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Filippo di Mauro, Marco Matani, Gianmarco Ottaviano

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Authors

Filippo di Mauro
The Competitiveness Research Network (CompNet)
E-mail: filippodimauro1@me.com

Marco Matani
Institut de Hautes Études Internationales et du Développement(IHEID)
E-mail: marco.matani@graduateinstitute.ch

Gianmarco Ottaviano
Bocconi University
E-mail: gianmarco.ottaviano@unibocconi.it

Editor

Halle Institute for Economic Research (IWH) – Member of the Leibniz Association

Address: Kleine Maerkerstrasse 8
D-06108 Halle (Saale), Germany
Postal Address: P.O. Box 11 03 61
D-06017 Halle (Saale), Germany

Tel +49 345 7753 60
Fax +49 345 7753 820

www.iwh-halle.de
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Abstract

Based on the sufficient statistics approach developed by Huang and Ottaviano (2024), we show how the state of technology of European industries relative to the rest of the world can be empirically assessed in a way that is simple in terms of computation, parsimonious in terms of data requirements, but still comprehensive in terms of information. The lack of systematic cross-industry correlation between export specialization and technological advantage suggests that standard measu-res of revealed comparative advantage only imperfectly capture a country's tech-nological prowess due to the concurrent influences of factor prices, market size, markups, firm selection and market share reallocation.

Keywords: comparative advantage, European cross-country data, firm heterogeneity, international trade, monopolistic competition, multi-product firms, productivity

JEL classification: B17, C19, C51, C80, D21, D43, F02, F12, F14, F61, L13, L25, O49

1 Introduction

The competitive position of the European Union is widely discussed these days, especially following the Draghi report (Draghi, 2024). The report emphasizes the EU's loss of technological prowess with respect to the United States, and increasingly China, in several sectors and suggests active industrial policy to reverse the trend. Yet, how to assess Europe's relative relative state of technology in a way that is simple in terms of computation, parsimonious in terms of data requirements, but still comprehensive in terms of information, remains an open issue.

In this paper we show how this hurdle can be overcome by applying the 'sufficient statistics' approach recently developed by Huang and Ottaviano (2024) in the case of China.[1] The idea is to leverage international trade data and firm information to infer a country's relative technological prowess from its sectoral export specialization with respect to the rest of world. This is akin to Balassa's idea of using export specialization to 'reveal' comparative advantage (Balassa, 1965). If with trade ('ex post') a country is relatively specialized in exporting in some sectors, then it must be that without trade ('ex ante') in those sectors it would be able to quote lower relative autarky prices than its trading partners.

Balassa's insight is based on traditional trade models, in which product markets are perfectly competitive and production exhibits constant returns to scale so that across sectors relative prices coincide with relative costs. While export specialization reflects relative cost advantage, it cannot be used to identify relative technology and relative factor prices as separate sources of such advantage (Deardorff, 1980). Identification faces additional challenges with scale economies and imperfectly competitive product markets. In this case, revealed comparative advantage may not coincide with relative cost advantage due to variable markups and scale effects as countries' relative market sizes disturb the transmission from relative costs to export specialization through relative prices. Firm heterogeneity further complicates the picture as endogenous trade-induced firm selection and market share reallocation add new disturbances, as highlighted for instance by Bernard et al. (2007) and Melitz and Ottaviano (2008).

All this has implications for the interpretation of the Balassa index of 'revealed comparative advantage' (BRCA), defined as the ratio of a sector's share of exports for a given country to its share for the rest of the world. Values of a country's BRCA larger (smaller) than one highlight the sectors in which the country enjoys a relative price advantage (disadvantage), but it is silent about the role of the different possible sources of the price advantage. In particular, it cannot be used to assess the extent to which the relative price advantage is driven by relative technological prowess. In other words, a country's relative export specialization in a sector is a sufficient statistics for its relative price advantage, but not for its relative state of technology.[2]

Huang and Ottaviano (2024) push Balassa's logic one step beyond. They show how the structure of a multi-country multi-sector general equilibrium model, encompassing all the aforementioned disturbances, can be used to define a set of sufficient statistics that together make it possible to recover a country's relative state of technology from trade data and firm information after filtering out the possible influences on exports of factor prices, market size, markups, selection and reallocation. Their model could be applied 'brute force' by using its equilibrium relations to calibrate the different countries' sectoral states of technology. Given the large number of equations and parameters involved (determined by the number of countries times the number of sectors), calibration requires targeting a long list of empirical moments as well as inverting a high-dimensional system of equations, which is clearly demanding in terms of both data and computation. What Huang and Ottaviano (2024) show is that a country's relative state of technology in a given sector can be alternatively assessed by relying on a single equilibrium equation and a very short list of empirical moments ('sufficient statistics'), mostly related to the country of interest, without having to calibrate the entire model.[3] These moments are the country's relative market size and relative factor prices, together with its sector-specific

[1]See Arkolakis et al. (2012) and Arkolakis et al. (2019) for a sufficient statistics approach to welfare analysis in the wake of Chetty (2009).

[2]See Costinot et al. (2012) and French (2017) for a related discussion.

[3]See, e.g., Costinot et al. (2012), Lagakos and Waugh (2013), Levchenko and Zhang (2016), Costinot et al. (2016), French (2017), and Redding and Weinstein (2018) for alternative approaches.

export propensity (i.e. share of firms that export), export intensity (i.e. export over total revenues), trade freeness (i.e. international market accessibility), and heterogeneity in firm productivity.

In this respect, the sufficient statistics approach proposed by Huang and Ottaviano (2024) offers a handy index of (revealed) 'relative state of technology' (RST). This is larger than one in sectors where the country has a better state of technology than the rest of the world, defined as relative 'start-up productivity', which is the minimum productivity firms can expect to achieve when entering the market (Eaton and Kortum, 2002). Their sufficient statistics approach also allows disentangling how a country's relative productivity changes across sectors as the country opens up to trade, with specific insights on the impact of pro-competitive effects related to variable markups.

We hereby provide the first comprehensive evaluation of the Europe's RST in manufacturing with special emphasis on its two biggest economies (France and Germany). Apart from being interesting in itself given the public debate, Europe provides an ideal setting to implement the sufficient statistics analysis thanks to the unique richness and quality of available harmonized micro-aggregated moments for several sectors in several countries. In particular, we can leverage CompNet, a micro-aggregated dataset of productivity indicators and their drivers, with special emphasis on trade. The final aim is twofold. First, by computing the RST, we want to uncover where Europe's relative technological advantage currently lies. Second, by comparing the patterns of RST and BRCA, we want to unveil the market forces that may misalign Europe's relative export specialization and its relative technological advantage.

We find that Europe has better state of technology than the rest of the world ($RST > 1$) in all manufacturing industries, but especially in wearing apparel, food, basic metals and furniture, and non-metallic mineral products. Among these industries, however, only in food and non-metallic mineral products Europe also exhibits export specialization ($BRCA > 1$). In other sectors, such as motor vehicles, wood, paper products, and machinery, Europe has strong export specialization despite less pronounced technological advantage. In general, the lack of systematic correlation between RST and BRCA confirms that revealed comparative advantage is an imperfect measure of a country's technological prowess due to the concurrent influences of factor prices, market size, markups, firm selection and market share reallocation.

The rest of the paper is organized in four sections. Section 2 describes the data we use. Section 3 presents the theoretical framework of the analysis. Section 4 reports the empirical results. Section 5 concludes.

2 Data

The analysis exploits two main data sources. The first is the 9^{th} Vintage of the CompNet dataset, an unbalanced panel dataset covering non-financial corporations across 22 European countries (CompNet, 2023).[4] This dataset is gathered by the Competitiveness Research Network, hosted by the Halle Institute for Economic Research, with collaboration from various institutions, including the European Commission, European Bank for Reconstruction and Development, European Investment Bank, European Stability Mechanism, France Stratégie, the German Council of Economic Experts, the German Federal Ministry for Economic Affairs and Climate Action, and the Tinbergen Institute.

