", and permissive

pattern matching that puts together an operating-surplus mask and a fixed-capital mask counts it twice; for Spain in 2024 the double count is 234 of 1,404 billion euro, 16.7 percent. Second, EXIOBASE 3.10.1 leaves the product-tax row identically zero and distributes net product taxes into industries, so the factor-inputs residual reconciles to gross domestic product at market prices, not to gross value added at basic prices: for Spain in 2019 the residual is 1,245,485 million euro against an official gross domestic product of 1,245,513 million (a 0.002 percent difference), while gross value added at basic prices is 1,127,455 million. The wedge is about 10 percent and is not proportional across industries. All EXIOBASE-side value-added figures in this paper are therefore labelled inclusive of net product taxes, and official INE branch accounts are used wherever basic-price value added is required.

4.7 Trade dependence, concentration, and the supply-risk index

Two import bases are used, one per layer of the analysis. The industry-level panel behind the risk index measures imports of each product in total, intermediate plus final demand; the distinction is quantitatively important, since final-demand imports were 254.1 billion euro in 2022, 51 percent of Spain's total. The sector-group panel of Table 2 and the figures of Section 5.5 instead measure tier-one intermediate imports, the foreign inputs each group's production purchases directly, which is the relevant basis for input-cost exposure. Supplier concentration is measured by the Herfindahl-Hirschman index across supplying regions, computed twice: over all 49 regions, and excluding the five rest-of-world continental aggregates, whose treatment as single suppliers overstates concentration by a factor of two to three precisely in the energy and commodity groups where concentration matters, while the European Union is split into 26 member suppliers. Both values are reported with the aggregate share, and the truth is argued to lie between them. Regions are additionally grouped into seven geopolitical blocs (European Union 27, other Europe, United States, China, Russia, Middle East and Africa, other Asia and Americas) with each rest-of-world aggregate assigned by continent.

A composite supply-risk index combines import intensity, supplier concentration, bloc dependence, and embodied-carbon exposure. Indicators are percentile-ranked on the pooled panel across years, so that a level in one year is comparable with the same level in another, and missing indicators propagate as missing rather than defaulting to the lowest rank. And because any such index embeds arbitrary weights, the full ranking is recomputed under five alternative weighting schemes; Section 5.8 shows that the resulting rank spread is large enough that the index should be read as a screening device, not a league table. The components are also correlated: on the pooled industry panel the rank correlation is 0.69 between the China and Russia shares and 0.57 between import intensity and embodied carbon, while supplier concentration is close to orthogonal to the single-country shares, a further reason to read the index as a screen rather than a ranking.

4.8 Price basis and deflation

All within-Spain and peer time comparisons are deflated with each economy's own gross-domestic-product deflator, rebased to 2019, from the World Development Indicators (WDI). Cumulative 2019-2024 deflation ranges from 5.7 percent for China to 38.6 percent for Poland among the peers, and much further afield in the full region set. One instrument is explicitly not used: a domestic deflator, denominated in local currency, applied to euro-denominated import flows. For economies with depreciating currencies the two diverge violently; Turkey's domestic price level rose 678 percent over 2019-2024 while the lira fell by a factor of 5.8, so hard-currency Turkish prices rose roughly 34 percent, and deflating euro flows by the domestic index would erase them. Supplier-bloc trade series are therefore reported in current euro and labelled as such. A gross-domestic-product deflator is also economy-wide, and Spanish industrial producer prices moved far more than the aggregate in 2022; sector-level deflation is flagged as the binding refinement, and every published series carries an explicit price-basis label.

4.9 Reconciliation against official statistics

Table 1 reconciles the assembled accounts against official benchmarks for every native year. The production-based total, industry emissions plus direct final-demand emissions, matches the World Bank inventory to within 0.3-1.8 percent, with the small excess consistent with the residence-versus-territory difference in accounting bases. Value added matches gross domestic product to within 0.1-1.1 percent. Employment matches the official series to within 1.5-1.7 percent. The consumption footprint exceeds the production total by 17-26 percent, the expected sign and magnitude for a net importer of embodied carbon.

Table 1. Reconciliation of the assembled accounts against official statistics, Spain 2019-2022

	2019	2020	2021	2022
Industry direct emissions, Scope 1 (Mt CO ₂ e)	246.9	223.1	221.4	216.9
Direct final-demand emissions (Mt CO ₂ e)	76.3	57.2	76.6	84.3
Production-based total (Mt CO ₂ e)	323.3	280.3	298.0	301.2
Official inventory, WDI (Mt CO ₂ e)	324.2	283.7	302.7	306.6
Ratio, production total / official	0.997	0.988	0.985	0.982
Consumption footprint (Mt CO ₂ e)	390.8	328.4	359.5	379.7
Ratio, footprint / production total	1.21	1.17	1.21	1.26
Value added incl. net product taxes / official GDP	1.000	0.997	0.989	0.999
Employment / official employment	1.016	1.015	1.017	1.016

Notes: Mt CO₂e denotes megatonnes of carbon-dioxide equivalent. The official inventory is total greenhouse-gas emissions excluding land use, land-use change and forestry (AR5 global warming potentials) from the World Development Indicators; the assembled accounts use AR6 potentials on a residence basis, which explains a ratio slightly below one being consistent with a small expected excess. The consumption footprint includes direct household emissions.

5. Results

5.1 National carbon accounts

Spain's production-based industrial emissions fell from 246.9 to 216.9 megatonnes of carbon-dioxide equivalent between 2019 and 2022, a decline of 12.2 percent, while direct household and government emissions rose from 76.3 to 84.3 megatonnes as mobility recovered from the pandemic trough. The production-based total therefore declined from 323.3 to 301.2 megatonnes, tracking the official inventory closely throughout (Table 1). The consumption footprint declined less, from 390.8 to 379.7 megatonnes, so that the gap between what Spain consumes and what it produces in carbon terms widened from 21 to 26 percent of the production total: Spain's decarbonization over the period is partly the replacement of domestic emissions with imported embodied carbon, a pattern familiar from the consumption-accounting literature and directly relevant to how the country should read its own progress.

