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Trade and Growth in the Age of Global Value Chains*

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Abstract

We revisit the relationship between trade and growth taking into account the recent expansion of global value chains (GVCs). We develop a new instrument for trade based on gravity estimations. Our instrument exploits a recent transportation shock: the sharp increase in the maximum size of container ships, which has more than tripled between 1995 and 2007. This shock has an asymmetric impact on different bilateral trade flows, based on the ex-ante presence of deep-water ports across countries, since these are the only ports that can accommodate the new larger ships. Our empirical set-up allows us to obtain instrumental variables not only for gross trade flows, but also for the different value added components of exports, for which we run separate gravity estimations based on WIOD data. We find that trade has a positive effect on GDP per capita, both in levels and in growth terms. Evidence at the country and industry level suggests that the effect works through both productivity improvements and capital deepening. We show that the effect of exports on income is crucially moderated by differences in their value added composition. In particular, we find evidence of stronger export effects on growth for countries that upgrade their positioning or improve their participation to GVCs more than others over time.

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1 Introduction

The debate about the benefits of trade has been recently revamped by the protectionist moves of President Trump and the Brexit negotiations. Many observers are warning about the negative effects that raising trade barriers could have on growth, especially on the grounds that national economies have become deeply connected through global value chains (GVCs). Yet, none of the available studies investigating the causal effect of trade on growth focuses on the implications of GVCs. In this paper, we aim to shed light on this issue.

Assessing the causal impact of trade on growth is a notoriously difficult exercise, because of the endogeneity of trade. For instance, countries whose income grows more for reasons that are not related to trade may still engage in more trade. Since the seminal paper of Frankel and Romer (1999), several instrumental variable strategies have been adopted in this context. The most recent studies provide evidence of a positive effect of trade on growth by exploiting shocks to transportation technology that have an asymmetric impact across bilateral trade flows, depending on some geographic characteristics of country pairs (Feyrer, 2018; Pascali, 2017). However, none of these studies considers the role played by global value chains. In fact, they exploit for identification historical shocks dating before the surge of GVCs, and they focus solely on gross exports data, which are not informative of the value-added contributions of each country to trade.

In the world of GVCs, as production processes get sliced across different nations, the gross exports of any country embody an increasing share of foreign value added. Moreover, there is substantial double counting in trade figures, as intermediate inputs cross borders multiple times before consumption takes place (Koopman et al., 2014; Johnson and Noguera, 2017). Finally, countries are different in the extent to which they participate to global value chains, and also in their positioning within them, i.e., from assembling to more upstream stages of the production chain. In this study, we set out to investigate the implications of such phenomena for the trade-growth nexus.

We make three main contributions. First, we develop a new instrument for trade based on gravity estimations. This instrument exploits a recent shock to transportation technology that is concomitant to the expansion of global value chains, and pivotal for their development: the sharp increase (more than tripling) in the maximum size of container ships between 1995 and 2007. Our methodology allows us to obtain instrumental variables not only for gross trade flows, but also for the different value added components of exports, for which we run separate gravity estimations. This enables us to investigate the growth implications of differences in the extent and modalities of GVCs involvement of countries, as captured by differences in the value added composition of their exports.

Second, endowed with the new instrument, we show that gross trade has a positive effect on GDP per capita over the sample period, 1995-2007, both in levels (with an elasticity of around 0.3) and in growth terms. This is the first evidence on the causal effect of trade on growth over a recent period witnessing a rapid expansion of GVCs. Moreover, we provide evidence on the microeconomic channels behind this effect, in terms of productivity growth and capital deepening. Specifically, we detect a positive effect of trade on both value added and capital per worker, not only at the country level but also at the industry level.

Third, using the export decomposition methodology developed by Wang et al. (2013), we show that differences in the value added composition of exports matter in moderating the effect of trade on income. Intuitively, we find that the elasticity of income to exports decreases with the share of foreign value embodied in a country's exports. However, the type of foreign value that is exported is also relevant. In particular, we find evidence of stronger growth effects for those countries where the composition of foreign value signals an upgrade in GVCs positioning, or an improvement in GVCs participation above the median over time. In such cases, indeed, exporting foreign value seems to generate higher positive spillovers for the domestic economy, as stemming from the enhanced involvement in global value chains.

The core of our analysis consists of identifying the effect of exports on GDP per capita, as in Pascali (2017). This choice is driven by our focus on global value chains. Indeed, the GVCs literature has developed the tools to decompose gross exports into their different value added components, starting from the fundamental difference between domestic vs. foreign value, and then decomposing these categories further (e.g., Koopman et al., 2014; Wang et al., 2013). Our main analysis covers the 40 countries included in the 2013 Release of the World Input-Output Database (WIOD), for which gross exports can be decomposed thanks to the availability of harmonized Input-Output tables.[1] The countries in the WIOD sample jointly account for more than 85% of global trade (Timmer et al., 2015), and all the major global players are included. Nevertheless, we also show that our main findings on gross export flows are robust to considering all countries for which data on trade and GDP per capita are available from UN-Comtrade and the World Development Indicators, respectively. Moreover, they are robust to considering total trade figures, thus encompassing both imports and exports. Our analysis spans the period 1995-2007, which covers the rapid expansion of global value chains up until the financial crisis (Koopman et al., 2014; Johnson and Noguera, 2017; Timmer et al. (2014)).

In line with the most recent studies on trade and growth (Feyrer, 2018; Pascali, 2017), we construct our instrument for trade by exploiting a shock to transportation technology that has an asymmetric impact across bilateral trade flows. Specifically, we exploit the fact that the maximum size of container ships has more than tripled over the sam-

[1] See Tables A1 and A2 for the full list of countries and industries in the WIOD sample.

ple period: from about 5,000 to 15,500 TEU.[2] This technological shift has been a game changer for the transportation industry. The new larger ships available have been widely adopted, leading to a rapid growth in the average capacity of the world container ships fleet, which has increased by 60%, moving from about 1,500 to around 2,400 TEU between the mid-90s and the mid-2000s (UNCTAD, 1997; UNCTAD, 2010). As a result, containerized trade has been the fastest growing modality of seaborne trade over the sample, ultimately accounting for about 40% of total trade in the world (WEO, 2012).

This transportation shock has affected different trade flows asymmetrically, depending on the cross-country presence of deep-water ports (DWPs), i.e., ports with a water depth of at least 16 meters. In fact, the new larger ships have a bigger draft and therefore can only enter deeper ports, which are unevenly distributed across countries. As a result, in a relatively short time, a restricted group of pre-existing deep-water ports has become increasingly central for global trade. In particular, in the sample of WIOD countries, we have identified only 47 deep-water ports with a container terminal where all the new ships can operate. The identification of DWPs has not been trivial, due to lack of ready-to-use data sources, and constitutes one of the contributions of our work. Specifically, we had to collect information on water depth (and other characteristics) for more than 4,700 ports, by performing a detailed text analysis on a number of different sources, the main one being *worldportsource.com*. As a result of this effort, we have created a new original database containing comprehensive information at the port level for all countries in the world.

Our main analysis involves regressing the GDP per capita of the exporting country over its exports. We construct our instrument by predicting export flows from gravity equations that include the following interaction term: the product between the time-varying maximum size of container ships available in the market, and the number of

[2] A TEU stands for a Twenty-foot Equivalent Unit, a unit of cargo capacity generally used to describe the capacity of container ships and container terminals. See *infra* for more details.

deep-water ports in each partner country (normalized by the length of its coast). The basic intuition is that, as larger ships become available, countries export relatively more towards partner countries that are more endowed with DWPs. In order to ensure the validity of the exclusion restriction, we employ the presence of deep-water ports *only* in partner countries. The identifying assumption is that, conditional on controls, the presence of DWPs in partner countries –combined with the increase in the size of container ships– affects domestic GDP in the exporting country only through the trade channel. Instead, had we used the number of DWPs in the exporting countries, one could wonder that those ports could be having an effect on domestic growth through channels other than trade, for instance by stimulating more domestic investments in infrastructures (Brooks et al., 2018). In the robustness section, we discuss a number of alternative specifications where we consider also the role of DWPs in the exporting country, with fully consistent results. In any case, it is important to notice that our identification strategy does not necessarily hinge on the joint presence of DWPs both in the exporter and in the partner country, as the transportation shock may have an impact on a country's exports independently on its type of sea access. For instance, even landlocked countries might start exporting relatively more towards partner countries endowed with DWPs as these become more important hubs for global trade, in line with the evidence discussed in Section 3.4.

In the methodology section, we address other potential concerns one might have with the exclusion restriction. These are related to both components of the interaction term included in the gravity equations: (1) the country-specific number of DWPs, and (2) the year-specific maximum size of container ships.

Concerning deep-water ports, their ex-ante distribution across countries is essentially related to geographic characteristics like location and coastal conformation. There is no significant correlation in our sample between the number of DWPs and the initial

GDP per capita across countries. Moreover, there is no evidence of higher pre-sample growth for countries that, at the beginning of the sample, export relatively more towards partner countries endowed with more DWPs.

One could still wonder that partner countries might invest in the artificial creation of new DWPs by dredging existing (shallower) ports in the expectation of higher growth in the exporting countries, thus leading to endogeneity. Yet, according to the port data, it is only after the end of our sample period (2007) that countries have systematically started to transform standard ports into deep-water ports by dredging (e.g., at New York and New Jersey Harbor). Hence, the number of DWPs in each country does not change over the sample, and is thus akin to a time-invariant geographic characteristic.[3] Even then, the artificial creation of new deep-water ports would not necessarily invalidate the exclusion restriction as long as one uses DWPs in partner countries only. In fact, an exporting country would arguably benefit from new deep-water ports in partner countries only through the trade channel. As a final consideration, the fact that in recent years several countries have undertaken significant investments for the creation of new deep-water ports corroborates the relevance of our instrument, as it signals the key role acquired by DWPs as main hubs for international trade.

