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Market Selection in Global Value Chains

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Abstract

The idea that market selection promotes survival and expansion of the "fittest" producers is a key principle underlying theories of competition. Yet, despite its intuitive appeal, the hypothesis that companies with superior productivity also exhibit higher growth lacks empirical support. One reason for this is that companies are not "islands" that produce goods and services in isolation but depend on their suppliers in value chains, implying that excessive growth can also originate in the superior productive performance of these value-chain partners. Neglecting these dependencies in empirical tests of the selection hypothesis leads to measurement errors and may impair the identification of competition for the market. In this paper, we use data from the World Input-Output Database to capture these global value-chain relationships in an empirical test for market selection, studying competition between country-sectors for a global market share in different economic activities. Compared to the conventional view that focuses on individual productivities, our value-chain perspective on the productivity-growth nexus provides stronger empirical support for market selection. This suggests that the scope of selection reaches beyond the level of individual producers and requires a systemic analysis of production networks. Our findings contribute to a better understanding of the determinants of selection in competitive environments and also represent a novel application of global value-chain data.

Keywords: competition; country–sector dynamics; input–output analysis; replicator dynamics; productivity decomposition

JEL Classification: C67; D22; L14; L16; L20

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1 Introduction

What determines the market success of producers in a competitive environment? One way to approach the process leading to economic success — usually measured in terms of market shares — roots in the evolutionary hypothesis of the "survival of the fittest" that is consistent with Darwinian principles. According to this view, market selection ensures that the fittest producers will see their share in the market grow, while the others will shrink and are eventually driven out of the market. This idea has inspired studies of firm-level market selection using variants of the so-called replicator dynamics model (Taylor and Jonker, 1978, Metcalfe, 1994). Yet, although this approach offers an intuitive explanation of differential growth driven by competition, the literature has until now barely succeeded in the task to turn analytical outcomes into compelling empirical evidence.

The reasons why the empirical evidence does not lend much support to the selection hypothesis are manifold. Possible explanations include the naïve interpretation of how selection works, misconceptions about the subjects and boundaries of selection (e.g., industry vs. (sub-)market), and the choice of irrelevant fitness measures. Typically, at the firm level, fitness is boiled down to a single indicator that reflects technological and economic characteristics of the individual producer (e.g., productivity, unit costs, or combinations of product characteristics, Cantner et al., 2012). The firm-specific (idiosyncratic) realization of this indicator is then employed to explain the success of the individual firm in the market. In this paper, we argue that the complexity of value chains, where producers buy intermediate inputs from upstream suppliers and sell their output to downstream customers, may undermine the selection mechanism at the level of individual producers. This is because less efficient producers can gain share in their own markets if they are linked to superior value chain partners in related markets, even if their own productive performance is relatively poor (and vice versa), as argued theoretically by Cantner et al. (2019). Put differently, it is not only the idiosyncratic fitness that determines the market success of an individual producer but also the fitness of the value chain the producer belongs to.

Against this background, the purpose of the present study is to empirically test the selection hypothesis extended to value chains. To map these value chains, we employ network panel data on production input linkages from the World Input Output Database (WIOD; see Timmer et al., 2015), providing sector-level data for 43 major economies over the period 2000-2014. Consequently, the unit of observation in our sample is not a firm in a given sector but a sector in a certain country (country-sector, henceforth), which competes with corresponding sectors in other countries on the global market. Compared to the prototypical example of firm-level value chains, for which we could not obtain suitable data, the advantage of the WIOD data is not only its global coverage but also the fact that it captures the full range of economic activities in the value chain, including all pre- and post-production phases before the output is sold to final consumers.

Building on these data, we use standard input-output accounting (Leontief, 1936) and a model of vertical production in the spirit of Pasinetti (1973) to compute direct and indirect input and value-added contributions of all suppliers participating in the global value chain (GVC) of a given country-sector. We then use these quantities to estimate (labor) productivity of the entire value chain, which represents a more thorough measure of productive performance than the idiosyncratic productivity of the individual country-sector. The explicit comparison between the two productivity measures enables us to assess the gains in explanatory power arising from the shift of attention away from individual producers towards value chains. Building on this approach, we conduct three different tests for market selection.

First, we consider an aggregate labor productivity index for each sector and decompose its change over time into a within and a between component. The latter captures the change in aggregate productivity arising from the transition of market shares from less to more productive producers. Under the hypothesis that the selection mechanism works properly, we expect that the between effect is positive and can explain a considerable fraction of the change in aggregate productivity. In other words, a country-sector operating above (below) the average productivity will experience an increase (decrease) of its share in global markets. We run this test based on the individual labor productivity and the productivity of the entire value chain and find that the consideration of the latter productivity leads to a higher median and mean between effect across all sectors, supporting the hypothesis that selection forces are stronger at the value-chain level.

Second, we turn to a more direct test for market selection by assessing the explanatory power of idiosyncratic versus value-chain productivity for output growth in regression analysis. Again, our results support the extended selection hypothesis as the productivity of the entire value chain can better explain variation in producers' growth in end-consumer markets than the individual productivity.

Third, we employ a spatial regression approach to assess the direct influence of the upstream suppliers' productivity on the growth of the focal country-sector. This model incorporates the productivity level and productivity change of the focal producer as well as the spatial lags of these variables for its direct and indirect suppliers, which enables us to separate the effect of the producer's idiosyncratic characteristics and the influence of the value-chain partners. Consistent with the extended selection hypothesis, our results suggest that the relation between the individual productivity change and its spatial lag on the one end and the output growth on the other end is significantly positive. We also find that the joint explanatory power of the individual and spatial productivity terms is almost identical to that of the value-chain productivity measure in our second test, and that the effect pertaining to the spatially lagged productivity terms is at least as strong as the direct influence of the individual productivity. Therefore, neglecting the former leads to a systematic underestimation of the strength of market selection, and can explain the weak empirical support for the market selection hypothesis in prior work. Overall, our results testify to the importance of value chains in shaping the success of producers in competitive markets.

The remainder of this paper is structured as follows. Section 2 provides a review of the pertinent literature. Section 3 describes the data and explains the measurement of productivity in GVCs based on world input–output tables. Section 4 introduces our empirical strategy and discusses the results of our analysis, while Section 5 concludes.

2 Related literature

Our work relates to different strands of literature. First and foremost, it is connected with studies on market selection and industry dynamics. Fueled by the growing availability of detailed firm and establishment level data in the last few decades (Bartelsman, 2010), a diverse literature has started to consider that there is "a great variability in the fate of similar firms over time" (Ericson and Pakes, 1995), evoking the question of how firm heterogeneity and market selection shape the evolution of industries. Models in this vein pertain to different research traditions, ranging from Jovanovic's (1982) classic selection model for industry evolution with passive learning to so-called Markov-perfect industry dynamics (Ericson and Pakes, 1995, Weintraub et al., 2008, Doraszelski and Satterthwaite, 2010, Hopenhayn, 1992) and evolutionary models (Winter et al., 2003). Yet, despite these different theoretical perspectives, researchers have applied similar empirical strategies to measure selection based on productivity decomposition (Maliranta and Määttänen, 2015) and evolutionary accounting (Metcalfe, 2008). Evolutionary models of market selection rely on the replicator dynamics model (Metcalfe, 1994, Mazzucato, 1998) as their standard workhorse. It predicts that firms whose fitness is above a benchmark (typically conceived as a market-share-weighted performance indicator) will gain market shares at the expense of their less fit competitors. The replicator dynamics model can be tested empirically either by assessing the "between" term in productivity decompositions (see, e.g., Foster et al., 2001), which captures the change in the aggregate productivity index originating in the reallocation of market shares between firms, or by directly estimating the relationship between the fitness of firms and their sales growth in regressions (Bottazzi et al., 2010). Yet, prior empirical tests of the replicator dynamics mechanism have largely failed to provide conclusive support to the theory. For example, Dosi et al. (2015) conduct an extensive empirical analysis of selection forces based on both decomposition and regression analysis for France, Germany, the United Kingdom, and the United States. They conclude that aggregate productivity gains originate predominantly in a learning process occurring within the firm, while the effect pertaining to the reallocation of market shares towards fitter producers is small and in some countries even negative. Although the results of their complementary regression analysis are slightly more optimistic about the strength of selection effects, attributing on average 14-19% of the variance in sales growth to idiosyncratic productivity terms, the overall evidence for the selection mechanism is relatively weak. Our idea to extend the scope of the empirical analysis to value chains is most closely related to the recent model by Cantner et al. (2019) that suggests that theories of market selection must incorporate interdependencies between producers. In particular, their work shows that the survival and growth of the fittest actors may hold at the value-chain level, while the empirically observed "regressive" selection dynamics may occur at individual layers of the value chain in the sense that firms with low fitness experience high growth due to the influence of their value-chain partners. The present study links to this model by providing the first empirical test of market selection in value chains.

