The 2023 edition of the OECD Analytical AMNE Database: methodology and new evidence on the role of multinational production in global value chains

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Abstract: Inter-country input-output (ICIO) tables and the global Leontief inverse have made it possible to measure international trade flows in value added terms rather than in gross terms and to identify the contribution of each country and industry to the value of final products. One aspect that this strand of literature has struggled to shed light on is the role of multinational enterprises (MNEs). MNEs are very important actors in global value chains (GVCs) and, while their foreign affiliates undisputedly contribute to value added in the host countries, they are also likely to retain strong ties with the parent economy. Thus, understanding the relative contribution made by domestic- and foreign-owned firms in global production can be a matter of great interest for policymakers. In this paper, we first discuss the latest update of the OECD Analytical AMNE database which extends the OECD ICIO tables by an ownership dimension for the period of 2000-2019. In a second part, we present empirical evidence on the role of multinational production in global value chains over the past two decades.

Introduction

The development of Inter-Country Input-Output (ICIO) tables has been a significant step towards better understanding global value chains (GVCs). These tables have allowed researchers and policymakers to measure trade in value-added terms and to identify the contribution of each country and industry to the value of final products. However, GVCs are not only composed of independent companies exporting and importing intermediate and final products. Many of the firms involved are multinational enterprises (MNEs) who have a network of foreign affiliates resulting from their foreign direct investment.

The activities of these MNEs have traditionally attracted a lot of policy attention. On the one hand, governments are keen to attract foreign direct investment because MNEs promote growth and employment by creating new jobs and by encouraging technology spillovers to domestic firms. On the other hand, activities of MNEs can raise concerns about profit shifting, responsible business conduct or a race to the bottom to attract foreign firms.

Despite the great interest and often heated debates around MNEs, empirical evidence on their activities is not widely available and largely incomplete, with data only available for a small number of economies. Furthermore, such data generally focus on activities of foreign affiliates, i.e. the activities of subsidiaries established by MNEs abroad, with data on the activities of MNEs in the home country even scarcer. To provide a better understanding of the activities of MNEs and the interdependencies of trade and investment in GVCs, the OECD developed the Analytical AMNE (AAMNE) database. This comprehensive database, which is publicly available, covers 77 economies and 41 industries over the period 2000-2019 in its 2023 edition (see Appendix).

The AAMNE database includes a set of ICIO tables derived from OECD ICIOs that are split according to ownership. Each row in these input-output tables (referring to output in a specific country and industry) is split between the output of domestic-owned firms and foreign-owned firms. Similarly, each column in the intermediate consumption matrix distinguishes inputs used by domestic-owned and foreign-owned firms

in each country and industry. In an additional set of ICIOs, rows and columns include a further split for the activities of domestic MNEs, as opposed to firms not involved in international investment.

1. Construction of the OECD AAMNE database

Data sources and methodology overview

The OECD AAMNE database is built on two main data sources: (1) data on the activities of multinational enterprises (AMNE) from official statistics, and (2) the OECD Inter-Country Input-Output (ICIO) tables.

Official statistics on the activities of MNEs are collected and published by national statistical offices and central banks, with data for many economies being available centrally in the OECD AMNE database and Eurostat. The coverage of AMNE data has been increasing over time, with a particularly good coverage for the United States and most EU countries (as an EU regulation obliges countries to provide AMNE data to Eurostat). The OECD AMNE database contains data for 33 OECD countries, more than 50 industries with the first year of reporting 1985. However, information is not equally available across countries, industries and years with data typically less available for earlier years and more disaggregated levels (e.g. bilateral at industry level). In addition to supplement these data sources, the construction also draws on information from foreign direct investment (FDI) statistics and the OECD Trade by Enterprise Characteristics (TEC) dataset.

The second main data source, the OECD ICIO tables, are harmonised global input-output tables built on the basis of national supply and use tables, trade data and other national accounts data. In this work, a preliminary version of the forthcoming 2023 OECD ICIO table release was used which covers 76 economies plus the rest of the world and 45 industries for the period of 1995-2020 in current basic prices. Due to limited data availability of AMNE statistics, the ICIO tables are collapsed to 41 sectors and the period covered limited to 2000-2019.

Building on these data sources, the methodology to construct the analytical AMNE database consists of two parts. In the first step, we estimate a breakdown of gross output, value added, exports and imports of intermediate inputs by ownership status (domestic versus foreign) for every industry, country and year. An important part of this process is the construction of a bilateral matrix of gross output. Year by year and industry by industry, this matrix breaks down global gross output along to dimensions: i) the country in which production takes place; ii) the country in which the controlling entity is based. (Clearly, in the case of domestic-owned firms, the two coincide.) Constructing such matrix poses various methodological challenges, ranging from reconciling AMNE statistics with the national accounts, to missing value imputation and balancing for accounting consistency. Once available, the ownership-split dataset is a key input for the second step of the procedure, in which it is used to disaggregate the ICIOs through a quadratic optimization approach. In practice, the entries of the Analytical AMNE are calculated as the solution to a constrained minimization problem. The objective function is a weighted sum of the square deviations from the estimates of value added, import and export by ownership obtained in the first step, as well as from a set of starting values generated under various proportionality assumptions. The main constraints, on the other hand, are that the Analytical AMNE aggregate values back to the original ICIO and that output by ownership matches the exogenous estimates in all countries and industries. This methodology is described in more detail in the following sections.

Populating an initial output matrix

To estimate a balanced bilateral output matrix, differences between AMNE and SNA statistics need to be reconciled. For each AMNE data source, sectors are converted from their national classification to consistent ISIC revision 4. In some cases, the conversion involves splitting the data to estimate values for sub-sectors where possible. The second step of harmonisation consists in converting turnover data to output

data (when only the turnover or sales are available). Turnover corresponds to the revenue of firms while gross output refers to production. When only turnover is available, the equivalent output needs to be estimated. This adjustment is based on data from countries with both turnover and output information. The ratio of gross output to turnover is calculated and applied to the turnover values.

The sector that is most adjusted is the wholesale and retail trade sector where turnover includes the value of all the goods sold while gross output is based on the margin of the wholesaler or retailer. Overall, adjusting for output reduces the total AMNE turnover in an economy by about one third.

From the harmonised AMNE statistics we compile an initial bilateral output matrix at the host-industry-parent level, as well as a set of constraints matrices on the output of foreign- and domestic-owned firms at the host, host-industry, parent, parent-industry, and parent-host level. These values are the first building block of the bilateral output matrix.

Estimating missing values

Official data sources do not cover all the year-host-parent-industry combinations needed for the construction of the output matrix and a significant number of data points are missing. When there is no observation on the activities of MNEs, these data are estimated using a gravity model in order to construct the remainder of the pre-optimisation matrix of output by year, host country, country of ownership and industry.

The gravity dataset comprises 198 countries that represent 96% of world GDP. The dependent variable is output. It is filled with the available figures at bilateral level using any AMNE data points available and including mirror statistics from outward AMNE statistics when the reporter's value is not available. Then, in order to distinguish between "missing values" and zeros, we consider that there is zero AMNE sales when there is zero investment. We use information coming from foreign direct investment (FDI) statistics to identify such cases. While FDI and AMNE data are different for several reasons, we assume that in case zero FDI is reported (as a stock) in a given sector for a specific parent country, no foreign affiliate of that home country was established in the host country and hence that output is zero. We estimate the gravity coefficients based on this dataset.

Gravity models have a solid theoretical foundation and have produced some of the most robust empirical results in the trade literature. Although originally used to explain trade flows, gravity models have also been successfully used to estimate FDI flows and foreign affiliate sales. The theoretical and empirical underpinning of this econometric approach is the framework developed by Bergstrand and Egger (2007[1]). Their model extends the knowledge-capital model pioneered by Markusen (2002[2]), providing a theoretical framework for estimating gravity equations of aggregate bilateral FDI and sales of foreign affiliates. This framework confirms that gravity variables are the main determinants of FDI patterns and foreign affiliate sales.