5.2 The economic weight of the strategic groups

Table 2 gives the 2022 cross-section. Measured on the official INE branch accounts, the seventeen groups jointly hold 27.1 percent of Spanish gross value added and 21.1 percent of employment, counting the plastics group only once since it is contained in chemicals. Construction (73.7 billion euro of value added, 1.41 million jobs) and agri-food (66.2 billion, 1.22 million) are the heavyweights, followed by data centres and telecommunications (42.8 billion) and the fuels group (35.7 billion). The automotive group proper, vehicle manufacturing plus components, holds 31.6 billion euro and 429 thousand jobs. At the other end, cement and ceramics are small in value terms, near 2.3-2.4 billion euro each, but appear prominently in the carbon columns; the asymmetry between economic size and emissions weight is key to understand transition challenges for Spain.

Table 2. The seventeen strategic groups in 2022: official weights and EXIOBASE carbon and trade indicators

Group	GVA (€m, INE)	% of GVA	Jobs (000s, INE)	Mt CO ₂ e	kg CO ₂ e/€	Imports (€m)	China share (%)
Construction	73,730	5.9	1,413	14.6	0.16	5,000	11.5
Agri-food	66,192	5.3	1,215	155.7	0.72	29,299	5.1
Data centres & telecom	42,806	3.4	626	6.3	0.07	5,376	9.2
Energy: fuels	35,669	2.8	20	100.6	0.94	40,486	1.0
Automotive	31,606	2.5	429	19.6	0.11	6,653	11.9
Chemicals	17,736	1.4	178	41.1	0.41	14,537	8.0
Steel	17,610	1.4	267	49.2	0.37	24,071	5.2
Energy: generation	11,592	0.9	6	48.2	2.73	1,577	6.6
Energy: transmission & distr.	8,925	0.7	5	4.0	0.29	1,083	11.9
Textiles	8,600	0.7	126	10.2	0.23	5,535	14.3
Plastics	7,548	0.6	97	31.3	0.42	12,456	8.1

Group	GVA (€m, INE)	% of GVA	Jobs (000s, INE)	Mt CO ₂ e	kg CO ₂ e/€	Imports (€m)	China share (%)
Pharmaceuticals	6,889	0.5	42	n.a.	n.a.	n.a.	n.a.
Mining	6,350	0.5	19	12.6	0.56	5,085	7.3
Paper & board	4,891	0.4	55	15.2	0.55	3,826	5.3
Defence & aerospace (OTE)	3,369	0.3	35	4.3	0.19	2,615	8.2
Cement	2,405	0.2	32	22.9	2.69	1,580	6.2
Ceramics	2,254	0.2	30	6.0	0.76	1,043	11.9

Notes: GVA denotes gross value added; OTE denotes other transport equipment (aerospace, naval, rail). GVA, its national share, and jobs are from the INE branch accounts at basic prices. Emissions (total Scope 1 + 2 + 3 footprint of gross output), carbon intensity, tier-one intermediate imports, and China's share of those imports are computed from EXIOBASE as described in Section 4. Pharmaceuticals cannot be resolved in the EXIOBASE classification and is reported from INE only. Plastics is a subset of chemicals and is never added to it. Emissions and monetary indicators come from different accounting layers and are never combined inside a single ratio.

5.3 Carbon intensity and where the emissions sit

Carbon intensity spans two orders of magnitude across the groups: from 0.07 kilograms of carbon-dioxide equivalent per euro of output in data centres and telecommunications to 2.69 in cement and 2.73 in electricity generation. Seven of the sixteen measurable groups sit above the basket average. The scope composition is as informative as the level. Scope 3, emissions embodied in purchased inputs other than electricity, is the largest of the three scopes in 13 of the 16 groups and carries 58 percent of the basket's total footprint; only cement, ceramics, and electricity generation are dominated by their own combustion. The implication is that for most of Spain's analyzed industries, the mitigation sits upstream, in the peer's electricity mix, the materials they purchase, and their import composition.

The trajectory over 2019-2022 adds a caution. Intensity declined in most groups, but it rose precisely where it was already highest: in current prices cement moved from 1.57 to 2.69 kilograms per euro, an increase of 72 percent (roughly 56 percent after deflation to constant 2019 prices), driven by output contraction against sticky process emissions, and electricity generation rose 9 percent to 2.73 as the 2022 fuel crisis pushed gas-fired output. Aggregate progress across the basket coexists with deterioration in the two most carbon-intensive groups.

5.4 Spain against its peers

Table 3 compares carbon intensity by group across the seven economies on the identical industry basket. Spain's basket-wide intensity, 0.47 kilograms per euro, exceeds Germany's 0.34 and France's 0.30, sits close to Italy's 0.42 and the United States' 0.43, and is well below Poland's 0.79 and China's 1.60; against the EU-27 average of roughly 0.40 computed on the same basket, Spain is about 16 percent more carbon-intensive, a result that is robust across all vintages of the sector mapping. Second, the aggregate gap decomposes very unevenly. Spanish cement runs at 2.8 times the German intensity and

2.3 times the peer median; Spanish ceramics at roughly twice the German and French levels; Spanish agri-food carries 0.72 against 0.52 in Germany and 0.46 in the United States. In the opposite direction, the Spanish automotive group is the cleanest per euro of all seven economies at 0.108, roughly half the German level, and Spanish electricity generation (2.73) is far below Poland (13.9), the United States (7.8), and Germany (4.5), though four times France's nuclear-dominated 0.67. Under a border-adjustment regime that prices embodied carbon, these sector-level positions, not the national average, determine who gains and who pays.