Concerning the transportation shock, a possible issue with our identification strategy is that the increase in the maximum size of container ships might be endogenous to countries' GDP growth. Intuitively, new larger ships are designed, launched, and widely adopted in the shipping industry because they allow for cost reductions in transport through economies of scale (OECD, 2015; Sys et al., 2008). Hence, besides technical feasibility issues that are overcome on the supply side, demand also plays a role. To the extent that positive expectations about future trade growth –and, relatedly, GDP growth–

[3]There is only one port in the sample of WIOD countries where dredging is happening in the early 2000s: Manzanillo, in Mexico. This is excluded from the baseline analysis, yet considered in a robustness check in the empirical section.

were driving technological change in transportation, one could then worry about the endogeneity of the transportation shock in our analysis. For this reason, for identification we *only* exploit variation across bilateral trade flows within each year. This variation is driven by the heterogeneous impact of the transportation shock across bilateral trade flows, as related to the uneven presence of DWPs across countries.[4]

We estimate gravity equations based on bilateral trade flows at the industry level, thus taking into account the fact that containerized trade might be more important in some industries than in others (Bernhofen et al., 2016). Moreover, we also include in the estimating equations the products between our main interaction term (ship size times number of DWPs in partner countries) and all the country-pair characteristics. By so doing, we allow the change in transportation technology to have a different impact across different trade flows not only based on the distribution of DWPs across partner countries, but also depending on factors such as bilateral distance or contiguity. One could in fact expect the transportation shock to be more relevant for long-distance exports, and less relevant for trade between contiguous countries. Indeed, Coşar and Demir (2018) find containerized trade to be more cost-effective at longer distances.

Our methodological approach is inherently flexible. Depending on the level of analysis, we build the instrument by aggregating predicted exports from the gravity models either at the country or at the industry level. Most importantly, we employ either gross exports data or the different value added components of exports. This allows us to obtain specific instruments for each of these components, and hence to construct instrumental variables for the measures of participation and positioning within global value chains. This is key for our research question.

The remaining of the paper is organized as follows. Section 2 reviews the related literature. Section 3 presents the identification strategy and the computation of the in-

[4]In addition, in Section 5 we present several robustness checks related to this potential issue.

struments. Section 4 presents the baseline empirical results on trade and growth, while Section 5 discusses the robustness checks. Finally, Section 6 concludes.

2 Literature

Our paper speaks to different strands of research. In particular, it contributes to the literature on trade and growth, in which a number of studies have adopted an instrumental variables approach based on gravity estimations. In their seminal paper, Frankel and Romer (1999) focused on geographic characteristics such as bilateral distance between countries. These characteristics are indeed powerful determinants of trade flows. However, the use of geographic characteristics as instruments for exports has later been criticized, since the same factors might affect countries' growth through channels other than trade, thus violating the exclusion restriction. Evidence on this issue has been provided, for instance, with respect to the role of distance from the equator (Rodriguez and Rodrik, 2001).[5]

More recent contributions have capitalized on the Frankel and Romer (1999) approach by interacting geographic characteristics with shocks to transportation technology, thus constructing time-varying instruments for trade (Feyrer, 2018, and Pascali, 2017). Working with panel data is crucial in this context. In fact, it allows to include country fixed effects in the regressions, thus controlling for any constant determinants of income, such as geographical, historical, and institutional factors. The identification strategy then relies on the assumption that the same transportation shock has a different impact on different countries, due to some exogenous geographic characteristics.[6]

[5] A recent paper by Maurer et al. (2017) exploits the connectivity of Mediterranean coastal areas in the Iron Age to show how more connected areas turn out to host more archaeological sites: a proxy for early development. While the study does not employ direct trade measures, the effect of coastal connectivity is interpreted as capturing the role of maritime connections.

[6] Felbermayr and Gröschl (2013) have also developed a time-varying instrument for trade in a gravity framework. They use natural disasters in partner countries as a source of variation over time, rather than

Specifically, Feyrer (2018) exploits the reduction in air transportation costs between 1960 and 1995, which has had a larger positive effect on trade for country-pairs where air distance is much shorter than sea distance. Pascali (2017) instead exploits the introduction of the steam engine in the shipping industry, between the 1860s and the 1870s, which has reduced shipping costs relatively more for trade routes that were not favored by wind patterns. None of these studies can take into account the role of global value chains. In fact, they exploit identification shocks that date before the recent surge of GVCs, whose expansion accelerated in the mid-90s. Moreover, they rely solely on gross exports data, which do not allow to capture differences in the participation and positioning of countries in GVCs.

In this paper, we follow a similar identification strategy as in Pascali (2017) and Feyrer (2018). However, we rely on a more recent shock to transportation technology, which is concomitant to the expansion of global value chains and crucial for their development. In addition, we exploit not only gross trade data but also their decomposed value added components. This allows us to investigate directly the influence of GVCs on the relationship between trade and growth.

Our work is also related to the growing literature on GVCs. From a methodological point of view, we capitalize on a number of contributions that have provided the tools for decomposing gross export flows into their different value added components (Johnson and Noguera, 2012; Koopman et al., 2014; Wang et al., 2013; Johnson, 2014a; Borin and Mancini, 2015; de Gortari, 2017), and have developed indicators for the participation and positioning of countries and industries within GVCs (Antràs et al., 2012; Fally, 2012; Antràs and Chor, 2013; Antràs and de Gortari, 2017; Antràs and Chor, 2018; Alfaro et al., 2018).

a transportation shock. Feyrer (2009) instead exploits the closure of the Suez canal between 1967 and 1975 as a natural experiment, to study the effect of distance on trade and the effect of trade on income through gravity estimations.

Several recent studies have exploited the decomposition methodologies in different contexts. Timmer et al. (2014) have used the WIOD data to show that the foreign value-added content of production has rapidly increased since the early 1990s, as production processes were progressively disintegrated across borders. A similar finding is obtained by Johnson and Noguera (2017) considering the value added share of gross exports. Other studies focus on the role of GVCs with respect to the synchronization of business cycles across countries (Johnson, 2014b; Wang et al., 2017). Our paper contributes to this literature by studying the implications of global value chains for the trade-growth nexus.

3 Identification strategy

In this section we present the identification strategy. We start by describing the transportation shock and the role of deep-water ports. We then move to the discussion of the identifying assumption and the exclusion restriction. Next, we present the gravity equations and estimates. Finally, we introduce the instruments for the GVCs indicators.

3.1 Container ships and deep-water ports

We exploit for identification the increase in the size of container ships between 1995 and 2007. Before introducing our instrument, it is however important to provide some historical background on the role of containerization.

Containers started to be used for commerce in the US during the mid 1950s, in parallel with the introduction of container ships. International standardization was achieved in 1965, and by the mid 1980s containers were widely adopted worldwide. In a sample of 157 countries used to track the development of containerization, Bernhofen et al. (2016)

find that 122 countries had adopted containerized trade (either by sea or rail) by 1983.[7] Containers improved dramatically the efficiency of sea-transportation, shortening the time spent into port facilities and allowing for smoother connections with intermodal inland transport. The diffusion of containerized trade had a large positive impact on international trade. According to Bernhofen et al. (2016), it gave a permanent boost to the level of trade through a short-lived increase in the growth rate of trade. In particular, they find that, during the period 1962-1990, the joint adoption of containerized trade for two trading partners could increase their bilateral trade flows by up to 900%, cumulatively over 15 years. Containerization has thus been identified as an important driver of globalization in those decades.

Our analysis covers a more recent period: 1995-2007. Over this time-span, building on the potential of containerization, a second shock to transportation technology has taken place: the sharp increase in the size of container ships. This is what we exploit for identification. In particular, between 1995 and 2007 the maximum capacity of container ships more than tripled, moving from about 5,000 to 15,500 TEU, as displayed in Figure 1. In simple terms, a capacity of 15,500 TEU means that a ship can accommodate up to 15,500 standard containers.[8] Figure 1 also shows (in the solid line) how the average capacity of operating container ships increased substantially over the same period –from around 1,500 TEU to more than 2,400 TEU– as the new larger ships were widely adopted by market operators (UNCTAD, 1997; UNCTAD, 2010).

The introduction of the new ships was made possible by significant technological improvements. Indeed, from the engineering point of view, increasing the maximum ship size by more than three times in less than fifteen years posed several challenges. A num-

[7] The remaining 35 countries were mostly developing economies, none of which appears in the WIOD sample.

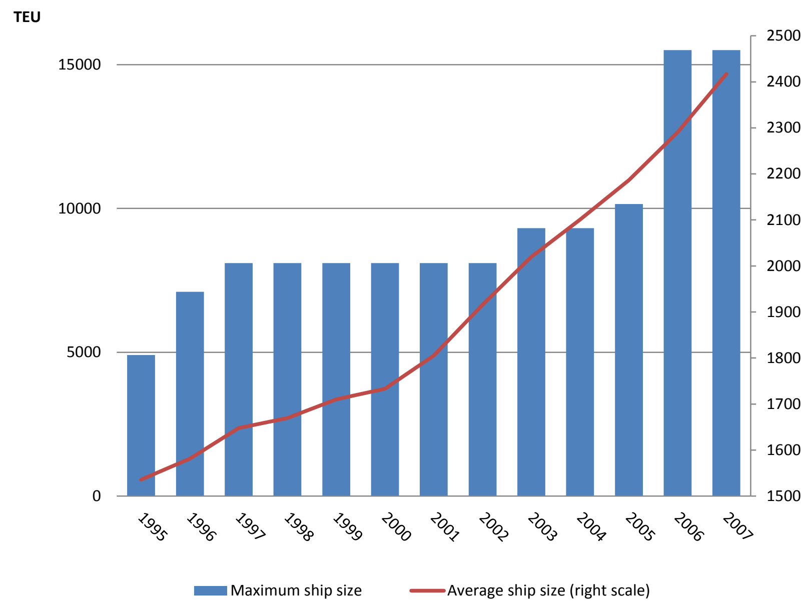
[8] TEU stands for Twenty-foot Equivalent Unit, based on the volume of an internationally standardized container. A standard intermodal container is 6.1 meters (20 ft) long and 2.44 meters (8 ft) wide. No precise standard exists on height, although the most common measure is 2.59 meters (8.6 ft), so as to fit into railway tunnels.

ber of innovations were introduced along different dimensions, ranging from the development of larger steel surfaces with appropriate thickness, to changes in the propulsion system and in the shaft alignment. Importantly, the new ships also needed new engines with higher torque in order to maintain a constant cruise speed and therefore being fuel efficient. In fact, the reduction of voyage costs per single container is one of the three main sources of economies of scale associated with larger ships, the other two being related to capital costs and operating costs (OECD, 2015).[9]

Overall, according to OECD estimates, an increase in capacity from 5,000 to 15,000 TEU reduces annual operation costs per container by almost 43%, from around 700$ to 400$, assuming an average utilization rate of 85% (OECD, 2015). As larger ships were adopted and scale economies were exploited, the volume of containerized seaborne trade has grown by almost four times over the sample: twice as much as compared to the rest of seaborne trade, which has roughly doubled (UNCTAD, 2014). Key for our research purposes, these developments in transportation technology have been pivotal for the expansion of global value chains. Indeed, it is widely recognized that the benefits associated with the break-up of production processes across countries could not be realized without significant parallel improvements in logistics and transportation (Notteboom and Rodrigue, 2008; Memedovic et al., 2008). As a matter of fact, our sample period coincides with the phase of rapid expansion of GVCs up until the financial crisis.

