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QUANTIFYING THE PRODUCTIVITY EFFECTS OF GLOBAL SOURCING

by Sara Formai[*] and Filippo Vergara Caffarelli [*†]

Abstract

This work analyses the effect of the global sourcing of intermediate goods on productivity growth. To identify the impact of global sourcing, we employ the methodology proposed in a different context by Rajan and Zingales (1998). In particular we interact the length and the width of sectoral production chains with a measure of the intensity of countries' intermediate imports. We find evidence indicating that off-shoring significantly increases labour productivity and total factor productivity at the sector level in countries that rely on global sourcing. The driver of total factor productivity growth depends on the structure of the global value chain that intermediates are sourced from: long chains trigger technology improvements while wide chains cause a reallocation of resources towards more productive firms within the same sector.

JEL Classification: D24, F62, F66.
Keywords: productivity growth, global sourcing, global value chains.

Contents

[*] Bank of Italy, Directorate General for Economics, Statistics and Research.

† Corresponding author, e-mail: filippo.vergaracaffarelli@bancaditalia.it

1 Introduction[1]

Global sourcing is a defining feature of modern manufacturing. It consists in the purchase of goods and services outside the geographical area to which the firm belongs (Golini and Kalchschmidt, 2011). Thanks to lower trade and investment barriers and to advances in information and communication technologies, firms are able to organise their operations internationally through outsourcing and off-shoring of activities, according to the comparative advantage of the different locations in increasingly specific tasks such as, for instance, R&D, production of individual parts and components, assembly, marketing, distribution. In parallel, international production, trade and investment are increasingly structured in global value chains (GVCs) where each country specialises in one or few stages of the overall production process.[2] All in all, this determines huge (international) flows of intermediate goods and services: more than half of world trade in manufacturing goods consists of intermediate goods and more than 70% of trade in services involves intermediate services (de Backer and Miroudot, 2013).

In this paper we quantify the effect on sector productivity growth of global sourcing. We find that there exist significant productivity benefits from global sourcing both in terms of labour productivity and of total factor productivity and that the structure of the GVCs (long vs. wide) matters for the mechanism determining total factor productivity growth.

From a micro perspective, as firms are profit maximizing agents, the decision to source intermediates from abroad should be motivated by higher productivity and competitiveness, for instance through the access to either cheaper or better intermediate goods and services. [3] From a macro perspective, global sourcing may have both positive and negative effects on a country's aggregate productivity, output and employment growth. This depends, for instance, on the share of value added produced by the production stages that are kept domestically compared to those that are outsourced, as well as on their technological or skill content. There is a widespread perception that the positive effects, both static (lower costs and better inputs) and dynamic (reallocation of factors towards more efficient tasks), more than offset any loss due to the outsourcing of valued added previously produced domestically. Nevertheless, especially due to data limitations, we still lack of empirical evidence to quantify these positive effects in terms

[1]We are grateful to Andrei Levchenko for kindly sharing with us the data used in the calculation of the technology levels and to Vasco Carvalho, Pietro Catte, Giancarlo Corsetti, Andrea Finicelli, Patrizio Pagano, Massimo Sbracia, Giacomo Oddo, Julia Wörtz and seminar participants at the Bank of Italy and the Universities of Cambridge and Nottingham for helpful comments. Parts of this paper were completed while Vergara Caffarelli was visiting the Faculty of Economics of the University of Cambridge, whose hospitality is gratefully acknowledged. A previous version of this paper circulated under the title "Quantifying productivity effects of global value chains". The opinions expressed in this paper are the authors' own and do not necessarily reflect those of the Bank of Italy.

[2]This is a well-known phenomenon labelled "international fragmentation of production" (Jones and Kierzkowski, 1990). Alternative terms used in the literature are: vertical specialisation (Hummels et al., 1998), global production sharing (Feenstra, 1998), international outsourcing (Grossman and Helpman 2002), international production networks (Ernst and Guerrieri, 1998).

[3]See, among others, Amiti and Konings (2006), Antras et al. (2014), Bernard et al. (2007), Blaum et al. (2015) and Halpern et al.(2015)

of some measure of macroeconomic performance.

This paper makes a first attempt to fill this gap: using country-sector data, we evaluate the impact of global sourcing on the growth of productivity and employment. In particular the analysis presented in this work focuses on the effects of GVC sourcing, defined as the propensity of an economy to exploit GVCs in order to obtain intermediate inputs from abroad. GVC sourcing is a narrower concept than global sourcing since imported inputs belongs to production chains of varying length and width. In the following we will use global sourcing when we generally refer to importing intermediates from abroad, and GVC sourcing when we refer to importing intermediates from a GVC.

We consider several measures of productivity, in order to shed some light on the channels through which GVC sourcing affects economic growth. First of all, we look at standard measures of labour productivity, such as output and value added per worker. Moreover, we look at aggregate employment to test whether the changes induced to labour productivity can be explained, at least in part, by changes in the number of workers employed.[4]

We then try to understand the effect of GVC sourcing on TFP growth. While any change in labour productivity can depend also on changes in the use of capital and, in the case of output per worker, in the use of intermediate goods, TFP is instead defined as the residual efficiency of the production process that cannot be explained by inputs' services. At the firm level, TFP growth is determined by technical and organizational innovations that improve the efficiency in the use and combination of inputs. We will refer to this component of TFP generically as technology. At a more aggregate level, for instance at the country-sector level that characterizes our analysis, TFP can vary not only in response to changes in technology within firms, but also in response to the reallocation of resources between firms with different levels of TFP. Borrowing from Finicelli et al. (2013), who build on Eaton and Kortum (2002), we will decompose the growth rate in aggregate TFP at the country-sector level into growth due to technology improvement and growth driven by resource reallocation. We will then assess the effect of GVC sourcing on the two components separately.

Our empirical strategy is based on the methodology introduced by Rajan and Zingales (1998) to deal with reverse causality between external finance and growth. Here we identify the effect of GVC sourcing on productivity and employment growth by exploiting the variation in the "reliance on global sourcing" across 50 countries and the "fragmentability" of the production process across 18 sectors.[5] The interaction term between the country-specific measure and the sector-specific measure captures how much a country is exploiting the sector's potential for GVC sourcing.

We measure "reliance on global sourcing" using various indices of specialization in importing

[4]Sourcing intermediate inputs from abroad is often perceived as reducing employment, because it leads to a reduction in the demand of workers employed in those stages of production that can be outsourced.

[5]The actual sample size varies depending on data availability.

intermediate goods. In defining "fragmentability", we distinguish between sequential GVCs (*snakes*) and horizontal GVCs (*spiders*) (Baldwin and Venables, 2013). Snake production chains require the processing of intermediates to be performed in sequential stages, until final assembly. Spider-type chains, instead, involve simultaneous production of all parts and components, which are then assembled in the final good. Baldwin and Venables (2013) show that the two architectures carry different consequences both at the micro (e.g. location decisions) and at the macro (e.g. volume of international trade) level. We will consequently measure both the length and the width of GVCs as they refer, respectively, to the snake and spider dimensions of the production chain, since different architectures may affect productivity growth through different channels.

We find that GVC sourcing positively affects labour productivity and TFP in sectors with long and wide production chains in countries specialised in importing intermediate goods. We also find that the impact on TFP in sequential GVCs comes from technology improvement, which could be driven both by the availability of a wider variety and better quality of inputs and by higher incentives to innovation. On the other hand, in horizontal GVCs TFP growth comes essentially from resource reallocation, probably due to an import competition effect.[6] Finally, there appears to be a negative effect on aggregate employment growth only in case of horizontal GVC.

Our approach carries some advantages (as well as disadvantages) with respect to the more common approach that employs micro (firm/plant level) data. Micro data may indeed be optimal to analyse the impact of imported intermediates on the technology level: for instance, Halpern et al. (2015), using Hungarian data, find that increasing the fraction of tradeable goods imported by a firm from zero to 100 per cent would increase revenue productivity by 22 per cent and that half of this effect is due to the higher variety of inputs available. Similar estimates are impossible with macro (country-sector level) data. However, since our unit of observation is the sector and not the single firm, we are able to uncover the existence of a reallocation effect due to the reallocation of resources between firms having different levels of productivity, which cannot be appreciated with micro-level data.