In the gravity framework, the main drivers of multinational production are: market size and market potential (i.e. host market and third-market size); relative production costs between host and partner country; and relative market access costs (i.e. all the costs associated with exporting to a market versus setting up a foreign affiliate there). Host-country-industry and partner-country-industry output data (X) are used as measures of expenditure and output in the location and investing country, respectively. GDP per capita captures relative production costs between countries and the fact that relatively cheaper production costs lower the cost to set up a foreign affiliate, increasing foreign affiliate sales. Finally, trade and investment costs are proxied through the geographical distance between countries i and j (distance), a dummy variable that equals one for countries that share a common land border (contig), a dummy variable that equals one for country pairs that share a common official language (comlang), a dummy variable that equals one if countries i and j were once in a colonial relationship (colony), a dummy variable that equals one for country pairs that were colonized by the same power (comcol), a dummy variable for shared legal

origins (comleg) and a dummy variable that equals one for country pairs which are currently in a colonial or dependency relationship. Additionally, a dummy variable is included on whether host or partner economies are considered offshore financial centres by the International Monetary Fund (IMF).

These measures account for the costs to set up a foreign affiliate in the location country. Host and partner fixed effects are included in order to account for the multilateral resistance terms (Anderson and van Wincoop, 2004[3]). Given the dependent variable, the multilateral resistance terms cannot be adequately captured by host and partner country fixed effects alone. Instead, to be consistent with the theoretical foundations of the model would require sector, host-sector-year, partner-sector-year and year fixed effects (Yotov et al., 2016[4]). But since the model is about estimating missing data (for countries for which specific fixed effects at the country-sector-year level cannot be adequately estimated), the alternative is to estimate the model using host, partner, sector and year fixed effects. The resulting econometric specification is the following:

$$y_{ijst} = \exp\left[\alpha_0 + \beta_1 \ln(X)_{ist} + \beta_2 \ln(X)_{jst} + \beta_3 \ln(GDP_{it}) + \beta_4 \ln(GDP_{jt}) + \beta_5 \ln\left(\frac{GDP}{capita_{it}}\right) + \beta_6 \ln\left(\frac{GDP}{capita_{jt}}\right) + \beta_7 \ln(distance)_{ij} + \beta_8 comlang_{ij} + \beta_9 contig_{ij} + \beta_{10} comcol_{ij} + \beta_{11} dependency_{ij} + \beta_{12} offshore_i + \beta_{13} offshore_j + \delta_t + \delta_i + \delta_j + \delta_s\right] * \varepsilon_{ijst}$$

where i stands for location country (host), j for controlling country (parent), s for sector and t for time.

The first challenge of the econometric analysis is to deal with zeros. The sample provides sector level foreign affiliate sales in host and source countries with a significant share of zero observations (approx. 10%), i.e. source countries with no presence in a host country. The second challenge is the inconsistency of the OLS estimator in the presence of heteroskedasticity in the error terms and log-transformed dependent variable. This is addressed by using the Poisson Pseudo Maximum Likelihood estimator (PPML), as proposed by Santos Silva and Tenreyro (2006[5]).

Regression results of sales of foreign affiliates are presented in Table 1, using the PPML estimator. The coefficients all have the expected sign and the pseudo-R squared is at 94%. The coefficient on distance is negative suggesting that higher trade and investment costs lower foreign affiliate sales. Trade and investment can be either complements (in the case of vertical efficiency seeking FDI) or substitutes (in the case of horizontal market seeking FDI where there is a trade-off between concentration and proximity). Distance is a proxy for both trade and investment costs and generally found in a negative relationship with multinational production in the literature. In addition, the variables approximating for lower set-up costs, such as having a border in common, a common language and being once in a colonial relationship, have all the expected positive signs.

Table 1. Econometric results of the regression on foreign affiliate sales

	PPML
Host country's output (log)	0.697***
	(0.013)
Ownership country's output (log)	0.449***
	(0.015)

Distance (log)	-0.370*** (0.013)
Host country's GDP (log)	0.042 (0.016)
Ownership country's GDP (log)	0.389*** (0.017)
Host country's GDP per capita (log)	-0.054*** (0.009)
Ownership country's GDP per capita (log)	0.232*** (0.013)
Contiguity	0.267*** (0.033)
Common language	0.794*** (0.026)
Common coloniser	-2.203*** (0.120)
Dependency relationship	1.180 (0.610)
Offshore financial centre host country	-0.180*** (0.025)
Offshore financial centre ownership country	0.157*** (0.024)
Constant	-11.024*** (0.259)
Observations	7,115,120
R squared	0.944

Note: Clustered standard errors by country pair in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Using the coefficients from this estimation, the missing output values are predicted for countries where no official AMNE data is available. The sum of estimated output values by source country may not align perfectly with ICIO values which is why estimates are rescaled to be consistent with the ICIO while preserving estimated total foreign affiliate shares in output and ownership country shares. Where only more aggregate AMNE data is available, the gravity estimates are further constrained by available industry aggregates. For example, gravity estimates for the chemical and pharmaceutical industries of a given country are rescaled to be consistent with the chemical and pharmaceutical industry aggregate available in AMNE data. Non-business industries such as public administration, activities of households and international organisations are assigned zero output for foreign-owned firms (11% of the observations), as these industries have by definition no foreign presence. For the 'rest of the world' -for which there is no AMNE data-, the values come from the sum of the predicted bilateral figures for the remaining countries which are not covered in the ICIO. Lastly, when AMNE data is available with gaps in the time series, predicted growth rates from the gravity model are applied to official data to fill missing values.

Balancing the bilateral output matrix

The available AMNE data (adjusted to match output in national accounts) and the estimates made in the previous section are used to build a full initial matrix of bilateral output by country (host and parent) and by industry for each year, as well as populate the five constraints matrices. Cells where the country of ownership (parent) is the same as the country of production (host) correspond to the output of domestic-owned firms. The other elements in the matrices, where the country of ownership differs from the country of production, reflect the output of foreign-owned firms.

The balanced bilateral output matrix must be fully consistent with the ICIO tables and between different aggregation levels. This is achieved by solving a quadratic minimisation problem. The objective function to be minimised consists of five additive components each reflecting one desirable property of estimates. First, the sum of all the output of foreign firms by country and industry should be equal to total foreign output by country and industry, as assessed on the basis of the AMNE data (and adjusted to be consistent with ICIO data). Second, the sum of all the output of firms by country (of output) and by country of ownership should be equal to the total by country and by country of ownership coming from the adjusted AMNE data. Third, the sum of all the output of foreign-owned firms by host should be equal to the total by host from the adjusted AMNE data. Fourth, the sum of all firms by parent and industry should be equal to total foreign output by parent and industry if outward AMNE data is available. Lastly, the sum of all firms by parent should be equal to total foreign output by parent if outward AMNE data is available

Binary variables are included to denote industries included in aggregates and the availability of data on outward AMNE activity. Values in the initial and objective matrices are assigned a confidence index value between 0 and 1, with highest confidence assigned to official AMNE data and lowest to gravity estimates. This confidence index is used as a weight in the quadratic optimisation to influence the results. The values in which there is more confidence have a higher weight in the objective function. The minimisation process therefore avoids significantly changing these values as compared to the ones less trusted that have a lower weight.