[9] Lower capital costs are obtained as the increase in construction costs for larger ships is less than proportional with respect to the increase in their capacity. Lower operating costs are instead related to cost savings per container on the crew, maintenance, and other operations.

Figure 1: Development of container ships (TEU), 1995-2007



Notes. Source: authors' elaboration from UNCTAD, Review of Maritime Transport, various years.

For identification purposes, we exploit the heterogeneity in the impact of the new container ships across different bilateral trade flows, as driven by the uneven presence of deep-water ports across countries. The underlying idea is very simple: larger ships have deeper draft, so they can only enter ports where water is deeper. Hence, the introduction of larger container ships over time constitutes an important source of exogenous variation in trade flows, which grow relatively more towards countries that are ex-ante relatively more endowed with deep-water ports.

More specifically, before 1994 all ports with at least 12.5 meters of depth could accommodate any container ships, as the "maximum draft" of operating ships was at most equal to 12 meters. In technical terms, the maximum draft of a ship is defined as the distance between the waterline and the lowest point of the keel. For ease of exposition, we refer to it simply as the draft in the rest of the paper. Until 1994, the size and draft of container ships were always compatible with the dimensions of the Panama Canal's lock chambers. This is why container ships of that period are commonly referred to as *Panamax* ships. In particular, according to the Panama Canal Authority, container ships could have a maximum draft of at most 12,04 meters (39.5 ft). This would allow them to safely fit within the Canal's original lock chambers, whose depth was 12.56 meters (41.2 ft).[10] From 1994 onwards, new larger ships have been progressively introduced and the maximum draft has increased from 12 to 15.5 meters, as reported in Table 1. This change has implied that a large number of ports with insufficient water depth has been progressively cut out from the main shipping routes operated by the new container ships, as it is well documented in the transport literature (e.g. Sys et al., 2008). Hence, over time, a restricted number of pre-existing deep-water ports has become increasingly central for global trade. Their uneven presence across countries generates the variation in trade flows that we exploit for identification.

At the operational level, we define deep-water ports (DWPs) as those ports that have a water depth of at least 16 meters. These ports can accommodate all the new container ships introduced over the sample period: 1995-2007. In fact, the largest series of ships introduced in 2006, with Emma Maersk being the first produced, have a draft of 15.5 meters. Allowing for the same half-meter operational depth buffer as applied for the Panama Canal leads to a required water depth of 16 meters for a port to be able to accommodate them. In particular, in our analysis we focus on deep-water ports that are also endowed with a container terminal, where container ships can be loaded and unloaded. These ports are the ones that really matter for our identification purposes. In fact, the new container ships could physically enter any deep-water port, but there would be no economic reason for doing that in the absence of a container terminal.

[10] More completely, the Panama Canal Authority set the maximum ship dimension as: 294,13 m (965 ft) in length, 32,31 m (106 ft) in width and 12,04 m (39.5 ft) in draft, which yielded a maximum capacity of around 4,500 TEU. The original Canal's lock chambers are 33.53 m (110 ft) wide, 320.04 m (1,050 ft) long, and 12.56 m (41.2 ft) deep.

Table 1: Evolution of largest container ships

Ship	Built (Year)	Capacity (TEU)	Length (m)	Breath (m)	Max Draft (m)
Panamax Class	pre-1994	4,500	294	32	12
NYK Altair	1994	4,900	300	37	13
Regina Maersk (Maersk Kure)	1996	7,100	318.2	42.8	14.6
Sovereign Maersk	1997	8,100	347	42.8	14
Axel Maersk	2003	9,310	352.6	42.8	15
Gudrun Maersk	2005	10,150	367.3	42.8	15
Emma Maersk	2006	15,500	397.7	56.4	15.5

Notes. Source: authors' elaboration from www.containership-info.com, Alphaliner and Maersk.

The collection of data on ports, including information on water depth and presence of container terminals, was all but trivial. We have started from an online repository of world ports, *worldportsource.com*, which contains information on 4,764 ports in 196 countries. For each of these ports, we have first gathered information on whether or not they are commercial ports. Then, focusing only on the group of commercial ports, we have obtained data on their water depth and whether or not they host a container terminal. This has been done by performing a detailed text analysis of the content of the website. When the necessary information was not available from *worldportsource.com*, the port websites have been consulted, and in some cases port offices have been contacted directly by mail or phone.

To give an idea of the type of work that was carried, it is important to stress how even the identification of the "relevant" water depth for a port is not obvious. For instance, if a port has a maximum depth which is greater than 16 meters, but the depth at the quays, or at the canal that must be used to access the quays, is lower than 16 meters, than we do not consider this port as being a deep-water one. Indeed, it would be impossible for a large ship to get loaded/unloaded by cranes at this port's facilities, as these operations require ships to be berthed at quays.[11] In other words, what matters for our purposes is the 'operational' depth of ports from the container ships perspective. Moreover, in order

[11]In this sense, container ships are different from oil carriers, as the latter can be loaded/unloaded while anchored, via specific floating storage and offloading units moored offshore.

to identify a port as endowed with a container terminal, it is not enough to know that the port is used for commercial purposes. In fact, that could also just mean that the port may handle dry bulk cargo, or oil. We had to make sure that a container terminal was present. This significant effort in terms of data collection has allowed us to produce a new original database including comprehensive information on world commercial ports.

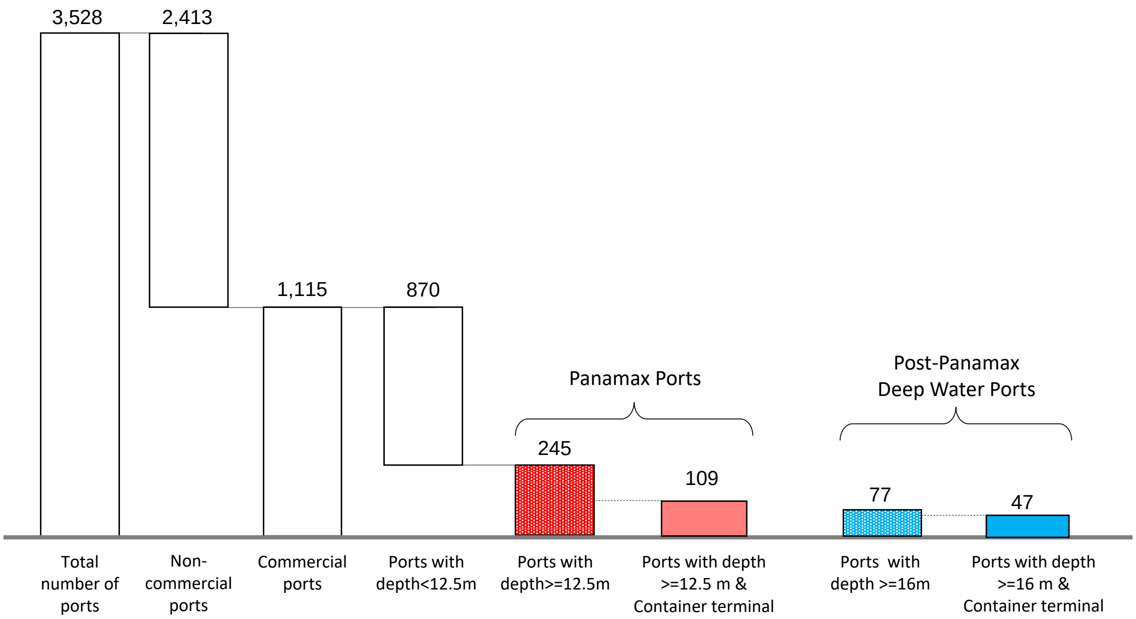
Figure 2 summarizes the information on ports in the 40 WIOD countries, which host a total of 3,528 ports. Out of this total, we first identified 1,115 commercial ports. Of these, 870 have water depth lower than 12.5 meters, which implies they could not even accommodate all the *Panamax* ships operating before 1994. Focusing instead on the 245 ports with water depth greater than 12.5, only 109 of them host a container terminal. Out of the latter, there are only 47 deep-water ports, i.e. ports with water depth greater than 16 meters. Their average depth is 18.3 meters. These 47 DWPs constitute the restricted group of ports becoming increasingly relevant for trade between 1995 and 2007. At the same time, the remaining 62 ports endowed with a container terminal, but with water depth between 12.5 and 16 meters, lose progressively relevance as bigger ships start operating. Importantly, all the 47 deep-water ports meet the two identification criteria –i.e., depth of at least 16 meters and presence of a container terminal– for the whole sample period. Hence, the endowment of DWPs is akin to a time-invariant geographic characteristic in our analysis.[12]

Table 2 displays the uneven distribution of DWPs across the WIOD countries: 19 countries have at least one DWP; 16 countries have access to the sea but do not have any deep-water port; 5 countries are landlocked. This heterogeneity is key for identification purposes. The 47 DWPs with container terminal are the main focus of our analysis and, unless differently specified, these are the ports we refer to when using the plain ex-

[12] In the robustness section, we show that our results are unaffected by the inclusion in the set of DWPs of four additional ports that satisfy the criteria only for part of the sample period. See next section for details.

pression deep-water ports in the rest of the paper. Yet, in the empirical analysis, we also discuss the sensitivity of our results with respect to considering the different groups of ports highlighted in Figure 2. Moreover, when extending the analysis to all countries in the world that are not included in WIOD, but for which trade and GDP data are available, we consider 15 additional DWPs therein located.

Figure 2: Summary of ports in WIOD countries



Notes. Source: authors' elaboration on data from worldportsource.com and other sources.