The dataset consists of micro-aggregated indicators derived from administrative balance sheet data from the 22 countries. Data providers are National Statistical Institutes (NSI) as well as researchers in National Central Banks and in selected academic institutions, which collect administrative firm-level data representative of the entire population of firms. All indicators are calculated using a harmonized data collection protocol, ensuring cross-country comparability.[5] Using a distributed micro-data approach, the CompNet

[4]We employ the s.c. "20e" dataset of CompNet, i.e., the dataset compiled by setting a harmonized reporting threshold for firms with at least 20 employees and re-weighted to align representativeness of sectors and size classes with Eurostat. This dataset contains information for 21 countries: BE, HR, CZ, DK, FI, FR, DE, HU, IT, LV, LT, MT, NL, PL, PT, RO, SK, SI, ES, SE and CH, among which trade information is available for all but BE, IT, LV, ES, and CH. Table A.1 in Appendix A reports the data coverage for the CompNet 20e dataset vis-Evis Eurostat SBS and OCED ICIO.

[5]See Altomonte et al. (2018) for a discussion of cross-country comparability of CompNet, and Altomonte and di Mauro (2022) for an application of CompNet to derive empirical evidence on policies aimed at increasing overall productivity.

team calculates indicators across multiple levels of aggregation, such as country, macro-sector, industry, region (NUTS2), technology/knowledge category, and company age.[6] At each aggregation level, there are nearly 600 variables organized into 6 main categories: finance, productivity, labor, competition, trade, and other areas. Each variable includes moments of the distribution, decompositions, and joint distributions, and CompNet also publishes transition matrices for selected variables. A detailed description of variables, country coverage, and data sources can be found in CompNet (2022). The CompNet dataset is publicly available on request for research purposes.

The other dataset we use is the OECD Inter-Country Input-Output tables (ICIO). For our purposes, the tables map international trade flows across countries and sectors of economic activity covering 45 ISIC Rev. 4 2-digit sectors in 76 countries and the rest of the world. In particular, the tables provide bilateral exchanges of goods and services for the manufacturing sectors (divisions in Nace Rev. 2 section C) in the 16 countries of our sample that report trade variables in CompNet. This allows us to match each exporting country and sector with the aggregate exports to all other countries and sectors, including those in the EU and extra-EU that are not represented in CompNet. ICIO information is necessary to compute two critical variables later described in the paper, namely trade freeness parameters and BRCA. However, while the OECD ICIO tables provide aggregate international flows, they do not feature micro trade data, especially export propensity (share of exporting firms), which we source from CompNet.[7]

3 Revealed Relative State of Technology: a Sufficient Statistics Approach

Our objective is to understand the extent to which a country's export specialization across industries is driven by their technological prowess relative to foreign industries. Technological prowess is, however, hard to measure directly as the observed productivity of an industry is detemined by many other concurring factors. To circumvent this problem, we apply the model by Huang and Ottaviano (2024), who modify the perfectly competitive general equilibrium approach Dornbusch et al. (1977, 1980) with a continuum of industries to allow them to feature monopolistic competition among heterogeneous firms as in Mayer et al. (2014). In the model export specialization is determined by the interplay of all the main sources of export specialization highlighted in the literature: relative state of technology (Ricardo); relative factor endowments (Heckscher-Ohlin); relative market size and relative market access (Krugman); relative competitive pressure and firm selection (Melitz). It thus provides a theory-consistent structural way to design a crosswalk between industries' export performance and technological prowess controlling for other factors.

The model considers two countries, the country of interest ('Home') and a benchmark country ('Foreign'), with given numbers of consumers L and L^* respectively, which we take as measures of their market sizes. In each country consumers are endowed with a unit of labor, which they supply inelastically so that L and L^* are also the countries' labor endowments. Each consumer is also endowed with K/L or K^*/L^* units of capital depending on the country of residence so that K and K^* are the countries' capital endowments. There is a continuum of industries indexed $z \in [0, 1]$, each of which supplies a set $\Omega(z)$ of horizontally differentiated varieties indexed $i \in \Omega(z)$. Labour and capital markets are perfectly competitive, whereas the product markets of the different industries are monopolistically competitive. While trade is free within countries, between them it faces iceberg frictions with $\tau(z) > 1$ units to be shipped for one unit to reach destination.

3.1 Preferences and Consumer Behavior

Consumers in both countries have identical preference. We focus on Home noting that symmetric expressions hold for Foreign. Individual utility is given by:

[6] See Bartelsman et al. (2004) and Lopez-Garcia and di Mauro (2015).

[7] For consistency, we also compute export intensity (exports on revenues) from CompNet although it is in principle observable in OECD ICIO.

$$U=\int_0^1 b(z)\ln\left(\alpha\int_{i\in\Omega(z)} q_i^c(z)di-\frac{\gamma}{1-\delta}\int_{i\in\Omega(z)} q_i^c(z)^{1-\delta}di\right)dz,$$

where $q_i^c(z)$ denotes individual consumption of the differentiated product variety i in industry z and $b(z)>0$ is the expenditure share of industry z with $\int_0^1 b(z)dz=1$. The parameters $\gamma>0$ and $\delta<0$ capture the substitutability between varieties within each industry, which is a decreasing function of both.[8] The budget constraint faced by a consumer is:

$$\int_0^1\int_{i\in\Omega(z)} p_i(z)q_i^c(z)didz=wL+rK/L,$$

where $p_i(z)$ is the price of variety i in industry z, while w and r are the wage of labor and the rental rate of capital. Solving the consumer's problem yields the following inverse individual demand for the differentiated varieties:

$$p_i(z)=p_{max}(z)-\frac{\gamma}{\lambda(z)}q_i^c(z)^{-\delta},$$

where $p_{max}(z)=\alpha/\lambda(z)$ is the 'choke price' above which demand is null, and $\lambda(z)$ is the marginal utility of income. The market demand for variety i in industry z is then given by:

$$q_i(z)=L\left(\frac{\gamma}{\lambda(z)}\right)^{\frac{1}{\delta}}(p_{max}(z)-p_i(z))^{-\frac{1}{\delta}}, \tag{1}$$

as L is the number of consumers in the home country. According to (1), the demand elasticity to price is a decreasing function of $p_{max}(z)$ and thus an increasing function of $\lambda(z)$. The choke price and the marginal utility of income can, therefore, be respectively taken as an inverse and a direct measures of industry z's endogenous competitive pressure.

3.2 Production and Firm Behaviour

In all industries firms employ both labor and capital as inputs in a Cobb-Douglas production function such that the price of a unit input bundle in industry z evaluates to $\omega(z)=w^{\iota(z)}r^{1-\iota(z)}/\left[(1-\iota(z))^{1-\iota(z)}\iota(z)^{\iota(z)}\right]$ with $\iota(z)\in(0,1)$. While labor intensity $\iota(z)$ differs across industries, within an industry it is the same for all firms, which nonetheless have different total factor productivity (TFP indexed by φ) or, equivalently different unit input requirement (UIR indexed by $c=1/\varphi$). Then, a firm in industry z with UIR c has marginal cost $\omega(z)c$ as in Corcos et al. (2012). Given demand (1), the firm's maximized profit evaluates to

$$\pi_D(z,c)=-\delta L\left(\frac{\gamma}{\lambda(z)}\right)^{\frac{1}{\delta}}\left(\frac{p_{max}(z)-\omega(z)c}{1-\delta}\right)^{1-\frac{1}{\delta}} \tag{2}$$

for domestic sales and

$$\pi_X(z,c)=-\delta L^*\left(\frac{\gamma}{\lambda^*(z)}\right)^{\frac{1}{\delta}}\left(\frac{p^*_{max}(z)-\tau(z)\omega(z)c}{1-\delta}\right)^{1-\frac{1}{\delta}} \tag{3}$$

for export sales.