Once the starting bilateral output matrix, the five objective matrices, and the ICIO constraints are ready, the following quadratic optimisation is run:

$$\min o(\hat{v}) = \sum_{i,j,k} \left(\gamma_{i,j,k} * \left(v_{i,j,k}^{starting} - \hat{v}_{i,j,k}\right)\right)^2 + \sum_{i,j} (\gamma_{i,j} * \left(v_{i,j}^{bil.obj.} - \sum_k \hat{v}_{i,j,k} * z_{i,j,k}\right))^2 + \sum_{i,k} (\gamma_{i,k} * (v_{i,k}^{ind.obj.} - \sum_j \hat{v}_{i,j,k}))^2 + \sum_i (\gamma_i * (v_i^{host\ obj.} - \left(\sum_k \sum_j \hat{v}_{i,j,k} * z_{i,k}\right))^2 + \sum_{j,k} z_{j,k} * (\gamma_{j,k} * \left(v_{j,k}^{par.ind.obj.} - \sum_i \hat{v}_{j,i,k}\right))^2 + \sum_j z_j * (\gamma_j * (v_j^{par.obj.} - \left(\sum_k \sum_i \hat{v}_{j,i,k} * z_{j,k}\right))^2$$

$$s.t. \sum_j \hat{v}_{i,j,k} = output_{i,k}^{ICIO}$$

where γ are the respective confidence indices, z are dummy variables, v are the values from the starting and objective matrices and $\hat{v}$ are the values estimated through minimisation of the above objective function. The resulting matrix is a balanced bilateral output matrix by country, country of ownership and industry that perfectly matches the ICIO output data (for all years in the dataset).

Value added and trade matrices

Once the bilateral output matrix is created, the next step is to produce value added and trade matrices (exports and imports) split according to ownership and consistent with ICIO data. For this, we again need to estimate missing values and reconcile differences between AMNE statistics and ICIO values, such as

purchaser versus basic prices for value added and corrections for merchanting in trade. The methodology for the value added matrix is presented below, but it is the exact same one used for the trade matrix.

First, value added at the sectoral level is split between domestic-owned and foreign-owned value added: $v = v_d + v_f$. Second, value added can be expressed as the value added per output unit times output:

$$v = \frac{v_d}{x_d}.x_d + \frac{v_f}{x_f}.x_f$$

where v corresponds to value added at the sectoral level, v_d is domestic-owned value added, x_d is domestic output and the subscript f applies to foreign firms for each variable.

Now let define parameter p as the premium ratio between foreign-owned firms value-added intensity and domestic-owned firms value-added intensity:

$$p = \frac{\frac{v_f}{x_f}}{\frac{v_d}{x_d}}$$

Integrating p into the equation leads to:

$$x_d + p.x_f = v * \left(\frac{x_d}{v_d}\right)$$

Domestic value added can be estimated as:

$$v_d = \frac{v}{1 + p.\left(\frac{x_f}{x_d}\right)}$$

Then foreign value-added is $v_f = v - v_d$.

Such methodology first reconciles the ICIO value added by industry with the information from AMNE data. Domestic value added plus foreign value added is equal to the ICIO total. Moreover, the methodology facilitates the estimation of missing values: the only information that is required from the AMNE database is the "premium" ratio which represents the difference in the value added to output ratio between foreign-owned firms and domestic-owned firms. When p is missing, we use the average value of the premium at the closest level available or for comparable countries and industries.

However, with such methodology, the estimation of value added can potentially provide values that are higher than output. It is the case when $p \leq \frac{v - x_d}{x_f}$, leading to values for domestic value added higher than domestic output, or when $p \geq \frac{x_d}{v - x_f}$ (in this case the foreign value added is higher than the foreign output). When this happens, the closest value of p that fits into the constraint of value added being lower than output is chosen.

For trade, the same methodology is employed, based on differences in export-intensity and import-intensity among domestic-owned and foreign-owned firms. The resulting matrices are exports and imports, by country, industry and type of ownership (domestic or foreign).

Splitting and balancing the ICIO by ownership

The next step consists in splitting the OECD ICIO along the ownership dimension using the output, value added and trade matrices previously constructed. For 76 economies plus a Rest of the World, 41 sectors and 2 types of firms (domestic-owned and foreign-owned), this splits the ICIO's intermediate consumption matrix into slightly below 40 million transactions, as opposed to "only" approximately 10 million in the initial ICIO. The split into three categories of ownership (foreign, domestic MNE and domestic non-MNE firms), which is not covered in this paper, further extends the intermediate consumption matrix to 90 million transactions.

The basic idea is to use the sector-ownership level gross output created in the previous steps to determine the relative proportion of domestic and foreign value within each sector as starting values. Value added, exports and imports data by country, sector and ownership also determine additional balancing conditions. The methodology estimates values through a quadratic programming model that fits the ICIO data with values as closely as possible to the AMNE matrices of gross output, value added, exports and imports while preserving as much of the original structure as possible. Using a simple example, this section first outlines how the initial split ICIO tables are constructed, followed by the balancing process to produce consistent tables which reconcile AMNE data with the original ICIO tables.

Let us define an ICIO composed of G countries and n sectors. Z_{ij} is an $n \times n$ matrix and its elements indicate the delivery of intermediate inputs from country i to country j, the special case i = j therefore corresponds to domestic deliveries. Let V_i define a vector of dimension $1 \times n$ whose elements indicate the value added in country i and Y_{ij} a matrix of dimension $n \times n$ that denotes final goods and services produced in country i and consumed in country j.

$X_i^{D^*}$ and $X_i^{F^*}$ are defined as country i's gross output of domestic-owned and foreign-owned firms respectively in the gross output matrix. $X_i^{D^*} + X_i^{F^*} = X_i$ where X_i is the vector of gross output for country i. Moreover, the vector of output ratios by domestic-owned firms is defined as $\sigma_i^D = X_i^{D^*}/X_i$ and the vector of output ratios by foreign-owned firms as $\sigma_i^F = X_i^{F^*}/X_i$.

Z_{ij} is split into four matrices using the proportionality assumption: Z_{ij}^{DD}, Z_{ij}^{DF}, Z_{ij}^{FD} and Z_{ij}^{FF}. This split produces the initial values in the balancing procedure, the coefficients will then change in the optimisation to reflect the constraints. At the end, the balancing will produce different production functions and a different mix of inputs for domestic- and foreign-owned firms both as suppliers of inputs and purchasers of inputs.

Z_{ij}^{DD} is the matrix of intermediate inputs supplied by domestic-owned firms to domestic-owned firms. Z_{ij}^{DF} is a matrix of intermediate inputs supplied by domestic-owned firms to foreign-owned firms; and so forth for Z_{ij}^{FD} and Z_{ij}^{FF}. The starting values of the four Z matrices are calculated as follows (with the hat notation used for the diagonal matrix of the vector):

$Z0_{ij}^{DD} = \hat{\sigma}_i^D Z_{ij} \hat{\sigma}_j^D$, $Z0_{ij}^{DF} = \hat{\sigma}_i^D Z_{ij} \hat{\sigma}_j^F$, $Z0_{ij}^{FD} = \hat{\sigma}_i^F Z_{ij} \hat{\sigma}_j^D$ and $Z0_{ij}^{FF} = \hat{\sigma}_i^F Z_{ij} \hat{\sigma}_j^F$

The Y_{ij} matrix also needs to be split into the two matrices: Y_{ij}^D and Y_{ij}^F where Y_{ij}^D is the final demand for the output of domestic-owned firms and Y_{ij}^F is the final demand for the output of foreign-owned firms. The starting values of these two matrices are calculated as follows:

$Y0_{ij}^D = \hat{\sigma}_i^D Y_{ij}$ and $Y0_{ij}^F = \hat{\sigma}_i^F Y_{ij}$

V_i is split into two vectors: V_i^D and V_i^F. V_i^D is the value-added vector for country i's domestic-owned firms and V_i^F is the value added vector for country i's foreign-owned firms. The starting values of these two vectors are extracted from the value added matrix created in the previous steps.