Since our work highlights the influence of supply-chain partners on the market success of individual producers, the present study also relates to the broader literature explaining how network structure shapes economic outcomes. Related effects have been explored in different research trajectories, ranging from abstract network games in which individual payoffs depend on the peer group (Galeotti et al., 2010) to concrete applications in the fields of the economics of innovation (Savin and Egbetokun, 2016, Korzinov and Savin, 2018), suggesting that network structure determines the firm's propensity to innovate or the technology one should innovate upon. The influence of peer groups and limited interactions between certain individuals also determine opinion dynamics in populations (van den Bergh et al., 2019), and the recent macroeconomics literature describes how input-output linkages facilitate the propagation of idiosyncratic shocks and thus contribute to aggregate fluctuations (Acemoglu et al., 2012, Carvalho and Tahbaz-Salehi, 2019, Carvalho and Grassi, 2019, Di Giovanni et al., 2014). Accounting for vertical relationships in production processes is also important for industrial policy, development, and international trade. Liu (2019) describes how sales distortions may compound through input-output linkages, thereby providing an incentive to subsidize upstream sectors because they are prone to these distortions. In a similar vein, King et al. (2019) show that carbon tax reforms targeting specific sectors based on their position in the production network may lead to a greater reduction in emissions, while Laursen and Meliciani (2000) explain sectors' export shares based on upstream and downstream industrial linkages, finding that these linkages are an important channel for innovation spillovers that determine the competitiveness in international markets. Last but not least, the relevance of production linkages is also stressed in the field of corporate strategy. For example, Wan and Wu (2017) propose a model of value distribution in vertical relationships and explain how suppliers can "climb" a value chain to compete with their downstream partners in the product market. The present paper contributes to this literature by analyzing the influence of network structure on the competitive process.

Last but not least, our study relates to the growing literature that explores and explains GVCs. Recent years have seen a surge of interest in GVCs because production processes increasingly rely on foreign value added, typically exhibiting complex "spider-like" configurations that go beyond the prototypical example of "snake-like" structures (Antràs, 2020). Analytical models of GVCs are variations of trade models with sequential production (Antràs and Chor, 2013, Costinot et al., 2013). These models shed light on the mechanisms behind the allocation of production stages to firms or countries (Chor, 2019, Alcacer and Delgado, 2016) and on the geographical location of given stages of production in the presence of trade barriers (Antràs and De Gortari, 2020). Parallel to the theoretical study of GVCs, the literature has progressed on the fronts of developing GVC governance models (Gereffi et al., 2005), empirical investigations into the determinants and consequences of participating in GVCs (Amador and Cabral, 2016, Antràs, 2020), and on the measurement of GVCs (Johnson, 2018). In this respect, the growing availability of global input-output data from sources such as WIOD (Timmer et al., 2015) has been particularly valuable. A main research topic in this field has been that of "slicing up" GVCs in order to understand the distribution of value added across countries (Timmer et al., 2014), and the measurement of "upstreamness" and "downstreamness" of producers to assess their distance to final consumers. (Antràs et al., 2012, Antràs and Chor, 2018). Moreover, López González et al. (2019) study the interplay between inter-industry linkages and patterns of specialization. Using WIOD data, they show that countries' participation in business services depends on the presence of domestic industries that are backward-linked to business services. In a recent publication, Amoroso and Martino (2020) use WIOD data to compute firms' distance to the technology frontier and study the efficacy of capital, labor, and product market policies in the technological catch-up process. Our work contributes to this literature by discussing a novel application of input-output data in the field of competition analysis and market selection.

3 Data and productivity measurement

Our analysis employs network panel data on global production input linkages for the period 2000-2014 across $N = 43$ countries. These include the current 27 member states of the European Union and 16 additional large economies such as the United States, China, Japan, India, Russia, Brazil, United Kingdom, and Canada, which together account for approximately 85% of world GDP at the end of the sample period. This data are obtained from the 2016 release of the World Input Output Database (WIOD) that reports annual trade flows in intermediate goods between $S = 56$ sectors (see Timmer et al., 2015, for a comprehensive introduction to the WIOD database). Therefore, our entire sample consists of $SN = 2408$ country-sectors such as, for instance, crop and animal production in Australia or manufacturing of pharmaceutical products in Spain.

The input-output network in Figure 1 illustrates intra- and inter-sectoral trade in intermediate inputs within and across countries. From 2000 to 2014 the number of production input linkages increased by almost 69% from 370,912 to 625,937, testifying to the rising complexity of the global production network over time. The high relevance of GVCs is also reflected in the share of total output sold to downstream sectors. Averaging across all sectors, this share increased from 52% in 2000 to 58% in 2014, suggesting that trade in intermediate inputs accounts for the major share of trade and became evidently more important over time, which motivates our interest in GVCs and their effect on competition in the first place.

In addition to these input-output data, WIOD provides information on the quantity of goods and services sold to end consumers domestically and abroad, which enables us to distinguish sector output by its utilization. It also includes data on total gross output, value added, and

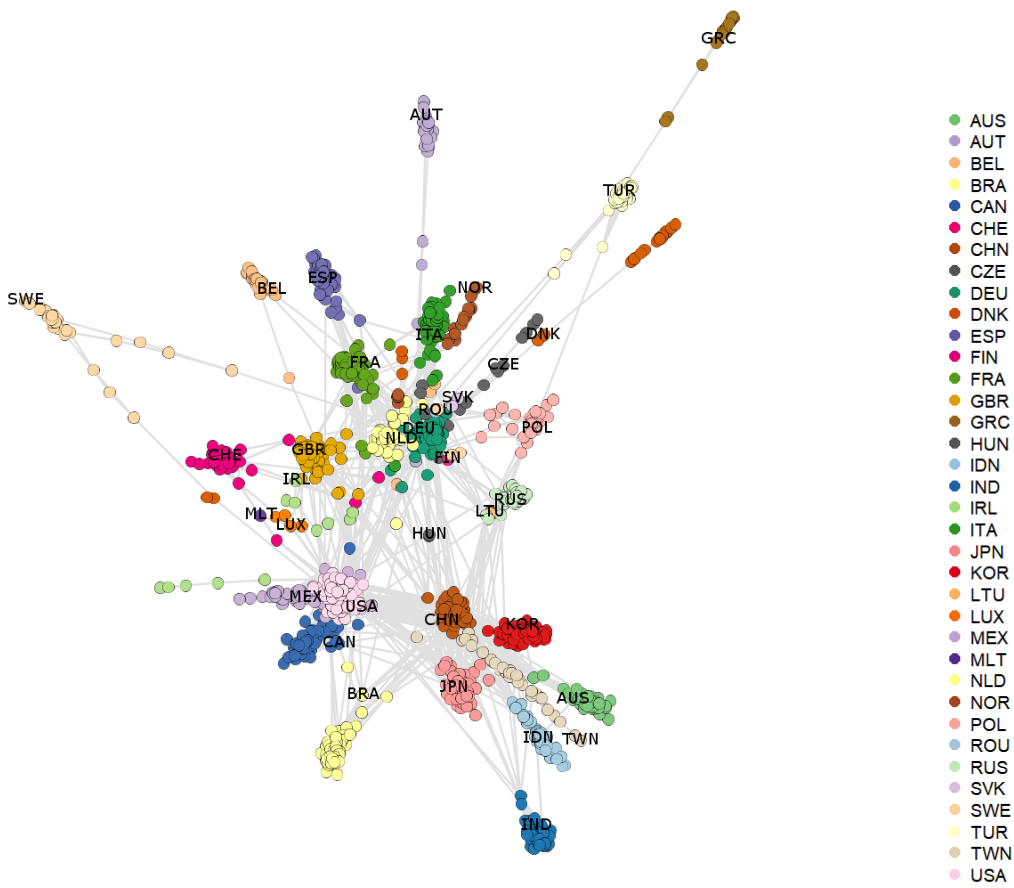

Figure 1: The global input-output network in 2014.

Note: Nodes represent country-sectors and edges illustrate trade in intermediate inputs. Colors represent the 43 countries. Edges with a weight below 1 billion USD have been removed to simplify the graphical exposition.

employment via the supplementary Socio-Economic Accounts that we use to assess the productivity of individual country-sectors and entire value chains. All these data are converted into US Dollars and adjusted for inflation using national price indexes with base year 2010.