In each industry firms face a sunk entry cost incurred in units of its unit input bundle. Specifically, firms entering industry z pay an entry cost $\omega(z)f_E$ as in Romalis (2004) and Bernard et al. (2007). After entry, they draw their UIR from a Pareto distribution $G(z,c)=(c/C_M(z))^{k(z)}$, defined over the support $[0,C_M(z)]$ with $k(z)>1$ measuring the concentration of density towards its upper bound. Accordingly, $k(z)$ inversely captures the heterogeneity of the firm TFP distribution in industry z. For given $k(z)$, larger $C_M(z)$ implies a higher probability of worse UIR draws. It can then be used to inversely measure the industry's 'state of technology'.

[8] For $\delta=-1$ utility is quadratic as in Mayer et al. (2014).

The fact that profits (2) and (3) are decreasing functions of c implies that, after all entrants have drawn their UIR, only those with c weakly lower than the domestic cutoff UIR $C_D(z) = p_{\max}(z)/\omega(z)$ make non-negative profits and sell in the domestic market. The others exit without producing. Among the survivors, only those with c weakly lower than the export cutoff UIR $C_X(z) = p^*_{\max}(z)/\left[\tau(z)\omega(z)\right] = \left[\omega(z)^* C^*_D(z)\right]/\left[\tau(z)\omega(z)\right] < C_D(z)$ also export to Foreign. Due to free entry in Home, the sum of expected profits from sales in the domestic and export markets equals the sunk entry cost:

$$\int_0^{C_D(z)} \pi_D(z,c)dG(z,c) + \int_0^{C_X(z)} \pi_X(z,c)dG(z,c) = \omega(z)f_E, \tag{4}$$

with an analogous expression holding for entrants in Foreign. After substituting the export cutoff in each country with its aforementioned expression in terms of the domestic cutoff in the other country, the free entry condition (4) for Home and its counterpart for Foreign can be solved together to obtain the domestic cutoffs. For Home, the solution is:

$$C_D(z) = \left[\frac{1-\rho(z)\left(\frac{\omega^*(z)}{\omega(z)}\right)^{k(z)+1}\left(\frac{C^*_M(z)}{C_M(z)}\right)^{k(z)}}{1-\rho(z)^2}\right]^{\frac{1}{k(z)+1}} C^A_D(z),$$

where $\rho(z) = \tau(z)^{-k(z)} \in [0,1]$ is an index of trade freeness, while $C^A_D(z)$ is the autarkic domestic cutoff

$$C^A_D(z) = \left[C_M(z)^{k(z)}\frac{f_E}{\beta(z)L}\left(\frac{\alpha}{\gamma}\right)^{\frac{1}{\delta}}\right]^{\frac{1}{k(z)+1}},$$

which corresponds to prohibitive trade frictions ($\rho(z) = 0$), where $\beta(z) = -\delta(1-\delta)^{(1-\delta)/\delta}k(z)B(k(z), 2-1/\delta)$ is a constant with $B(\cdot)$ denoting the Beta function.[9] As $C^A_D(z)$ is an increasing function of $C_M(z)$ and a decreasing function of L, in autarky competitive pressure, and thus firm selection, is stronger the better the country's state of technology and the larger its market size. In addition, for $\omega(z) = \omega^*(z)$ and $C_M(z) = C^*_M(z)$, $C_D(z)$ is a decreasing function of $\rho(z)$: freer trade (larger $\rho(z)$) raises competitive pressure and fosters firm selection (reduces $C_D(z)$).

3.3 Industry Productivity and Trade Performance

These expressions can be used to explore the relation between a Home industry's average productivity and its trade performance at both the extensive and intensive margins. For productivity, Huang and Ottaviano (2024) define the TFPQ of Home industry z as the industry's output per unit of input bundle. They then use $\overline{\Phi}(z)$ and $\overline{\Phi}(z)^A$ to denote Home TFPQ with and without trade respectively. For trade, they use $\chi(z) = \left(C_X(z)/C_D(z)\right)^{k(z)}$ to denote the industry's 'export propensity' defined as the fraction of its firms that export, and $\theta(z)$ to denote its 'export intensity' defined as the ratio of export revenues to total revenues.

Based on these definition, they highlight three key properties. First, they show that export propensity $\chi(z)$, trade freeness $\rho(z)$, firms herogeneity $k(z)$ and relative market size L/L^* regulate the relation between relative TFPQ with and without trade. In particular, relative TFPQ with trade can be decomposed as the product of relative TFPQ in autarky ('ex-ante component') and two factors ('ex-post components') capturing the parallel amplifying and dampening effects of trade liberalization on the translation of relative TFPQ without trade into relative TFPQ with trade:

$$\frac{\overline{\Phi}(z)}{\overline{\Phi}^*(z)} = \underbrace{\frac{\overline{\Phi}^A(z)}{\overline{\Phi}^{A*}(z)}}_{ex\text{-}ante\ component}\underbrace{\left(\frac{\frac{L}{L^*}\rho(z)+\left(\frac{\chi(z)}{\rho(z)}\right)^{\frac{k(z)+1}{k(z)}}}{\frac{L^*}{L}\rho(z)+\left(\frac{\chi(z)}{\rho(z)}\right)^{-\frac{k(z)+1}{k(z)}}}\right)^{\frac{k(z)}{k(z)+1}}}_{ex\text{-}post\ amplifying\ component\ >\ 1}\underbrace{\frac{\rho(z)\chi(z)^{-1}+\frac{L^*}{L}\rho(z)}{\rho(z)^{-1}\chi(z)+\frac{L}{L^*}\rho(z)}}_{ex\text{-}post\ dampening\ component\ <\ 1}, \tag{5}$$

[9] The Beta function is defined as $B(x,y) = \int_0^1 t^{x-1}(1-t)^{y-1}dt$.

where $\overline{\Phi}^A(z)/\overline{\Phi}^{A*}(z) = C_D^{A*}(z)/C_D^A(z)$ is the industry's relative TFPQ in autarky. Which ex-post component prevails cannot be determined theoretically but only empirically. Intuitively, in industries with higher export propensity $\chi(z)$, firm selection into exporting is weaker. This reduces the productivity premium of exporters relative to non-exporters and thus industry TFPQ at the extensive margin. On the other hand, industries with higher $\chi(z)$, also have a larger share of exporters. As these are more productive than non-exporters, that raises industry TFPQ.

Second, export intensity $\theta(z)$, trade freeness $\rho(z)$, firm hereogeneity $k(z)$ and relative market size L/L^* regulate the relation between relative TFPQ in autarky and relative unit input prices with trade:

$$\frac{\overline{\Phi}^A(z)}{\overline{\Phi}^{A*}(z)} = \frac{\omega(z)}{\omega^*(z)} \left[\rho\left(1-\theta(z)\right) + \rho^{-1}\theta(z)\right]^{\frac{1}{k(z)+1}} \left(\frac{L}{L^*}\right)^{\frac{1}{k(z)+1}}. \tag{6}$$

Third and last, export intensity $\theta(z)$, trade freeness $\rho(z)$ and firm hereogeneity $k(z)$ determine the relation between relative state of technology and relative unit input prices with trade:

$$\frac{C_M^*(z)}{C_M(z)} = \left(\frac{\omega(z)}{\omega^*(z)}\right)^{\frac{k(z)+1}{k(z)}} \left[\rho\left(1-\theta(z)\right) + \rho^{-1}\theta(z)\right]^{\frac{1}{k(z)}}. \tag{7}$$

This expression defines the theory-based index of Revealed Relative State of Technology (RST).