The existence of a positive link between productivity growth and firms' access to new inputs through imports is not novel in the literature: other papers document the beneficial effect of imported intermediates. Amiti and Konings (2006) show that using data from Indonesia a reduction in import tariffs generates the largest productivity gains (in comparison with a reduction of export tariffs), since it stimulates intermediate imports. The existence of a link between intermediate imports and productivity is also confirmed by Bas and Strauss-Kahn (2014) and Blaum (2015) in France, by Kasahara and Rodrigue (2008) and Kasahara and Lapham (2013) in Chile and by Halpern et al. (2015) in Hungary. Bernard et al. (2007) show that U.S. importers are on average more than twice as large and about 12 percent more productive than

[6]See for instance Amiti and Konings (2007), Trefler (2004) and Roberts and Tybout (1991).

non-importers. In India, Goldberg et al. (2010) and Topalova and Khandelwal (2011) also uncover substantial gains from trade through access to previously unavailable imported inputs. According to Bloom et al. (2016), in the EU import competition from China has led to an increase in technical change within firms and a reallocation of employment towards more technologically advanced firms; these effects account for almost one sixth of EU technology upgrading between 2000 and 2007. Antras et al. (2014) present a model of global sourcing that explicitly connects productivity and sourcing showing that more productive firms source from more foreign suppliers hence increasing their cost advantage.

The rest of the paper is organised as follows. Section 2 describes our empirical methodology and the key regressors. Section 3 presents the productivity measures which will be the dependent variables in the empirical analysis contained in section 4. Section 5 presents some concluding remarks. The appendices collect some supplementary material and all the tables.

2 Empirical strategy

Interpreting the relation existing between a country's economic performance (*e.g.* productivity) and its degree of GVC sourcing as causal can present several challenges. There can be omitted variables underlying the correlation between the two phenomena: for instance, GVC sourcing is positively correlated with trade openness, and trade openness tends to be positively correlated with real GDP and productivity growth (Alcalà and Ciccone, 2004). Another problem is given by reverse causality: is it GVC sourcing that drives productivity growth or higher productivity growth that makes it easier for countries to source from GVCs?

Finding evidence of the mechanism through which GVC sourcing affects macroeconomic performance can help to interpret these correlations in a more causal sense. GVC sourcing could allow a country to increase productivity by enabling firms to access the best intermediate inputs, by stimulating the reallocation of resources towards more efficient tasks or by triggering technological advances. Of course these effects tend to be larger, the more the production process characterising a given sector can indeed be fragmented into many separate production stages. We then test whether sectors whose technical characteristics make them more "fragmentable" are relatively "better off" in economies with a high degree of GVC sourcing. This simple test, inspired by Rajan and Zingales (1998), has two main virtues. First, it focuses on the mechanism via which GVC sourcing could affect macroeconomic performance, thus providing a stronger test of causality. Second, as it is based on the simultaneous variation of both a country-specific and a sector-specific dimension, it allows to control for missing variables using fixed effects for both countries and industries.

Our empirical model is thus given by:

$$z_{i,s} = \alpha + \beta Y_i \times W_s + \delta ln(Z_{i,s}) + \gamma \Phi_{i,s} + \theta_i + \omega_s + \epsilon_{i,s} \quad (1)$$

where $z_{i,s}$ is the growth rate of macroeconomic variable $Z_{i,s}$ (either productivity or employment) in country i and sector s between the '90s and the 2000s, Y_i is the country-specific measure for global sourcing, W_s is a sector-specific measure of the possibility to fragment the production process and $\Phi_{i,s}$ is any country-sector control. All the right-hand-side variables are computed with data referring to the beginning of the period (the '90s) in order to avoid further problems of reverse causality. Our specification also includes country fixed effects, θ_i, so as to capture all those sector-invariant country characteristics that could affect macroeconomic performance (*e.g.* trade openness and specialization, institutional development, etc.); industry fixed effects, ω_s, to capture any industry-specific characteristics that could also affect the economic performance (*e.g.* technological content, level of world demand, etc.); and the level of the dependent variable in the '90s, $ln(Z_{i,s})$, to control for the initial condition. Our task is to estimate the coefficient β for the interaction term between the country-specific and the sector-specific variables. A positive coefficient would tell us that the benefits from a GVC sourcing are higher for sectors that provide greater opportunities to fragment the production process in countries more involved in global sourcing.

As we aim at describing the long-run relationship between GVC sourcing and macroeconomic performance, avoiding short-term fluctuations, our variables are constructed as ten-year averages, with the '90s given by the period 1990-1999 and the 2000s by 2000-2009. We thus focus on the growth rate between the '90s and the 2000s, when GVCs and global sourcing became defining features of international trade flows.

In order to estimate equation (1), we take as a measure of countries' global sourcing intensity a Balassa (1965) index that measures a country's propensity to import intermediate goods relative to the world average, as well as a refinement of the same index that controls for sectoral specialisation in international trade. As for the sectors' technological propensity to production fragmentation, we construct two measures. The first is the length of the production process in terms of the number of stages embodied in each product; the second is the complexity, i.e. width, of the assembly operations in terms of the number of parts and components from different sectors put together to produce the final product. In both cases the interpretation is the same: the larger the number of inputs, the greater the feasible fragmentation across different locations. The following subsections describe the key regressors in detail.

2.1 Measures of fragmentability

Our empirical strategy requires us to measure the extent to which production in each sector can be efficiently fragmented. Our goal is to capture fragmentability as a technological feature of each sector, with the idea that it is the engineering of the production process that dictates the way in which different stages of production are linked and can be unbundled. This constitutes only a prerequisite for actual fragmentation to take place: only if the country has the propensity and the capabilities needed to efficiently split the production process can the fragmentation indeed occur, domestically or internationally, again depending on country's characteristics.

A GVC is a production network that connects the different phases of an internationally fragmented production process, i.e. such that different stages of production take place in different countries. GVCs can be rather complex production networks. Figure 1, borrowed directly from Baldwin and Venables (2013), depicts a "general" GVC which may have a rather intricate architecture.

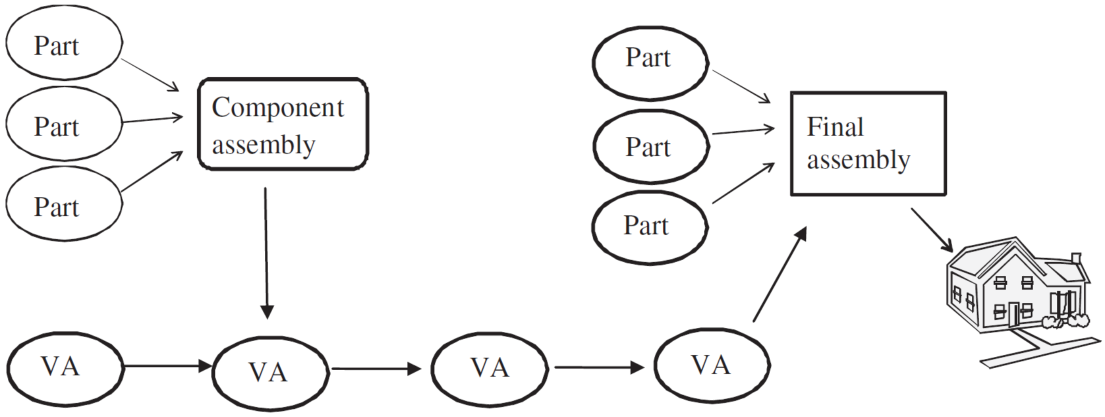

Figure 1: A general GVC (from Baldwin and Venables, 2013)

In line with Baldwin and Venables (2013) we consider two extreme structures for the production process: snakes and spiders. Snakes are production networks where value is added sequentially in each stage of the process, from upstream to downstream, up to final assembly (fig. 2). A spider is a production network where the parts are produced simultaneously and shipped to a hub to form a body (final assembly, in fig.3), which may be the final product or a new component. Indeed most GVCs are complex mixtures of the two, and the interest in studying these extreme cases lies in the fact that they are the elementary building blocks of any production network. Cotton to yarn to fabric to shirts is a snake-like process, but adding buttons is a spider-type element. Silicon to chips to computers is snake-like, but much of value added in producing a computer is spider-like final assembly of parts from different sources.