Table 3. Carbon intensity of gross output by group and economy, 2022 (kg CO₂e per euro, current basic prices)

Group	ES	DE	FR	IT	PL	US	CN
Agri-food	0.72	0.52	0.59	0.60	1.09	0.46	1.09
Automotive	0.11	0.19	0.14	0.17	0.37	0.28	0.75
Cement	2.69	0.95	0.84	1.11	1.59	1.20	6.85
Ceramics	0.76	0.39	0.33	0.59	0.54	0.76	1.54
Chemicals	0.41	0.27	0.22	0.34	0.70	0.58	1.80
Construction	0.16	0.22	0.20	0.22	0.47	0.33	1.24
Data centres & telecom	0.07	0.04	0.05	0.05	0.12	0.12	0.46
Defence & aerospace (OTE)	0.19	0.13	0.15	0.17	0.44	0.23	1.15
Energy: fuels	0.94	0.46	0.36	0.72	0.53	1.43	1.33
Energy: generation	2.73	4.51	0.67	1.42	13.89	7.81	14.52
Energy: transmission & distr.	0.29	0.69	0.42	0.56	0.21	0.08	15.02
Mining	0.56	0.72	0.42	0.59	1.59	0.14	1.72
Paper & board	0.55	0.51	0.39	0.46	0.73	0.47	1.65
Plastics	0.42	0.27	0.22	0.35	0.62	0.48	1.52
Steel	0.37	0.37	0.32	0.43	0.72	0.55	1.99
Textiles	0.23	0.19	0.15	0.19	0.35	0.24	0.66
All groups (basket)	0.47	0.34	0.30	0.42	0.79	0.43	1.60

Notes: total (Scope 1 + 2 + 3) footprint of gross output divided by gross output, computed from EXIOBASE 3.10.1 with the decomposition of Section 4.2, on the identical basket of mapped industries in every economy. ES: Spain; DE: Germany; FR: France; IT: Italy; PL: Poland; US: United States; CN: China. Pharmaceuticals is omitted (not resolvable in the classification).

Specialization patterns contextualize the intensity gaps. Spain's automotive group holds 9.0 percent of national value added on the EXIOBASE measure, the highest share among the seven economies (Germany 4.3 percent), while Spain is thin in chemicals, 1.3 percent of value added against Germany's 4.3, and in data centres and telecommunications, 3.9 percent against Germany's 8.7 and the United States' 7.2. Poland stands out for the employment weight of these industries generally; Spain's employment concentration is highest in construction and agri-food.

5.5 Import dependence and supplier concentration

Measured on tier-one intermediate imports, supply to the seventeen groups is dominated by the EU-27, which provides close to half of imports for most groups: 50 percent for agri-food, 52 percent for steel, 53 percent for the automotive group. Two structural exceptions carry most of the geopolitical exposure. The fuels group imports 40.5 billion euro, by far the largest import bill of the seventeen, of which only 7.6 percent comes from the EU-27 while 42.6 percent comes from the Middle East and Africa and a further 3.6 percent from Russia; its import intensity, imports relative to gross output, is 38 percent, the highest of the seventeen and well above the next highest, mining at 23 percent. And China's supplier share, while moderate at group level, peaks in textiles (14.3 percent), the automotive group, ceramics, and electricity transmission and distribution (each near 12 percent), and rises dramatically at finer industry resolution: for electrical machinery and apparatus, an input to the electricity and digital groups, China supplies roughly 70 percent of Spanish imports and the supplier Herfindahl-Hirschman index reaches 0.82.

5.6 Where the carbon in the supply chains comes from

Decomposing each group's footprint intensity by the region of the emitting supplier shows that Spain's strategic-industry carbon is still mostly domestic, but unevenly so. In cement, 85 percent of the embodied carbon per euro originates in Spain, and in agri-food 79 percent, consistent with process- and land-based emissions close to home. The automotive group is the mirror image: under half of its embodied carbon per euro is domestic, with the rest imported through the components chain, so its exposure to carbon pricing arrives mainly through its suppliers. Steel is similar, with 44 percent of its embodied carbon domestic and "other Asia" the largest foreign source; in fuels, 60 percent is domestic and most of the remainder originates in the Middle East and Africa. The supplier-origin split reconciles back to each group's total intensity to numerical precision, a property guaranteed by the decomposition of Section 4.2.

5.7 Competitiveness in value-added terms

Table 4 reports domestic value added ultimately absorbed abroad and the revealed-comparative-advantage index computed on it. In 2022, 198.8 billion euro of the seventeen groups' value added was absorbed by foreign final demand; the sum counts the plastics group's 6.9 billion twice, since plastics is contained in chemicals, and the union net of that overlap is roughly 192 billion. The largest absolute contributions come from the automotive group (38.4 billion), agri-food (37.3 billion), construction (35.5 billion, largely embodied in other exported products and services), and steel (31.1 billion). Export orientation varies widely: ceramics sells 75 percent of its value added to the world, the defence and aerospace group 73 percent, and cement 67 percent, against 18 percent for data centres and telecommunications. On the Balassa index over the six peers, Spain is specialized above parity in six groups, most strongly construction (15.0) and the automotive group (3.1), with agri-food, transmission and distribution, the defence group,

and steel just above one; it is markedly under-specialized in mining (0.04), chemicals, data centres, plastics, and textiles.