3.2 Identification

In our main analysis, we regress income per capita in a given country and year over its exports, in levels or in growth terms. To provide evidence on the microeconomic channels of the trade effect, we also regress labor productivity (and capital per worker) at the country-industry level over country-industry exports. We construct our instrument

Table 2: DWPs by country

Country	DWPs	Country	DWPs
Australia	2	Japan	2
Austria	0	Latvia	0
Belgium	1	Lithuania	0
Brazil	1	Luxembourg	0
Bulgaria	0	Malta	0
Canada	0	Mexico	1
China	9	Netherlands	1
Cyprus	0	Poland	0
Czech Republic	0	Portugal	0
Denmark	0	Romania	1
Estonia	1	Russia	0
Finland	0	Slovakia	0
France	3	Slovenia	0
Germany	1	South Korea	3
Greece	1	Spain	8
Hungary	0	Sweden	0
India	2	Taiwan	3
Indonesia	0	Turkey	0
Ireland	0	UK	1
Italy	2	USA	4

Notes. Source: authors' elaboration on data from worldportsource.com and other sources.

for exports by predicting export flows through gravity estimations, in the spirit of Frankel and Romer (1999), and in line with more recent work by Pascali (2017) and Feyrer (2018). In particular, we first estimate gravity equations using bilateral export data at the industry level. Then, having obtained the predicted exports from the gravity estimations, we aggregate them up at the country level, or country-industry level, to compute the appropriate instrument depending on the regression to be estimated.

To capture the role of the transportation shock, and its heterogeneous impact across different trade flows, we augment the gravity specification with the following term: the interaction between the maximum size of container ships operating in a given year, and the number of deep-water ports with container terminal that are present in the destination country (normalized by the number of kilometers of its coast). This interaction term captures the basic intuition behind our identification strategy: the introduction of new larger ships reduces transportation costs and boosts exports in general, but relatively more towards partner countries that are more endowed with deep-water ports where the new container ships can operate.

Moreover, we also interact the interaction variable just described with the other controls included in the gravity specification, i.e., bilateral distance, contiguity, and landlockedness. These additional interactions are meant to capture the fact that the same change in transportation technology may have, for instance, a stronger impact on trade flows between countries that are located farther away from each other, and less of an impact on trade between contiguous countries. In fact, the cost-effectiveness of containerization has been shown to increase with distance (Coşar and Demir, 2018). Moreover, running separate gravity estimations by industry allows us to account for the fact that the incidence of containerized trade, and therefore the impact of the transportation shock, may vary across industries, due to their technological characteristics (Bernhofen et al., 2016).

The identifying assumption in our analysis is that, conditional on controls, the presence of deep-water ports in partner countries, combined with the increase in the size of container ships, affects domestic GDP in the exporting country only through the trade channel. In the baseline analysis, we do not include an additional interaction between the size of container ships and the number of DWPs in the exporting country, as these ports could have an impact on GDP through channels other than trade, thus violating the exclusion restriction. For instance, a recent paper by Brooks et al. (2018), finds that US counties located near container ports have grown faster than others between 1950 and 2010. And yet, in the context of our paper, one could wonder that the exports of a given country might not be affected by the transportation shock if the country does not host any DWPs itself. In the results section, we provide several robustness checks on this issue, where we take into account the number of DWPs of the exporting country in different ways. The results are always consistent with the baseline analysis.

One might have additional concerns with respect to the exclusion restriction, as related to the two main drivers of our identification strategy: (1) the country-specific number of DWPs, and (2) the year-specific maximum size of container ships. We discuss possible threats to identification in what follows.

First, one could worry about the exogeneity of the number of DWPs across countries. Intuitively, the presence of deep-water ports in a country is related in the first place to its geographic characteristics, such as location and coastal conformation. For instance, oceanic coasts are more likely to host deep-water harbors as compared to the coasts of internal seas, like the Baltic or the Black Sea. Yet, besides geographic factors, investment in supporting infrastructure is also required in order to develop deep-water ports that can accommodate and handle container ships. This investment could then be endogenous to the GDP of hosting countries. However, we actually do not detect any significant correlation between the number of DWPs in a country (normalized or not by the coastal length) and its GDP per capita at the beginning of the sample.

Most importantly, given the set-up of our gravity, there is no evidence of higher pre-sample growth for countries that, at the beginning of the sample, export relatively more towards partner countries that are endowed with more DWPs. Specifically, there is no significant relation between a country's GDP growth over five years before the beginning of the sample, and the trade-weighted number of DWPs in the partner countries evaluated in the first year of the sample (1995).

Still, one could worry that partner countries might invest in creating new DWPs by dredging existing ports or, when possible, by adding container terminals to natural deep-water ports. This would create an endogeneity problem to the extent that such investments take place in the expectation of higher GDP growth in the exporting country. This is not an issue in our sample, where we focus on 47 deep-water ports that are operational throughout the time-period 1995-2007. There is only one port in the WIOD countries where artificial dredging above 16 meters has happened in the early 2000s: Manzanillo, in Mexico. This is not included in the set of 47 DWPs considered in the baseline analysis. Moreover, there are three ports where water depth was always greater than 16 meters, but a container terminal was only added over the sample period, after 2002: Ambarli, in Turkey; Marsaxlokk, in Malta; and Sines, in Portugal. These three ports are also excluded from the set of 47 DWPs used for the baseline analysis. Nevertheless, in the robustness analysis we show that our results are essentially unaffected when these ports and Manzanillo are included in the set of DWPs.

More in general, it is important to point out that dredging activities have taken place in many countries only after 2007, mainly in preparation for the launch of a new class of ultra-large container ships between 2013 and 2015 (with draft up to 16 meters)[13], and following the expansion of the Panama Canal locks, which started in 2009 and was completed in 2016.[14] This is for instance the case of the ports of New York and New Jersey, Baltimore, and Miami in the US, where dredging activities have been systematically undertaken only after 2010. These post-sample investments actually corroborate the relevance of our IV strategy, as they signal the importance acquired by DWPs for global trade over the period of analysis.

Another possible concern with our identification strategy is that the increase in the size of container ships might be endogenous to GDP growth. Indeed, as for any technological innovation, the supply side also responds to demand factors. The introduction of new larger ships is certainly related to technological innovations, as already discussed, but also to positive expectations on the utilization of ship capacity in the future. To the extent that such positive expectations about future trade growth are at the same time related to GDP growth, one could worry about the endogeneity of the transportation shock.

[13] The Maersk Triple E Class was launched in 2013; the CSCL Globe class in 2014, and the MSC 'Oscar' class in 2015.

[14] The maximum dimension of ships that can access the new Panama Canal locks is: 366 m (1,200 ft) in length, 49 m (160.7 ft) in width, and 15.2 m (49.9 ft) in draft.

In light of these considerations, for identification purposes we only exploit variation across bilateral trade flows in each given year, as induced by the heterogeneous impact of the transportation shock, based on the uneven presence of deep-water ports in destination countries and other characteristics of each country pair, such as bilateral distance. This is done by including a battery of fixed effects in the gravity models that are used for constructing the instruments. In particular, we employ two different specifications of the gravity. In the first one we include exporting-country and importing-country fixed effects, as well as year fixed effects. In the second one we include exporter-year and importer-year fixed effects, to control for multilateral resistances (Anderson and van Wincoop, 2003). Clearly, in the latter case we have to drop the main interaction term between maximum ship size and DWPs in the partner country, hence the transportation shock is allowed to play a role only through the remaining interactions with the dyadic variables, such as distance and contiguity.

On top of all this, we also perform additional robustness checks in which we exclude from the sample China, Denmark, and South Korea. These are three countries for which endogeneity concerns related to the transportation shock might be more relevant, for various reasons. In the case of China, where GDP growth is known to be strongly export driven, one could be worried that Chinese exports account for a large part of the increase in trade volumes across the Europe-Asia route, which does not use the Panama Canal. As this route becomes more important over the sample, there is growing demand for larger container ships that would not pass through the Canal. The increase in the size of container ships could then be endogenous to GDP growth in China.

In the case of Denmark and South Korea the concern is different. Indeed, these two countries are characterized by large shipping and shipbuilding industries. As these industries experience sustained growth over the sample, with the launch of new ships and the surge of containerized trade, the transportation shock could impact their GDP growth not only through higher exports, e.g. of ships, but also through other channels, thus violating the exclusion restriction.

Reassuringly, our results are largely unchanged when excluding China, Denmark, and South Korea from the analysis. Notably, in these robustness checks we do not only exclude these countries from the regressions of income over exports, but also from the gravity estimations, that is, from the construction of the instruments. In any case, all our baseline regressions of GDP per capita over exports include year and country fixed effects, which are meant to soak up any specific characteristics of countries, such as the ones just discussed.

Moreover, in an additional battery of robustness checks, we augment the baseline regressions of income over exports with controls for underlying trends and contemporaneous shocks. To capture underlying trends, we include in the specification a set of interactions between the year dummies and a number of initial country characteristics. These include the levels of GDP per capita, capital intensity, TFP, the ratio of imports to GDP, and the ratio of exports to GDP, all measured at the beginning of the sample (1995). Alternatively, we interact the year dummies with the pre-sample growth rates of all these variables, measured between 1990 and 1995. By so doing, we aim to control for country-specific underlying trajectories that might affect the relation between exports and income over time.

To control for contemporaneous shocks, we interact the year dummies with dummies denoting groups of countries witnessing a similar economic performance over the sample period. Performance is assessed, alternatively, in terms of: GDP per capita growth, capital intensity growth, TFP growth, and growth in the ratio of imports and exports to GDP. For each of these variables, we compute the country-specific changes between 1995 and 2007. Then, for each variable, we group together the sample countries in four groups, based on the quartiles of the distribution of growth rates. By so doing, we identify the effect of exports on GDP per capita only based on the remaining variation within similar groups of countries in each year. The results are robust across the board.

3.3 Gravity specifications and data

We estimate two different specifications of the gravity model. The first is as follows:

$$\begin{aligned}\ln Export_{ijz,t} = \beta_{z0} + \beta_{z1} \ln Distance_{ij} + \beta_{z2} Contiguity_{ij} + \beta_{z3} Landlocked_{ij} + \beta_{z4} \ln Pop_{i,t} \\ + \beta_{z5} \ln Pop_{j,t} + \beta_{z6} DWP_j * \ln MaxSize_t + Z_{ij,t} \delta'_z + \alpha_{zi} + \alpha_{zj} + \alpha_{zt} + \epsilon_{ijz,t},\end{aligned} \tag{1}$$

where $Export_{ijz,t}$ is the export flow from country i to country j, in industry z and year t. All the β coefficients are industry-specific (the z index), as we estimate the equation separately for each industry. α_{zi}, α_{zj} and α_{zt} are industry-specific fixed effects for, respectively, exporting country i, partner country j, and year t.