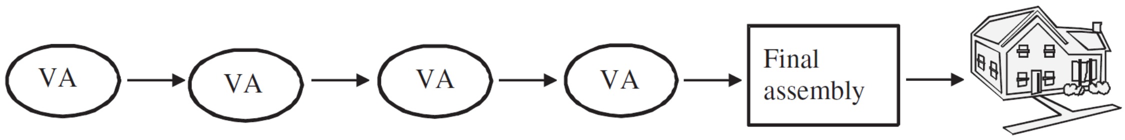

Figure 2: A snake GVC

Snakes and spiders can also be interpreted as two different dimensions of fragmentability: the

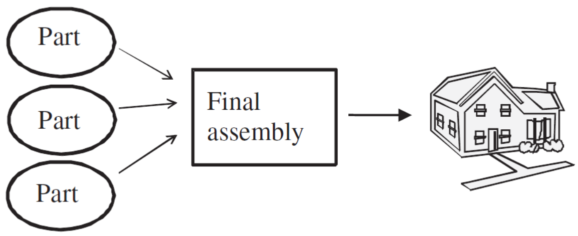

Figure 3: A spider GVC

first vertical, the second horizontal. We thus define two sector-specific indicators that characterize the fragmentability of the production process:

i. N_s^{Snake}, for the length of the value chain, borrowed from Fally (2012), that measures the number of production stages required for producing the final output of a given industry s (vertical fragmentability);

ii. N_s^{Spider}, for the width of the production process in a given industry s, that measures the number of commodities used in the final production stage (horizontal fragmentability).

Both indicators are based on I-O data for the US provided by the Bureau of Economic Analysis (BEA). The I-O tables provide a detailed snapshot of the economy, as they show the number and the quantity of commodity inputs that are used by each industry to produce its output (the so called "use table"), the commodities produced by each industry (the "make table"), and the use of commodities by final consumers. This offers us a sort of recipe book for the production in the US .

The index N_s^{Snake} is defined recursively: the average number of production stages of each industry depends on the number of production stages required by the inputs used:

$$N_s^{Snake} = 1 + \sum_k \mu_{sk} N_k^{Snake}. \tag{2}$$

where μ_{sk} is the value of input k used to produce 1 dollar value of output of industry s. In other words, the index is equal to 1 (the final production stage), plus the number of stages required to produce each of the inputs, weighted according to the unit input requirements. Equation (2) provides a system of linear equations that, for $\sum_k \mu_{sk} < 1$, has a unique solution for the vector $\boldsymbol{N}^{Snake}$.

In practice, starting from the make and use tables, first we derive the direct requirement table: this is an n-by-n matrix DR with entries μ_{sk}. Then, we obtain the n-by-n total requirement table $TR = (I - DR)^{-1}$, which shows the production required of a given commodity k, both directly and indirectly, per dollar value of delivery to final use by each industry s.[7] For instance,

[7] Playing around with the make and use tables, it is possible to derive different version of the direct and total

if the diagonal entry for the computer and electronic good industry and the computer and electronic commodities is equal to 1.2, it means that, to provide final users with \$1 billion of output from the computer and electronic good industry, requires \$1.2 billion of computer and electronic products, both directly and indirectly in the production of other commodities (for instance in producing machinery and equipment, that are then used as direct inputs by the computer and electronic good industry). The solution to the system in (2) is simply the sum of the total requirements of each industry.

As shown by Fally (2012), the "snake" measure is the average number of stages of the production chain, in which each stage is weighted by the share of value added in that stage. High values of the index indicate that many sectors are involved in the process, thus making it feasible to reallocate different production phases in different countries. With this index we aim at capturing only the potential, not the actual, extent of (international) fragmentation. One limitation of Fally's (2012) index is that it takes into account only the sequence of the different stages without considering their horizontal complexity. For instance, a good that is produced using one input only, which is also produced using only one input, produced again with one input, has three production stages, each properly weighted, while a good produced by assembling 3 different raw materials as inputs has only one production stage.

In order to account for the horizontal complexity of the production process, we define the index N_s^{Spider} simply as the number of inputs k used by industry s, considering only those inputs that enter directly in the final stage of the production process:

$$N_s^{Spider} = \sum_k \mathbf{1}_{\{\mu_{sk}>0\}}, \tag{3}$$

meaning that we count the row's entries μ_{sk} of the commodity-industry direct requirement table that are different from zero.[8]

The spider-type index is a measure of width of the production process. As such it strictly counts the number of inputs that are put together in the last stage for final assembly.[9] The higher the number of the components needed to assemble the final good, the more complex the production process, irrespective of the contribution of each component to the overall value

requirement tables: commodity-by-industry, commodity-by-commodity, industry-by-industry, and industry-by-commodity (see also Horowitz and Planting, 2006), where the distinction between industries and commodities comes from the fact that some firms are classified into industries according to their primary commodity output, but they could produce more then one commodity. Following Fally (2012), we present the results using the commodity-by-industry approach, meaning that the tables present the value of commodities required as inputs for the output of the different industries. Nevertheless, our results are robust to using alternative approaches, as the fragmentability measures computed with the different approaches are highly correlated.

[8]Nunn (2007) uses the same indicator to measure a firm's difficulty to vertical integrate, as the greater the number of inputs, the harder is for a firm to vertical integrate with all its suppliers.

[9]Alternatively, as we did for the snake-measure, we could have counted the number of inputs used both directly and indirectly, not just those in the last stage. The index then would not allow us to distinguish between horizontal and vertical features of the process.

added. For this reason, we do not weight the inputs in terms of their contribution to the vale of the final good. This is an important difference with respect to the snake-measure: in that case, as we are interested in measuring the length of the production process, we have to consider the contribution of all the inputs ever used in any of the stages that brings to the final assembly. It is then necessary to weight each intermediate stage's contribution in order to take into account its relevance in the overall production chain.

We compute both our indicators for the 127 industries (53 thereof belong to manufacturing) that enter the BEA's I-O table at the NAICS 4 digit-level of disaggregation. We then aggregate[10] the indexes at the same level of the of the productivity data provided by Levcehnko and Zhang (2014), which is 2-digit ISIC rev. 3 with few adjustments, encompassing 18 manufacturing sectors (see table 1).[11]

We use US data, as we want to measure a technological feature of the production process that does not depend on each single country's characteristics. Industries in the US, being on average on the technological frontier and not heavily constrained by institutional inefficiencies and frictions, should be able to organise the production process in a way that is as close as possible to the optimum and that best reflects the technological characteristics of the sectors. In other words, technical and institutional characteristics of the US economy should allow firms to fragment the production process as much as it is profitable, given the technical characteristics of the sector. We are well aware that by doing so we are underestimating the length and the complexity of the foreign part of US production chains, since all foreign production steps are collapsed into a single commodity, generically labelled as "imports". Indeed we are imposing for each sector that the length of its global production chain is given by the longest domestic chain. However, as on aggregate the US rely relatively little on global sourcing[12] and the sectors we consider are rather large, we believe that the size of this measurement error is small.

Data are from the 1997 I-O tables, because this is the earliest release adopting the current NAICS (North American Industry Classification System), which has a cleaner correspondence with the ISIC classification than the one previously used in the period covered by our analysis (1990-2009). A problem with this choice could be that, if the structure of the US production changes fast, then 1997 is not necessarily representative of the entire period we analyse. To provide evidence that this is not the case, we computed N_s^{Snake} and N_s^{Spider} using both the 1997 and the 2002 release of the I-O tables. According to Table 3 in the appendix, for both

[10]The aggregation is given by the weighted average of the indicators for the sectors at the NAICS 4 digit-level that match into the same ISIC 2-digit-level, according to the concordance table provided by UNSTAT. A perfect correspondence between ISIC rev. 3 and NAICS is not possible, even when we consider the NAICS at the 6 digit level: some sectors are associated with more than one ISIC 2-digit code. We chose to match the 4 digit NAICS I/O code with the more frequently corresponding 2-digit ISIC rev. 3 code.

[11]Alternatively we could have "translated" from NAICS 4 digit to ISIC 2 digit the use and make table, before computing the indicators. Although this approach implies the loss of valuable information in understanding the inter-linkages between industries, which can be more easily captured the more disaggregated the data are, our results are robust to the use of this alternative way of computing the fragmentability indicators.

[12]As shown in figure 6, below.

measures, the indexes computed in 1997 and 2002 are highly correlated ($\geq .90$). This suggests that the production structure in the US tends to remain quite stable over time and, if anything, we are committing a small mistake. Also note that the snake- and spider-measures are little correlated with each other, suggesting that we are indeed capturing different dimensions of fragmentability.

Figure 4 shows the values of the length of the production chains we computed for the sectors considered in our analysis, while figure 5 depicts their width, i.e. the spider dimension.[13] The length of the average production chain is 2.4 (table 2). This means that, on average, weighting each production stage by the value added in that stage, the number of stages in the production chain is 2.4. The longest chains are found in the Food and Beverages, Electrical Machinery, Communication Equipment and Textiles sectors (respectively 2.78, 2.69 and 2.67 stages) while the shortest are in Tobacco Products, Medical, Precision, and Optical Instruments and Rubber and Plastics Products (respectively 1.78, 2.02 and 2.05 stages).