Table 4. Value-added exports and revealed comparative advantage, 2022

Group	DVAX (€m)	Share of basket DVAX (%)	DVAX / GVA (%)	RCA
Automotive	38,371	19.3	31.7	3.11
Agri-food	37,342	18.8	51.6	1.19
Construction	35,459	17.8	47.0	15.04
Steel	31,150	15.7	53.3	1.01
Textiles	9,892	5.0	62.0	0.49
Data centres & telecom	9,561	4.8	18.3	0.37
Chemicals	8,714	4.4	49.6	0.37
Defence & aerospace (OTE)	7,201	3.6	73.1	1.04
Plastics	6,883	3.5	47.3	0.46
Energy: generation	3,253	1.6	48.4	1.00
Energy: fuels	3,241	1.6	26.0	0.76
Paper & board	3,120	1.6	50.5	0.92
Ceramics	2,386	1.2	75.2	0.61
Energy: transmission & distr.	1,316	0.7	33.4	1.53
Mining	635	0.3	53.7	0.04
Cement	267	0.1	66.9	0.61

Notes: DVAX denotes domestic value added absorbed by foreign final demand, computed through the global Leontief inverse so that intermediates crossing borders repeatedly are not double counted. RCA is the Balassa index of each group's share in Spanish DVAX relative to its share in the DVAX of the six-peer set (Germany, France, Italy, Poland, United States, China). GVA here is the EXIOBASE-side measure inclusive of net product taxes. Values in current euro. The basket-share column includes the plastics-chemicals overlap.

5.8 How much do composite risk rankings mean?

Table 5 reports the ten industries with the highest composite supply-risk score in 2022 at full industry resolution, together with their ranks under four alternative weighting schemes and the spread across all five. A handful of exposures are robust: coal and lignite mining, air transport, nitrogen fertilizer and above all electrical machinery, which ranks first under three of the five schemes, never leaves the top ten, and combines a 70 percent China supplier share with extreme concentration. It is important to note that these rankings vary substantially. Electricity from coal ranks tenth at baseline and sixty-first when the geopolitical indicators are emphasized; the petroleum refinery moves across 24 ranks; meat production across 19. The median rank spread among the top 25 baseline entries exceeds 15 positions. Composite indices of this kind are useful as screening devices to shortlist industries for qualitative scrutiny; presented as point rankings, they manufacture precision that the underlying indicators cannot support.

Table 5. Top-10 composite supply-risk industries, 2022, and rank sensitivity to indicator weights

Industry	Baseline	Equal	Geopolitical	No carbon	Concentration	Spread
Mining of coal and lignite; peat	1	1	6	6	4	5
Air transport	2	2	5	3	6	4
Electrical machinery and apparatus	3	10	1	1	1	9
Nitrogen fertilizer	4	6	8	2	5	6
Meat animals n.e.c.	5	3	10	14	22	19
Cultivation of oil seeds	6	11	9	9	14	8
Petroleum refinery	7	4	13	13	28	24
Ceramic goods	8	16	14	12	26	18
Coke oven products	9	5	16	24	35	30
Electricity by coal	10	19	61	21	2	59

Notes: ranks under five weighting schemes over percentile-ranked indicators of import intensity, supplier concentration, bloc dependence, and embodied-carbon exposure, pooled across 2019-2022. Spread is the difference between each industry's best and worst rank. n.e.c. denotes not elsewhere classified.

6. Discussion

Read together, the results organize Spain's strategic industries into three policy positions. A first group is competitive and comparatively clean: the automotive industry combines the strongest manufacturing specialization in the peer set with the lowest carbon intensity per euro among the seven economies, which under a border-adjusted carbon price is an asset; its main vulnerability is upstream, since most of its embodied carbon and much of its input risk arrive through the components chain. A second group is competitive but exposed: ceramics and cement sell two thirds to three quarters of their value added abroad while running at two to three times the intensity of the best European producers, so the same trade orientation that makes them valuable makes them the exposed to carbon pricing at the border unless their process emissions fall. A third group is strategic and vulnerable on the import side: fuels, with the largest import bill, the highest import intensity, and a supplier base concentrated outside Europe; and specific manufactured inputs, led by electrical machinery, where a single supplier holds around 70 percent of the market.

Two cross-cutting implications follow. First, because Scope 3 dominates the footprint of thirteen of sixteen groups, sectoral decarbonization policy aimed at the firms' own emissions addresses a minority of the relevant carbon; the levers with basket-wide reach are the electricity mix, materials substitution, and the carbon content of imports. Spain's electricity generation is already far cleaner than the coal-heavy benchmarks and four times dirtier than France's, so continued grid decarbonization propagates mechanically into every group's Scope 2 and, through domestic supply chains, into Scope 3. No double counting arises between the two: Scope 2 contains only a sector's own electricity purchases, while the electricity its suppliers consume is embedded in the suppliers' total intensities and reaches the sector through Scope 3, so each tonne of generation emissions enters a given footprint once. Second, the widening gap between Spain's consumption footprint and its production-based total is a reminder that national

decarbonization achieved through import substitution of embodied carbon is partly an accounting transfer; border carbon pricing will progressively expose this margin.

7. Limitations

The industry resolution of EXIOBASE cannot isolate defence or aerospace manufacturing, which is proxied by the whole of other transport equipment including shipbuilding and rail, and contains no pharmaceutical industry at all, so that group rests on national-accounts. The monetary tables exist only in current basic prices; deflation with economy-wide gross-domestic-product deflators corrects the aggregate but understates relative price movements in energy-intensive sectors during 2021-2022, so the intensity trends of Section 5.3 carry wider uncertainty than the levels. Supplier-bloc trade series remain in current euro pending import unit-value indices, since domestic deflators are the wrong instrument for cross-currency flows. The 2023 and 2024 tables were excluded from all emissions work for the reasons of Section 3.2, which limits the sample to a period bracketed by a pandemic and an energy crisis; structural interpretation of the trends should be correspondingly modest. Value added on the EXIOBASE side includes net product taxes and exceeds basic-price value added by roughly 10 percent non-uniformly across industries, which is why official branch accounts are used for national weights. Emissions are compiled on a residence basis against territory-based official inventories, with an expected wedge of a few percent. Finally, the composite risk index inherits the arbitrariness of any weighted index; it is presented with its sensitivity bounds and should not be consumed without them.