The specification includes three dyadic variables. $Distance_{ij}$ is the population-weighted distance between the exporter and the partner country. $Contiguity_{ij}$ is a dummy taking value one if the two countries share a border. $Landlocked_{ij}$ is a dummy equal to one in case at least one of the two countries is landlocked. In terms of country-specific controls, $Pop_{i,t}$ is the population of the exporting country, while $Pop_{j,t}$ refers to the partner country. Essentially, this part of the specification is the same as in Frankel and Romer (1999). The only difference is that we do not include the size of countries in terms of land area. In fact, the latter is a time-invariant geographic characteristic that is subsumed in our specification by the country fixed effects, which Frankel and Romer (1999) could not include in their cross-sectional analysis. In what follows, we explain how we further augment their basic specification following our identification strategy.

$DWP_j * \ln MaxSize_t$ is the interaction between the number of deep-water ports with container terminal in partner country j (normalized by the number of kilometers of its coast), and the maximum size of container ships operating in year t (in TEU). This interaction term is meant to capture the role of the transportation shock, with its differential impact on different country-pairs, as induced by differences in the presence of DWPs across countries. $Z_{ij,t}$ is a vector of interactions between $DWP_j * \ln MaxSize_t$ and, in turn, the population variables, and the three dyadic terms: distance, contiguity, and landlocked. These interactions further capture a potential heterogeneous impact of the transportation shock across different country-pairs, depending not only on the number of DWPs in the partner country but also on other characteristics.

The second specification of the gravity is as follows:

$$\begin{aligned} \ln Export_{ijz,t} = \beta_{z0} + \beta_{z1} \ln Distance_{ij} + \beta_{z2} Contiguity_{ij} + \beta_{z3} Landlocked_{ij} \\ + W_{ij,t} \delta'_z + \alpha_{zi,t} + \alpha_{zj,t} + \epsilon_{ijz,t} \end{aligned} \tag{2}$$

The key difference with respect to the first specification is the inclusion of industry-specific exporter-year and partner-year fixed effects: $\alpha_{zi,t}$ and $\alpha_{zj,t}$, respectively. Consistent with the recent gravity literature, these dummies are meant to capture the so-called multilateral resistance terms (MRTs). That is, in simple terms, the average barrier to trade for each country, in a given year, with respect to all other countries. The concept of multilateral resistance has been first introduced by Anderson (1979), and then operationalized in the seminal paper by Anderson and van Wincoop (2003), which provided a microfoundation of the empirical gravity equation.

The inclusion of these country-year fixed effects implies dropping from the specification the two population variables and, most importantly, the main interaction term capturing the role of the transportation shock: $DWP_j * \ln MaxSize_t$. Hence, in this gravity model we exploit the impact of new container ships only through the vector $W_{ij,t}$, which includes the interactions between $DWP_j * \ln MaxSize_t$ and the three dyadic variables: distance, contiguity, and landlocked.

Endowed with the industry-specific gravity estimates (from either one of the specifications) we obtain the country-level instrument for exports by aggregating predicted export flows for each exporting country i over partner countries (j) and industries (z). Specifically, the instrument is computed as follows:

$$Instrument_{i,t} = \sum_j \sum_z (\widehat{Export}_{ijz,t}). \quad (3)$$

For the regressions where we investigate the impact of trade on country-industry outcomes, such as labor productivity, we build up the instrument by aggregating predicted exports over partner countries (j) only, separately for each exporting country i and industry z:

$$Instrument_{iz,t} = \sum_j (\widehat{Export}_{ijz,t}). \quad (4)$$

These two different aggregations are suggestive of the flexibility of our IV approach. In the econometric analysis, we exploit this flexibility to assess the sensitivity of our results with respect to, e.g., changing the set of countries, or the set of industries that are considered in the construction of the instrument.

Data on dyadic variables and population are sourced from the CEPII database (Head et al., 2010). For the main analysis, trade data are sourced from the 2013 Release of the World Input Output Database (WIOD). The sample includes 40 countries, as listed in

Table A1. The bilateral export flows that we use span the period 1995-2007, and are available for 35 disaggregated industries, encompassing agriculture and mining, manufacturing, and services. The description of industries is available in Table A2. Consistent with our identification strategy, in most of the analysis we focus on trade in manufacturing goods, for which container ships are directly relevant. Specifically, we consider 14 manufacturing industries: c03-c16 of Table A2. Nevertheless, as additional evidence, we also present results based on non-manufacturing industries and total trade figures. Finally, when we extend the analysis to non-WIOD countries, we source trade data from the CEPII-BACI database, which is based on UN-Comtrade.

3.4 Gravity estimates

Table 3 reports a summary of our industry-specific gravity estimates from the first specification, which includes the main interaction term between DWPs in partner countries and the time-varying maximum size of container ships ($DWP_j * \ln MaxSize_t$). Specifically, row 1 reports the estimated coefficients for this term in four alternative estimations. For each of them, we report both the average and the median estimates across the industry-specific regressions. The same is done in the remaining rows for the coefficients of the three dyadic variables –distance, contiguity, and landlocked– and for their interactions with $DWP_j * \ln MaxSize_t$.

The first two columns of Table 3 refer to our baseline gravity estimates, where: (1) we focus only on manufacturing exports; and (2) we consider only the restricted number of 47 deep-water ports which have at least 16 meters of depth *and* do host a container terminal. These are the ports where all the new larger container ships can not only be accommodated but also loaded/unloaded by cranes. Our identification strategy hinges on the fact that these ports become increasingly central for trade as larger ships start operating over time. If that is the case, in our gravity estimates we should observe that, *ceteris* *paribus*, relatively more exports are directed towards partner countries where more of these ports are located. In line with the expectations, both the average and the median estimated coefficients of $DWP_j * \ln MaxSize_t$ are positive, as can be seen in the first row of columns 1 and 2, respectively. As a matter of fact, the coefficient of $DWP_j * \ln MaxSize_t$ is positive in all the industry-specific estimations, and statistically significant in most cases. Among the few exceptions we find the oil industry, which is not surprising given that this industry is less container-intensive than other manufacturing industries.[15]

What is the substantive magnitude of these estimates? Consider that DWP_j is defined as the number of DWPs in the partner country j divided by the number of kilometers of its coast, in thousands. Then, the average coefficient in column 1 (1.86) implies that one extra DWP in a partner country per one thousand kilometers of coast is associated to higher exports towards that country by 1.86*$\ln MaxSize_t$ percentage points. Taking the average of $\ln MaxSize_t$, which is equal to 9.09, the result is an increase in trade by around 16.9% (1.86*9.09) in a year, all else equal. Considering that $\ln MaxSize_t$ grows from a minimum of 8.5 in 1995 to a maximum of 9.65 in 2007, the elasticity ranges roughly between 15.8 and 17.9%. To give an idea, for a country like Germany, which has 3.624 thousand kilometers of coast, one additional DWP would be associated, on average, to an increase in yearly exports directed to the country by around 4.7%: far from negligible. This figure is obtained by multiplying 16.9 times 0.28, which is the ratio between one new port and 3.624 thousand kilometers of coast.

In columns 3-6 of Table 3 we assess the sensitivity of the gravity results to using alternative groups of ports for the computation of DWP_j. Specifically, in columns 3-4 we consider the entire group of 77 WIOD ports with water depth of at least 16 meters, as presented in Figure 2, thus including also the 30 ports which do not host a container terminal. All the new container ships introduced until 2007 could enter such ports, as

[15]Table A3 in the Appendix reports all the industry-specific estimates.

Table 3: Gravity estimations - summary statistics

Dependent Variable: ln(export)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Depth:	Ports >= 16 m.		Ports >= 16 m.		Ports >=12.5 m.		Ports >= 16 m.	
Only with container terminal:	Yes		No		Yes		Yes	
Sectors:	Manufacturing		Manufacturing		Manufacturing		All Sectors	
Summary statistic:	Avg.	Med.	Avg.	Med.	Avg.	Med.	Avg.	Med.
Partner DWPs * ln(MaxSize)	1.860	1.550	0.224	0.190	0.391	0.263	0.564	0.842
Distance	-1.668	-1.648	-1.647	-1.629	-1.665	-1.644	-1.363	-1.303
Distance * Partner DWPs * ln(MaxSize)	0.005	0.005	0.001	0.001	0.002	0.002	0.005	0.005
Contiguity	0.543	0.578	0.556	0.598	0.541	0.577	0.606	0.572
Contiguity * Partner DWPs * ln(MaxSize)	-0.003	-0.004	-0.004	-0.005	-0.001	-0.001	-0.002	-0.003
Landlocked	-0.317	-0.156	-0.360	-0.185	-0.317	-0.158	-0.212	-0.141
Landlocked * Partner DWPs * ln(MaxSize)	0.003	0.002	0.004	0.004	0.001	0.000	0.003	0.003

Notes. The table reports average and median estimates of selected coefficients across the industry-specific gravity regressions. These are estimated according to Equation 1, using gross exports as dependent variable. The underlying industry-specific estimates are presented in Table A3. The column headers specify which ports and sectors are considered in the estimations.

they are deep enough, but there would be no economic reason for doing this, due to the lack of a container terminal. The estimated coefficients of $DWP_j * \ln MaxSize_t$ are much smaller in this case as compared to the baseline estimates in columns 1-2. A similar decline in the coefficients can be observed in columns 5 and 6, where we consider the group of 109 ports that do host a container terminal and have water depth of at least 12.5 meters. In this case, on top of our baseline 47 DWPs, we are considering 62 extra ports with depth between 12.5 and 16 meters (see Figure 2). These ports could accommodate all the container ships operating until 1994, but were then progressively cut out from the main shipping routes operated by the new larger ships.