The practical relevance of these properties comes for the fact that relative autarkic TFPQ ($\overline{\Phi}^A(z)/\overline{\Phi}^{A*}(z)$) is unobservable in the absence of data on a counterfactual situation without trade, while relative state of technology ($C_M^*(z)/C_M(z)$) would remain unobservable even if those data were available since $C_D^A(z)$ depends not only on $C_M(z)$ but also on L as already discussed. What (6) and (7) allow one to do is to use the observed export intensity $\theta(z)$, trade freeness $\rho(z)$, firm heterogeneity $k(z)$, relative market size L/L^* and relative unit input price $\omega(z)/\omega^*(z)$ to compute the unobserved relative autarkic TFPQ and state of technology without having to calibrate the entire model. Huang and Ottaviano (2024) call this a 'sufficient statistics approach'.

4 The Technological Prowess of France, Germany and the EU

We are now ready to apply the sufficient statistics approach by Huang and Ottaviano (2024) to investigate the extent to which European export specialization across industries is driven by their technological prowess relative to foreign industries. As a measure of export specialization, we use the traditional index of 'revealed' comparative advantage (Balassa, 1965), henceforth called BRCA. For an industry in a country, the corresponding BRCA is defined as its share of national exports divided by the industry's share of exports in a group of reference countries, which we consider to be the Rest of the World (RoW). If the value of its BRCA is larger than 1, the country's relatively stronger export specialization in the industry 'reveals' its comparative advantage in that industry. Analogously, a value of its BRCA smaller than 1 reveals the country's relatively weaker export specialization in the industry.

4.1 Sufficient Statistics

Following Huang and Ottaviano (2024), for a given year relative unit input prices $\omega(z)/\omega^*(z)$ are retrieved from the Penn World Table 10.01. For the country of interest we compute the wage rate as real GDP multiplied by the labor share and divided by total employment. The labor share $\iota(z)$ is calculated as the industry-level median of firm labor cost relative to value added for each industry from CompNet.[10] For the rental rate of capital, we take the real internal rate of return. Measures for the RoW are obtained as weighted average across all countries without missing data, with the wage rate weighted by employment and the interest rate weighted by capital stock. These pieces of information allow us to evaluate the country-industry price of a unit input bundle in industry z, which we defined as $\omega(z) = w^{\iota(z)}r^{1-\iota(z)}/\left[w^*(z)^{\iota(z)}r^*(z)^{1-\iota(z)}\right]$.

[10]However, when retrieving the EU aggregate, we consider the average industry labor share across countries.

As for relative market size and trade freeness, we compute them in a model-consistent way as

$$\frac{L(z)}{L^*(z)} = \frac{1-\theta(z)}{\theta(z)}\chi(z)^{\frac{k+1}{k}}\rho(z)^{-\frac{1}{k}}$$

and, following Head and Ries (2001), as

$$\rho(z) = \sqrt{\frac{Exp(z)}{S(z)}\frac{Exp^*(z)}{S^*(z)}},$$

where $Exp(z)$ and $S(z)$ are industry z's exports and domestic sales of the country of interest while $Exp^*(z)$ and $S^*(z)$ are the analogues for the RoW. These are lifted from the OECD Inter Country Input Output tables. For the country of interest, $Exp(z)$ is equal to total industry output $Out(z)$ minus domestic sales: $Exp(z) = Out(z) - S(z)$. For the RoW, we proceed as follows. We use superscript $^\circ$ to label a RoW country, such that $Exp^\circ(z) = Out^\circ(z) - S^\circ(z)$. We then sum $Exp^\circ(z)$ and $S^\circ(z)$ across all RoW countries to obtain $Exp^*(z) = \sum_o Exp^\circ(z)$ and $S^*(z) = \sum_o S^\circ(z)$. This implies that

$$\frac{Exp^*(z)}{S^*(z)} = \frac{\sum_o S^\circ(z)\frac{Exp^\circ(z)}{S^\circ(z)}}{\sum_o S^\circ(z)}$$

is a weighted average of $Exp^\circ(z)/S^\circ(z)$ across RoW countries with weights given by their shares $S^\circ(z)/\sum_o S^\circ(z)$ of total RoW domestic sales. Hence, $Exp^*(z)/S^*(z)$ is specific to the country of interest because the RoW includes all countries except that country. Note that, in the case of the RoW, sales between its composing countries are classified as 'exports' rather than 'domestic sales' within an integrated RoW market. The same method is used for the countries in our sample when calculating the aggregate for the European Union.

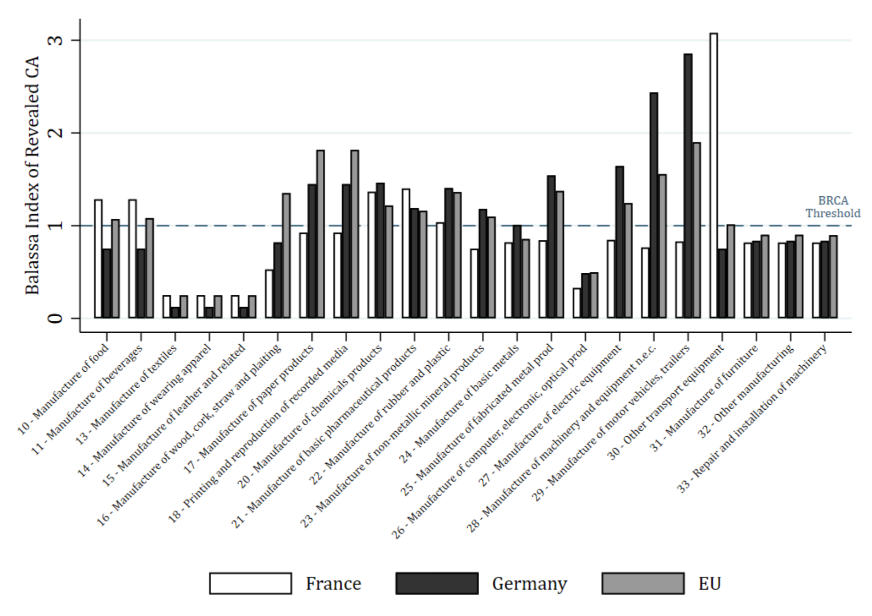
Finally, firm heterogeneity $k(z)$ is obtained by averaging across countries the skewness of the within-industry firm distribution of TFP 3 in CompNet, which results from the estimation of TFP following Ackerberg et al. (2015).

To summarize, for a given year, export propensity $\chi(z)$, export intensity $\theta(z)$, relative unit input price $\omega(z)/\omega^*(z)$, relative market size $L(z)/L^*(z)$ and trade freeness $\rho(z)$ vary across countries and industries, while firm hereogeneity $k(z)$ varies across industries. Summary statistics for France, Germany and the European Union are reported in Appendix B.

4.2 Export Specialization and State of Technology

The BRCA for France, Germany, and the European Union with respect to the rest of the world is illustrated in Figure **1**. The figure shows that France and Germany are remarkably different in their actual export performance. France has a BRCA in sectors 10 and 11 (Food and Beverages), 20 and 21 (Chemical product and Pharmaceutical products), marginally in 22 (Rubber and plastic) and strongly in 30 (Other transport equipment; likely driven by Airbus). While Germany shares with France its BRCA in sectors 20, 21 and 22, it does not share its BRCA in sectors 10, 11 and 30. It has, however, a BRCA in several other sectors: 17 (Paper), 18 (Printing), 23 (Non-metallic mineral), 25 (Fabricated metal), 27 (Electric equipment), 28 (Machinery) and 29 (Motor vehicles). In both countries strong revealed comparative disadvantage characterizes not only relative low-tech sectors such as 13 (Textiles), 14 (Wearing apparel) and 15 (Wood), but also a high-tech sector such as 26 (Computer).