The width of the average production chain is 96 (out of the 127 that we consider), i.e. on average each final good requires assembling 96 inputs from both the manufacturing and the service sector. The widest production chains are found in Food and Beverages, Rubber and Plastics Products, Furniture and other Manufacturing and Transport Equipment, while the narrowest are Leather Products and Tobacco Products. As this measure is not weighted, it depends on the level of aggregation of the data. For instance, in our case the index could never exceed 127. To eliminate any issue about the scale, in our empirical specification we will take the natural log of this variable.

The comparison between the two indices also leads to interesting remarks: Optical Instruments is a sector with a short but wide production chain; in Tobacco Products it is both short and narrow; in Leather Products it is long and narrow; and in Transport Equipment it is both long and wide.

2.2 Index of intensity of global sourcing

To measure the intensity in global sourcing we employ a variant of the Revealed Comparative Advantage index (Balassa, 1965), proposed by Hoen and Oosterhaven (2006). This index compares the share of intermediate goods in manufacturing imports for each country with the average world share:

$$RCA_i = \frac{\sum_{j \in S} M_{i,j}^{\text{Int}}}{\sum_{j \in S} M_{i,j}^{\text{Tot}}} - \frac{\sum_{i,j \in S} M_{i,j}^{\text{Int}}}{\sum_{i,j \in S} M_{i,j}^{\text{Tot}}} \tag{4}$$

[13] We exclude Coke, petroleum products and nuclear fuels.

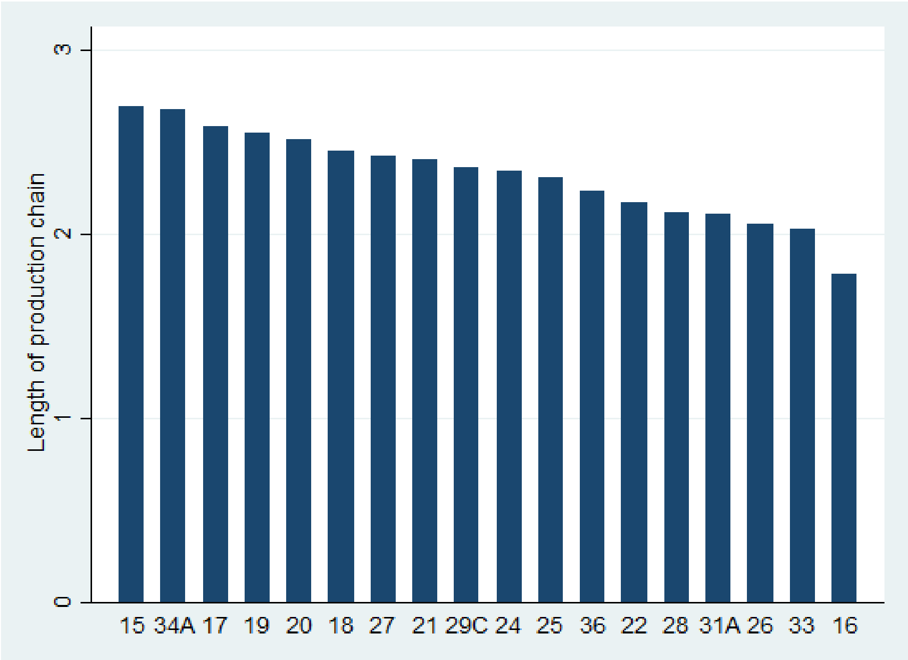

Figure 4: Length of value chains from 1997 Input-Output US data (snake dimension)

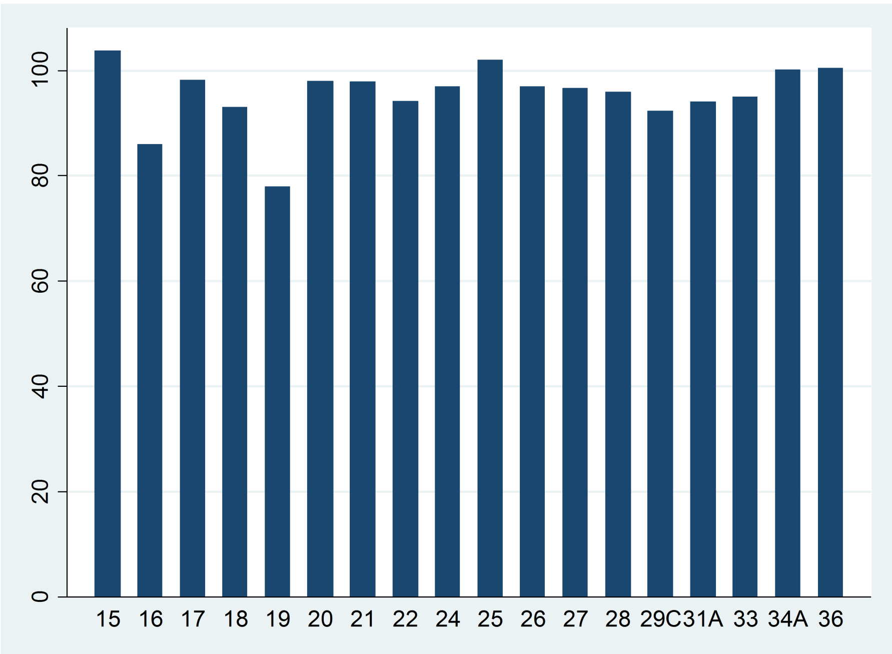

Figure 5: Width of value chains from 1997 Input-Output US data (spider dimension)

where M stands for imports of manufacturing products, the superscripts Int and Tot refer to intermediate-good and total trade flows respectively, i is the country whose imports are considered, j the partner country and S is the set of countries under analysis;[14] all the data

[14]The countries analysed in this paper account for most of world trade and are listed in Appendix A.

refer to the '90s. Goods belonging to the ISIC division 23 (Coke, petroleum products and nuclear fuels) are been excluded from total trade to minimise the effect of oil price volatility on trade values.[15]

The range of the indices is $[-1, +1]$: positive (negative) values indicate that the country is relatively (de)specialised in the trade of intermediate goods with respect to the world average. We interpret an index above zero as an indication that producers in country i engage in global sourcing. In particular, RCA_i measures the relative specialisation in the assembly operations of goods using imported intermediates. Data are from the Bilateral Trade in Goods by Industry and End-use Category Database by the OECD (Zhu et al., 2011), which provides values of imports and exports of goods broken down by industrial sectors and by end-use categories (intermediate goods, household consumption goods and capital goods).

New measures of international fragmentation are being continuously proposed in the literature.[16] Most of these measure provide an in-depth view on the role of a country within the GVC, i.e. the position in the "value-added ladder", which is the snake dimension of the GVC; unfortunately they cannot account for the spider dimension of the GVC. We then prefer to stick with a more traditional Balassa (1965) type index because it captures the involvement in global sourcing using a very simple logic: i) global sourcing determines trade flows in intermediates, which can be easily measured, and ii) the relative intensity of these trade flows reveals the countries' specialisation in intermediate intensive-activities, i.e. measures the intensity in global sourcing. The "roughness" of our index of choice is compensated with the interaction with the measures of length and width of the GVC, which allows us to quantify the effect on productivity growth of sourcing from GVCs with different architectures.

One possible concern is that a country could have a high RCA measure because it imports more from sectors that involve a higher share of intermediate goods, rather than more intermediates within each sector. This means that the variation of the measure across countries could depend more on their trade specialization than on their propensity to fragment production. To address this issue we decomposed the RCA measure into two components: one that accounts for the variation in the share of intermediates across sectors, and therefore depends on the sectoral specialization; the other that accounts for the variation in the share of intermediate within each sector (see Johnson and Noguera, 2013):

[15]Consequently we leave raw materials completely out of our analysis as i) we restrict to manufacturing, hence excluding agricultural and mining raw materials, and ii) we explicitly exclude ISIC division 23 goods.