Overall, this evidence supports our identification strategy based on the presence of deep-water ports with container terminals across countries. Indeed, when we intentionally make our measure of the relevant DWPs less precise, by considering larger groups of ports, the elasticity of exports to the number of ports in the partner countries is significantly reduced, by almost one order of magnitude. This is suggestive of the central role played by our core group of 47 ports.

To further explore the sensitivity of the gravity results, in columns 7 and 8 of Table 3 we report coefficients based on gravity estimates that include also 19 service industries (c17-c35 in Table A2), as well as agriculture and mining (c01-c02 in Table A2). The ports considered in this case are the 47 DWPs used for the baseline estimates of columns 1-2. The average coefficient of $DWP_j * \ln MaxSize_t$, in column 7, is reduced by almost 70% as compared to column 1. The median coefficient, in column 8, is reduced by around 46% as compared to column 2. This evidence further corroborates our research design. In fact, we did expect the impact of new container ships, combined with the presence of DWPs across countries, to be stronger for manufacturing trade. To the extent that trade in services is complementary to trade in goods, the transportation shock could have an impact also on services exports. Yet, this impact would be intuitively less important. Similar considerations apply to agriculture and mining, which are also less container-intensive than manufacturing. Consistently, and in line with earlier literature, in most of the empirical analysis we focus on manufacturing exports, for which our instrument is most relevant. Nevertheless, we also show that our main results are robust to considering total trade as well.

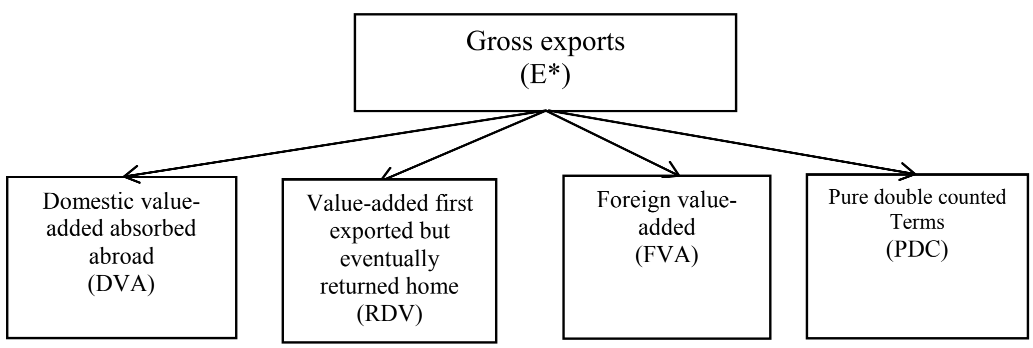
Concerning the other gravity coefficients reported in Table 3, we retrieve across the board the usual negative (and significant) estimates for distance and the landlocked dummy, along with positive estimates for the contiguity dummy. Besides this, it is important to comment on the interactions between these variables and $DWP_j * \ln MaxSize_t$, to further characterize the role played by the transportation shock. In particular, the interaction with distance is positive, in line with the idea that the negative impact of distance on trade is reduced by improvements in transportation technology. The negative interaction term with contiguity is also intuitive, as economies of scale in sea shipping are less relevant for contiguous countries. It is instead less intuitive, at least at first sight, to observe positive coefficients for the interaction between $DWP_j * \ln MaxSize_t$ and the landlocked dummy. Yet, one should keep in mind that this dummy indexes all cases in which either the exporter or the partner country are landlocked. The positive interaction might then reflect the fact that landlocked countries export progressively more towards partner countries that are more endowed with DWPs. Indeed, as the maximum size of container ships grows over time, these partners might become more important as mediators for the exports of landlocked countries to the rest of the world, for instance by hosting more assembling plants where intermediates produced in landlocked countries are used. This type of dynamics would explain why the transportation shock, combined with the presence of DWPs, reduces the negative impact of landlockedness on trade.

3.5 The role of global value chains

Our analysis so far was based on gross exports data from official trade statistics. However, focusing only on gross trade figures would not allow us to investigate directly the role of global value chains. In fact, as already discussed, the expansion of GVCs raises three main issues with such data. First, the gross exports of any country embody an increasing share of foreign value added. Second, intermediate inputs cross borders multiple times before being finally absorbed in a country, thus generating double-counting in official trade statistics. Third, given the same gross exports figures, countries may be different in terms of *participation* and *positioning* within GVCs. To investigate the implications of these phenomena for the trade-growth nexus, we move on to decomposing gross exports into their different value added components.

We employ the methodology developed by Wang et al. (2013), which generalizes the export decomposition by Koopman et al. (2014). The advantage of the Wang et al. (2013) approach with respect to earlier alternatives is that of allowing for a precise value added partition of bilateral export flows not only at the country level but also by industries, in line with our empirical approach. This feature of the methodology derives from a "backward-linkage" modeling approach, which identifies, within each industry's gross exports, the domestic value added produced not only in the industry itself but also in all the upstream domestic industries. This is different from the "forward-linkage" approach adopted for instance by Koopman et al. (2014). In particular, the latter approach would attribute to each industry also the value added indirectly exported via the gross exports of other industries in the same exporting country, thus breaking the one-to-one link between value added exports and gross exports at the industry level. This difference in the two approaches would not matter when considering the total gross exports at the country-level, for which exactly the same decomposition is obtained by Koopman et al. (2014) and Wang et al. (2013), but it is crucial for our purposes, as we estimate gravity models based on bilateral industry-specific data.

Figure 3: Main value added components of exports



Notes. Source: Wang et al. (2013)

At a first level of analysis, the methodology by Wang et al. (2013) allows to decompose each industry-level gross export flow in four main components, whose sum is equal to the export flow itself. These components are highlighted in Figure 3, and explained in what follows:

- **Domestic Value Added** (DVA): this is the value added generated in the exporting country that is absorbed abroad. As explained above, this "backward-linkage" measure takes into account all the domestic value added embodied in the exports of a given industry, no matter in which domestic industry such value added has been generated in the first place. Thus, it considers the creation of domestic value added along all the vertically related industries in the exporting country.

- **Returned Domestic Value Added** (RDV): this is the domestic value added embodied in the export flow which returns home at a later stage. This term includes the export of intermediates that are processed abroad and then return back, embodied either in final goods or in more complex intermediate goods.

- **Foreign Value Added** (FVA): this is the foreign value added embodied in domestic exports, both of final goods and of intermediates.

- **Pure Double Counting** (PDC): this is the portion of gross exports accounted for by intermediates crossing borders multiple times before being finally absorbed in a country. PDC may include value added generated both in the exporting country and in foreign countries. To clarify how PDC works, imagine the following situation: country A produces and exports an intermediate input of value X to country B, where further processing happens and a semi-finished product is produced. Country B then exports the semi-finished product to country C, where additional value is added and a final good is produced. Finally, country C exports the final good to country D, where it is absorbed by consumers. In the end, the initial intermediate produced in country A has crossed borders three times. According to the methodology by Wang et al. (2013), in the first export flow, from A to B, its value X is counted as domestic value added (DVA). In the second step, from B to C, value X is counted as pure double counting (PDC). It is only in the third and final step, from C to D, that X is counted as foreign value added (FVA). If there would be n additional steps before the final one, value X would always be counted as PDC until the final export flow, reflecting the multiple border-crossing from the country where value added is originally generated to the country in which it is finally absorbed.

Table 4 reports descriptive statistics on the four main components of gross exports for the WIOD countries. These figures are obtained as summary statistics from the pooled database of bilateral export flows across all countries and manufacturing industries, over 1995-2007. DVA accounts on average for about 70% of gross exports, followed by FVA with around 22%, and PDC with slightly more than 7%. RDV is on average much less relevant, below 1%, but it rises up to 33% for some export flows. Overall, the relative importance of the four components may change substantially across different export flows. These changes reflect differences in the relevance and shape of global value chains across countries and industries.

Comparing the first and last year of the sample, 1995 and 2007, the average share of domestic value added decreases by around 6 percentage points, from about 73 to 67%. At the same time, foreign value added and pure double counting become on average more relevant, by around 3 percentage points each. These patterns are consistent with the expansion of global value chains, as also highlighted in earlier contributions (Timmer et al., 2014;Johnson and Noguera, 2017), and provide an important motivation for our analysis.

Table 4: Value added shares

Variable	Obs.	Mean	Std. Dev.	Min	Max
Share DVA	278,700	0.698	0.136	0.070	1
Share RDV	278,700	0.004	0.012	0	0.338
Share FVA	278,700	0.224	0.112	0	0.924
Share PDC	278,700	0.074	0.067	0	0.662

Notes. Source: authors' elaboration based on WIOD data using the value added decomposition by Wang et al. (2013).

Each of the four main value added components identified by the Wang et al. (2013) methodology can be further decomposed into sub-components. For our purposes, it is crucial to consider the breakdown of foreign value added and pure double counting, as presented in Figure 4. In particular, FVA can be decomposed in two parts: foreign value added embodied in final goods (FVA_FIN) vs. intermediates exports (FVA_INT). A two-parts decomposition also applies to PDC, where we can disentangle pure double counting deriving from domestic (DDC) vs. foreign sources (FDC). The share of exports accounted for by the sum of the two components of FVA (FVA_FIN + FVA_INT), plus PDC from foreign sources (FDC), constitutes the so-called "vertical specialization" (VS) share initially identified by Hummels et al. (2001) and highlighted in Figure 4. This captures the overall foreign value embodied in gross export flows.

We begin our analysis of the trade-growth nexus by regressing GDP per capita over gross exports, instrumented using the predicted export flows from the gravity estimations discussed in the previous section. Next, we extend the analysis to investigate separately the role of different value added components of gross exports. In order to do this, we obtain different instrumental variables for each of the components described above, by running separate gravity estimations where we consider as a dependent variable one component at the time. By so doing, we allow the transportation shock to have a potentially different impact on different types of trade flows.

For illustrative purposes, Table 5 reports the gravity estimates for the four main value added components: DVA, RDV, FVA, and PDC. As in Table 3, we report the average and median coefficients across the industry-specific regressions.[16] These estimates refer to our baseline approach, where we focus on manufacturing trade and on the set of 47 DWPs with container terminal. Therefore, they are fully comparable with the figures in columns 1 and 2 of Table 3, which refer to gross exports.