8. Conclusion

Spain's strategic basket is somewhat more carbon-intensive than its main European competitors, but the gap lives in four groups out of the seventeen analyzed; most of the basket's carbon sits upstream, in electricity and purchased inputs, where policy leverage is collective rather than sectoral; competitiveness in value-added terms is concentrated, led by an automotive industry that would enter carbon-pricing with a genuine intensity advantage; and import vulnerability is dominated by fuels and a short list of electrical inputs rather than by generalized dependence.

9. References

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Appendix A. The sector concordance

Table A1 gives the full concordance: for each of the seventeen groups, the EXIOBASE industries it contains after the corrections described in Section 4.4, the INE branches used for the official national weights, and the forty industries left outside the mapping. A machine-readable version, with a tier attribute and a changelog recording every departure from the original mapping together with its measured effect, accompanies the replication files.

Table A1. The full sector concordance: each group's EXIOBASE industries and INE branches

Group	EXIOBASE industries (official names)
Agri-food (34) Agroindustria	Animal products nec; Cattle farming; Composting of food waste, incl. land application; Cultivation of cereal grains nec; Cultivation of crops nec; Cultivation of oil seeds; Cultivation of paddy rice; Cultivation of plant-based fibers; Cultivation of sugar cane, sugar beet; Cultivation of vegetables, fruit, nuts; Cultivation of wheat; Fishing, operating of fish hatcheries and fish farms; service activities incidental to fishing (05); Forestry, logging and related service activities (02); Incineration of waste: Food; Landfill of waste: Food; Manufacture of beverages; Manufacture of fish products; Manufacture of tobacco products (16); Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials (20); Manure treatment (conventional), storage and land application; Meat animals nec; Pigs farming; Poultry farming; Processed rice; Processing of Food products nec; Processing of dairy products; Processing of meat cattle; Processing of meat pigs; Processing of meat poultry; Processing vegetable oils and fats; Production of meat products nec; Raw milk; Sugar refining; Waste water treatment, food
Automotive (2) Automoción	Manufacture of motor vehicles, trailers and semi-trailers (34); Sale, maintenance, repair of motor vehicles, motor vehicles parts, motorcycles, motor cycles parts and accessories
Cement (2) Cemento	Manufacture of cement, lime and plaster; Re-processing of ash into clinker
Ceramics (4) Cerámica	Manufacture of bricks, tiles and construction products, in baked clay; Manufacture of ceramic goods; Manufacture of glass and glass products; Re-processing of secondary glass into new glass
Chemicals (8) Química	Chemicals nec; Incineration of waste: Plastic; Landfill of waste: Plastic; Manufacture of rubber and plastic products (25); N-fertiliser; P- and other fertiliser; Plastics, basic; Re-processing of secondary plastic into new plastic
Construction (2) Construcción	Construction (45); Re-processing of secondary construction material into aggregates
Data centres & telecom (4) Centros de Datos (Teleco)	Computer and related activities (72); Manufacture of office machinery and computers (30); Manufacture of radio, television and communication equipment and apparatus (32); Post and telecommunications (64)
Defence & aerospace (OTE) (1) Defensa y Aeronáutica	Manufacture of other transport equipment (35)
Energy: fuels (7) Energía - Combustibles y otros	Biogasification of food waste, incl. land application; Biogasification of paper, incl. land application; Biogasification of sewage sludge, incl. land application; Manufacture of gas; distribution of gaseous fuels through mains; Manure treatment (biogas), storage and land application; Petroleum Refinery; Processing of nuclear fuel
Energy: generation (12) Energía - Generación	Production of electricity by Geothermal; Production of electricity by biomass and waste; Production of electricity by coal; Production of electricity by gas; Production of electricity by hydro; Production of electricity by nuclear; Production of electricity by petroleum and other oil derivatives; Production of electricity by solar photovoltaic; Production of electricity by solar thermal; Production of electricity by tide, wave, ocean; Production of electricity by wind; Production of electricity nec

Group	EXIOBASE industries (official names)
Energy: transmission & distr. (2) Energía - Transporte y Distribución	Distribution and trade of electricity ; Transmission of electricity
Mining (15) Minería	Extraction of crude petroleum and services related to crude oil extraction, excluding surveying ; Extraction of natural gas and services related to natural gas extraction, excluding surveying ; Extraction, liquefaction, and regasification of other petroleum and gaseous materials ; Mining of aluminium ores and concentrates ; Mining of chemical and fertilizer minerals, production of salt, other mining and quarrying n.e.c. ; Mining of coal and lignite; extraction of peat (10) ; Mining of copper ores and concentrates ; Mining of iron ores ; Mining of lead, zinc and tin ores and concentrates ; Mining of nickel ores and concentrates ; Mining of other non-ferrous metal ores and concentrates ; Mining of precious metal ores and concentrates ; Mining of uranium and thorium ores (12) ; Quarrying of sand and clay ; Quarrying of stone
Paper & board (6) Papel y Cartón	Composting of paper and wood, incl. land application ; Incineration of waste: Paper ; Landfill of waste: Paper ; Paper ; Pulp ; Re-processing of secondary paper into new pulp
Pharmaceuticals (1) Farmacéutica	Manufacture of medical, precision and optical instruments, watches and clocks (33)
Plastics (3) Plásticos	Manufacture of rubber and plastic products (25) ; Plastics, basic ; Re-processing of secondary plastic into new plastic
Steel (17) Siderurgia	Aluminium production ; Casting of metals ; Copper production ; Incineration of waste: Metals and Inert materials ; Landfill of waste: Inert/metal/hazardous ; Lead, zinc and tin production ; Manufacture of basic iron and steel and of ferro-alloys and first products thereof ; Manufacture of fabricated metal products, except machinery and equipment (28) ; Manufacture of other non-metallic mineral products n.e.c. ; Other non-ferrous metal production ; Precious metals production ; Re-processing of secondary aluminium into new aluminium ; Re-processing of secondary copper into new copper ; Re-processing of secondary lead into new lead, zinc and tin ; Re-processing of secondary other non-ferrous metals into new other non-ferrous metals ; Re-processing of secondary precious metals into new precious metals ; Re-processing of secondary steel into new steel
Textiles (6) Textil	Incineration of waste: Textiles ; Landfill of waste: Textiles ; Manufacture of textiles (17) ; Manufacture of wearing apparel; dressing and dyeing of fur (18) ; Tanning and dressing of leather; manufacture of luggage, handbags, saddlery, harness and footwear (19) ; Wool, silk-worm cocoons
Outside the mapping (40) Otros / revisar	Activities auxiliary to financial intermediation (67) ; Activities of membership organisation n.e.c. (91) ; Air transport (62) ; Collection, purification and distribution of water (41) ; Education (80) ; Extra-territorial organizations and bodies ; Financial intermediation, except insurance and pension funding (65) ; Health and social work (85) ; Hotels and restaurants (55) ; Incineration of waste: Oil/Hazardous waste ; Incineration of waste: Wood ; Inland water transport ; Insurance and pension funding, except compulsory social security (66) ; Landfill of waste: Wood ; Manufacture of coke oven products ; Manufacture of electrical machinery and apparatus n.e.c. (31) ; Manufacture of furniture; manufacturing n.e.c. (36) ; Manufacture of machinery and equipment n.e.c. (29) ; Other business activities (74) ; Other land transport ; Other service activities (93) ; Private households with employed persons (95) ; Public administration and defence; compulsory social security (75) ; Publishing, printing and reproduction of recorded media (22) ; Re-processing of secondary wood material into new wood material ; Real estate activities (70) ; Recreational, cultural and sporting activities (92) ; Recycling of bottles by direct reuse ; Recycling of waste and scrap ; Renting of machinery and equipment without operator and of personal and household goods (71) ; Research and development (73) ; Retail sale of automotive fuel ; Retail trade, except of motor vehicles and motorcycles; repair of personal and household goods (52) ; Sea and coastal water transport ; Steam and hot water supply ; Supporting and auxiliary transport activities; activities of travel agencies (63) ; Transport via pipelines ; Transport via railways ; Waste water treatment, other ; Wholesale trade and commission trade, except of motor vehicles and motorcycles (51)