$V0_i^D = V_i^{D^*}$ and $V0_i^F = V_i^{F^*}$

To obtain the unobservable I-O coefficients, the new intermediate input blocks in the ICIO table: Z_{ij}^{DD}, Z_{ij}^{DF}, Z_{ij}^{FD} and Z_{ij}^{FF}, the new final demand blocks, $\mathrm{Y}_{\mathrm{ij}}^{\mathrm{D}}$ and $\mathrm{Y}_{\mathrm{ij}}^{\mathrm{F}}$, as well as the new value added vectors, V_i^D and V_i^F need to be estimated. Each block should satisfy these constraints: 1) the sum of the split new blocks should be equal to the original matrices/vectors in the ICIO tables; 2) the new ICIO should be balanced, i.e. the sum of each row and sum of each column should be equal to output. These constraints can be written as follows:

$$Z_{ij}^{DD} + Z_{ij}^{DF} + Z_{ij}^{FD} + Z_{ij}^{FF} = Z_{ij}$$

$$\mathrm{Y}_{\mathrm{ij}}^{\mathrm{D}} + \mathrm{Y}_{\mathrm{ij}}^{\mathrm{F}} = \mathrm{Y}_{\mathrm{ij}}$$

$$V_i^D + V_i^F = V_i$$

$$\sum_j Z_{ij}^{D\circ} + \sum_j Y_{ij}^D = \sum_j Z_{ji}^{\circ\mathrm{D}} + V_i^D = X_i^{D^*}$$

$$\sum_j Z_{ij}^{F\circ} + \sum_j Y_{ij}^F = \sum_j Z_{ji}^{\circ\mathrm{F}} + V_i^F = X_i^{F^*}$$

where the notation ○ corresponds to the set {D, F} that identifies the domestic and foreign blocks in the split ICIO tables.

Additional constraints are needed to split the exports and imports data in a way consistent with the matrices created with AMNE data. These constraints are:

$$E_i^D = \sum\nolimits_j Z_{ij}^{D\circ} + \sum\nolimits_j Y_{ij}^D, j \neq i, E_i^F = \sum\nolimits_j Z_{ij}^{F\circ} + \sum\nolimits_j Y_{ij}^F, j \neq i$$

$$M_i^D = \sum\nolimits_j Z_{ij}^{\circ\mathrm{D}} + \sum\nolimits_j Y_{ij}^D, j \neq i, M_i^F = \sum\nolimits_j Z_{ij}^{\circ\mathrm{F}} + \sum\nolimits_j Y_{ij}^F, j \neq i$$

Using the above notations, the objective function in the optimisation is specified as:

$$Min\ S = \sum_{i,j} \frac{(Z_{ij}^{DD} - Z0_{ij}^{DD})^2}{Z0_{ij}^{DD}} + \sum_{i,j} \frac{(Z_{ij}^{DF} - Z0_{ij}^{DF})^2}{Z0_{ij}^{DF}} + \sum_{i,j} \frac{(Z_{ij}^{FD} - Z0_{ij}^{FD})^2}{Z0_{ij}^{FD}} + \sum_{i,j} \frac{(Z_{ij}^{FF} - Z0_{ij}^{FF})^2}{Z0_{ij}^{FF}}$$
$$+ \sum_{i,j} \frac{(Y_{ij}^D - Y0_{ij}^D)^2}{Y0_{ij}^D} + \sum_{i,j} \frac{(Y_{ij}^F - Y0_{ij}^F)^2}{Y0_{ij}^F} + 100*(\sum_i \frac{(V_i^D - V0_i^D)^2}{V0_i^D} + \sum_i \frac{(V_i^F - V0_i^F)^2}{V0_i^F})$$
$$+100*(\sum_i \frac{(E_i^D - E_i^{D\bullet})^2}{E_i^{D\bullet}} + \sum_i \frac{(E_i^F - E_i^{F\bullet})^2}{E_i^{F\bullet}} + \sum_i \frac{(M_i^D - M_i^{D\bullet})^2}{M_i^{D\bullet}} + \sum_i \frac{(M_i^F - M_i^{F\bullet})^2}{M_i^{F\bullet}})$$

where $E_i^{D^*}$, $E_i^{F^*}$, $M_i^{D^*}$ and $M_i^{D^*}$ are the exports and imports values from the AMNE matrices created in the previous steps.

This process allows a full split of the ICIO tables by domestic and foreign ownership, producing balanced tables which are fully consistent with the initial tables that do not distinguish between foreign-owned and domestic-owned firms.

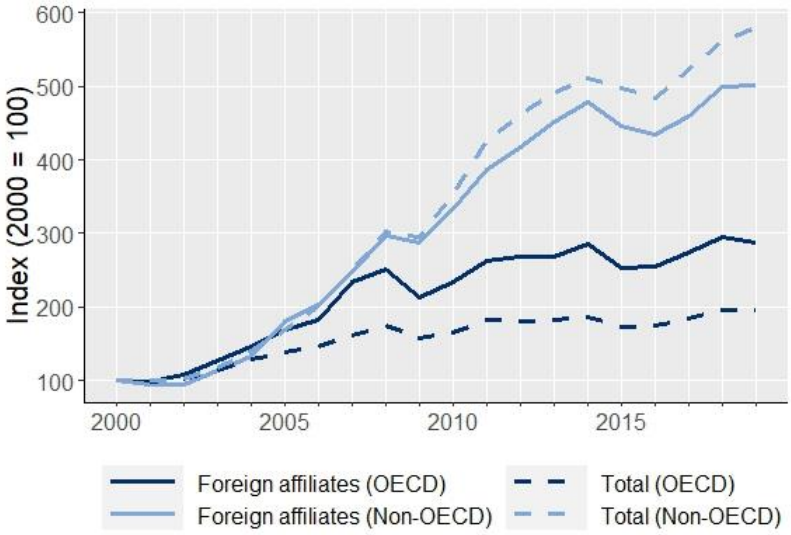
2. Empirical evidence on multinational production based on the 2023 edition of the AAMNE database

The role of MNEs in global production

MNEs account for a very significant share of the world economy. In 2019, the most recent year in our database, the gross output of foreign affiliate (FA) firms added up to a total of USD 26 trillion, about 15% of the global gross output. This figure does not include the domestic activities of MNEs (those of the headquarters and other home country establishments), which are estimated to be responsible for an additional 20% of global gross output.

This is the result of a remarkable expansion in international activities that took place over the past couple of decades. For comparison, in 2000 the global output of foreign affiliates stood at about USD 7.3 trillion. Still, the pace of growth over the period spanned by our database has not been even. The 2000s were a time of very rapid increase in outward products. After a break due to the 2008-2009 Financial Crisis growth resumed and by 2011 foreign affiliate output had already reached USD 23 trillion globally. The years that followed, on the other hand, have been characterized by a slowdown. Even so, with outward activity remaining at or close to its historical maximum, it is difficult to interpret this as evidence of deglobalisation (Jaax, Miroudot and van Lieshout, 2023[6]).