The patterns that emerge on the four value added components are in line with the evidence on gross exports. Most importantly, the average and median estimated coeffi-

[16] See Tables A4-A7 in the Appendix for all the industry-specific results.

cients of $DWP_j * \ln MaxSize_t$ are always positive, and the interactions with the dyadic terms follow the same patterns as for gross exports. The DVA estimates are the closest to the gross exports figures in columns 1 and 2 of Table 3, which is not surprising given that DVA accounts on average for the largest share of exports. Some intuitive differences emerge in the RDV estimates, where the coefficients on distance and contiguity are almost twice as big. These findings are consistent with the two-way trade flows implied by RDV, which corresponds to value added that is first exported and then returns back, thus amplifying both the cost disadvantages of distance and the advantages of contiguity. RDV displays also the lowest coefficients on $DWP_j * \ln MaxSize_t$, consistent with a lesser role played by large container ships for this type of trade. The same coefficients are instead somewhat higher for FVA, signaling a higher elasticity of this component of exports to the transportation shock. Our IV approach allows us to exploit this heterogeneity for identification.

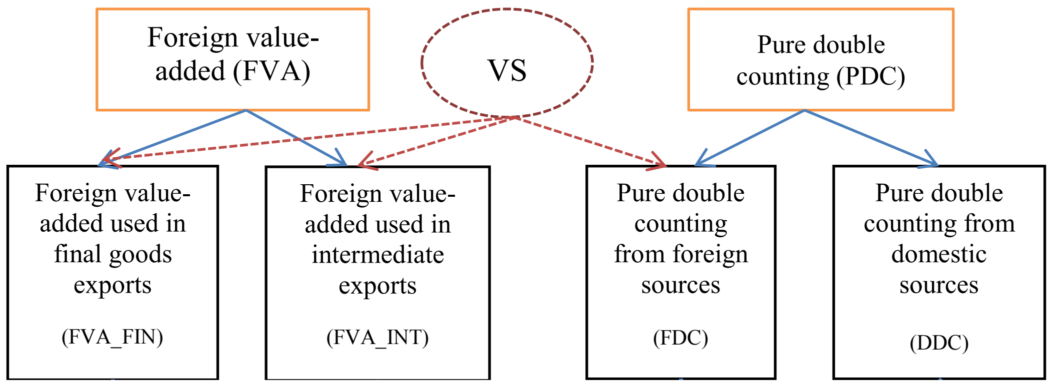
Table 5: Gravity estimates - value added components

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent Variable (ln):	DVA		RDV		FVA		PDC	
Summary statistic:	Avg.	Med.	Avg.	Med.	Avg.	Med.	Avg.	Med.
Partner DWPs * ln(MaxSize)	1.854	1.552	0.758	0.621	2.080	1.763	1.170	0.995
Distance	-1.662	-1.644	-2.682	-2.680	-1.657	-1.639	-1.724	-1.708
Dist. * Part. DWPs * ln(MaxSize)	0.005	0.005	0.007	0.007	0.005	0.005	0.005	0.005
Contiguity	0.533	0.564	0.962	0.991	0.553	0.575	0.533	0.569
Cont. * Part. DWPs * ln(MaxSize)	-0.003	-0.004	-0.006	-0.006	-0.003	-0.004	-0.004	-0.004
Landlocked	-0.323	-0.165	-0.456	-0.342	-0.295	-0.139	-0.310	-0.180
Land. * Part. DWPs * ln(MaxSize)	0.003	0.002	0.004	0.004	0.003	0.002	0.002	0.002

Notes. The table reports average and median estimates of selected coefficients across the industry-specific gravity regressions. These are estimated according to Equation 1. The column headers specify which value added component of gross exports is considered as dependent variable. The underlying industry-specific estimates are presented in Tables A4-A7.

As a first extension to the baseline regressions of income over gross exports, we split the latter in two main components: domestic value vs. foreign value. The domestic content of exports is the sum of three components: domestic value added (DVA), returned domestic value added (RDV), and the domestic component of pure double counting (DDC). The foreign content (VS), as explained above, is the sum of foreign value added (FVA_INT + FVA_FIN) and the foreign component of pure double counting (FDC). We employ as instrumental variables the sum of predicted trade flows for each component. For instance, the instrument for the domestic component of exports is computed as the sum of predicted DVA, RDV, and DDC, each obtained from separate gravity estimations.

Figure 4: FVA, PDC, and VS



Notes. Source: Wang et al. (2013)

The distinction between domestic and foreign content of gross exports is very intuitive and relevant as we aim to assess the impact of trade on income. Indeed, while exports of domestic value added contribute directly to domestic GDP in the exporting country, there is not such a direct link when it comes to exports of foreign value. Therefore, one could wonder about the very existence of a growth effect of exports in a context in which we observe a systematic reduction of the domestic component in favor of the foreign one, as driven by the expansion of GVCs. However, exporting foreign value may still generate positive spillovers for the domestic economy, and thus a positive effect on GDP per capita.

Next, we focus on the potential implications of differences in the composition of the foreign component of exports (VS). In particular, the relative shares of the three components of VS, i.e., FVA_INT, FVA_FIN, and FDC, can be used to construct indicators for participation and positioning within GVCs. Specifically, as an indicator for GVCs participation we take the ratio between the foreign component of pure double counting (FDC) and the overall foreign value embodied in exports (VS). As discussed by Wang et al. (2013), FDC can only be there when there is back and forth trade of intermediate goods. Thus, for given vertical specialization, an increasing weight of FDC in VS indicates the deepening of cross-country production sharing, with the exporting country becoming more embedded in global value chains. As an indicator for GVCs positioning we take the ratio between foreign value added embodied in intermediates (FVA_INT) and the overall foreign value of exports (VS). This approach is inspired by Wang et al. (2013), who notice how an increase in the relevance of FVA_INT captures the fact that a country is upgrading its industries to start producing intermediates that are exported to other countries for final goods production. We instrument each indicator by taking the relevant ratio of predicted trade flows from the corresponding gravity estimations. For instance, GVCs positioning is instrumented with the ratio of predicted FVA_INT over predicted VS. In the income regressions, we interact VS, alternatively, with the country-level changes in GVCs participation and positioning, evaluated over the whole sample period. This allows us to investigate the extent to which changes in GVCs performance influence the effect of foreign value exports on growth.

4 Trade and income

4.1 Baseline results

To investigate the impact of exports on income, in line with Feyrer (2018) and Pascali (2017) we start by estimating regressions of the following form:

$$\ln GDPpc_{i,t} = \beta_0 + \beta_1 \ln Export_{i,t} + \alpha_i + \alpha_t + \epsilon_{i,t}, \tag{5}$$

where $GDPpc_{i,t}$ is the GDP per capita of country i in year t; $Export_{i,t}$ stands for the aggregate manufacturing exports of country i in year t; while α_i and α_t are country and year fixed effects, respectively.

Table 6 reports the baseline estimates of Equation 5. The first two columns refer to the WIOD sample, while the second two columns show regression results for the enlarged sample including all the 184 countries for which data on gross exports and GDP per capita are available from CEPII-BACI (Comtrade) and WDI, respectively. For each sample, the first column reports the OLS estimates, while the second column reports the IV results. The instrumental variables are computed as in Equation 3, by aggregating the industry-level predicted exports from the second specification of the gravity model (Eq. 2), which includes exporter-year and importer-year fixed effects, i.e., the multilateral resistance terms (MRTs). This is our favorite specification, as it is fully consistent with the theoretical microfoundations of the gravity model (Anderson and van Wincoop, 2003). Nevertheless, in the robustness section we show that our findings are essentially unchanged when using as instruments the predicted exports from the first specification of the gravity (Eq. 1). The latter does not include the MRTs and therefore allows to identify the main interaction term between the maximum size of container ships and the number of DWPs in partner countries, as discussed in the previous section.

Our findings suggest that exports have a positive effect on GDP per capita. According to the IV estimates, a one percent increase in exports leads to higher GDP per capita by around 0.28-0.32 percent. The estimated effect is very close in the two samples, and it is slightly lower than the 0.5 trade elasticity estimated by Feyrer (2018) over the period 1960-1995. While comparing coefficients across different empirical studies is inherently problematic, a lower elasticity between trade and income over 1995-2007 might be consistent with the contemporaneous decrease in the domestic value added contribution to exports that we have documented. We provide evidence in line with this idea when considering the role of GVCs.[17]

As to the instruments, the first-stage coefficients are positive and significant, pointing to the expected positive correlation between predicted and actual export flows. The F-statistic is also reassuringly high in both cases, corroborating the strength of the instruments. The estimated elasticity between export and GDP per capita is somewhat higher in the IV estimates than in the OLS ones. This result is in line with earlier evidence in the literature, from the seminal paper of Frankel and Romer (1999) onwards. A possible explanation for the downward bias in OLS is related to measurement error. As discussed by Frankel and Romer (1999), trade might be an imperfect measure of the income-enhancing interactions between countries. Besides that, as noticed by Felbermayr and Gröschl (2013), any instrument might be identifying the effect of trade on income relatively more on countries and years for which such nexus tends to be stronger, as a sort of local average treatment effect (see Angrist and Pischke, 2009).

In Table 7 we take a long differences approach. Specifically, we regress the change in GDP per capita between the first and last year of the sample (1995-2007) against the change in exports evaluated over the same 12-year interval. This cross-sectional analysis allows us to capture the causal effect of exports on income over a long period of time, in which different channels for the effect of trade might operate. Table 7 has the same structure of Table 6, and displays consistent results despite the drop in the number of observations.[18]

To investigate the growth effect further, in Table 8 we regress GDP per capita growth over lagged export growth. We focus on the WIOD sample, which is our baseline choice

[17] In a recent paper, Constantinescu et al. (2018) also find that the trade elasticity declined significantly in the 2000s even before the crisis.

[18] In the WIOD sample, which includes 40 countries, we have a total of 39 observations. This is due to lack of GDP per capita data for Taiwan in the World Development Indicators.