Throughout this study our measure of productivity is value added per hour of labor. To test for market selection in value chains and to compare our network approach to prior literature, we consider two variations of labor productivity: (i) the individual labor productivity of each country-sector (idiosyncratic productivity), and (ii) the productivity of the entire value chain of each country-sector, including the focal producer that sells output to final consumers and all its direct and indirect suppliers (value-chain productivity). For the value-chain productivity measure, we compute the ratio of the sum of value added across all layers of the GVC to the sum of both direct and indirect labor demand for producing a particular final good or service. Since the accounting identity implies that the sum of value added across all contributing country-sectors equals the output sold to end consumers, we measure the former as final demand. To compute the total labor demand across all layers of the GVC, we combine standard methodology in input-output analysis (Leontief, 1936) with the model of vertical production initially proposed

Table 1: Mean and median growth rate and idiosyncratic and value chain labor productivity.

Growth			Productivity					
			Idiosyncratic			Value-chain		
Obs.	Mean	Median	Obs.	Mean	Median	Obs.	Mean	Median
30,764	0.03681	0.04193	32,979	62.39	35.76	32,619	49.04	40.91

Note: Productivity is in USD per labor hour and is measured in constant prices as of 2010 as explained in the main text.

by Pasinetti (1973) and later applied to productivity measurement by Timmer and Ye (2017).[1] Building on this approach, the labor requirements matrix is given by

$$\mathbf{L} = \mathbf{l}(\mathbf{I} - \mathbf{A})^{-1}\mathbf{f}, \tag{1}$$

where $(\mathbf{I} - \mathbf{A})^{-1}$ is known as the Leontief-inverse with the identity matrix $\mathbf{I}$. $\mathbf{A}$ is a $SN \times SN$ matrix of technical coefficients, with the element in row m and column n quantifiying the output shipped from country-sector m to country-sector n, divided by the output of the receiving country-sector. $\mathbf{l}$ in Eq. (1) is an $SN \times SN$ matrix with the direct labor coefficients on the main diagonal and zero otherwise. These direct labor coefficients reflect the labor demand of a particular country-sector, measured in terms of labor hours, per unit of gross output. If we post-multiply these direct labor coefficients with the Leontief inverse, we obtain the direct and indirect labor requirements of each country-sector per unit of final output. Finally, we derive the matrix of direct and indirect labor requirements, $\mathbf{L}$, by post-multiplying this result with the diagonal matrix $\mathbf{f}$ with dimension $SN \times SN$, capturing the final demand of each country-sector. For the country-sector in a given column of $\mathbf{L}$, the pertinent column sum measures the absolute quantity of direct and indirect labor that is necessary to produce the final output of this country-sector, while its row sum quantifies the total hours worked in this country-sector. Notice that the latter also includes labor to produce intermediates for other domestic and foreign sectors.

In addition to the value-chain productivity measure, we also consider the idiosyncratic labor productivity of the focal country-sector to compare our results to the case where value chain linkages are ignored, i.e. following the strategy adopted in prior studies (cf. Section 2).[2] To this end, we proceed in the standard way and compute the ratio of the country-sector's gross output minus its intermediate use to the total hours worked in this particular country-sector. The crucial difference between the value-chain and idiosyncratic productivity measures is that the former sums up the labor and value added contributions of all domestic and foreign sectors in the value chain to produce output for the target country-sector, while the latter focuses on the target country-sector and thus disregards that a significant fraction of output is sold to other producers as an intermediate input. The explicit comparison of the two measures enables us to assess the change in explanatory power of productivity on growth arising from the consideration of value-chain linkages in the replicator dynamics model.

Table 1 reports summary statistics for the output growth rate and the two alternative productivity measures calculated across all time periods and country-sectors in our dataset. The results suggest that country-sectors grow with an annual rate of 3.7% on average, while the median

[1] Unlike our study, Timmer and Ye (2017) construct a measure of total factor productivity (TFP) for value chains. Yet, for the sake of consistency with previous work, and because TFP might be biased in the presence of technologically heterogeneous firms and input complementarities (Dosi and Grazzi, 2006), we focus on labor productivity.

[2] Yet, here we consider the country-sector instead of the firm-sector level.

growth rate is 4.2%, indicating a negatively skewed distribution. Comparing the two productivity measures, we find that the idiosyncratic productivity has a mean of 62 USD per hour of labor, while the value-chain productivity is smaller with a value of 49 USD per hour of labor. One potential explanation of the larger idiosyncratic productivity measure is that end-consumer markets in some sectors have very high profit margins, which renders the entry of upstream suppliers into these markets so attractive (Wan and Wu, 2017).

Table 2 shows the standard deviations of growth rates and (the log of) idiosyncratic and value chain productivity. Consistent with the view that idiosyncratic shocks are averaged out at the higher level of aggregation due to diversification, we find that the variability of growth rates is considerably smaller on the country-sector level than what is usually found for individual firms. For example, Dosi et al. (2015) report median standard deviations for firm growth in France, Germany, UK, and the US in the range 0.2-0.4, while for our data the median standard deviation across all sectors amounts to 0.15.

Comparing the dispersion of labor productivity to estimates obtained for firm-level data, we find that the dispersion of sector-level productivity is typically larger. While our estimates are between 0.8 and 1.1, Dosi et al. (2015) report standard deviations between 0.5 and 0.6 for developed economies. One way to rationalize this disparity is that our global sample also includes developing countries or economies in transition, e.g. Russia, for which the standard deviation of productivity is much higher (around 1.7 on average; see Savin et al., 2020). Our estimates imply that a country in a given sector which is one standard deviation above the mean is about seven times more productive than a country whose productivity is one standard deviation below the mean.[3] It is worth noting, however, that the consideration of value-chain linkages reduces productivity dispersion to some extent, consistent with the view that the global perspective on production processes leads to convergence in productivities because the vast majority of producers are connected via input-output linkages. Yet, even at the value-chain level, there is large variation of productivity across countries to warrant a meaningful analysis of its effect on differential growth. We will turn to this question in the next section.

4 Empirical strategy and results

In this section, we outline our empirical strategy and then present three related sets of results testing market selection in value chains. The empirical strategy is geared to the recent study by Cantner et al. (2019), which extends the replicator dynamics model to value chains. In their model, firms in a value chain are connected to each other by contracts that regulate the delivery of intermediate products. The authors show that value-chain fitness, which results from the aggregation of the performance of all firms in a given value chain, governs the success of the firm in the end-consumer market and its upstream suppliers. In other words, the model predicts that the selection dynamics works properly at the bottom layer of the value chain under the condition that the performance of all upstream suppliers is incorporated, while it may fail when solely the individual performance of the firm at the end of the value chain is considered.

In the present study, the unit of observation is not a firm operating in a given sector but a country-sector in a global market. The latter are connected by input linkages characterizing value chains. To test whether market selection dynamics should be assessed based on the idiosyncratic performance of a country-sector or the performance of the whole value chain, we compute and compare the explanatory power of the two productivity measures introduced in Section 3. If the value-chain labor productivity measure yields stronger evidence for selection dynamics, we

[3]For comparison, US firms whose productivity is one standard deviation above the mean are about three times more productive than companies which operate one standard deviation below the mean (Dosi et al., 2015).

Table 2: Standard deviations of growth and (log) labor productivity.