[16]See, among others, Lafay (1992), Hummels et al. (2001), Johnson and Noguera (2013), Koopman et al. (2014), Alfaro et al (2015) and Borin and Mancini (2015).

$$RCA_i = \underbrace{\frac{1}{2}\sum_s \left(\frac{M^{INT}_{i,s}}{M^{TOT}_{i,s}} - \frac{\sum_j M^{INT}_{j,s}}{\sum_j M^{TOT}_{j,s}}\right)\left(\frac{M^{TOT}_{i,s}}{\sum_s M^{TOT}_{i,s}} + \frac{\sum_j M^{TOT}_{j,s}}{\sum_{j,s} M^{TOT}_{j,s}}\right)}_{RCA_i^{\text{within}}} \tag{5}$$

$$+ \underbrace{\frac{1}{2}\sum_s \left(\frac{M^{TOT}_{i,s}}{\sum_s M^{TOT}_{i,s}} - \frac{\sum_j M^{TOT}_{j,s}}{\sum_{j,s} M^{TOT}_{j,s}}\right)\left(\frac{M^{INT}_{i,s}}{M^{TOT}_{i,s}} + \frac{\sum_j M^{INT}_{j,s}}{\sum_j M^{TOT}_{j,s}}\right)}_{RCA_i^{\text{between}}} \tag{6}$$

We will then be interested in first the component, RCA_i^{within}, which by construction is free from any effect driven by trade specialisation.

Figure 6 shows the values of the index and its decomposition in the within and between components for the countries in our estimation sample. Most of the variability in the total index comes from the within component, which on average accounts for roughly 80% of the overall RCA. India, Korea and Indonesia have the highest comparative advantage in final assembly (with index values respectively of .27, .15 and .15), while Norway, Australia and the US the least (respectively equal to -.05, -.08 and -.08). The fact that the index for the US is very low confirms that the country is a relatively closed economy that imports few intermediates. This evidence further corroborates our choice of calculating the indices of fragmentability on the domestic I-O tables for the US: indeed the foreign part of the US final-good production chains is small.

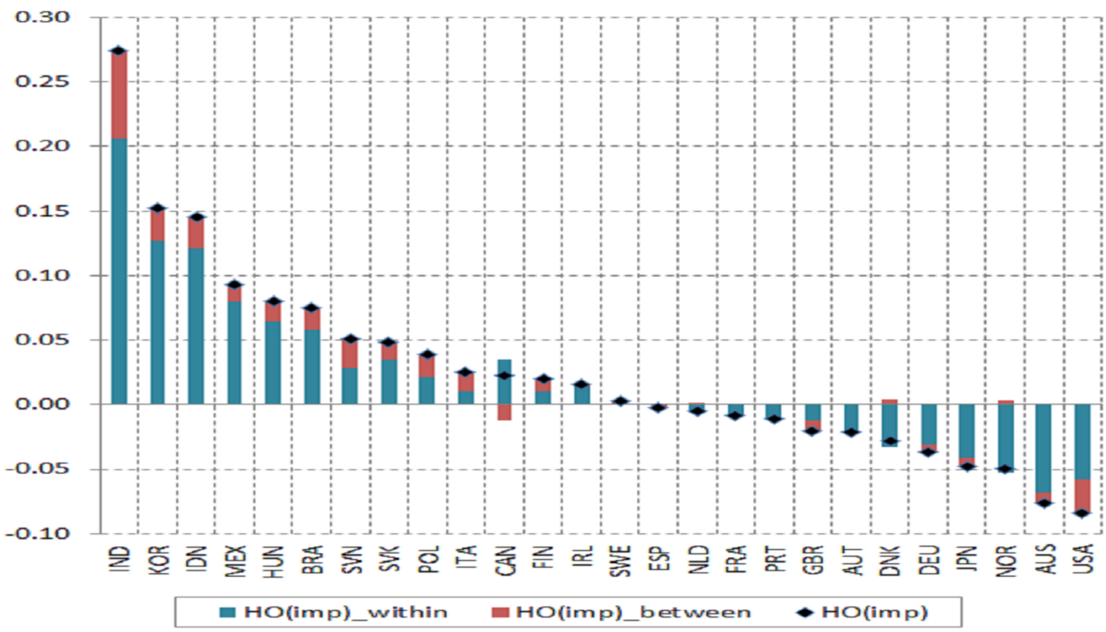

Figure 6: RCA Index and within and between components

3 Measures of productivity

We start our analysis by looking at the effects of GVC sourcing on some common measures of macroeconomic performance: labour productivity and employment. We will then turn to theory to estimate a measure of TFP.

3.1 Labour productivity and employment

We measure labour productivity as both (real) output per worker and (real) value added per worker. Changes in output and value added per worker however do not fully account for the effect of GVC sourcing on productivity. An increase in output can be explained by an increase in TFP and/or in the use of other inputs (capital and intermediate goods). By definition, an increase in value added, instead, is not driven by an increase in the quantity of intermediate goods and thus value added per worker could be a better measure of labour productivity. However, an improvement in the quality of the inputs can be hardly expected to be captured by a standard measure of value added, while it would result in an increase of TFP. Unfortunately, we are not able to control for changes in the capital stock, which can also affect output and value added per worker: no data with a sufficient time span exists for the required country-sector coverage.[17] This data limitation is a common problem in cross-country analysis and no satisfactory solution has been proposed yet.

Output per worker and value added per worker could increase also in response to a decline in sectoral employment. In fact, besides the effects of GVC sourcing on productivity growth, those on total employment are also widely discussed in both the academic and the policy debate. International outsourcing may reduce the demand of domestic workers in those countries and sectors that source more from GVC. To address this possibility, we consider as another measure of macroeconomic performance the growth rate of employment at the country-industry level.

Output, value added and employment data come from the 2013 UNIDO Industrial Statistics Database at the country-industry level. Raw data are expressed in nominal terms. To obtain real measures of output and value added we use the Producer Price Index (PPI) as the main deflator. PPIs are collected from OECD (Main Economic Indicators) and IMF (International Financial Statistics, IFS), supplemented by national sources. Following Rajan and Zingales (1998), for high-inflation countries, where the difference in collection times between UNIDO data and the PPI may induce sizeable measurement errors, we replace the PPI with an implicit deflator of industrial production, given by the ratio between UNIDO nominal manufacturing output and the index of (real) industrial production (from IMF IFS).

[17] The EU KLEMS (O'Mahony and Timmer, 2009) database, which to our knowledge has the best coverage, provides data on capital stock and gross fixed capital formation for just 17 countries and only 14 manufacturing sectors from 1970 to 2007, with the same gaps for both series. This is too little to include the stocks variables as controls in a regression as well as to fill the gaps in the stock series using methods such as perpetual inventory.

According to Table 2, which presents the summary statistics based only on those observations that enter our estimations, excluding outliers, the average growth of output per worker across countries and manufacturing sectors between the 90s and the 00s has been around 20%. The average growth in value added per worker has been lower (11%), while average employment slightly decreased (−3%). This could probably be explained by an increase in the share of services, excluded from our analysis, in many of the countries that enter our sample.

3.2 TFP and its components

This section describes the method used to estimate TFP at the country-sector level. Unlike the measures of productivity described above, TFP is usually defined as the residual efficiency of the production process that cannot be explained by inputs' services (labour, capital and intermediate inputs). Estimating TFP has always been tricky, as it is a non observable parameter of the production function. We obtain a model-based measure of TFP from the structural estimation of a set of Eaton and Kortum (2002) gravity equations, using some calibration and measurements from US data.

Levchenko and Zhang (2013), building on Finicelli et al. (2013), show that in a multi-sectoral version of the Eaton and Kortum (2002) model the average TFP, Λ_i^s, of an open economy i in sector s is given by:

$$\Lambda_i^s = \left[T_i^s \left(1 + \sum_{n \neq i} \frac{X_{in}^s}{X_{ii}^s} \right) \right]^{1/\theta}, \tag{7}$$

where T_i^s is a technological parameter, X_{in}^s are the imports of country i from country n in sector s, X_{ii}^s is production net of exports of county i in sector s, and θ is a parameter that captures the dispersion in the distribution of the technological level across firms. In this theoretical framework, T_i^s characterizes the mean of the country-sector-specific distribution of firms' productivities and it can be interpreted as the state of technology of sector s in country i.[18] The term

$$\Omega_i^s \equiv \left(1 + \sum_{n \neq i} \frac{X_{in}^s}{X_{ii}^s} \right) = \left(1 + \frac{IMP_i^s}{PROD_i^s - EXP_i^s} \right) \tag{8}$$

is a measure of trade openness and captures the effect that the allocation of resources across firms with different productivities has on the average country-sector productivity.

According to this framework, a technological improvement that increases the mean of firms' productivity is captured by an increase in T_i^s and leads to an increase of average TFP.[19] Analogously, anything that induces a reallocation of resources from the least to the most productive

[18] Eaton and Kortum (2002) assume a Frechet distribution for firm productivity.