Figure 1. Gross output of foreign-owned firms versus total economy



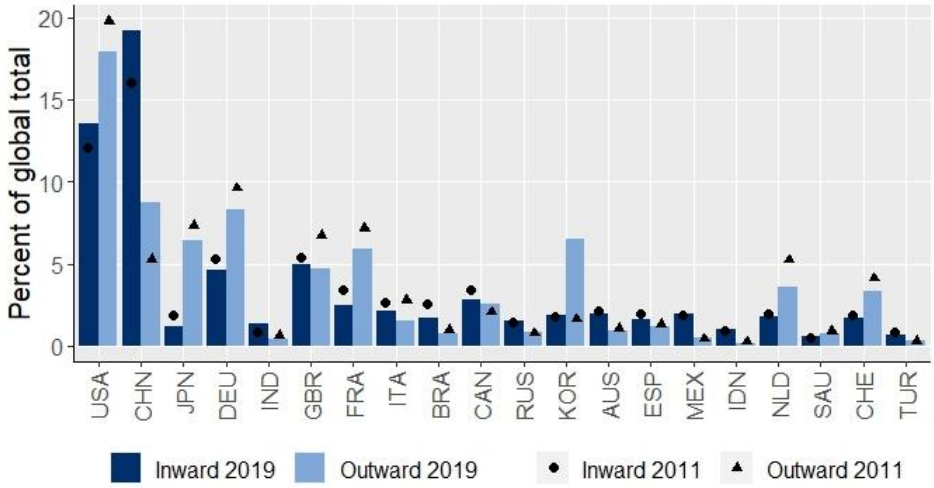
Source: Authors' calculations using the 2023 Analytical AMNE database.

Over the period under analysis, the activity of foreign-owned firms increased faster in non-OECD than in OECD countries (Figure 1), although from a lower starting point. This is true especially after the Financial Crisis. Overall, between 2000 and 2019 the output of foreign-owned firms based in non-OECD countries went from USD 2.4 trillion to USD 11.9 trillion. It is worth noting, however, that in the same period the total gross output of those economies grew at even higher rates. In OECD countries, by contrast, the gross

output of FAs increased faster than in the rest of the economy, particularly in the years leading to the Financial Crisis. Accordingly, the share of output that accrues to foreign-owned firms has increased for OECD countries and decreased for non-OECD countries, but is still lower in the former (14.6%) than in the latter group of countries (15.9%).

At the country level, large economies tend to account for comparatively large shares of both inward and outward FA activity, but there are a number of exceptions. This can be appreciated from Figure 2, which - for a selection of twenty major economies - displays a country's share of global FA output both as a parent and as a host of foreign-owned firms. Several countries display large asymmetries between the inward and the outward side. China, for instance, has a much larger share of inward (19%) than of outward production (9%). The reverse is true of countries like France, Japan, Korea, the Netherlands and Switzerland. In addition, large economies like India's appear to be characterized by remarkably low levels of FA activity on both the inward and the outward side. Taken together, in 2019 the countries in Figure 2 controlled approximately three-quarters of global outward production and two-thirds of global inward production. In the aggregate, these shares have not changed much relative to 2011, but the weight of the various countries has sometimes changed. Most notably, China and Korea have gained prominence as sources of outward activity.

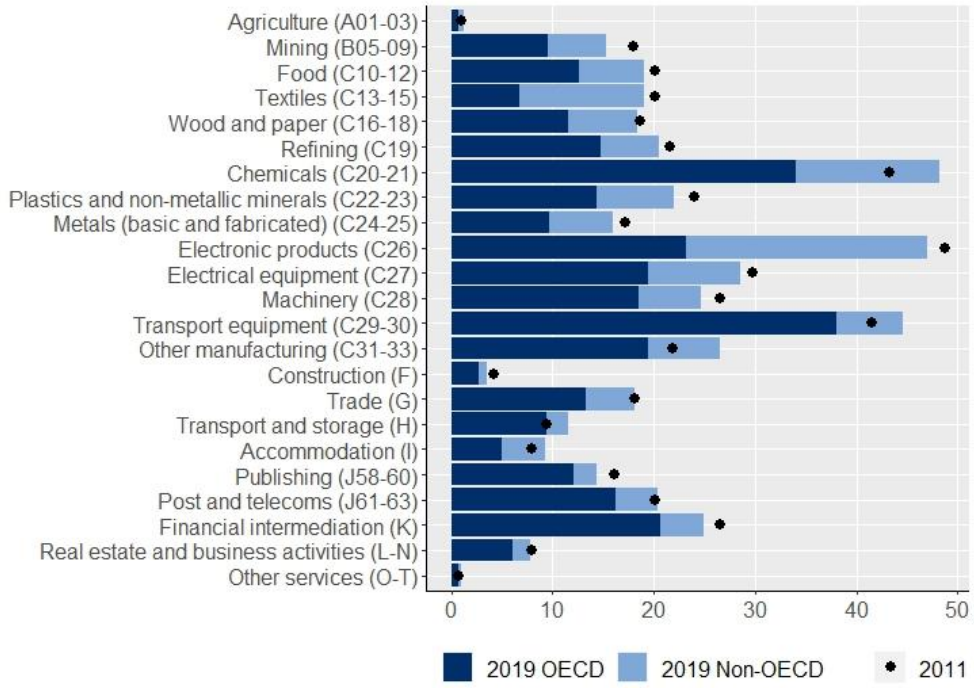
Figure 2. Share in global output of foreign affiliates (selected countries)



Source: Authors' calculations using the 2023 Analytical AMNE database.

Unsurprisingly, the presence of foreign-owned firms is more prevalent in certain industries than in others (Figure 3). FA activity is especially significant in Chemicals, Electronics and Transport equipment, where it accounts for more than two-fifths of global output. However, it is also substantial in various other segments of manufacturing, as well as in service industries like Financial intermediation and Post and telecoms. In a typical industry, almost three quarters of FA output is controlled by firms whose parent companies are based in OECD countries. Two notable exceptions to the pattern are Textiles and Electronics, where the OECD-controlled shares are 36% and 49%, respectively.

Figure 3. Foreign affiliates' share in global output by industry and parent company origin



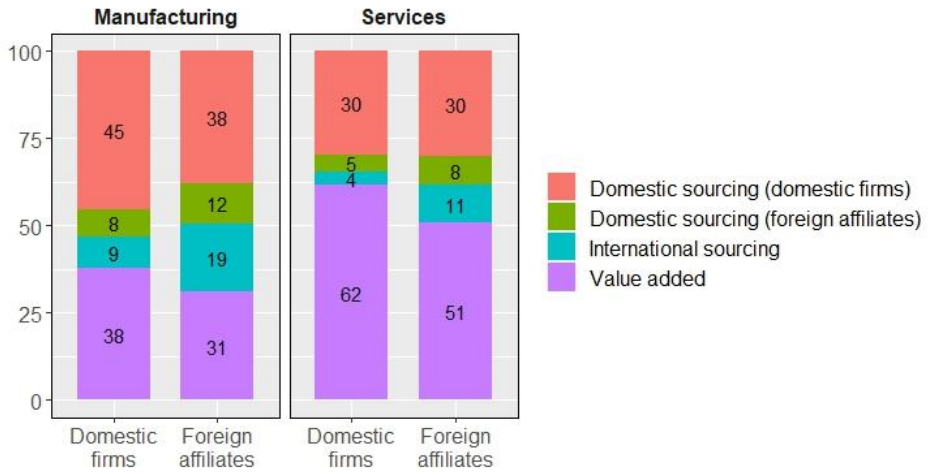
Source: Authors' calculations using the 2023 Analytical AMNE database.

Difference in sourcing strategies

Foreign-owned firms and domestic-owned firms display important differences with regard to their sourcing strategies (Figure 4). On average, FAs use comparatively more intermediates and consequently have lower value-added-to-output ratios. Furthermore, those intermediates are relatively more likely to be sourced from abroad or from other foreign affiliates. Overall, however, FAs' purchases of intermediate inputs from the host country's domestic economy are still substantial. In fact, on a per dollar of output basis, they do not depart much from the values observed for domestic firms. This general pattern holds equally for companies that operate in the manufacturing and in the service sector, even though the weight carried by the various sources in clearly quite different.