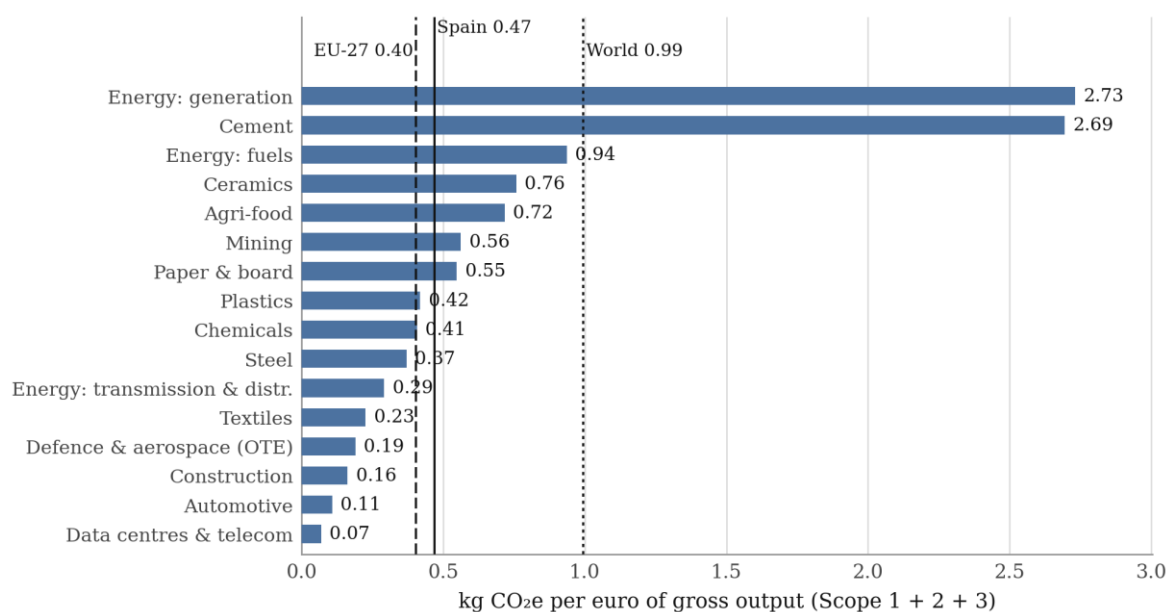
Notes: OTE denotes other transport equipment (aerospace, naval, rail). Numbers in parentheses count each group's EXIOBASE industries. In the INE column, a percentage denotes the share of a branch that several groups split; the shares are allocated by EXIOBASE output. The three plastics industries appear in both Plastics

and Chemicals by design and are never summed. The industry mapped to Pharmaceuticals carries no Spanish output in EXIOBASE, so that group is reported from the INE branch accounts only.