[19] In the original Eaton and Kortum (2002) model without technological change, T_i^s is an exogenous and constant primitive of the model.

firms is captured by an increase in Ω_i^s, and also leads to an increase in average TFP.

We obtain estimations for T_i^s and Ω_i^s, and then study the effect of GVCs participation on TFP growth via the two different channels. The dependent variable and the results from our analysis depend on the assumptions that characterise Eaton and Kortum's (2002) model. Nevertheless, as all measures of TFP are either based on proxies or derived from the estimation of an underling production function, we believe that our approach should not necessarily entail more serious measurement error problems than other approaches.

3.2.1 The estimation of TFP

The multi-sectoral version of the Eaton and Kortum (2002) model, besides the TFP decomposition described above, provides simple structural equations for bilateral trade between any two countries in terms of the relative technology level and geographic barriers:

$$\frac{X_{in}^s}{X_{ii}^s} = \frac{T_n^s(c_n^s \tau_{in}^s)^{-\theta}}{T_i^s(c_i^s)^{-\theta}}, \tag{9}$$

where c_i^s is the unit cost of country i in sector s and τ_{in}^s is a measure for the trade costs between countries i and n for sector s, that can be accounted by bilateral distances (d_{in}^s), border effects (b_{in}^s), regional trade agreements RTA_{in}^s, global remoteness (captured by an exporter fixed effect ex_n^s, see Waugh, 2010) and an error term:

$$ln\tau_{in}^s = d_{in}^s + b_{in}^s + RTA_{in}^s + ex_n^s + \eta_{in}^s$$

Taking logs and plugging in the above expression, equation (9) becomes:

$$ln\left(\frac{X_{in}^s}{X_{ii}^s}\right) = ln\left(T_n^s(c_n^s)^{-\theta}\right) - \theta ex_n^s - ln\left(T_i^s(c_i^s)^{-\theta}\right) - \theta(d_{in}^s + b_{in}^s + RTA_{in}^s) - \theta\eta_{in}^s$$

and it can be estimated, for each sector and period separately, using OLS with exporter and importer fixed effects.[20] The estimated importer fixed effects provide a measure for the technology-cum-unit-cost term $T_i^s(c_i^s)^{-\theta}$. Given the available degrees of freedom, the estimation performed by Levchenko and Zhang (2013) is expressed in relative terms with respect the US, taken as reference country.

The authors kindly provided us with the estimated measure $\frac{T_i^s}{T_{US}^s}$ for 75 countries, 20 sectors and the five decades from the 60s to the 00s. As we are interested, not only in the cross-country variation, but also in the time variation of the technological productivity, we need to estimate

[20] All variables used for the estimation by Levchenko and Zhang (2013) are taken as ten-year averages of the underlying yearly series.

T^s_{US} in order to pin down each country's T^s_i. The production function used in Levchenko and Zhang (2013) implies:

$$lnQ^s_{US} = ln\Lambda^s_{US} + \alpha^s\beta^s lnL^s_{US} + (1-\alpha^s)\beta^s lnK^s_{US} + (1-\beta^s)\sum_k \gamma_{ks} lnM^{ks}_{US}$$

where Q^s is the output in sector s, α^s and β^s are Cobb Douglas parameters, L^s denotes labour, K^s denotes capital, M^{ks} denotes intermediate inputs from each other sector k, with total requirement γ^{ks}, and Λ^s_{US} is the total factor productivity. Using data on output, inputs of labour, capital, and intermediates from the NBER-CES Manufacturing Industry Database together with the values for α^s and β^s calibrated by Levchenko and Zhang (2013), we compute the observed US TFP level, Λ^s_{US}, for each manufacturing tradeable sector implied by the above equation. As in Levchenko and Zhang (2013), with Comtrade data we derive Ω^s_{US} from (8) and use it, together with the estimated Λ^s_{US} to get T^s_{US} from (7). Finally, from the $\frac{T^s_i}{T^s_{US}}$ provided by Levchenko and Zhang (2013), we can pin down each T^s_i and, using again the same two equations, obtain Ω^s_i and the overall TFP for all the other 74 countries.

According to Table 2, the average growth rate in TFP between the 90s and the 00s in our sample was 8%, mainly driven by technological change (6%). Growth driven by an improvement in resource allocation was contained (2%). The sectors "Electrical Machinery and Communication Equipment" and "Office, Accounting, Computing, and Other Machinery" are, not surprisingly, among those with the highest TFP growth, especially in emerging and eastern European economies (as Mexico and Bulgaria). Among the sectors with negative TFP growth, we find "Wearing Apparel, Fur", "Printing and Publishing" and, more surprisingly, "Medical, Precision and Optical Instruments", both in advanced economies (as Japan and Australia) and emerging economies (Brazil).

Figure 7 shows the non-parametric distribution of the growth rate for the technological parameter T^s_n for all the country-sector couples for which we have data, regardless of the observation entering the estimations. Compared to a Normal distribution, the empirical distribution has a fat tail to the right, indicating that some sectors grew exceptionally fast. We obtain a similar picture for the distributions of TFP and Ω. This is a further assurance of the plausibility of our model-based estimates.

4 Estimation Results

In this section we discuss the estimation of equation (1):

$$z^s_i = \alpha + \beta Y_{i,90} \times W_s + \delta ln(Z^s_{i,90}) + \gamma VAshare_{i,90} + \theta_i + \omega_s + \epsilon_{is}$$

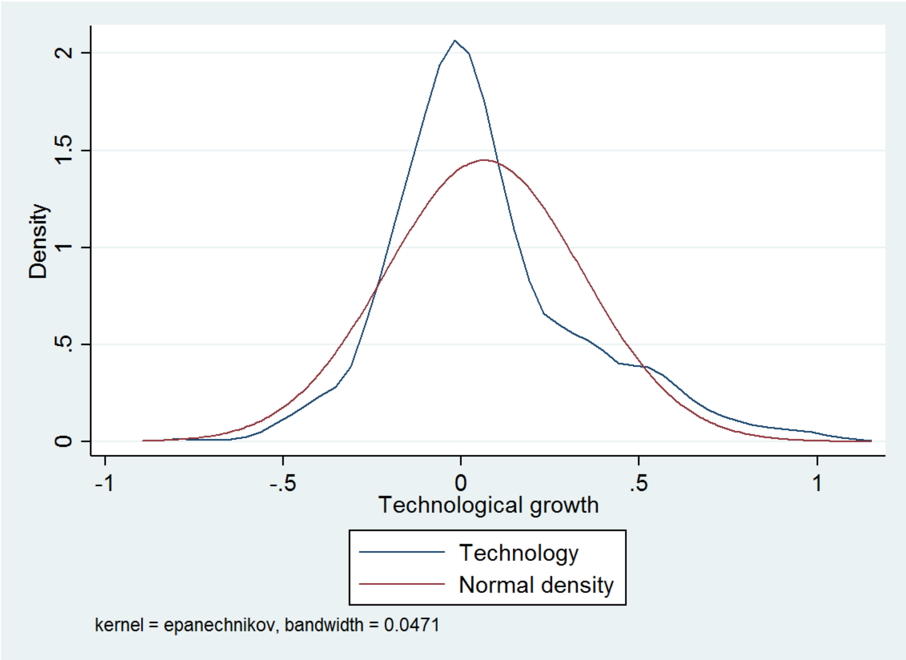

Figure 7: Distribution of the estimated technological growth rates

for different choices of the variable of interest $Z^s_{i,t}$ and for the different measures of fragmentability W_s and intensity in global sourcing $Y_{i,90}$ discussed in the previous sections. As we study the effect of GVC sourcing on the growth rate z^s_i between the years 90s and 00s, our specification includes the initial value of the dependent variable, $Z^s_{i,90}$. In addition to country and sector fixed effects θ_i and ω_s, we also control for the value added share of each sector in each country at the beginning of the period, $VAshare_{i,90}$. This variable aims to capture any effect coming from countries' sectoral specialization. In the estimation we exclude outliers, defined as observations which are more than 3 standard deviations away from the sample mean.[21]

Table 4 displays the results for the specification using the "snake" measure of fragmentability that, as broadly discussed above, measures the backward length of the production chain: the higher N^{Snake}_s, the higher the number of production stages required to produce s, accounting also for the stages embodied in the inputs. The length measure is interacted with country i's overall revealed comparative advantage for the imports of intermediate goods, RCA_i. The higher the index, the more a country is specialized in importing intermediate goods. The first two columns show the effect of GVC sourcing on the standard measures of labour productivity: for both real output per worker and real value added per worker, the coefficients of the interaction terms are positive, statistically different from zero and close in magnitude between the two equations. This means that, for sectors that are at the end of long vertical production chains, labour productivity growth has been stronger between the 90s and the 00s in those countries that, at the beginning of the period, were highly involved in global sourcing by spe-

[21]We also exclude from the estimation sample goods belonging to the ISIC division 23 (Coke, petroleum products and nuclear fuels).

cializing in importing intermediate goods. The coefficient of the variable capturing the initial condition is always significant with the expected negative sign, while the coefficient for sectoral specialization is not statistically different from zero.