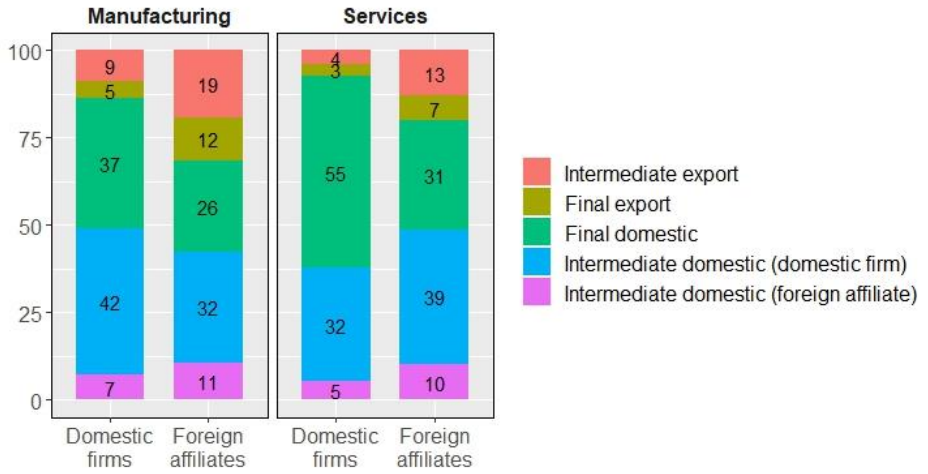
FAs also differ markedly from domestic firms in terms of how their outputs are used (Figure 5). Most obviously, they tend to export much larger portions of their product (31% versus 14% for manufacturers, 20% versus 7% for services). In addition, their outputs are more likely to be destined to intermediate as opposed to final use. The imbalance is particularly striking in the case of services, where intermediate uses account for as much as 62% for FAs but only 42% for domestic firms.

Figure 4. Sources of inputs, 2019



Source: Authors' calculations using the 2023 Analytical AMNE database.

Figure 5. Destination of outputs, 2019



Source: Authors' calculations using the 2023 Analytical AMNE database.

Decomposition of final demand

Finally, the Analytical AMNE tables support various types of decomposition analysis. In Table 2, for example, global final demand is broken down among domestic-owned firms, foreign-owned firms and foreign firms (i.e. imports) along two dimensions: i) what type of firm made the sale; ii) what type of firm is the origin of the value added. The analysis is performed for the world economy as a whole (that is, adding up over all sectors), as well as for three distinct industry aggregates (Textiles, Electronics and Transport equipment).

Table 2. Value added decomposition of final demand, 2019

Components	Industry			
	All	Textiles (C13-15)	Electronics (C26)	Transport equiment (C29-30)
Sales by domestic-owned firm	*81.2*	*53.0*	*30.6*	*37.3*
Domestic VA - domestic firms	70.1	41.1	23.1	27.1
Domestic VA - foreign affiliates	3.3	3.4	1.8	2.4
Imported value added	7.7	8.5	5.8	7.8
Sales by foreign-owned firms	*8.6*	*10.4*	*20.5*	*29.8*
Domestic VA - domestic firms	2.8	4.3	6.5	11.4
Domestic VA - foreign affiliates	4.1	3.9	8.3	10.2
Imported value added	1.7	2.2	5.7	8.1
Imports	*10.2*	*36.6*	*48.9*	*32.9*
Domestic VA - domestic firms	0.1	0.4	1.1	0.9
Domestic VA - foreign affiliates	0.0	0.1	0.2	0.2
Imported value added	10.0	36.1	47.5	31.8
Total	***100***	***100***	***100***	***100***
Domestic VA - domestic firms	73.1	45.8	30.7	39.4
Domestic VA - foreign affiliates	7.5	7.3	10.3	12.9
Imported value added	19.4	46.9	59.0	47.7

Source: Authors' calculations using the 2023 Analytical AMNE database.

Across all sectors of the global economy, about 81% of all final sales are made by domestic-owned firms, with FAs responsible for a further 8%. Accordingly, foreign firms account for the residual tenth of final demand, yet their share of value added is almost twice as large (19.4%).

In fact, such grand averages hide a lot of variation across value chains. For instance, in the three manufacturing sectors examined in the rightmost columns of Table 1 the incidence of foreign and domestic foreign-controlled firms in total sales is larger than for the economy as a whole. In the case of Transport equipment, FAs account for a remarkable 30% of all final sales. These are often products that are comparatively costly to trade across borders and easy to assemble near consumers, which tends to make setting up a FA attractive for a would-be exporter. By contrast, in the Textile industry it is more common for production arrangements to be regulated by arm's length contracts. In this sector, final sales are indeed dominated by domestic and foreign firms, with FAs accounting for about 10% of the total. In the case of Electronics, on the other hand, about half of all final uses are met by imports. In all cases, however, the sales of FAs contain significant portions of domestic value added.

Estimation and analysis of bilateral multinational production costs

In the trade literature, estimates of bilateral trade costs are derived from bilateral trade flows using the structural gravity model (Anderson and van Wincoop, 2003[7]; Anderson and Yotov, 2010[8]). From the equations of the model, one can derive formulas to directly calculate partial equilibrium bilateral trade costs (Head and Ries, 2001[9]; Novy, 2012[10]). More recent methods combine some estimation and calibration with gravity equations where bilateral fixed effects capture the bilateral trade costs (Egger and Nigai, 2015[11]; Anderson, Larch and Yotov, 2018[12]; Egger et al., 2021[13]).

While developed in the context of trade flows, the gravity equation can also be derived for FDI (Kleinert and Toubal, 2010[14]; Anderson, Larch and Yotov, 2019[15]) or multinational production (Ramondo, Rodríguez-Clare and Tintelnot, 2015[16]; Alviarez, 2019[17]; Miroudot and Rigo, 2021[18]). Therefore, the methods developed by Egger and Nigai (2015[11]) and Egger et al. (2021[13]) to estimate bilateral trade costs can also be used in the context of multinational production costs

For each industry *s* and year *t* in the Analytical AMNE database, we estimate the following gravity model with a set of constraints:

$$\frac{X_{ph}}{X_{hh}} = e_p + d_{ph} - e_h \text{ such that } e_p = e_h \; \forall p = h$$

where X_{ph} is the output of foreign affiliates from parent country *p* in host country *h*, X_{hh} is the output of domestic-owned firms in host country *h*, e_p are parent country fixed effects, e_h are host country fixed effects, and d_{ph} are parent-host pair fixed effects. The equation is estimated with the Poisson Pseudo-Maximum Likelihood Estimator (PPML) with no constant and robust clustered standard errors. The term d_{ph} can also be understood as a residual once accounting for parent and host fixed effects. The constrained regression allows the residual to be interpreted as an unbiased estimate of bilateral MP costs, as explained by Egger and Nigai (2015[11]) in the case of bilateral trade costs.

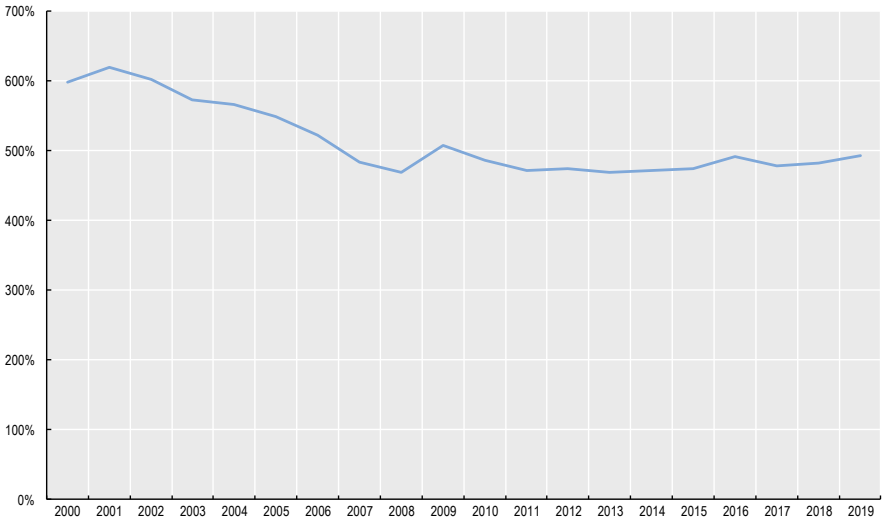
Estimated coefficients of the parent-host fixed effects are used to recover bilateral MP costs. The ad valorem equivalent of partial equilibrium bilateral MP costs is calculated as $\tau_{ph} = \widehat{d_{ph}}^{-\frac{1}{\theta}} - 1$ with θ a parameter that is assumed to be equal to 5.[1] Since the gravity equation divides the output of foreign affiliates by the output of domestic-owned firms, the bilateral MP costs tell us how many times costs are higher for foreign-owned firms as compared to domestic-owned firms. By removing one, the calculated bilateral MP costs can be interpreted as tariff equivalents.