Sector	Growth	Productivity	
		Idiosyncratic	Value-chain
Crop and animal production	0.12	1.12	0.95
Forestry and logging	0.19	1.19	1.04
Fishing and aquaculture	0.17	1.20	1.05
Mining and quarrying	0.15	1.30	0.97
Manufacture of food products	0.10	0.84	0.77
Manufacture of textiles	0.13	1.06	0.86
Manufacture of wood	0.14	0.95	0.83
Manufacture of paper	0.14	0.85	0.73
Printing and reproduction of recorded media	0.14	0.80	0.69
Manufacture of coke and refined petroleum products	0.24	1.33	0.95
Manufacture of chemicals and chemical products	0.19	0.98	0.74
Manufacture of basic pharmaceutical products	0.13	1.04	0.74
Manufacture of rubber and plastic products	0.14	0.89	0.70
Manufacture of other non-metallic mineral products	0.15	0.90	0.75
Manufacture of basic metals	0.18	0.93	0.69
Manufacture of fabricated metal products	0.16	0.86	0.66
Manufacture of computer	0.19	1.07	0.79
Manufacture of electrical equipment	0.18	0.92	0.71
Manufacture of machinery and equipment n.e.c.	0.17	0.91	0.69
Manufacture of motor vehicles	0.21	0.84	0.64
Manufacture of other transport equipment	0.21	0.98	0.71
Manufacture of furniture	0.16	1.03	0.82
Repair and installation of machinery and equipment	0.17	0.75	0.64
Electricity, gas, steam and air conditioning supply	0.15	1.07	0.80
Water collection, treatment and supply	0.12	1.14	0.92
Sewerage	0.14	0.85	0.63
Construction	0.14	0.86	0.73
Wholesale and retail trade and repair of motor vehicles	0.15	0.83	0.73
Wholesale trade, except of motor vehicles and motorcycles	0.12	0.86	0.73
Retail trade, except of motor vehicles and motorcycles	0.11	0.76	0.72
Land transport and transport via pipelines	0.15	0.81	0.72
Water transport	0.19	1.23	0.85
Air transport	0.22	1.07	0.75
Warehousing and support activities for transportation	0.15	0.81	0.75
Postal and courier activities	0.25	0.83	0.77
Accommodation and food service activities	0.11	0.80	0.77
Publishing activities	0.15	0.96	0.70
Motion picture, video and television	0.15	0.84	0.69
Telecommunications	0.12	1.02	0.85
Computer programming and consultancy	0.13	0.72	0.66
Financial service activities	0.12	0.81	0.75
Insurance, reinsurance and pension funding	0.15	0.90	0.78
Activities auxiliary to financial services and insurance	0.22	0.83	0.57
Real estate activities	0.10	1.35	0.98
Legal and accounting activities	0.12	0.88	0.79
Architectural and engineering activities	0.15	0.77	0.69
Scientific research and development	0.17	0.93	0.77
Advertising and market research	0.19	0.77	0.61
Other professional, scientific and technical activities	0.16	0.85	0.68
Administrative and support service activities	0.13	0.83	0.75
Public administration and defence	0.09	0.84	0.79
Education	0.09	1.02	0.97
Human health and social work activities	0.09	0.90	0.82
Other service activities	0.11	0.79	0.74
Activities of households as employers	0.14	1.05	1.01
Weighted mean	0.13	0.93	0.80
Median	0.15	0.90	0.75

Note: Weights for the weighted mean have been computed as the (relative) size of each sector in terms of direct (idiosyncratic productivity) or the sum of direct and indirect labor (value-chain productivity), respectively.

conclude that value-chain linkages carry additional and so far neglected information on the interplay of competition and selection outcomes. We now turn to three distinct but complementary approaches to test the selection hypothesis and assess the effect of value-chain linkages in this process.

4.1 Decomposition of global sector-level productivity change

We start to assess the strength of market selection by decomposing the aggregate (global) labor productivity index for sector j at time t,

$$\Pi_{j,t} = \sum_{i \in j} s_{i,t} \pi_{i,t}, \tag{2}$$

where $\pi_{i,t}$ denotes the labor productivity of country i in that sector. $s_{i,t}$ is the country's market share in that sector, measured as the quantity of labor hours employed in that country in percent of the global number of labor hours in that sector. To decompose this productivity index, we employ the method proposed by Griliches and Regev (1995). It splits the change in aggregate productivity into two components

$$\Delta\Pi_{j,t} = \sum_{i \in j} \bar{s}_i \Delta\pi_{i,t} + \sum_{i \in j} \Delta s_{i,t} \bar{\pi}_i, \tag{3}$$

where a bar over a variable stands for average of that variable over two consecutive years $t-1$ and t. The first term on the right-hand side of Eq. (3) represents the so-called *within effect*, i.e. the sum of country-specific changes in productivity in a given sector, weighted by the share of each country. This component captures the change in productivity resulting from idiosyncratic efforts (e.g. due to innovation). It measures how much of the global productivity growth in sector j originates in improvements in productivity within countries. The second term on the right-hand side of Eq. (3) is the so-called *between effect*, i.e. the sum of the changes in countries' market shares in a given sector, weighted by the productivity levels of these sectors. Since the sum of shares is constant and equal to unity by construction, a positive between term reflects to what extent market shares reallocate to country-sectors operating above the average productivity level. Therefore, it can explain why a rise in aggregate productivity is consistent with a situation in which individual productivities remain unchanged, but global competition reallocates market shares from less to more productive producers.

A formal test of the selection hypothesis can be conducted based on the between effect: a large and positive between effect indicates that a substantial fraction of aggregate productivity growth occurs because market shares reallocate from less to more productive producers that compete for the global market in a given sector. Therefore, if the between effect is larger for the value-chain than for the idiosyncratic productivity measure, this sustains the presumption that value-chain effects are relevant for market selection between individual country-sectors and thus must be taken into consideration. Notice that a negative between term would speak against the selection mechanism in the sense that less productive producers gain a larger share in the global market of the respective sector. On the other hand, a negative sign of the within effect would imply that countries shift their production from more to less valuable (e.g., less technologically-intensive) activities.[4]

Given that the WIOD dataset covers a period of 15 years, we are interested in the aggregate

[4] It is noteworthy that our decomposition does not separate out the so-called covariance effect that sometimes appears in dynamic decompositions based on Foster et al. (2001). Yet, it is straightforward to show that Eq. (3) splits the covariance term equally between the within and the between component (see Savin et al., 2019).

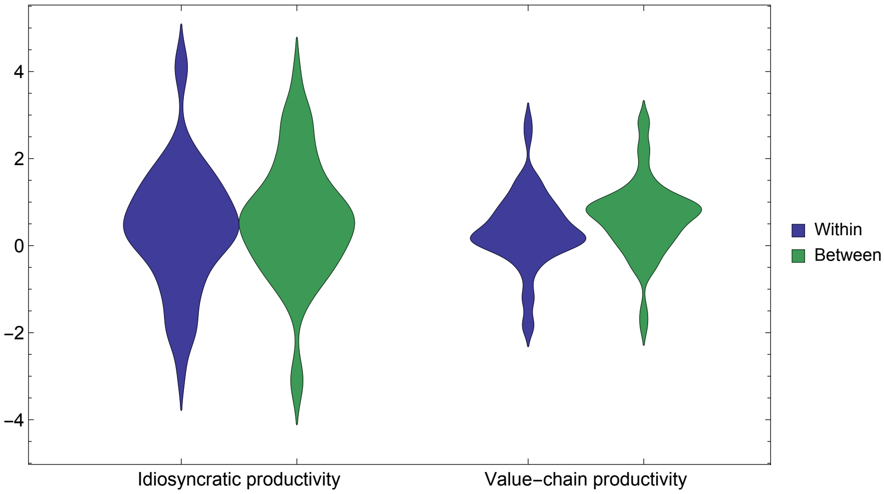

Figure 2: Distributions of sectoral between and within components.

effects over multiple years. To this end, we compute the overall contribution of the within and between components by running the decomposition for different pairs of consecutive years and summing the results over the years, which yields

$$\sum_t \Delta\Pi_{j,t} = \sum_t \sum_{i\in j} \bar{s}_i \Delta\pi_{i,t} + \sum_t \sum_{i\in j} \Delta s_{i,t}\bar{\pi}_i. \tag{4}$$

Moreover, to ease the comparison of the relative importance of between and within effects obtained from Eq. (4), we follow Dosi et al. (2015) and report percentage shares of the two components for total productivity change. For example, for the between effect we have

$$\left(\sum_t \sum_{i\in j} \Delta s_{i,t}\bar{\pi}_i\right) / \left(\sum_t \Delta\Pi_{j,t}\right) = \sum_t \left[\left(\frac{\sum_{i\in j}\Delta s_{i,t}\bar{\pi}_i}{\Delta\Pi_{j,t}}\right)\left(\frac{\Delta\Pi_{j,t}}{\sum_t \Delta\Pi_{j,t}}\right)\right]. \tag{5}$$

Prior empirical tests of the replicator dynamics model on the firm-level identified a dominant within effect.[5] What we find in Table 3 at the country-sector level is, first, that the between effect is considerably higher, with a median of 64% for the idiosyncratic productivity measure. Second, and more importantly, there is a rise of the median between effect to 79% if we employ the value-chain instead of the idiosyncratic productivity measure. The consideration of the (weighted) mean instead of the median between effect indicates a smaller increase due to extreme realizations in some sectors. Yet the improvement is still positive, consistent with the extended selection hypothesis. The violin plots in Figure 2 confirm the increase in the relative importance of the between effect and further suggest that the distributions of the within and between effects for the value-chain measure become less dispersed, concentrating around 0.9 for the between and 0.1 for the within effect. Overall, these results are consistent with the hypothesis that the consideration of GVC linkages in a productivity-based fitness indicator facilitates the identification of selection effects.

[5]For example, Dosi et al. (2015) report that less than 10% of the aggregate sector productivity growth can be explained by market share reallocation.

Table 3: Decomposition of productivity change.