Appendix B. Principal figures

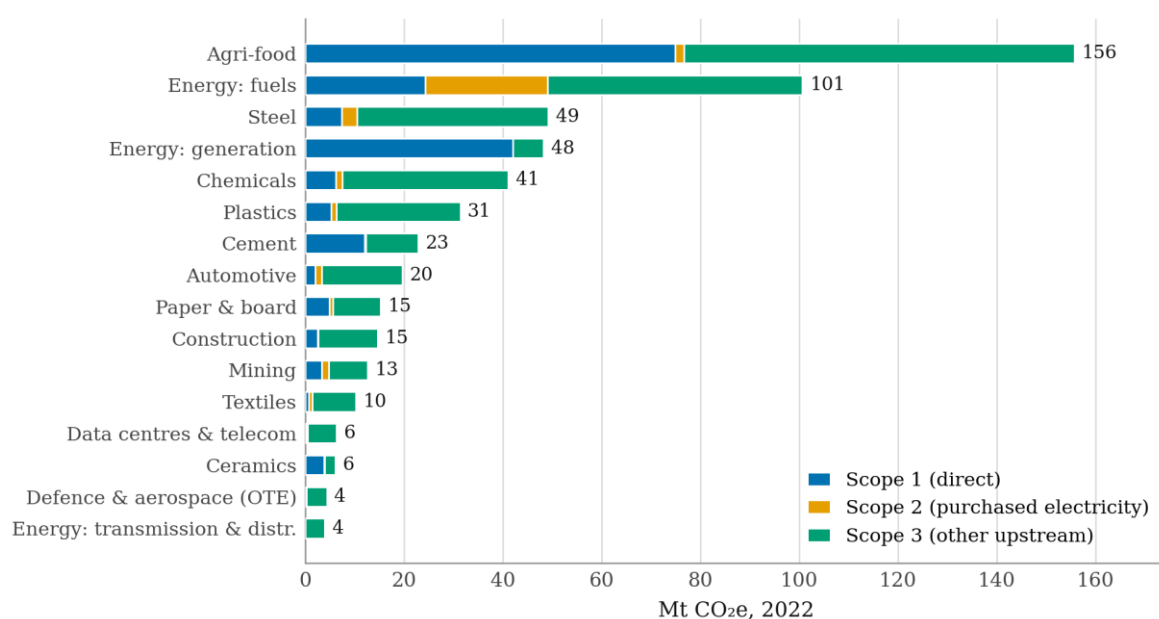
Figures B1 to B5 collect the principal graphical results for the 2022 cross-section: the carbon-intensity ranking against the three benchmarks, the scope decomposition, the peer comparison, the geographic origin of the carbon embedded in each group's supply chain, and the competitiveness map. All values are computed from EXIOBASE 3.10.1 as described in Section 4; monetary aggregates are in current basic prices. Pharmaceuticals is not resolvable in the EXIOBASE classification and is absent throughout.

Figure B1. Carbon intensity of gross output by group, Spain, 2022



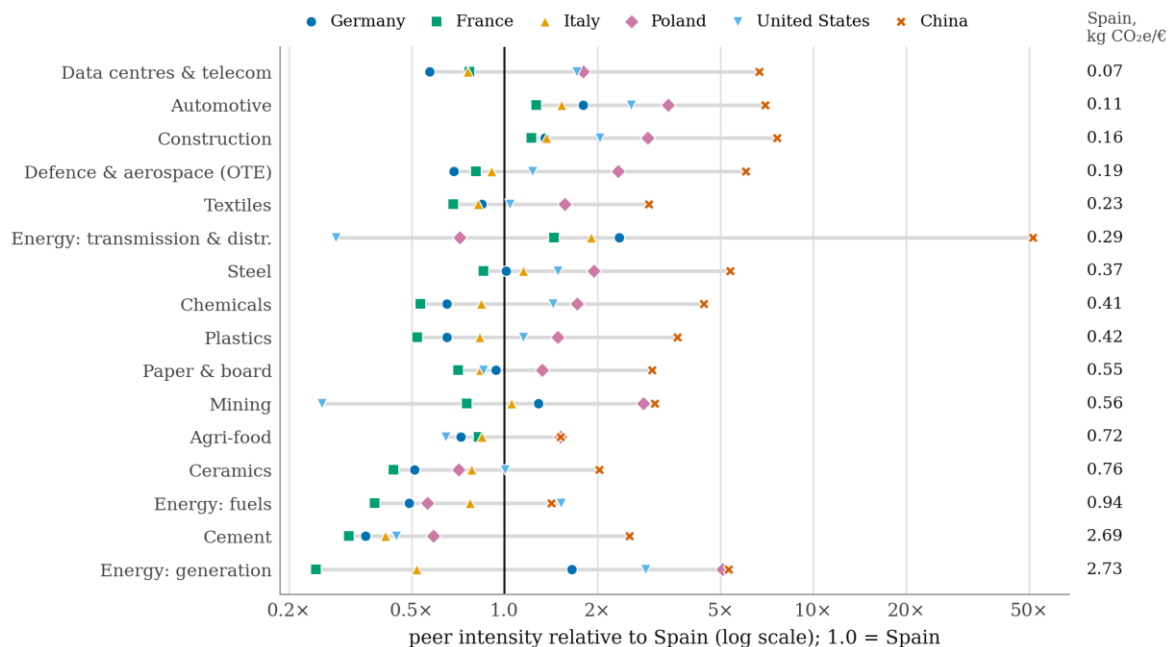
Notes: total (Scope 1 + 2 + 3) footprint per euro of gross output. The vertical lines are output-weighted averages over the identical basket of mapped industries: Spain 0.47, EU-27 0.40, world 0.99 kg CO₂e per euro. Source: EXIOBASE 3.10.1; own calculations.