Figure 1: Balassa Revealed Comparative Advantage in France and Germany



Source: CompNet, OECD ICIO, and calculations by the authors.
Note: The dashed blue line represents the threshold for the *Balassa Index of Revealed CA* to indicate specialization. The OECD ICIO tables consolidate sectors 10, 11, 13, 14, 15, 31, 32, and 33 into broader categories. For these sectors, the figure for the corresponding category is reported. Average from 2010 to 2018.

All this is very much in line with what one would expect, but how does it compare with the revealed relative state of technology (RST)? Figure 2 shows the results obtained from computing the RST of French sectors based on expression (7). While France has a better state of technology than the world average in virtually all sectors, the RST pattern across sectors is quite different from the BRCA one. Only sectors 20 and 21 exhibit alignment in relative position across both BRCA and RST. The remaining French sectors display divergent patterns. Specifically, sectors 13, 14, 15, 23, 24 (Basic metals), 25, 26 and 32 (Other manufacturing) show particularly unfavorable relative BRCA values with respect to their corresponding RST. In contrast, sector 30 - the sector with the highest BRCA - is much relatively more successful in terms of BRCA than RST.

Figure 2: Balassa Revealed Comparative Advantage and Relative State of Technology in France

Source: CompNet, OECD ICIO, and calculations by the authors.
Note: *Relative State of Technology* is computed like in equation (7). *Balassa Index of Revealed CA* and *Relative State of Technology* are represented on the left-hand and right-hand axes, respectively. The dashed blue line represents the threshold for the *Balassa Index of Revealed CA* to indicate specialization. The dashed orange line is the maximum value of *Relative State of Technology*. The OECD ICIO tables consolidate sectors 10, 11, 13, 14, 15, 31, 32, and 33 into broader categories. For these sectors, the *Balassa Index of Revealed CA* for the corresponding category is reported. Average from 2010 to 2018.

Figure 3 reports the corresponding results for Germany. As for France, there are sectors with relatively high BRCA (such as 27, 28, and 29) that are not 'backed' by relatively high RST. For sectors 24, 14, 10 and 13, the divergence between BRCA and RST is particularly high, implying that relative export performance has rather little to do with the relative state of technology.

Figure 3: Balassa Revealed Comparative Advantage and Relative State of Technology in Germany

Source: CompNet, OECD ICIO, and calculations by the authors.
Note: *Relative State of Technology* is computed like in equation (7). *Balassa Index of Revealed CA* and *Relative State of Technology* are represented on the left-hand and right-hand axes, respectively. The dashed blue line represents the threshold for the *Balassa Index of Revealed CA* to indicate specialization. The dashed orange line is the maximum value of *Relative State of Technology*. The OECD ICIO tables consolidate sectors 10, 11, 13, 14, 15, 31, 32, and 33 into broader categories. For these sectors, the *Balassa Index of Revealed CA* for the corresponding category is reported. Average from 2010 to 2018.

When considering the EU as a whole in Figure 4, a picture similar to the German one emerges. Specifically, sectors 29, 18, 17, 28, and 27 are relatively much more successful in terms of BRCA than RST. In contrast, sectors 14, 10 and 24 show particularly unfavorable BRCA relative to the corresponding RST.

Notably, the highest BRCA of France in sector 30 (Other transport equipment) is associated with an RST of 1.60, which is low compared to the largest RST in France (3.70 for sector 15 Leather). It is also lower than the RST of the very same sector 30 in Germany (4.98) and in the EU on average (3.2). This divergence between French BRCA and RST is likely driven by Airbus and may be explained in terms of the important role played by scale economies in aircraft production.

Figure 4: Balassa Revealed Comparative Advantage and Relative State of Technology in the EU

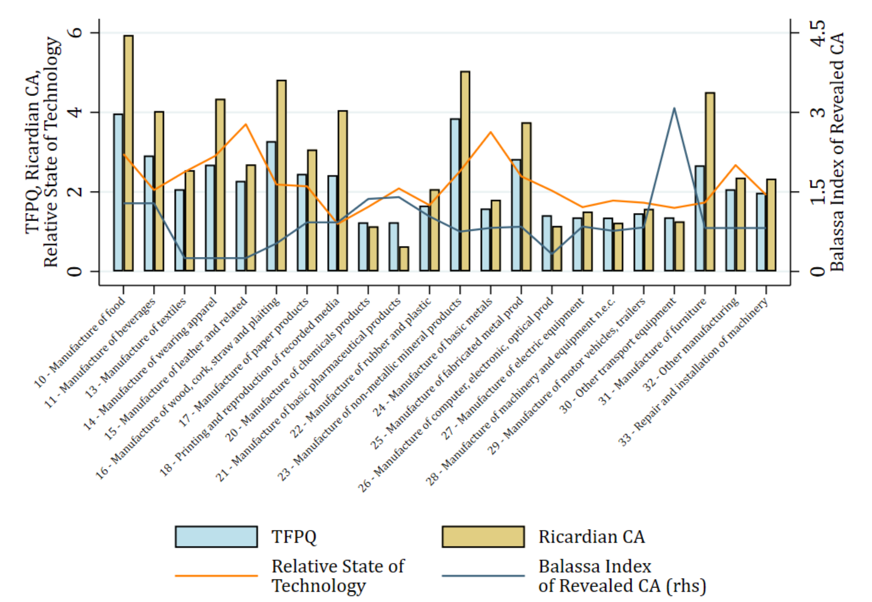
Source: CompNet, OECD ICIO, and calculations by the authors.
Note: *Relative State of Technology* is computed like in equation (7). *Balassa Index of Revealed CA* and *Relative State of Technology* are represented on the left-hand and right-hand axes, respectively. The dashed blue line represents the threshold for the *Balassa Index of Revealed CA* to indicate specialization. The figures for the EU are derived by aggregating components (exports, export intensity, export propensity, trade freeness, and relative unit input prices) across the EU countries included in our sample: HR, CZ, DK, FI, FR, DE, HU, LT, MT, NL, PL, PT, RO, SK, SI, and SE. The OECD ICIO tables consolidate sectors 10, 11, 13, 14, 15, 31, 32, and 33 into broader categories. For these sectors, the *Balassa Index of Revealed CA* for the corresponding category is reported. Average from 2010 to 2018.

4.3 TFPQ and Ricardian CA

The observed discrepancies between the patterns of BRCA and RST in Europe may arise because the state of technology is very imperfectly reflected in the actual industry productivity. Indeed, the model implies that the mapping from RST ($C^*_M(z)/C_M(z)$) to relative TFPQ ($\overline{\Phi}(z)/\overline{\Phi}^*(z)$) is determined only after competitive pressure has selected the firms that are able to produce and eventually export. We therefore turn our attention to the comparison between BRCA and relative TFPQ across sectors. We also investigate the extent to which export specialization is related to relative TFPQ in autarky ($\overline{\Phi}^A(z)/\overline{\Phi}^{A*}(z)$). This is important as the variation of relative TFPQ in autarky across industries determines their relative autarkic prices, which in turn define the canonical notion of comparative advantage discussed in Section 1: Home has a comparative advantage in an industry with respect to Foreign if the autarkic price of that industry relative to other industries is lower in Home than in Foreign.

To compute relative TFPQ with trade ($\overline{\Phi}(z)/\overline{\Phi}^*(z)$) and without trade ($\overline{\Phi}^A(z)/\overline{\Phi}^{A*}(z)$), we rely on expression (5) and (6). To avoid confusion, we call the former simply TFPQ and the latter Ricardian (i.e. productivity-based) comparative advantage (CA). Figure 5 reports the results for France. It shows that TFPQ does not consistently correlate with either BRCA or Ricardian CA. This disconnect is particularly relevant in sectors 20, 21 and 30, where high export specialization contrasts with lackluster relative productivity performance, no matter whether measured as TFPQ or Ricardian CA. Conversely, sectors 10 and 11 exhibit both strong BRCA and relatively high TFPQ, as well as relatively hight RST as seen before.