Sector	Idiosyncratic		Value-chain	
	Within	Between	Within	Between
Crop and animal production	0.09	0.91	0.06	0.94
Forestry and logging	0.13	0.87	0.11	0.89
Fishing and aquaculture	0.17	0.83	0.09	0.91
Mining and quarrying	1.17	-0.17	1.34	-0.34
Manufacture of food products	-12.01	13.01	-8.30	9.30
Manufacture of textiles	0.80	0.20	0.54	0.46
Manufacture of wood	1.27	-0.27	0.85	0.15
Manufacture of paper	-1.19	2.19	-0.05	1.05
Printing and reproduction of recorded media	19.73	-18.73	-1.81	2.81
Manufacture of coke and refined petroleum products	1.07	-0.07	1.04	-0.04
Manufacture of chemicals and chemical products	0.68	0.32	0.74	0.26
Manufacture of basic pharmaceutical products	0.58	0.42	0.54	0.46
Manufacture of rubber and plastic products	24.36	-23.36	-0.39	1.39
Manufacture of other non-metallic mineral products	1.01	-0.01	0.15	0.85
Manufacture of basic metals	0.16	0.84	1.03	-0.03
Manufacture of fabricated metal products	-6.58	7.58	-0.43	1.43
Manufacture of computer	-0.30	1.30	0.20	0.80
Manufacture of electrical equipment	-1.96	2.96	0.03	0.97
Manufacture of machinery and equipment n.e.c.	-1.91	2.91	-0.16	1.16
Manufacture of motor vehicles	-0.61	1.61	0.07	0.93
Manufacture of other transport equipment	-0.18	1.18	0.11	0.89
Manufacture of furniture	1.69	-0.69	1.46	-0.46
Repair and installation of machinery and equipment	2.12	-1.12	2.50	-1.50
Electricity, gas, steam and air conditioning supply	1.05	-0.05	1.07	-0.07
Water collection, treatment and supply	1.83	-0.83	1.63	-0.63
Sewerage	-2.03	3.03	0.19	0.81
Construction	1.35	-0.35	0.76	0.24
Wholesale and retail trade and repair of motor vehicles	-1.88	2.88	-0.31	1.31
Wholesale trade, except of motor vehicles and motorcycles	-0.23	1.23	0.21	0.79
Retail trade, except of motor vehicles and motorcycles	4.05	-3.05	-42.14	43.14
Land transport and transport via pipelines	1.58	-0.58	1.00	0.00
Water transport	0.78	0.22	0.82	0.18
Air transport	0.36	0.64	0.36	0.64
Warehousing and support activities for transportation	-0.81	1.81	-0.09	1.09
Postal and courier activities	2.34	-1.34	2.87	-1.87
Accommodation and food service activities	4.15	-3.15	26.14	-25.14
Publishing activities	0.18	0.82	0.28	0.72
Motion picture, video and television	0.46	0.54	0.56	0.44
Telecommunications	0.84	0.16	0.77	0.23
Computer programming and consultancy	-0.76	1.76	-0.09	1.09
Financial service activities	0.41	0.59	0.50	0.50
Insurance, reinsurance and pension funding	0.24	0.76	0.38	0.62
Activities auxiliary to financial services and insurance	0.64	0.36	0.63	0.37
Real estate activities	1.28	-0.28	1.19	-0.19
Legal and accounting activities	0.21	0.79	0.32	0.68
Architectural and engineering activities	-0.17	1.17	0.12	0.88
Scientific research and development	-1.03	2.03	0.14	0.86
Advertising and market research	-1.25	2.25	0.14	0.86
Other professional, scientific and technical activities	1.75	-0.75	0.18	0.82
Administrative and support service activities	-4.01	5.01	-1.17	2.17
Public administration and defence	-2.93	3.93	-0.73	1.73
Education	1.61	-0.61	1.47	-0.47
Human health and social work activities	-12.43	13.43	-1.87	2.87
Other service activities	-33.94	34.94	-1.25	2.25
Activities of households as employers	0.47	0.53	0.55	0.45
Weighted mean	-1.41	2.41	-1.49	2.49
Median	0.36	0.64	0.21	0.79

Note: Weights for the weighted mean have been computed as the (relative) size of each sector in terms of direct (idiosyncratic productivity) or the sum of direct and indirect labor (value-chain productivity), respectively.

4.2 Regression analysis of the output growth-productivity relationship

One of the main drawbacks of the decomposition analysis is that market shares are measured in terms of the number of labor hours to warrant consistency with the labor productivity measure. Yet it is more realistic to assume that competition is reflected in sales (output) instead of labor (input). To account for this shortcoming of the decomposition analysis and to measure the strength of competition directly, we next turn to regression analysis and estimate the effect of sector-level productivity on output growth. To this end, we follow Bottazzi et al. (2010) and estimate the growth equation

$$g_{i,t} = a + b_t + \beta_\Delta \Delta\pi_{i,t} + \beta_m \bar{\pi}_{i,t} + c_i + \epsilon_{i,t}, \tag{6}$$

where $g_{i,t}$ denotes the (log) growth rate of output of country-sector i from year $t-1$ to t. b_t is a time dummy. $\Delta\pi_{i,t}$ stands for the (log) growth rate of labor productivity. $\bar{\pi}_{i,t}$ is the level of productivity, measured in terms of the time average over the years t and $t-1$. c_i represent country fixed effects, and $\epsilon_{i,t}$ is the error term. Since we estimate Eq. (6) individually for each sector, the presence of time dummies is equivalent to consider the deviation of individual productivity from the sectoral average in a given year, implying that countries' relative efficiency within those sectors serves as the explanatory variable for output growth (Dosi et al., 2015).

Using firm-level data, Dosi et al. (2015) showed that out of the two productivity terms in Eq. (6) the change in productivity is the main driver of output growth. Here we revisit this hypothesis at a higher level of aggregation and consider the level of productivity and the productivity change as two alternative drivers of growth for country-sectors on the global markets. An additional and ultimately more important question for us is, however, whether value-chain productivity exhibits higher explanatory power on growth than idiosyncratic productivity. Put differently, does a more fine-grained econometric test of the mechanism behind the replicator dynamics model provide additional empirical support for the hypothesis that market selection is stronger on the level of entire GVCs? To answer these questions, we estimate Eq. (6) for the two different measures of productivity and rely on the Shapley decomposition of the pertinent R^2 to determine the explanatory power of $\bar{\pi}_{i,t}$ and $\Delta\pi_{i,t}$ from

$$S^2 = \frac{\mathrm{Var}(\beta_\Delta \Delta\pi_{i,t} + \beta_m \bar{\pi}_{i,t})}{\mathrm{Var}(g_{i,t})}, \tag{7}$$

which measures the share of the growth variance explained by the two productivity terms.

Table 4 summarizes the estimation results. While the influence of the level of productivity is small and mostly insignificant, we find that the coefficient of the change in productivity is positive and statistically significant at the 0.1% level across all sectors. The stronger influence of the dynamic productivity component on growth is confirmed by the Shapley decomposition in Table 5, which shows that the explanatory power of the change in productivity is twice as high as that of the level of productivity across all sectors. The median share of the growth variance explained by Eq. (6) amounts to 27% for the idiosyncratic productivity measure, and 12 percentage points of which pertain to the two productivity terms.

Turning to the value-chain productivity measure, our regression results confirm the findings of the decomposition exercise obtained earlier. In particular, we obtain stronger empirical support for selection in the context of value chains than for individual producers. The median share of the variance explained by Eq. (6) across all sectors rises to 35%, and 18 percentage points of which must be attributed to the value-chain-based productivity terms. Figure 3 provides a graphical illustration of the Shapley decomposition, confirming that the focus on value chains leads to a rise in explanatory power of productivity on output growth.

Table 4: Estimation results for the fixed effects model in Eq. (6).