Any increase in output and value added per worker in sector s could be driven by a decrease in the denominator, the number of people employed in the same sector, L_s. For instance, GVC sourcing could imply the outsourcing of inputs previously produced domestically and, for those inputs that belong to s, this could reduce the total employment in the sector. We check for this possibility by estimating the effect of GVC sourcing on the growth rate of employment. Column (3) of Table 4 shows that this is not significantly different from zero. In other words, the positive effect on labour productivity is not achieved by a reduction in the number of workers, but by an increase in the output and value-added they produce.

The last three columns of Table 4 show the results for the effect of GVC sourcing on the model-based measure of TFP and its components: technology and resource allocation (columns (5) and (6), respectively). Our intent is to assess whether the positive effect we found on labour productivity is driven only by an increase in the use of inputs other than labour, as well as by an overall improvement in the way inputs are combined either at the micro or aggregate level. According to column (4) there is a positive and significant effect on TFP and this is entirely driven by a positive effect on T_i^s, the technological component (column (5)). In fact, the parameter that captures the effect via Ω_i^s is statistically null (column (6)). Global value chains increase the variety and the quality of the inputs available for production, and this would have a direct effect on TFP, see also Amiti and Konings (2007), Kasahara and Lapham (2013) and Halpern et al. (2015). There could also be an indirect effect on the incentives to innovate, given by a higher profitability stemming from the use of better inputs and the need to meet the possibly higher technological standards of the imported inputs. Both effects would show up in the technological parameter T_i^s.

One possible concern with the results shown in Table 4 is that, by construction, the RCA measure takes into account the sectoral specialization of a country, not only its intensity in the use of imported intermediated inputs. This means that a given country i could have a high RCA measure because it imports more from sectors that involve a higher share of intermediate goods, rather than more intermediates within each sector. To address this issue we decomposed the RCA measure into two components, one that accounts for the variation in the share of intermediates across sectors, and depends on the sectoral specialization, the other that accounts for the variation in the share of intermediate within each sector (see section 2.2). Table 5 reports the estimation results when the overall RCA measure is replaced by its "within" component. The findings are unchanged: the parameters have the same sign and significance than in Table 4, if anything they are slightly higher in magnitude.

The effects we find are economically relevant. For instance, consider the case of a country increasing its GVC sourcing from the 25th to the 75th percentile of the distribution of the overall RCA measure, everything else being held constant.[22]. The positive effect on TFP would be between 9 percentage points for the sector with the shortest production chain (Tobacco products) and about 14 percentage points for the sector with the longest production chain (Food products and beverages). This is a sizeable impact given that the average growth rate of the technology level between the 90s and the 2000s in our sample is 7.4% (table 2).

When we turn to the 'spider' measure of fragmentability, which assesses the horizontal complexity of the production process, the picture looks slightly different. Sectors that use a greater variety of inputs in their last production stage experience a much stronger increase in labour productivity in countries that specialize in importing intermediates (columns (1) and (2) of Table 6). This result is in large part driven by a decrease in sectoral employment: the coefficient of the interaction term in column (3) is negative and significantly different from zero. According to column (4), there is also a positive and significant effect on TFP which, unlike for the 'snake' measure, arises from a more efficient allocation of resources across firms at the sector-country level (column (6)). On the other hand, the effect on the technological component of TFP is not statistically different from zero. When the overall RCA measures is replaced by the 'within' measure (Table 7), findings are basically unchanged.

The results confirm the positive effect of GVC sourcing on both labour productivity and TFP, but they also suggest that the technological improvement triggered by a greater variety and quality of inputs is not the only mechanism that can lead to this outcome. Many studies found positive import competition effects on productivity, see for instance Amiti and Konings (2007), Trefler (2004) and Roberts and Tybout (1991). The main idea is that imported varieties increase competition on the domestic market, forcing least productive domestic firms out of business and spurring reallocation of resources toward the more productive surviving ones. As the 'spider' measure considers only the last stage of production, many of the inputs tend to be closely related to the output and to belong to the same ISIC 2 digit-sector (i.e. the majority of inputs lie on the diagonal of the direct requirement matrix). If the country tends to import a relatively high share of intermediates, in this sector competition from foreign varieties increases. Competition pushes employment either towards the most efficient firms in the sector, or towards firms in other sectors. In the end, this increases labour productivity and TFP at the country-sector level, even if employment decreases.

We perform several robustness checks: we exclude from our sample the United States, which we used as a benchmark for the length and width measures, as well as in the calculation of TFP and its components; we reintroduce the ISIC rev.3 code 23 (Coke, petroleum products and nuclear fuels), which was excluded from our baseline sample; and we control for some measure of capital stock.[23] The results are not affected by such changes. We also test whether the effect

[22]This would corresponds to a country such as South Africa to increases global sourcing to the level of Brazil.

[23]As said, there are no good measure for capital stock at the country and sectoral level of our analysis. We included the cumulate gross fixed capital formation at the country-sector level from the UNIDO IndStat data base.

is different between countries and sectors: we did not find any evidence when distinguishing between advanced and emerging economies and between low- and high-R&D intensive sectors. As a final robustness exercise we insert the interaction terms with both the 'snake' and the 'spider' measures of fragmentability that, according to Table 3, are positively, yet weakly, correlated (0.38). Results are reported in Table 8. Signs and magnitudes of coefficients are basically unchanged In particular, all findings concerning the 'spider' measure are confirmed while the effect of 'snake'-type fragmentability loses significance on labour productivity but remains positive and significant on TFP thanks to the effect of the technological channel.

Overall our results suggest that countries that are involved in global production chains via the import of intermediate goods experience a stronger productivity growth in sectors with high fragmentability. Productivity gains can occur thanks to both the availability of more and better inputs, which increases firms' TFP, and import competition that forces the reallocation of resources towards the most efficient firms within a given sector.

5 Conclusions

In this paper, we present an analysis of the effect of global sourcing on labour productivity and total factor productivity (TFP). We apply the methodology that Rajan and Zingales (1998) proposed to overcome possible reverse causality between external finance and growth to the relationship between sourcing intermediate goods from a Global Value Chain (GVC) and productivity growth. To this aim we develop several indicators: at the sector level we measure both the length and the width of GVCs, and at the country level we consider the overall involvement in imports of intermediate goods as well as a measure that excludes the effect of trade sectoral specialisation.

Our results support the widespread perception that importing intermediate goods through GVCs increases productivity in the importing countries. Sectors with long GVCs operating in countries specialised in importing intermediates experience a boost in labour productivity (in terms of both output per worker and value added per worker) and in TFP. The latter effect is entirely driven by a technological advancement, whereas employment levels are unchanged and no effect comes from resource reallocation. When we turn our attention to sectors with wide GVCs (i.e. GVCs involving the use of many direct inputs from a variety of different sectors) we confirm the result on labour productivity and on TFP, yet the channels are different. Notwithstanding a contraction in employment, there appears to be a significant impact of resource reallocation but not of technological change.

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A List of countries

The countries analysed in this paper are: Argentina (ARG), Australia (AUS), Austria (AUT), Belgium-Luxembourg (BLX), Brazil (BRA), Bulgaria (BGR), Canada (CAN), Chile (CHL), China (CHN), Czech Republic (CZE), Denmark (DNK), Finland (FIN), France (FRA), Germany (DEU), Greece (GRC), Hungary (HUN), Iceland (ISL), India (IND), Indonesia (IDN), Ireland (IRL), Israel (ISR), Italy (ITA), Japan (JPN), Malaysia (MYS), Mexico (MEX), Netherlands (NLD), New Zealand (NZL), Norway (NOR), Philippines (PHL), Poland (POL), Portugal (PRT), Romania (ROM), Russia (RUS), Saudi Arabia (SAU), Slovakia (SVK), Slovenia (SVN), South Africa (ZAF), South Korea (KOR), Spain (ESP), Sweden (SWE), Switzerland (CHE), Taiwan (TWN), Thailand (THA), Turkey (TUR), United Kingdom (GBR), and United States (USA).