Figure 5: TFPQ and Ricardian Comparative Advantage in France

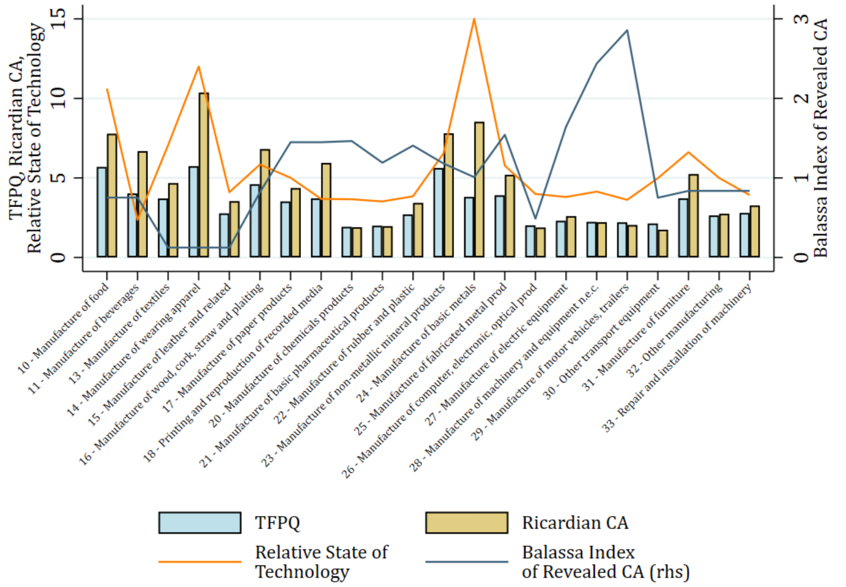


Source: CompNet, OECD ICIO, and calculations by the authors.
Note: *TFPQ* and *Ricardian CA* are computed like in equations (5) and (6), respectively. *Relative State of Technology* is computed like in equation (7). *TFPQ*, *Ricardian CA*, and *Relative State of Technology* are represented on the left-hand axis. *Balassa Index of Revealed CA* is represented on the right-hand axis. The OECD ICIO tables consolidate sectors 10, 11, 13, 14, 15, 31, 32, and 33 into broader categories. For these sectors, the *Balassa Index of Revealed CA* for the corresponding category is reported. Average from 2010 to 2018.

Interestingly, approximately half of the French sectors display a Ricardian CA higher than their RST, suggesting vibrant endogenous firm selection already in the domestic market prior to trade liberalization. However, in almost all sectors, relative TFPQ sits below Ricardian CA, a pattern that we will further explore in the next section.

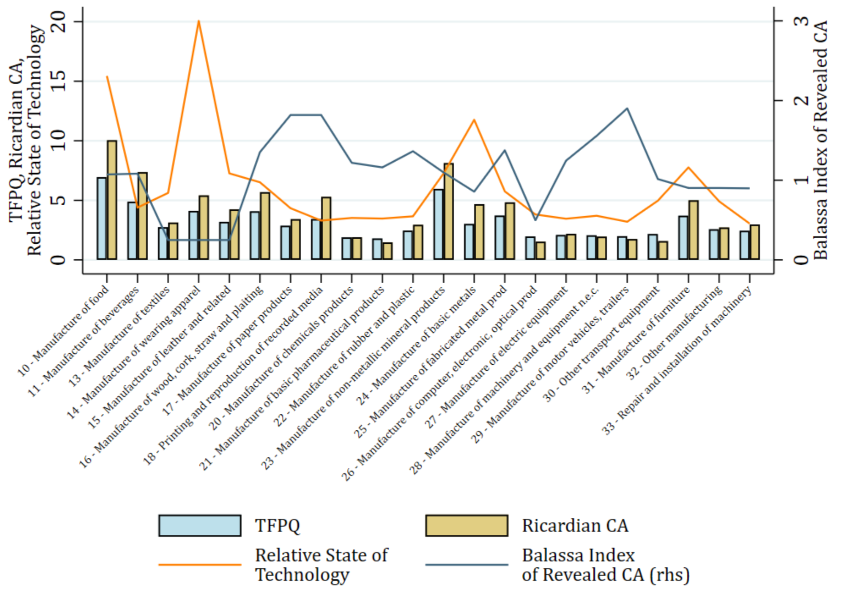
In the case of Germany (Figure 6) the mismatch between the most productive sectors in relative terms (as measured by either relative TFPQ or Ricardian CA) and those with relatively high BRCA is even more pronounced. Sectors 20, 21, 27, 28, and 29 rank among the lowest in terms of relative productivity. Additionally, Ricardian CA lags behind RST across most sectors, hinting at weak domestic firm selection relative to other countries. Similarly to France, TFPQ consistently falls below Ricardian CA. These observations also apply to the EU aggregate (Figure 7).

Figure 6: TFPQ and Ricardian Comparative Advantage in Germany



Source: CompNet, OECD ICIO, and calculations by the authors.
Note: *TFPQ* and *Ricardian CA* are computed like in equations (5) and (6), respectively. *Relative State of Technology* is computed like in equation (7). *TFPQ*, *Ricardian CA*, and *Relative State of Technology* are represented on the left-hand axis. *Balassa Index of Revealed CA* is represented on the right-hand axis. The OECD ICIO tables consolidate sectors 10, 11, 13, 14, 15, 31, 32, and 33 into broader categories. For these sectors, the *Balassa Index of Revealed CA* for the corresponding category is reported. Average from 2010 to 2018.

Figure 7: TFPQ and Ricardian Comparative Advantage in the EU



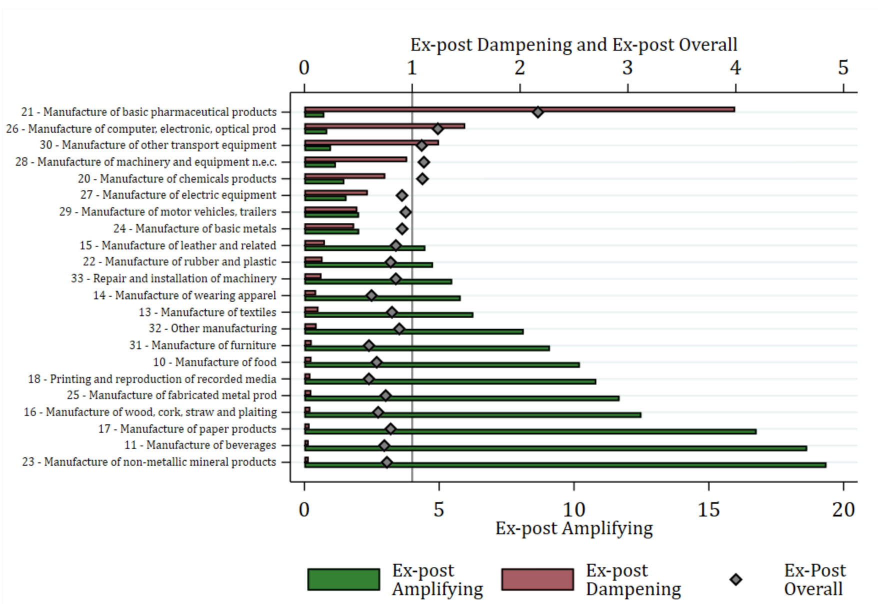
Source: CompNet, OECD ICIO, and calculations by the authors.
Note: *TFPQ* and *Ricardian CA* are computed like in equations (5) and (6), respectively. *Relative State of Technology* is computed like in equation (7). *TFPQ*, *Ricardian CA*, and *Relative State of Technology* are represented on the left-hand axis. *Balassa Index of Revealed CA* is represented on the right-hand axis. The figures for the EU are derived by aggregating components (exports, export intensity, export propensity, trade freeness, and relative unit input prices) across the EU countries included in our sample: HR, CZ, DK, FI, FR, DE, HU, LT, MT, NL, PL, PT, RO, SK, SI, and SE. The OECD ICIO tables consolidate sectors 10, 11, 13, 14, 15, 31, 32, and 33 into broader categories. For these sectors, the *Balassa Index of Revealed CA* for the corresponding category is reported. Average from 2010 to 2018.