Sector	Idiosyncratic		Value-chain	
	β_Δ	β_m	β_Δ	β_m
Crop and animal production	0.42***	0	0.66***	0.01***
Forestry and logging	0.46***	0	0.66***	0
Fishing and aquaculture	0.29***	0	0.51***	0
Mining and quarrying	0.38***	0	0.52***	0.01*
Manufacture of food products	0.41***	0	0.63***	0.01***
Manufacture of textiles	0.38***	−0.01**	0.66***	0
Manufacture of wood	0.42***	−0.01	0.65***	0
Manufacture of paper	0.24***	−0.02**	0.63***	−0.01
Printing and reproduction of recorded media	0.34***	−0.03***	0.62***	−0.02**
Manufacture of coke and refined petroleum products	0.16***	0	0.54***	0.02
Manufacture of chemicals and chemical products	0.45***	−0.01	0.5***	0
Manufacture of basic pharmaceutical products	0.31***	0.01	0.44***	0.01*
Manufacture of rubber and plastic products	0.32***	−0.02***	0.74***	−0.01***
Manufacture of other non-metallic mineral products	0.44***	−0.01*	0.71***	0
Manufacture of basic metals	0.26***	0	0.31***	0.01
Manufacture of fabricated metal products	0.46***	−0.01**	0.81***	0
Manufacture of computer	0.45***	−0.04***	0.91***	−0.01
Manufacture of electrical equipment	0.43***	−0.03***	0.8***	−0.02*
Manufacture of machinery and equipment n.e.c.	0.45***	−0.01*	0.72***	0
Manufacture of motor vehicles	0.46***	−0.03***	0.73***	−0.01
Manufacture of other transport equipment	0.37***	−0.01	0.49***	0
Manufacture of furniture	0.57***	−0.02***	0.76***	−0.02**
Repair and installation of machinery and equipment	0.53***	−0.01	0.85***	0
Electricity, gas, steam and air conditioning supply	0.26***	0	0.53***	0.01*
Water collection, treatment and supply	0.19***	0.01	0.34***	0.01**
Sewerage	0.33***	0	0.55***	0
Construction	0.62***	−0.01*	0.77***	0
Wholesale and retail trade and repair of motor vehicles	0.61***	−0.01*	0.82***	−0.02***
Wholesale trade, except of motor vehicles and motorcycles	0.49***	0	0.72***	0
Retail trade, except of motor vehicles and motorcycles	0.67***	0	0.79***	0
Land transport and transport via pipelines	0.61***	−0.01	0.8***	0
Water transport	0.24***	0	0.47***	0.01
Air transport	0.08***	0	0.45***	0
Warehousing and support activities for transportation	0.46***	0	0.7***	0.01**
Postal and courier activities	0.57***	−0.02*	0.96***	0
Accommodation and food service activities	0.52***	−0.01**	0.69***	0
Publishing activities	0.29***	0	0.51***	0
Motion picture, video and television	0.37***	−0.01*	0.66***	−0.01*
Telecommunications	0.28***	−0.01	0.46***	0
Computer programming and consultancy	0.33***	−0.02**	0.48***	−0.01
Financial service activities	0.5***	−0.01***	0.59***	0
Insurance, reinsurance and pension funding	0.37***	−0.01	0.58***	0
Activities auxiliary to financial services and insurance	0.34***	0.01	0.57***	0
Real estate activities	0.28***	0	0.3***	0
Legal and accounting activities	0.4***	−0.01**	0.51***	0
Architectural and engineering activities	0.36***	−0.01	0.56***	−0.01*
Scientific research and development	0.26***	0.01	0.38***	0.02*
Advertising and market research	0.14***	−0.05***	0.55***	−0.04**
Other professional, scientific and technical activities	0.31***	−0.02**	0.32***	0
Administrative and support service activities	0.54***	−0.01**	0.59***	0.01**
Public administration and defence	0.58***	0	0.74***	0.01**
Education	0.64***	0	0.69***	0*
Human health and social work activities	0.62***	0	0.68***	0.01***
Other service activities	0.44***	0	0.64***	0
Activities of households as employers	0.15***	−0.01	0.22***	−0.01*

Note: Entry 0 stands for values $< 5 \times 10^{-3}$. ***, **, and * indicate statistical significance at the 0.1%, 1%, and 5% level, respectively.

Table 5: Shapley decomposition results for the fixed effects model in Eq. (6).

Sector	Idiosyncratic			Value-chain		
	R^2	$S^2_{\Delta\pi}$	$S^2_{\bar{\pi}}$	R^2	$S^2_{\Delta\pi}$	$S^2_{\bar{\pi}}$
Crop and animal production	0.38	0.15	0.07	0.52	0.24	0.06
Forestry and logging	0.36	0.13	0.06	0.50	0.27	0.01
Fishing and aquaculture	0.21	0.06	0.05	0.32	0.14	0.00
Mining and quarrying	0.28	0.07	0.06	0.49	0.17	0.08
Manufacture of food products	0.32	0.10	0.05	0.47	0.14	0.12
Manufacture of textiles	0.23	0.05	0.07	0.34	0.08	0.10
Manufacture of wood	0.34	0.11	0.04	0.37	0.13	0.06
Manufacture of paper	0.17	0.04	0.01	0.34	0.11	0.08
Printing and reproduction of recorded media	0.24	0.07	0.04	0.31	0.14	0.02
Manufacture of coke and refined petroleum products	0.10	0.02	0.01	0.30	0.11	0.01
Manufacture of chemicals and chemical products	0.24	0.08	0.03	0.12	0.03	0.01
Manufacture of basic pharmaceutical products	0.23	0.09	0.02	0.25	0.10	0.04
Manufacture of rubber and plastic products	0.22	0.03	0.07	0.43	0.12	0.12
Manufacture of other non-metallic mineral products	0.28	0.10	0.01	0.39	0.13	0.08
Manufacture of basic metals	0.15	0.04	0.01	0.15	0.02	0.03
Manufacture of fabricated metal products	0.31	0.08	0.05	0.48	0.21	0.06
Manufacture of computer	0.32	0.07	0.09	0.46	0.19	0.05
Manufacture of electrical equipment	0.36	0.13	0.04	0.44	0.17	0.06
Manufacture of machinery and equipment n.e.c.	0.32	0.08	0.08	0.40	0.13	0.08
Manufacture of motor vehicles	0.32	0.13	0.01	0.31	0.13	0.01
Manufacture of other transport equipment	0.21	0.07	0.03	0.15	0.06	0.00
Manufacture of furniture	0.36	0.12	0.09	0.35	0.16	0.07
Repair and installation of machinery and equipment	0.25	0.06	0.06	0.41	0.21	0.04
Electricity, gas, steam and air conditioning supply	0.12	0.02	0.03	0.39	0.14	0.05
Water collection, treatment and supply	0.14	0.03	0.03	0.22	0.07	0.03
Sewerage	0.22	0.05	0.05	0.30	0.12	0.02
Construction	0.34	0.09	0.08	0.36	0.13	0.06
Wholesale and retail trade and repair of motor vehicles	0.50	0.27	0.02	0.53	0.24	0.12
Wholesale trade, except of motor vehicles and motorcycles	0.43	0.19	0.02	0.52	0.27	0.03
Retail trade, except of motor vehicles and motorcycles	0.60	0.27	0.11	0.62	0.28	0.13
Land transport and transport via pipelines	0.27	0.11	0.04	0.33	0.17	0.04
Water transport	0.16	0.06	0.01	0.24	0.08	0.04
Air transport	0.03	0.00	0.00	0.13	0.04	0.01
Warehousing and support activities for transportation	0.32	0.13	0.02	0.38	0.18	0.02
Postal and courier activities	0.35	0.16	0.03	0.47	0.17	0.07
Accommodation and food service activities	0.42	0.14	0.10	0.51	0.20	0.11
Publishing activities	0.20	0.07	0.00	0.16	0.03	0.04
Motion picture, video and television	0.26	0.07	0.05	0.39	0.17	0.05
Telecommunications	0.25	0.07	0.04	0.30	0.11	0.03
Computer programming and consultancy	0.23	0.08	0.01	0.27	0.10	0.01
Financial service activities	0.43	0.17	0.06	0.43	0.19	0.04
Insurance, reinsurance and pension funding	0.34	0.15	0.02	0.39	0.17	0.04
Activities auxiliary to financial services and insurance	0.23	0.09	0.00	0.33	0.15	0.01
Real estate activities	0.23	0.05	0.05	0.15	0.04	0.03
Legal and accounting activities	0.29	0.10	0.02	0.28	0.11	0.01
Architectural and engineering activities	0.21	0.06	0.00	0.29	0.10	0.02
Scientific research and development	0.11	0.03	0.02	0.14	0.04	0.01
Advertising and market research	0.09	0.01	0.03	0.19	0.06	0.03
Other professional, scientific and technical activities	0.22	0.09	0.01	0.10	0.03	0.01
Administrative and support service activities	0.40	0.18	0.01	0.29	0.15	0.01
Public administration and defence	0.48	0.14	0.13	0.61	0.22	0.15
Education	0.55	0.16	0.16	0.59	0.20	0.16
Human health and social work activities	0.50	0.21	0.09	0.51	0.19	0.11
Other service activities	0.29	0.07	0.07	0.42	0.14	0.09
Activities of households as employers	0.09	0.01	0.03	0.17	0.02	0.06
Weighted mean	0.38	0.14	0.07	0.45	0.17	0.08
Median	0.27	0.08	0.04	0.35	0.14	0.04

Note: Weights for the weighted mean have been computed as the (relative) size of each sector in terms of direct (idiosyncratic productivity) or the sum of direct and indirect labor (value-chain productivity), respectively.