Figure B2. The scope decomposition of each group's footprint, 2022



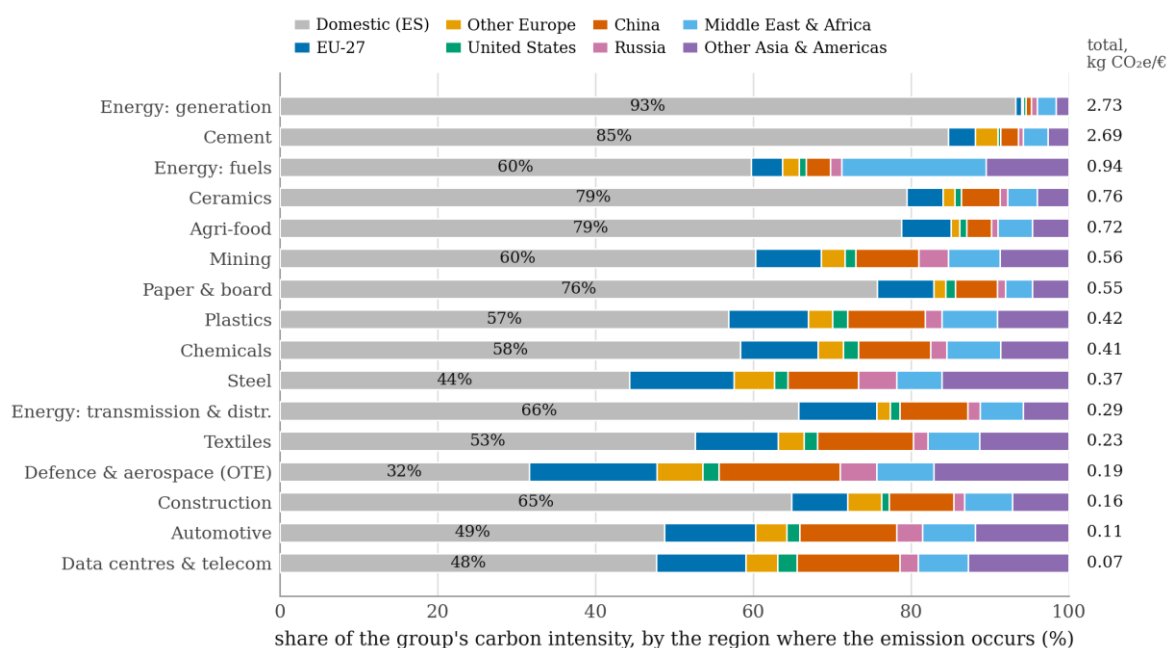
Notes: the exact additive decomposition of equation (2). Scope 2 covers purchased electricity, steam and heat; Scope 3 all other upstream emissions. Bar-end labels give the total in Mt CO₂e. Source: EXIOBASE 3.10.1; own calculations.

Figure B3. Carbon intensity relative to Spain, six peer economies, 2022



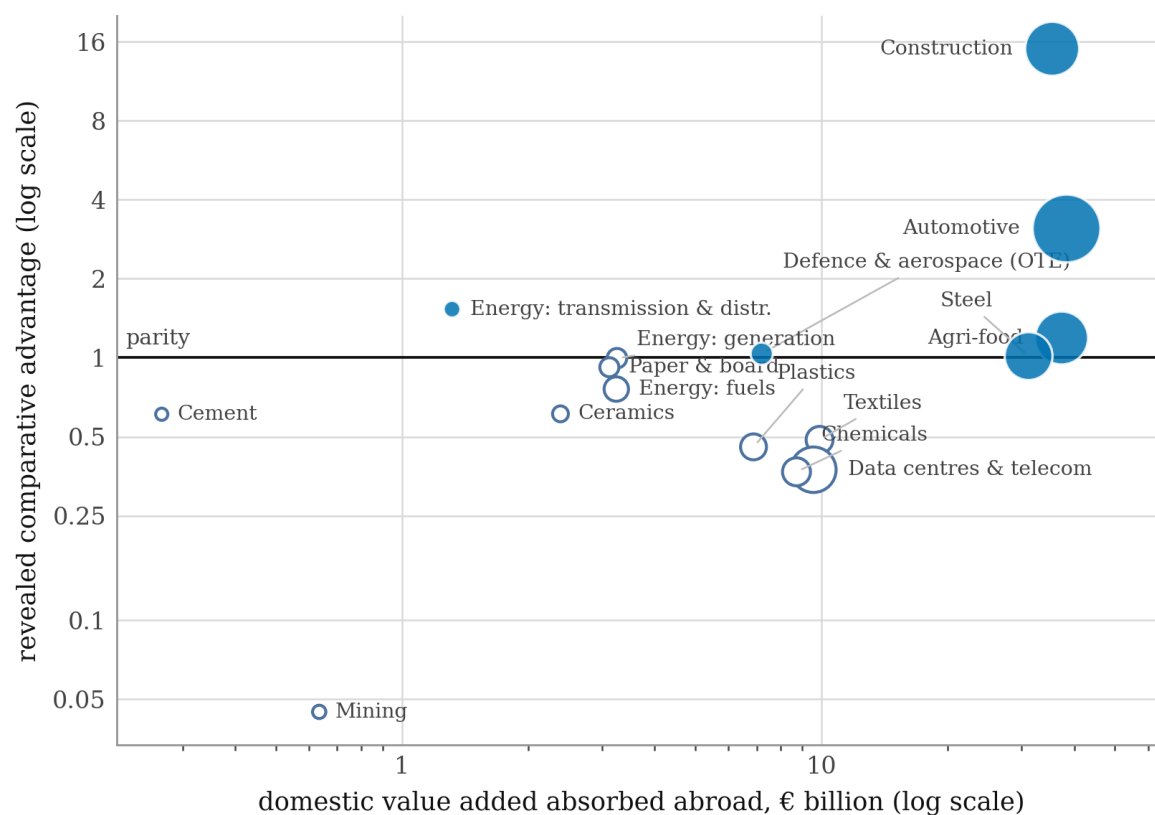
Notes: each marker is a peer's intensity for the group divided by Spain's, on a log scale; markers right of the line at 1.0 are more carbon-intensive than Spain. Spain's own level in kg CO₂e per euro appears in the right-hand column. Source: EXIOBASE 3.10.1; own calculations.

Figure B4. Where the carbon in the supply chains originates, 2022



Notes: full multi-tier attribution of each group's footprint intensity to the region where the emission physically occurs; shares sum to 100 percent and the group's total intensity appears in the right-hand column. The split reconciles to each group's intensity to numerical precision (Section 4.2). Source: EXIOBASE 3.10.1; own calculations.

Figure B5. The competitiveness map: scale abroad against specialization, 2022



Notes: the horizontal axis is domestic value added ultimately absorbed by foreign final demand; the vertical axis is the Balassa index over the six-peer set, with filled markers above parity. Bubble area is proportional to the group's value added. Source: EXIOBASE 3.10.1; own calculations.