4.4 Does Trade Dampen or Amplify Ricardian CA?

We have seen that, for both France and Germany, in almost all sectors relative TFPQ is smaller than Ricardian CA. From a theoretical viewpoint, as already discussed in Section 3, there is no reason why relative TFPQ should unambiguously be larger or smaller than Ricardian CA. This can be explained in terms of two opposite effects. In industries with higher export propensity, firm selection into exporting is weaker, which reduces the productivity premium of exporters relative to non-exporters and thus dampens industry TFPQ at the extensive margin. At the same time, industries with higher export propensity also have a larger share of exporters, which amplifies industry TFPQ as they are more productive than non-exporters.

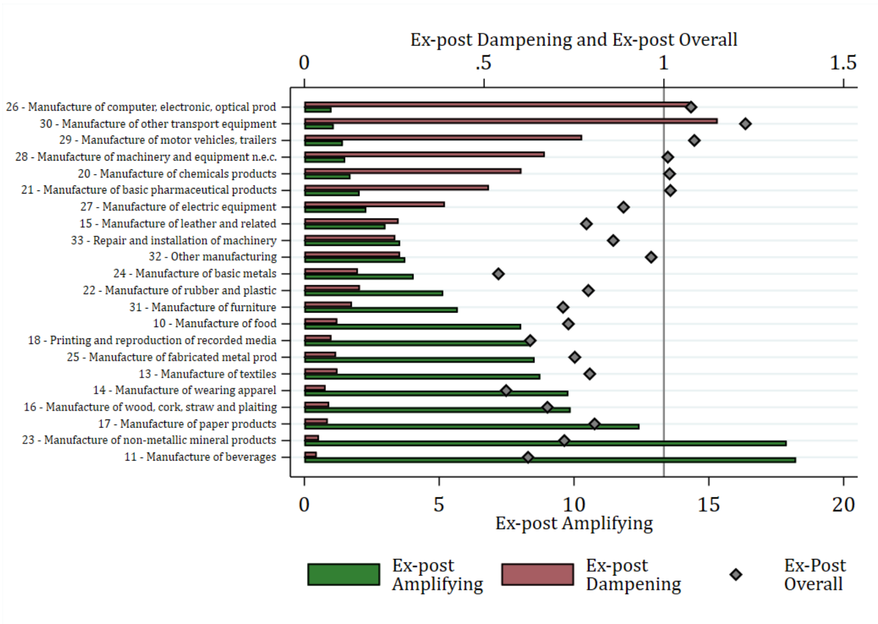
The quantitative relevance of these effects can be assessed based on expression (5). Figures 8, 9, and 10 depict the results for France, Germany, and the EU respectively, highlighting the ex-post dampening and amplifying components of TFPQ as well their overall net effect. For France, the ex-post component enhances TFPQ only in sectors 21, 26, 30, 28, and 20, three of which also exhibit BRCA. Although these sectors do not rank particularly high in terms of Ricardian CA, they gain from their engagement in international trade. In contrast, in all other sectors the dampening component dominates the amplifying one.

Figure 8: Ex-post Components of Relative TFPQ in France



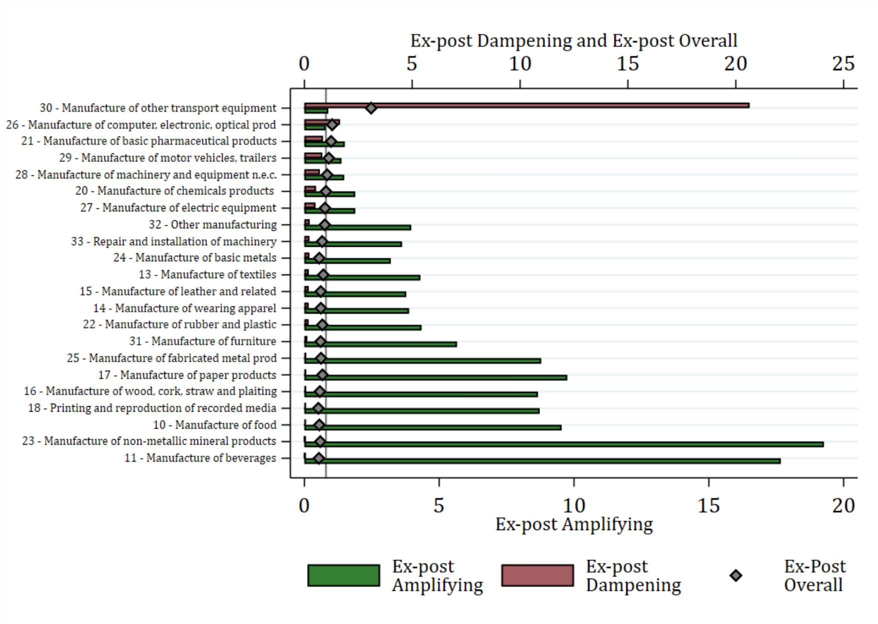
Source: CompNet, OECD ICIO, and calculations by the authors.
Note: *Ex-post Dampening* and *Ex-post Amplifying* are computed like in equation (5) and are represented on the upper and lower axes, respectively. *Ex-post Overall* is the product of *Ex-post Dampening* and *Ex-post Amplifying* and is represented on the upper axis. Average from 2010 to 2018.

Figure 9: Ex-post Components of Relative TFPQ in Germany



Source: CompNet, OECD ICIO, and calculations by the authors.
Note: *Ex-post Dampening* and *Ex-post Amplifying* are computed like in equation (5) and are represented on the upper and lower axes, respectively. *Ex-post Overall* is the product of *Ex-post Dampening* and *Ex-post Amplifying* and is represented on the upper axis. Average from 2010 to 2018.

Figure 10: Ex-post Components of Relative TFPQ in the EU



Source: CompNet, OECD ICIO, and calculations by the authors.
Note: *Ex-post Dampening* and *Ex-post Amplifying* are computed like in equation (5) and are represented on the upper and lower axes, respectively. *Ex-post Overall* is the product of *Ex-post Dampening* and *Ex-post Amplifying* and is represented on the upper axis. The figures for the EU are derived by aggregating components (exports, export intensity, export propensity, trade freeness, and relative unit input prices) across the EU countries included in our sample: HR, CZ, DK, FI, FR, DE, HU, LT, MT, NL, PL, PT, RO, SK, SI, and SE. Average from 2010 to 2018.

The dampening component is also dominant in most sectors in Germany and, more broadly, across the EU, where only sectors 26, 30, 29, 28, 20 and 21 experience an increase from Ricardian CA to TFPQ. Interestingly, in both French and German sectors where relative productivity improves through trade, this effect is primarily due to an ineffective ex-post dampening component rather than a strong ex-post amplifying one. This contrasts with the other sectors, where significant ex-post amplifying components are completely neutralized by ex-post dampening ones. It also suggests that sectors with BRCA may be shielded from trade-related consequences that could jeopardize their productivity advantages.