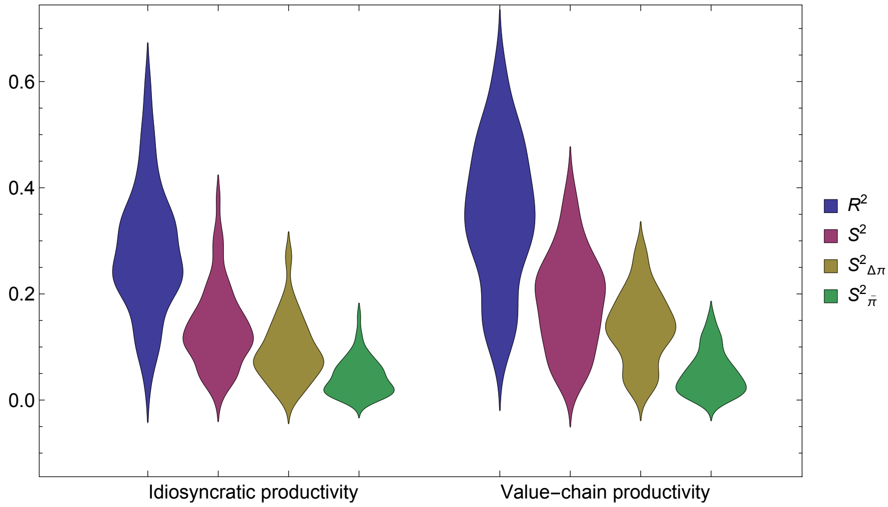

Figure 3: Explanatory power of idiosyncratic and value-chain productivity terms.

4.3 Spatial regression analysis

Our third test considers whether the idiosyncratic fitness of any supplier j of the focal producer $i \neq j$ has a direct effect on the output growth of i. It builds on a spatial panel model with fixed effects for growth that incorporates the spatial lags of the two productivity terms in Eq. (6) as additional explanatory variables. Therefore, this augmented regression model does not only test whether the output growth of country-sector i at time t is determined by its own (idiosyncratic) productivity but also by the weighted average idiosyncratic productivity of its value-chain partners. Formally, we estimate

$$g_{i,t} = a + b_t + \beta_\Delta \Delta\pi_{i,t} + \beta_m \bar{\pi}_{i,t} + \gamma_\Delta SL(\Delta\pi_{i,t}) + \gamma_m SL(\bar{\pi}_{i,t}) + c_i + \epsilon_{i,t}, \tag{8}$$

where the spatial lag $SL(\Delta\pi_{i,t})$ represents the weighted average productivity change and $SL(\bar{\pi}_{i,t})$ is the weighted average productivity level, respectively, of the direct and indirect suppliers of the focal country-sector i. Following the methodology outlined in Section 3, we determine the weights for the productivities of all direct and indirect suppliers based on the suppliers' labor contributions to the focal country-sector. Specifically, the weights are obtained from Eq. (1) by dividing the elements in each column of the matrix $\mathbf{L}$ by the respective column sum. Since the typical country-sector consumes a significant portion of its own output, however, idiosyncratic productivity and the spatially lagged productivity terms obtained from these weights would be highly correlated without further corrections. To avoid biased results due to collinearity, we therefore set the elements on the main diagonal of $\mathbf{L}$ equal to zero before computing the column sum and the respective labor shares. This correction excludes domestic intra-industry transactions and thus separates the focal country-sector from the set of its suppliers. The resulting shares sum up to one for each focal producer and thus serve as appropriate weights in the spatial regression model.

Table 6 presents the estimation results for the spatial regression model in Eq. (8). We find that the essence of the results from Section 4.2 remains valid as the change in productivity is quantitatively still more important for growth than the productivity level, testifying to the robustness of our previous findings. The spatial lag of the productivity change is positive and

Table 6: Estimation results for the spatial panel regression model in Eq. (8).

Sector	β_Δ	β_m	γ_Δ	γ_m
Crop and animal production	0.34***	0	0.47***	0.01
Forestry and logging	0.43***	−0.01	0.36***	0.03*
Fishing and aquaculture	0.25***	0	0.52***	−0.01
Mining and quarrying	0.30***	0	0.56***	0
Manufacture of food products	0.25***	0.01	0.57***	−0.01
Manufacture of textiles	0.26***	0	0.62***	−0.03**
Manufacture of wood	0.33***	0	0.47***	−0.02*
Manufacture of paper	0.14***	0	0.78***	−0.02*
Printing and reproduction of recorded media	0.24***	−0.01	0.65***	−0.03*
Manufacture of coke and refined petroleum products	0.15***	0.01	0.36*	−0.02
Manufacture of chemicals and chemical products	0.42***	0	0.34***	−0.02
Manufacture of basic pharmaceutical products	0.25***	0.01	0.56***	−0.01
Manufacture of rubber and plastic products	0.12***	−0.02*	0.98***	−0.02
Manufacture of other non-metallic mineral products	0.22***	0	0.78***	−0.02
Manufacture of basic metals	0.20***	0	0.56***	−0.01
Manufacture of fabricated metal products	0.27***	−0.01	0.78***	−0.02
Manufacture of computer	0.38***	−0.04***	0.54***	0.01
Manufacture of electrical equipment	0.37***	−0.01	0.58***	−0.03*
Manufacture of machinery and equipment n.e.c.	0.35***	0	0.53***	−0.01
Manufacture of motor vehicles	0.38***	−0.02*	0.69***	−0.02
Manufacture of other transport equipment	0.30***	0.01	0.76***	−0.04*
Manufacture of furniture	0.47***	−0.02*	0.42***	0
Repair and installation of machinery and equipment	0.51***	0	0.23	−0.01
Electricity, gas, steam and air conditioning supply	0.20***	0	0.48***	0
Water collection, treatment and supply	0.14***	0.01	0.55***	0
Sewerage	0.27***	0	0.53***	0
Construction	0.33***	0.01	0.76***	−0.03*
Wholesale and retail trade and repair of motor vehicles	0.49***	0	0.53***	−0.03**
Wholesale trade, except of motor vehicles and motorcycles	0.32***	0.01	0.57***	−0.02**
Retail trade, except of motor vehicles and motorcycles	0.50***	0.01	0.41***	−0.02**
Land transport and transport via pipelines	0.48***	0.01	0.45***	−0.03*
Water transport	0.20***	0	0.47***	0.01
Air transport	0.06**	0.02	0.8***	−0.03
Warehousing and support activities for transportation	0.38***	0.01	0.45***	−0.02
Postal and courier activities	0.54***	0	0.21*	−0.02
Accommodation and food service activities	0.27***	0	0.59***	−0.01*
Publishing activities	0.26***	0.01	0.36***	−0.03
Motion picture, video and television	0.27***	−0.02*	0.65***	0.01
Telecommunications	0.19***	−0.01*	0.64***	0
Computer programming and consultancy	0.21***	−0.01	0.73***	−0.02
Financial service activities	0.39***	−0.01*	0.4***	0
Insurance, reinsurance and pension funding	0.32***	−0.01	0.45***	−0.01
Activities auxiliary to financial services and insurance	0.31***	0.01	0.58***	−0.01
Real estate activities	0.17***	0	0.54***	−0.01
Legal and accounting activities	0.30***	−0.02*	0.45***	0.01
Architectural and engineering activities	0.25***	−0.01	0.56***	0
Scientific research and development	0.22***	0	0.67***	0.02
Advertising and market research	0.13***	−0.06***	0.44**	0.02
Other professional, scientific and technical activities	0.27***	−0.01	0.43***	−0.02
Administrative and support service activities	0.41***	0	0.43***	−0.02**
Public administration and defence	0.36***	0	0.47***	0.01
Education	0.37***	0	0.4***	−0.01
Human health and social work activities	0.32***	0	0.5***	0.01
Other service activities	0.23***	−0.02*	0.68***	0.02*
Activities of households as employers	0.15***	−0.01	−0.05	0.01

Note: Entry 0 stands for values $< 5 \times 10^{-3}$. ***, **, and * indicate statistical significance at the 0.1%, 1%, and 5% level, respectively.

statistically significant at the 0.1% level in more than 96% of all industries. Merely two sectors (repair and installation of machinery and equipment and activities of households as employers) exhibit no significant spatial effects of productivity on output growth. It turns out that these two sectors exhibit the weakest dependence on suppliers across all 43 countries in the entire sample, with a ratio of direct and indirect labor contributions from upstream suppliers in percent of total labor demand of merely 12% and 23%, respectively, which explains the insignificant influence of the suppliers on the focal actor in these sectors.[6] Thus, our third test provides direct empirical evidence for the argument that production units may grow not only because their own productive performance is above the average but also because they have suppliers with superior performance in their value chain.