Once bilateral MP costs are calculated for all parent-host country pairs, industries and years, they can be aggregated (using output weights) and analysed. Figure shows the evolution over time of the average bilateral MP costs for all OECD countries as host. In line with the evolution of world output of foreign affiliates (Figure 1), there was a decline in MP costs before the 2008-2009 Great Financial Crisis. But MP costs have stagnated after and seem even to slightly increase in the recent period (i.e. after 2017). The Figure also illustrates that, expressed as tariff equivalents, bilateral MP costs are quite high, in the range of 500% and higher than tariff equivalents generally calculated for bilateral trade. However, such high costs are necessary to explain that only a small share of output in each country is the result of activities of foreign firms. These costs capture all what can explain the lower sales of foreign firms compared to domestic firms, including the preference of consumers for local products. Bilateral MP costs do not capture only the impact of restrictive FDI polices and regulations that introduce discriminations for foreign-owned firms.

[1] The parameter θ reflects the shape of the underlying Pareto distribution of firm productivity in sector *s*. Higher values of θ are associated with a smaller dispersion of productivity in the sector and therefore a higher elasticity of MP to changes in MP costs. We follow Ramondo et al. (2015[16]) and assume that θ is equal to 5. While the level of MP costs is affected by the value of this elasticity, it is not the case for their evolution over time.

Figure 6. Average bilateral MP costs over time, OECD countries

Ad valorem tariff equivalent, %

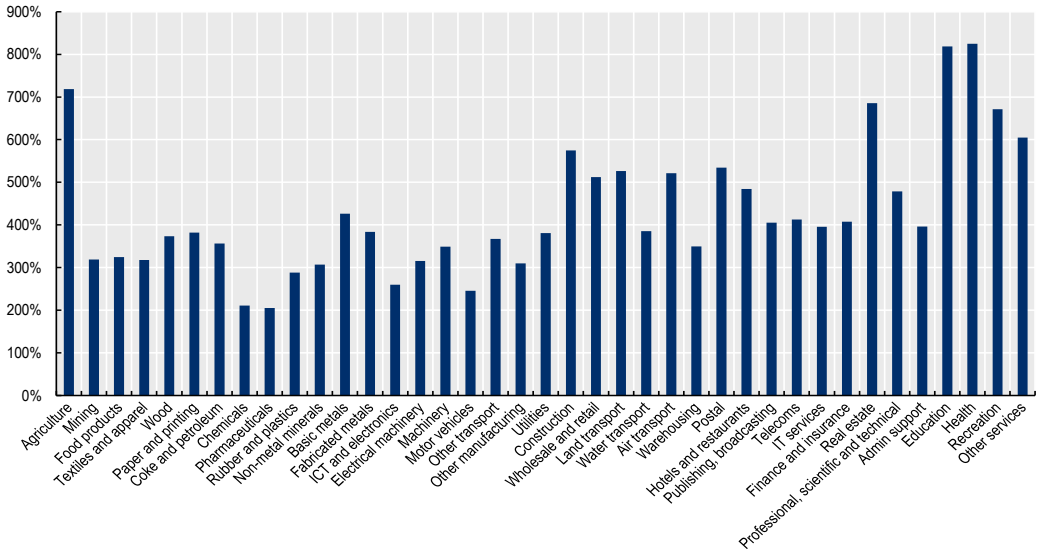


Note: Weighted average across country pairs and industries (OECD countries as host) based on output.
Source: Authors' calculations using the 2023 Analytical AMNE database.

As illustrated on Figure , average bilateral MP costs are very different across sectors. Services sectors generally have higher MP costs together with agriculture. The lowest MP costs are found in manufacturing sectors such as chemicals and pharmaceuticals. High barriers to multinational production exist in sectors such as education and health (where there is often a government provision) but also construction, real estate or recreation services.

Figure 7. Average bilateral MP costs by sector, OECD countries, 2019

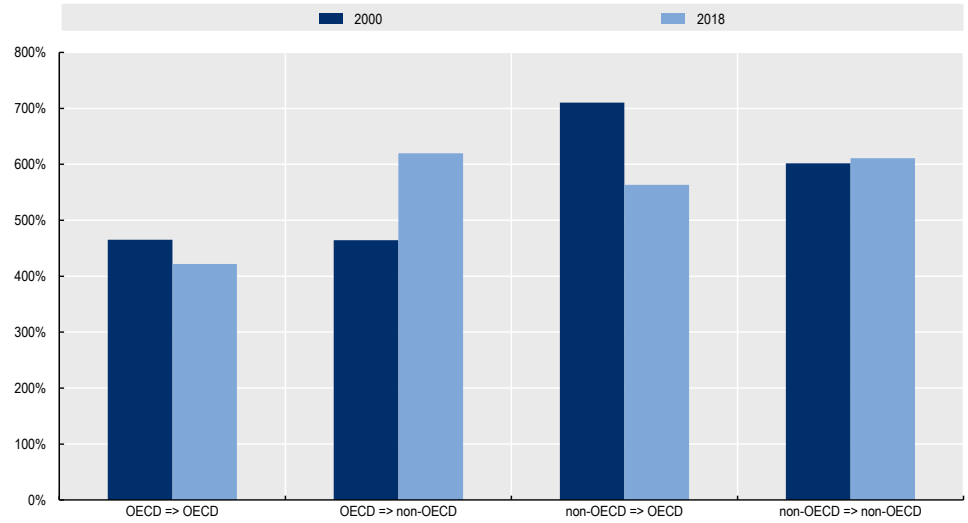
Ad valorem tariff equivalent, %



Note: Weighted average across country pairs (OECD countries as host) based on output.
Source: Authors' calculations using the 2023 Analytical AMNE database.