B tables

Table 1: List of sectors

$ISIC_{LVK}$	description
15	Food and Beverages
16	Tobacco Products
17	Textiles
18	Wearing Apparel, Fur
19	Leather, Leather Products, Footwear
20	Wood Products (excluding Furniture)
21	Paper and Paper Products
22	Printing and Publishing
23	Coke, Refined Petroleum Products, Nuclear Fuel
24	Chemical and Chemical Products
25	Rubber and Plastics Products
26	Non-Metallic Mineral Products
27	Basic Metals
28	Fabricated Metal Products
29C	Office, Accounting, Computing, and Other Machinery
31A	Electrical Machinery, Communication Equipment
33	Medical, Precision, and Optical Instruments
34A	Transport Equipment
36	Furniture and Other Manufacturing

Table 2: Summary statistics

Variable	**Mean**	**Std. Dev.**	**Min.**	**Max.**	**N**
$\Delta ln(Q/L)$	0.21	0.32	-0.89	1.38	546
$\Delta ln(VA/L)$	0.11	0.33	-1	1.15	546
$\Delta ln(L)$	-0.03	0.39	-1.72	1.56	546
$\Delta ln(TFP)$	0.08	0.24	-0.42	0.84	501
$\Delta ln(T)$	0.06	0.25	-0.56	0.79	546
$\Delta ln(\Omega)$	0.02	0.07	-0.53	0.49	501
N_s^{Snake}	2.36	0.24	1.79	2.72	546
N_s^{Spider}	96	6	78	104	546
RCA_i	0.03	0.08	-0.1	0.27	546
RCA_i^{within}	0.02	0.06	-0.1	0.21	546

Table 3: Measures of Fragmentability - Correlations

	N_{1997}^{Snake}	N_{1997}^{Spider}	N_{2002}^{Snake}	N_{2002}^{Spider}
N_{1997}^{Snake}	1.00	-	-	-
N_{1997}^{Spider}	0.38	1.00	-	-
N_{2002}^{Snake}	0.94	0.61	1.00	-
N_{2002}^{Spider}	0.32	0.90	0.52	1.00

Table 4: Snake-type GVCs and overall RCA in intermediates

	(1) $\Delta ln\frac{Q}{L}$	(2) $\Delta ln\frac{VA}{L}$	(3) ΔlnL	(4) ΔlnTFP	(5) ΔlnT	(6) $\Delta ln\Omega$
$N_s^{Snake} \times RCA_i$	1.20**	1.05**	0.05	0.48**	0.31*	-0.14
	(0.45)	(0.51)	(0.72)	(0.22)	(0.17)	(0.11)
$VAshare_{90s}$	0.19	-0.09	-0.22	0.43***	0.66***	-0.48***
	(0.53)	(0.56)	(0.64)	(0.13)	(0.15)	(0.12)
$Depend_{90s}$	-0.09*	-0.14**	-0.01	-0.42***	-0.24***	-0.52***
	(0.05)	(0.06)	(0.04)	(0.06)	(0.07)	(0.11)
$Constant$	1.51**	2.13***	-0.27	0.68***	0.42***	0.03***
	(0.68)	(0.71)	(0.35)	(0.10)	(0.10)	(0.01)
N	546	546	546	501	546	501

All regressions include country and sector fixed effects. Robust standard errors in parentheses. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$

Table 5: Snake-type GVCs and "within-sector"RCA in intermediates

	(1) $\Delta ln\frac{Q}{L}$	(2) $\Delta ln\frac{VA}{L}$	(3) ΔlnL	(4) ΔlnTFP	(5) ΔlnT	(6) $\Delta ln\Omega$
$N^{Snake} \times RCA^{within}$	1.51**	1.28**	-0.09	0.61**	0.45**	-0.19
	(0.59)	(0.62)	(0.91)	(0.28)	(0.20)	(0.14)
$VAshare_{90s}$	0.18	-0.10	-0.22	0.43***	0.66***	-0.48***
	(0.53)	(0.56)	(0.63)	(0.13)	(0.15)	(0.12)
$Depend_{90s}$	-0.09*	-0.14**	-0.01	-0.42***	-0.24***	-0.52***
	(0.05)	(0.06)	(0.04)	(0.06)	(0.07)	(0.11)
$Constant$	1.52**	2.13***	-0.27	0.68***	0.42***	0.03***
	(0.69)	(0.71)	(0.35)	(0.10)	(0.10)	(0.01)
N	546	546	546	501	546	501

All regressions include country and sector fixed effects. Robust standard errors in parentheses. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$

Table 6: Spider-type GVCs and overall RCA in intermediates

	(1) $\Delta ln\frac{Q}{L}$	(2) $\Delta ln\frac{VA}{L}$	(3) ΔlnL	(4) ΔlnTFP	(5) ΔlnT	(6) $\Delta ln\Omega$
$ln(N^{Spider}) \times RCA$	8.06***	7.95***	-6.95**	1.62**	0.37	0.87**
	(1.92)	(1.89)	(2.87)	(0.63)	(0.55)	(0.34)
$VAshare_{90s}$	0.31	0.03	-0.01	0.46***	0.66***	-0.47***
	(0.51)	(0.53)	(0.61)	(0.12)	(0.15)	(0.12)
$Depend_{90s}$	-0.09*	-0.15**	-0.030	-0.41***	-0.23***	-0.52***
	(0.05)	(0.06)	(0.04)	(0.06)	(0.07)	(0.11)
$Constant$	0.69	1.28*	0.74	0.50***	0.37***	-0.07*
	(0.68)	(0.71)	(0.55)	(0.12)	(0.13)	(0.04)
N	546	546	546	501	546	501

All regressions include country and sector fixed effects. Robust standard errors in parentheses. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$

Table 7: Spider-type GVCs and "within-sector"RCA in intermediates

	(1) $\Delta ln\frac{Q}{L}$	(2) $\Delta ln\frac{VA}{L}$	(3) ΔlnL	(4) ΔlnTFP	(5) ΔlnT	(6) $\Delta ln\Omega$
$ln(N^{Spider}) \times RCA^{within}$	9.93***	9.34***	-8.76**	2.09**	0.57	1.15**
	(2.27)	(2.19)	(3.81)	(0.77)	(0.66)	(0.44)
$VAshare_{90s}$	0.30	0.01	-0.01	0.46***	0.66***	-0.47***
	(0.51)	(0.53)	(0.60)	(0.12)	(0.15)	(0.12)
$Depend_{90s}$	-0.09*	-0.14**	-0.03	-0.41***	-0.23***	-0.52***
	(0.05)	(0.06)	(0.04)	(0.06)	(0.07)	(0.11)
$Constant$	0.83	1.46**	0.60	0.52***	0.37***	-0.06*
	(0.68)	(0.71)	(0.52)	(0.11)	(0.12)	(0.03)
N	546	546	546	501	546	501

All regressions include country and sector fixed effects. Robust standard errors in parentheses. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$

Table 8: Snake and spider-type GVCs and "within-sector"RCA in intermediates

	(1) $\Delta ln\frac{Q}{L}$	(2) $\Delta ln\frac{VA}{L}$	(3) ΔlnL	(4) ΔlnTFP	(5) ΔlnT	(6) $\Delta ln\Omega$
$N^{Snake} \times RCA$	0.89	0.66	0.61	0.49*	0.44**	-0.31*
	(0.59)	(0.57)	(0.90)	(0.25)	(0.20)	(0.15)
$ln(N^{Spider}) \times RCA$	8.94***	8.58***	-9.51**	1.54***	0.08	1.52***
	(2.21)	(2.08)	(4.10)	(0.55)	(0.59)	(0.55)
$VAshare_{90s}$	0.27	-0.01	-0.00	0.45***	0.66***	-0.47***
	(0.51)	(0.53)	(0.61)	(0.13)	(0.15)	(0.12)
$Depend_{90s}$	-0.10*	-0.15**	-0.03	-0.42***	-0.24***	-0.53***
	(0.05)	(0.06)	(0.04)	(0.06)	(0.07)	(0.11)
Constant	0.95	1.52**	0.66	0.56***	0.42***	-0.09**
	(0.67)	(0.70)	(0.53)	(0.10)	(0.11)	(0.04)
N	546	546	546	501	546	501

All regressions include country and sector fixed effects. Robust standard errors in parentheses. ${}^{*}p < 0.10$, ${}^{**}p < 0.05$, ${}^{***}p < 0.01$

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