Considering the results for goodness of fit and the Shapley decomposition in Table 7, the median share of the growth variance explained by the spatial model amounts to 36% across all sectors, which is nearly identical to the result obtained for the value-chain productivity measure in Table 5. We thus conclude that the explanatory power of the value-chain productivity measure used in the previous two tests can be decomposed into two terms: (i) idiosyncratic productivity and (ii) the productivity of upstream suppliers in the value chain. Neglecting the latter in prior empirical studies must have led to a systematic underestimation of the strength of market selection, contributing to the weak evidence for the replicator dynamics mechanism obtained in the extant literature, especially because Table 7 suggests that the spatial productivity terms explain at least as much variation in growth as the individual productivity terms in the majority of sectors.

Finally, we also studied the relationship between the influence of the suppliers on the focal actor as the dependent variable, measured in terms of the variance explained by the spatial lags divided by the variance explained by all productivity terms in Eq. (8), and the aforementioned measure of dependence on the upstream suppliers as the explanatory variable. Fitting a linear model to this relationship using (weighted) ordinary least squares yields a slope of 0.66 ± 0.20 with a p-value of 0.002 ($R^2 = 0.17$), implying that the explanatory power of the spatially lagged productivity terms increases with the dependence on the direct and indirect suppliers.[7] These findings further testify to our argument that the performance of the value-chain partners is of utmost importance for the market success of an individual producer.

5 Conclusions

This paper demonstrates empirically that market success of a producer is not only determined by its individual productive performance but also by the performance of its upstream suppliers in global value chains. Using WIOD data on production input linkages to map these relationships between individual producers, we employ productivity decomposition and regression analysis to study the influence of idiosyncratic productivity, the productivity of upstream suppliers, and the productivity of the entire value chain on the growth of a producer. Our study thus contributes to the literature on market selection and industry dynamics by providing the first empirical test of the replicator dynamics model extended to GVCs.

Our empirical tests provide several important and noteworthy findings. First and foremost, they suggest that the productivity of entire value chains is a more thorough performance indicator than idiosyncratic productivity when it comes to testing the market selection hypothesis, which carries additional information on the nexus between productivity and growth. In particular, our spatial regression approach shows that the influence of upstream suppliers on individual growth

[6] The median realization of this ratio across all sectors is 53%.
[7] Observations are weighted by the (relative) size of each sector in terms of labor.

Table 7: Shapley decomposition results for the spatial panel model in Eq. (8).

Sector	R^2	$S^2_{\Delta\pi}$	$S^2_{\bar{\pi}}$	$S^2_{SL(\Delta\pi_{i,t})}$	$S^2_{SL(\bar{\pi}_{i,t})}$
Crop and animal production	0.46	0.16	0.00	0.11	0.05
Forestry and logging	0.39	0.09	0.02	0.05	0.10
Fishing and aquaculture	0.26	0.06	0.04	0.05	0.02
Mining and quarrying	0.35	0.08	0.03	0.08	0.03
Manufacture of food products	0.50	0.08	0.02	0.13	0.11
Manufacture of textiles	0.34	0.05	0.06	0.07	0.02
Manufacture of wood	0.42	0.11	0.01	0.10	0.04
Manufacture of paper	0.34	0.05	0.01	0.12	0.03
Printing and reproduction of recorded media	0.35	0.08	0.00	0.12	0.00
Manufacture of coke and refined petroleum products	0.10	0.02	0.01	0.01	0.02
Manufacture of chemicals and chemical products	0.25	0.07	0.01	0.02	0.04
Manufacture of basic pharmaceutical products	0.31	0.06	0.02	0.06	0.07
Manufacture of rubber and plastic products	0.46	0.03	0.02	0.14	0.12
Manufacture of other non-metallic mineral products	0.43	0.06	0.06	0.13	0.03
Manufacture of basic metals	0.21	0.03	0.02	0.05	0.01
Manufacture of fabricated metal products	0.44	0.06	0.06	0.12	0.05
Manufacture of computer	0.36	0.06	0.05	0.05	0.05
Manufacture of electrical equipment	0.40	0.09	0.03	0.04	0.11
Manufacture of machinery and equipment n.e.c.	0.38	0.07	0.09	0.05	0.03
Manufacture of motor vehicles	0.39	0.10	0.01	0.09	0.03
Manufacture of other transport equipment	0.28	0.04	0.02	0.05	0.07
Manufacture of furniture	0.38	0.10	0.09	0.05	0.04
Repair and installation of machinery and equipment	0.25	0.06	0.07	0.01	0.01
Electricity, gas, steam and air conditioning supply	0.16	0.02	0.01	0.02	0.04
Water collection, treatment and supply	0.29	0.04	0.02	0.09	0.01
Sewerage	0.28	0.04	0.06	0.04	0.05
Construction	0.48	0.08	0.08	0.13	0.05
Wholesale and retail trade and repair of motor vehicles	0.57	0.18	0.03	0.11	0.13
Wholesale trade, except of motor vehicles and motorcycles	0.56	0.12	0.06	0.13	0.11
Retail trade, except of motor vehicles and motorcycles	0.66	0.15	0.04	0.09	0.19
Land transport and transport via pipelines	0.32	0.07	0.04	0.05	0.09
Water transport	0.20	0.06	0.01	0.05	0.01
Air transport	0.11	0.01	0.01	0.03	0.02
Warehousing and support activities for transportation	0.37	0.12	0.02	0.09	0.01
Postal and courier activities	0.35	0.12	0.03	0.03	0.05
Accommodation and food service activities	0.56	0.07	0.13	0.13	0.08
Publishing activities	0.24	0.05	0.00	0.04	0.04
Motion picture, video and television	0.35	0.03	0.06	0.05	0.10
Telecommunications	0.41	0.06	0.00	0.15	0.02
Computer programming and consultancy	0.38	0.06	0.03	0.11	0.02
Financial service activities	0.51	0.12	0.06	0.10	0.08
Insurance, reinsurance and pension funding	0.39	0.13	0.01	0.08	0.04
Activities auxiliary to financial services and insurance	0.27	0.10	0.01	0.05	0.01
Real estate activities	0.39	0.06	0.01	0.11	0.07
Legal and accounting activities	0.35	0.07	0.03	0.08	0.05
Architectural and engineering activities	0.28	0.04	0.02	0.07	0.00
Scientific research and development	0.18	0.03	0.01	0.04	0.03
Advertising and market research	0.11	0.01	0.03	0.02	0.00
Other professional, scientific and technical activities	0.25	0.07	0.01	0.06	0.03
Administrative and support service activities	0.45	0.14	0.01	0.11	0.03
Public administration and defence	0.58	0.09	0.15	0.13	0.05
Education	0.64	0.10	0.17	0.12	0.05
Human health and social work activities	0.60	0.11	0.11	0.14	0.11
Other service activities	0.47	0.04	0.09	0.11	0.11
Activities of households as employers	0.09	0.01	0.02	0.00	0.01
Weighted Mean	0.48	0.09	0.07	0.11	0.07
Median	0.36	0.07	0.02	0.08	0.04

Note: Weights for the weighted mean have been computed as the size of each sector in terms of direct (idiosyncratic productivity) and the sum of direct and indirect labor (value-chain productivity), respectively.

is not only statistically significant and, therefore, non-negligible in empirical studies on market selection. It also implies that its influence is at least as strong as the direct effect pertaining to the productive performance of the focal producer. This suggests that effective supply-chain management, e.g. careful selection of new suppliers or joint efforts with existing partners to improve productivity, has a crucial influence on the market success of individual producers. Moreover, since the value-chain perspective increases the explanatory power of productivity on growth, our results imply that the effect of competition on market outcomes is stronger than suggested in the existing empirical literature. This does not imply, however, that competitive selection based on productive performance is the only factor that explains the growth of individual producers, and we are aware that our global analysis based on aggregated input-output tables neglects many factors influencing individual growth dynamics. Our main contribution here is that the consideration of GVC linkages, ceteris paribus, improves the explanatory power of the selection mechanism relative to the situation in which value-chain linkages are ignored.

We conclude by describing avenues for further research. A front for immediate extension of our empirical framework is to apply it to firm-level micro data. While we find it remarkable that selection effects can be identified even at the more aggregated country-sector level, assessing the explanatory power of our approach based on more granular data would certainly enhance our understanding of competition in value chains, and would also allow to study the mediating effects of various firm specificities such as firm size, diversification and internationalization patterns on the influence of value-chain productivity on individual growth. A second promising trajectory would be to evaluate the relative contributions of suppliers' and customers' fitness on individual growth. This paper approaches value-chains from the last production unit that sells output to final consumers, focusing on the network effect pertaining to the upstream suppliers. To generalize this perspective, one should focus on arbitrary stages of the value chain and assess the relative influence of supply- and demand-driven network effects, potentially as a function of the producer's position in the value chain. We hope that our study will stimulate more empirical work in this direction.

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