Figure 8. Average bilateral MP costs for OECD and non-OECD economies, 2000 and 2019

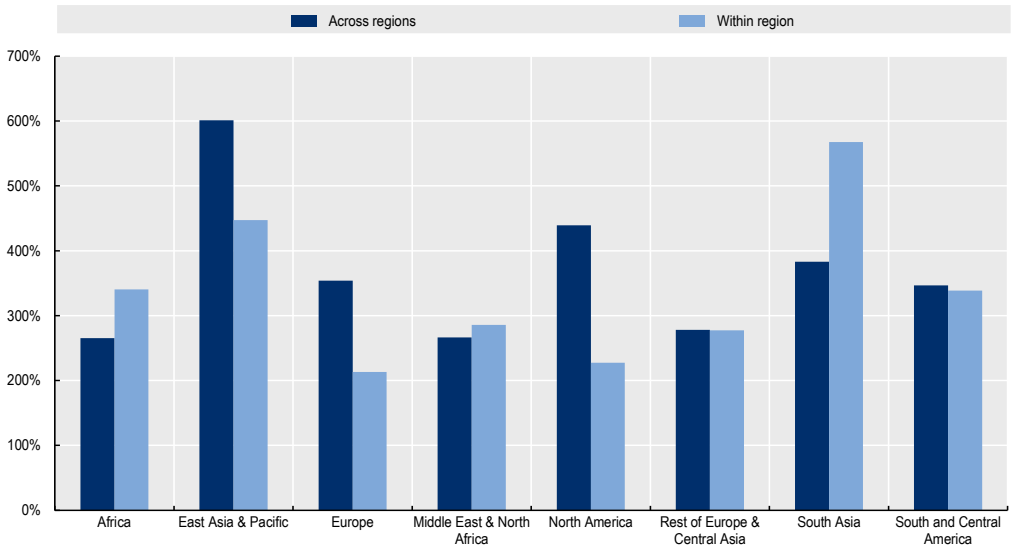
Ad valorem tariff equivalent, %



Note: Labels refer to the parent and host economy of foreign affiliates. For example, 'OECD => OECD' means multinational production costs for affiliates of OECD firms (parent) established in OECD countries (host). Weighted average across country pairs based on output.
Source: Authors' calculations using the 2023 Analytical AMNE database.

Figure 9. Average bilateral MP costs within and across region by host region, 2019

Ad valorem tariff equivalent, %



Note: Weighted average across country pairs and industries based on output.
Source: Authors' calculations using the 2023 Analytical AMNE database.

Across countries, there are also differences in average bilateral MP costs with such costs generally lower between OECD countries (i.e. when both the parent and host countries are OECD) and higher when the host country is non-OECD (Figure). There is also an important heterogeneity across regions (Figure). Bilateral MP costs are higher in the East Asia & Pacific region, especially when the parent country is

outside the region ('across regions'), while the opposite is observed in South Asia (where 'within region' MP costs are higher). It is within Europe that the lowest bilateral MP costs are observed.

The above charts illustrate that the Analytical AMNE database can also be used to analyse MP costs and as it is done for bilateral trade costs, one can then use different quantitative methods to further decompose these costs and identify the role of specific variables (such as cultural differences, social connectedness, policies, barriers to FDI, etc.).

Concluding remarks

While MNEs are a very significant and hotly debated part of the global economy, little statistical information exists on their activities. To fill this gap, the OECD has developed the Analytical AMNE database, a time series of extended input-output tables with information on firm ownership. After documenting the methodology underlying its construction, this paper has presented some examples of how the database can be used to perform economic analysis. Still, the range of potential applications is much wider, encompassing descriptive analyses of MNEs' role in specific value chains, estimations of profit shifting and the measurement of MNE carbon footprints. The Analytical AMNE database will be freely available to all users from the OECD's website. The current release of data should be considered preliminary and will be subject to revisions as the underlying ICIOs are updated.

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Appendix

Table 3. List of countries and territories covered

OECD code	OECD countries	Non-OECD code	Non-OECD economies
AUS	Australia	ARG	Argentina
AUT	Austria	BGR	Bulgaria
BEL	Belgium	BGD	Bangladesh
CAN	Canada	BLR	Belarus
CHL	Chile	BRA	Brazil
COL	Colombia	BRN	Brunei Darussalam
CRI	Costa Rica	KHM	Cambodia
CZE	Czech Republic	CMR	Cameroon
DNK	Denmark	CHN	China (People's Republic of)
EST	Estonia	CIV	Côte d'Ivoire
FIN	Finland	HRV	Croatia
FRA	France	CYP	Cyprus [2]
DEU	Germany	EGY	Egypt
GRC	Greece	HKG	Hong Kong, China
HUN	Hungary	IND	India
ISL	Iceland	IDN	Indonesia
IRL	Ireland	JOR	Jordan
ISR	Israel [1]	KAZ	Kazakhstan
ITA	Italy	LAO	Lao People's Democratic Republic
JPN	Japan	MYS	Malaysia
KOR	Korea	MLT	Malta
LVA	Latvia	MAR	Morocco
LTU	Lithuania	MMR	Myanmar
LUX	Luxembourg	NGA	Nigeria
MEX	Mexico	PAK	Pakistan
NLD	Netherlands	PER	Peru
NZL	New Zealand	PHL	Philippines
NOR	Norway	ROU	Romania
POL	Poland	RUS	Russian Federation
PRT	Portugal	SAU	Saudi Arabia
SVK	Slovak Republic	SEN	Senegal
SVN	Slovenia	SGP	Singapore
ESP	Spain	ZAF	South Africa
SWE	Sweden	TWN	Chinese Taipei
CHE	Switzerland	THA	Thailand
TUR	Türkiye	TUN	Tunisia
GBR	United Kingdom	UKR	Ukraine
USA	United States	VNM	Viet Nam
		ROW	Rest of the World

Notes:
1. Data are presented for 76 countries (i.e. 38 OECD countries and 38 non-OECD economies) and the Rest of the World.
2. The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities or third party. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

3. Footnote by Turkey: The information in this document with reference to “Cyprus” relates to the southern part of the Island. There is no single authority representing both Turkish and Greek Cypriot people on the Island. Turkey recognizes the Turkish Republic of Northern Cyprus (TRNC). Until a lasting and equitable solution is found within the context of the United Nations, Turkey shall preserve its position concerning the “Cyprus issue”. Footnote by all the European Union Member States of the OECD and the European Union: The Republic of Cyprus is recognised by all members of the United Nations with the exception of Turkey. The information in this document relates to the area under the effective control of the Government of the Republic of Cyprus.

Table 4. Industry classification

Code	Industry	ISIC Rev.4
A01T03	Agriculture, forestry and fishing	01, 02, 03
B05T09	Mining and extraction of energy producing products	05, 06, 07, 08, 09
C10T12	Food products, beverages and tobacco	10, 11, 12
C13T15	Textiles, wearing apparel, leather and related products	13, 14, 15
C16	Wood and products of wood and cork	16
C17T18	Paper products and printing	17, 18
C19	Coke and refined petroleum products	19
C20	Chemicals and chemical products	20
C21	Pharmaceuticals, medicinal chemical and botanical products	21
C22	Rubber and plastic products	22
C23	Other non-metallic mineral products	23
C24	Basic metals	24
C25	Fabricated metal products	25
C26	Computer, electronic and optical products	26
C27	Electrical equipment	27
C28	Machinery and equipment, nec	28
C29	Motor vehicles, trailers and semi-trailers	29
C30	Other transport equipment	30
C31T33	Other manufacturing; repair and installation of machinery and equipment	31, 32, 33
D35_E36T39	Electricity, gas, water supply, sewerage, waste and remediation services	35,36, 37, 38, 39
F41T43	Construction	41, 42, 43
G45T47	Wholesale and retail trade; repair of motor vehicles	45, 46, 47
H49	Land transport and transport via pipelines	49
H50	Water transport	50
H51	Air transport	51
H52	Warehousing and support activities for transportation	52
H53	Postal and courier activities	53
I55T56	Accommodation and food services	55, 56
J58T60	Publishing, audiovisual and broadcasting activities	58, 59, 60
J61	Telecommunications	61
J62T63	IT and other information services	62, 63
K64T66	Financial and insurance activities	64, 65, 66
L68	Real estate activities	68
M69T75	Professional, scientific and technical activities	69, 70, 71, 72, 73, 74, 75
N77T82	Administrative and support services	77, 78, 79, 80, 81, 82
O84	Public admin. and defence; compulsory social security	84
P85	Education	85
Q86T88	Human health and social work	86, 87, 88
R90T93	Arts, entertainment and recreation	90, 91, 92, 93
S94T96	Other service activities	94, 95, 96
T97T98	Private households with employed persons	97, 98