5 Conclusion

The Draghi report (Draghi, 2024), has put technological prowess at the center of the policy debate on EU competitiveness. Based on the sufficient statistics approach developed by Huang and Ottaviano (2024), we have shown how the state of technology of European industries relative to the rest of the world can be empirically assessed in a way that is simple in terms of computation, parsimonious in terms of data requirements, but still comprehensive in terms of information. This has allowed us to answer two main questions on where Europe's relative technological advantage currently lies, and whether market forces may misalign its relative technological advantage and its relative export specialization.

We have found that Europe has better state of technology than the rest of the world in all manufacturing industries, but especially in wearing apparel, food, basic metals and furniture, and non-metallic mineral products. Among these industries, however, Europe also exhibits export specialization only in food and non-metallic mineral products. In other industries, such as motor vehicles, wood, paper products, and machinery, Europe has strong export specialization despite less pronounced technological advantage.

In general, the lack of systematic cross-industry correlation between relative export specialization and technological advantage suggests that standard measures of revealed comparative advantage only imperfectly capture a country's technological prowess due to the concurrent influences of factor prices, market size, markups, firm selection and market share reallocation. This can be explained in terms of competitive pressures and scale effects associated with national market size and international trade.

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Appendices

A CompNet Data Coverage

Table A.1: CompNet Coverage against Eurostat SBS and OECD ICIO, by key variables

	Employment	Revenues	Export	Labor Productivity
Country				
Croatia	0.82	0.93	1.35	1.15
Czech Republic	0.97	0.92	0.82	1.01
Denmark	0.85	0.90	1.24	1.11
Finland	0.87	0.80	0.77	0.96
France	0.75	0.69	0.89	0.91
Germany	0.96	1.03	1.07	1.03
Hungary	0.88	0.84	1.03	0.95
Lithuania	0.84	0.88	0.85	1.04
Malta	1.77	3.54	0.82	0.62
Netherlands	0.87	0.89	0.80	0.89
Poland	0.88	0.86	0.88	0.98
Portugal	0.74	0.73	0.84	0.92
Romania	0.87	0.82	1.32	0.99
Slovakia	0.88	0.79	0.78	0.95
Slovenia	0.84	0.88	0.94	1.06
Sweden	0.90	0.92	1.05	1.13
Industry				
10T12-Food products, beverages and tobacco	0.82	0.91	1.02	1.05
13T15-Textiles, textile products, leather and footwear	0.92	1.07	1.46	1.17
16-Wood and products of wood and cork	0.70	0.79	0.83	1.26
17_18-Paper products and printing	0.83	0.90	0.91	1.05
20-Chemical and chemical products	1.00	0.93	0.95	0.90
21-Pharmaceuticals, medicinal chemical and botanical products	1.08	0.83	1.18	1.04
22-Rubber and plastics products	0.95	1.01	0.95	1.06
23-Other non-metallic mineral products	0.84	0.87	0.91	1.12
24-Basic metals	0.95	0.85	0.76	0.94
25-Fabricated metal products	0.79	0.85	1.00	1.16
26-Computer, electronic and optical equipment	0.95	0.77	0.80	0.68
27-Electrical equipment	1.00	1.07	0.97	1.05
28-Machinery and equipment, nec	0.99	1.05	1.01	1.05
29-Motor vehicles, trailers and semi-trailers	0.94	0.87	1.06	0.92
30-Other transport equipment	0.95	0.84	1.02	1.02
31T33-Manufacturing nec; repair and installation of machinery and equipment	0.76	0.81	1.01	1.18
Year				
2010	0.87	0.90	0.91	1.01
2011	0.88	0.92	0.86	1.05
2012	0.90	0.91	0.95	1.01
2013	0.90	0.92	0.92	1.03
2014	0.90	0.90	0.89	0.98
2015	0.91	0.93	1.10	1.01
2016	0.89	0.89	1.09	0.96
2017	0.89	0.89	1.08	0.97
2018	0.84	0.89	1.04	0.99

Source: CompNet, Eurostat SBS, OECD ICIO.
Notes: *Employment*, *Revenues*, and *Labor Productivity* are the ratios of the respective measures in CompNet over Eurostat SBS for the matched year-country-industry combinations. *Labor Productivity* is computed like revenue per employee. *Export* is the ratio of the respective measure in CompNet over OECD ICIO for the matched year-country-industry combinations. The panel *Country* reports the ratio for the sums of *Employment*, *Revenues*, and *Export* and for the means of *Labor Productivity* by country over industries and years. The panel *Industry* reports the ratio for the sums of *Employment*, *Revenues*, and *Export* and for the means of *Labor Productivity* by industry over countries and years. The considered year-country-industry combinations are for the countries and industries in the table, and for years between 2010 and 2018.

B Summary Statistics

Table A.2: Summary Statistics for Key Variables

Variable	Obs	Mean	P10	P25	P50	P75	P90	SD
All Countries								
Relative Unit Input Price $\frac{\omega}{\omega^*}$	2,771	1.56	1.17	1.30	1.45	1.85	2.11	0.36
Trade Freeness ρ	2,771	0.43	0.17	0.25	0.40	0.57	0.73	0.23
Firms Heterogeneity κ	2,771	1.15	0.74	0.93	1.12	1.39	1.56	0.32
Relative Market Size $\frac{L}{L^*}$	2,771	4.81	0.29	0.66	1.45	4.00	10.59	13.99
European Union								
Relative Unit Input Price $\frac{\omega}{\omega^*}$	193	1.95	1.69	1.82	1.92	2.03	2.24	0.21
Trade Freeness ρ	193	0.39	0.17	0.23	0.33	0.54	0.63	0.19
Firms Heterogeneity κ	193	1.15	0.70	0.93	1.12	1.38	1.54	0.31
Relative Market Size $\frac{L}{L^*}$	193	3.29	0.59	0.93	2.25	4.12	8.31	3.34
France								
Relative Unit Input Price $\frac{\omega}{\omega^*}$	196	1.27	1.12	1.19	1.27	1.35	1.43	0.13
Trade Freeness ρ	196	0.38	0.16	0.19	0.28	0.56	0.70	0.25
Firms Heterogeneity κ	196	1.16	0.74	0.93	1.13	1.39	1.62	0.32
Relative Market Size $\frac{L}{L^*}$	196	4.60	0.61	1.11	2.68	6.90	11.21	4.45
Germany								
Relative Unit Input Price $\frac{\omega}{\omega^*}$	198	2.01	1.75	1.97	2.04	2.12	2.18	0.17
Trade Freeness ρ	198	0.37	0.16	0.23	0.29	0.53	0.65	0.19
Firms Heterogeneity κ	198	1.16	0.74	0.93	1.13	1.39	1.62	0.32
Relative Market Size $\frac{L}{L^*}$	198	4.48	0.80	1.01	2.93	6.57	10.00	4.51

Source: CompNet, OECD ICIO, and calculations by the authors.
Notes: *Relative Unit Input Price*, *Trade Freeness*, *Firms Heterogeneity*, and *Relative Market Size* are compute like in subsection 4.1. The unit of observation is a year-country-industry combination, for counties, industries, and years in Table A.1, the only exception being *Firms Heterogeneity* which is computed like the year-industry average. The figures for the *European Union* are derived by aggregating variables across the EU countries included in our sample: HR, CZ, DK, FI, FR, DE, HU, LT, MT, NL, PL, PT, RO, SK, SI, and SE.

Halle Institute for Economic Research –
Member of the Leibniz Association

Kleine Maerkerstrasse 8
D-06108 Halle (Saale), Germany

Postal Adress: P.O. Box 11 03 61
D-06017 Halle (Saale), Germany

Tel +49 345 7753 60
Fax +49 345 7753 820

www.iwh-halle.de
www.comp-net.org

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