Table 6: Income regressions - baseline

Dependent Variable: ln(GDP p.c.)	(1)	(2)	(3)	(4)
Sample:	WIOD		All countries	
ln(Export)	0.270***	0.321***	0.165***	0.277***
	[0.051]	[0.029]	[0.041]	[0.034]
Estimator	OLS	2SLS	OLS	2SLS
Country effects	yes	yes	yes	yes
Year effects	yes	yes	yes	yes
Obs.	507	507	2,363	2,363
R2	0.82	-	0.72	-
First-stage results				
Predicted trade flows from gravity	-	0.592***	-	0.716***
	-	[0.025]	-	[0.030]
Kleibergen-Paap F-Statistic	-	569.5	-	571.9

Notes. The dependent variable is the logarithm of GDP per capita. ln(Export) is the logarithm of gross exports at the country level. The regressions in columns (1) and (2) are estimated on the WIOD sample; the regressions in columns (3) and (4) are estimated on all the 184 countries for which trade and GDP per capita data are available from CEPII-BACI and WDI, respectively. The regressions in columns (1) and (3) are estimated by OLS; the regressions in columns (2) and (4) are estimated by 2SLS. Robust standard errors in brackets. ***, **, * indicate significance at the 1, 5 and 10% level, respectively.

given the focus on GVCs. We measure growth by taking differences over different time intervals, from one to five years. Lags of export growth are always taken according to the considered time interval. For instance, when we compute GDP growth between year t and t-3, export growth is then measured between t-3 and t-6. Clearly, the longer the time interval, the less observations we have in the estimations. In each case, we report both the OLS and the IV results. The estimated coefficients on export growth are always positive and statistically different from zero. The effect of trade on growth tends to increase as we consider longer stacked differences, from one to four years, while it seems to stabilize at five.

Table 7: Income regressions - long differences

Dependent Variable: Δ ln(GDP p.c.) 12 years	(1)	(2)	(3)	(4)
Sample:	WIOD		All countries	
Δ ln(Export) 12 years	0.331***	0.379***	0.306	0.685**
	[0.075]	[0.082]	[0.213]	[0.273]
Estimator	OLS	2SLS	OLS	2SLS
Obs.	39	39	184	184
R2	0.47	-	0.01	-
First-stage results				
Predicted trade flows from gravity	-	0.646***		0.875***
	-	[0.060]		[0.065]
Kleibergen-Paap F-Statistic	-	115.8		182.9

Notes. The dependent variable is the 12-year growth of GDP per capita, computed between 1995 and 2007. Δ ln(Export) 12 years is the 12-year growth of gross exports at the country level, computed between 1995 and 2007. The regressions in columns (1) and (2) are estimated on the WIOD sample; the regressions in columns (3) and (4) are estimated on all the 184 countries for which trade and GDP per capita data are available from CEPII-BACI and WDI, respectively. The regressions in columns (1) and (3) are estimated by OLS; the regressions in columns (2) and (4) are estimated by 2SLS. Robust standard errors in brackets. ***, **, * indicate significance at the 1, 5 and 10% level, respectively.

Table 8: Income regressions - stacked differences

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Dependent Variable:	Δ ln(GDP p.c.) 1 year		Δ ln(GDP p.c.) 2 years		Δ ln(GDP p.c.) 3 years		Δ ln(GDP p.c.) 4 year		Δ ln(GDP p.c.) 5 years	
Δ ln(Export) 1 year (lag)	0.069***	0.088***								
	[0.013]	[0.019]								
Δ ln(Export) 2 years (lag)			0.103***	0.129***						
			[0.017]	[0.022]						
Δ ln(Export) 3 years (lag)					0.142***	0.173***				
					[0.024]	[0.032]				
Δ ln(Export) 4 years (lag)							0.174***	0.213***		
							[0.039]	[0.053]		
Δ ln(Export) 5 years (lag)									0.175***	0.200**
									[0.055]	[0.079]
Estimator	OLS	2SLS	OLS	2SLS	OLS	2SLS	OLS	2SLS	OLS	2SLS
Obs.	429	429	351	351	273	273	195	195	117	117
R2	0.06	-	0.12	-	0.15	-	0.14	-	0.11	-
KP F-Stat.		298.1		484.6		355.3		210.2		108.3

Notes. The dependent variable is the growth of GDP per capita; the column headers specify whether this growth is computed over 1, 2, 3, 4, or 5 years. Δ ln(Export) is the lagged growth of gross exports at the country level, computed over the same number of years as the dependent variable. The regressions in columns (1), (3), (5), (7), and (9) are estimated by OLS; the regressions in columns (2), (4), (6), (8), and (10) are estimated by 2SLS. Robust standard errors in brackets. ***, **, * indicate significance at the 1, 5 and 10% level, respectively.

4.2 Channels

In this section we provide evidence on some of the mechanisms through which exports might affect income. Specifically, we focus on two traditional channels emphasized by the literature: labor productivity growth and capital deepening. Labor productivity is proxied by value added per worker, while information on capital per worker is used to investigate capital deepening. Data on value added and capital per worker are sourced from the World Input-Output Database (WIOD). We run regressions both at the country level and at the country-industry level. The industry-level instruments for exports are obtained as in Equation 4, by aggregating predicted export flows separately for each industry in each country.

In Table 9 we run regressions in levels, with the same empirical specification as for the income regressions (Eq. 5). For each dependent variable –and for each level of analysis– we report both OLS and IV estimates. The coefficients on exports are always positive, and highly significant in the instrumental variables regressions. Similar evidence is obtained in Table 10, where we take the long differences approach. Overall, our findings suggest that exports have a positive impact on GDP growth by inducing both higher productivity growth and more investment per worker. Interestingly, the estimated elasticities are somewhat higher at the country level than at the industry level. This result is consistent with the existence of positive spillovers across industries, which are best captured when focusing on aggregate outcomes at the country level.

Table 9: Channels - baseline

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dep. Variable:	ln(VA per worker)				ln(Capital per worker)			
Level of analysis:	Country-level		Industry-level		Country-level		Industry-level	
ln(Export)	0.559***	0.567***	0.258***	0.314***	0.108*	0.129***	0.032	0.102***
	[0.194]	[0.116]	[0.044]	[0.027]	[0.062]	[0.037]	[0.035]	[0.023]
Estimator	OLS	2SLS	OLS	2SLS	OLS	2SLS	OLS	2SLS
Country effects	yes	yes	no	no	yes	yes	no	no
Country-Industry effects	no	no	yes	yes	no	no	yes	yes
Year effects	yes	yes	yes	yes	yes	yes	yes	yes
Obs.	507	507	7,032	7,032	507	507	7,032	7,032
R2	0.52	-	0.45	-	0.48	-	0.37	-
Kleibergen-Paap F-Statistic		565.2		1,536		565.2		1,536

Notes. The dependent variable in columns (1)-(4) is the logarithm of value added per worker; the dependent variable in columns (5)-(8) is the logarithm of capital per worker. ln(Export) is the logarithm of gross exports. The regressions in columns (1), (2), (5) and (6) are estimated at the country level; the regressions in columns (3), (4), (7) and (8) are estimated at the country-industry level. The regressions in columns (1), (3), (5), and (7) are estimated by OLS; the regressions in columns (2), (4), (6), and (8) are estimated by 2SLS. Robust standard errors in brackets. ***, **, * indicate significance at the 1, 5 and 10% level, respectively.

Table 10: Channels - long differences

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dep. Variable:	Δ ln(VA per worker) 12 years				Δ ln(Capital per worker) 12 years			
Level of analysis:	Country-level		Industry-level		Country-level		Industry-level	
Δ ln(Export) 12 years	1.089***	1.037***	0.458***	0.436***	0.185**	0.204**	0.114**	0.177***
	[0.330]	[0.353]	[0.067]	[0.077]	[0.086]	[0.097]	[0.048]	[0.050]
Estimator	OLS	2SLS	OLS	2SLS	OLS	2SLS	OLS	2SLS
Obs.	39	39	534	534	39	39	534	534
R2	0.24	-	0.12	-	0.11	-	0.03	-
Kleibergen-Paap F-Statistic		116.4		741.5		116.4		741.5

Notes. The dependent variable in columns (1)-(4) is the 12-year growth of value added per worker, computed between 1995 and 2007; the dependent variable in columns (5)-(8) is the 12-year growth of capital per worker, computed between 1995 and 2007. Δ ln(Export) 12 years is the 12-year growth of gross exports, computed between 1995 and 2007. The regressions in columns (1), (2), (5) and (6) are estimated at the country level; the regressions in columns (3), (4), (7) and (8) are estimated at the country-industry level. The regressions in columns (1), (3), (5), and (7) are estimated by OLS; the regressions in columns (2), (4), (6), and (8) are estimated by 2SLS. Robust standard errors in brackets. ***, **, * indicate significance at the 1, 5 and 10% level, respectively.

4.3 The role of global value chains

So far we have investigated the growth effects of gross exports, in line with the received literature on trade and income. Our contribution with respect to earlier studies was that of exploiting a relatively recent transportation shock, allowing us to analyze the trade-growth nexus over a time period characterized by a rapid expansion of GVCs. In this section, we move forward by studying more directly how global value chains might have an impact on the identified link between exports and income. We work on WIOD data, which allow to decompose gross exports into value added components.

For ease of comparison, column 1 of Table 11 replicates the baseline IV regression of GDP per capita over exports, as reported in column 2 of Table 6. As a first extension, we consider the domestic and the foreign components of gross exports, first separately (columns 2 and 3) and then jointly (column 4). These components are defined as explained in Section 3.5. Specifically, the domestic component is the sum of domestic value added (DVA), returned domestic value added (RDV), and the domestic part of pure double counting (PDC). The foreign component is the sum of foreign value added (FVA_INT + FVA_FIN) and the foreign part of pure double counting (FDC). Intuitively, one could expect a lower trade elasticity of income in contexts where foreign value acquires a more prominent role as a share of total exports, since the foreign component of exports is not directly related to domestic activities that would contribute to GDP in the exporting country. However, exporting foreign value might still be complementary to a whole range of domestic activities –from manufacturing to transportation and other services– which may not be reflected in the exports of domestic value added, but are certainly captured by GDP per capita.

We find a higher elasticity of income with respect to domestic value than to foreign value: 0.37 vs. 0.21. When we include both variables in the same regression, in column 4, the coefficient on domestic value rises to 0.48, while the one on foreign value becomes negative: -0.10. Overall, in line with the expectations, these results are suggestive of a lower elasticity of income to gross exports in contexts where the foreign component of exports is relatively more important. To clarify, the negative coefficient on the foreign component should not be read as evidence that exporting foreign value is detrimental for income. As a matter of fact, domestic and foreign value are part of the same export flows and they are positively correlated. Moreover, there is no export of foreign value without a complementary domestic component in our data. Consistently, if we compute the overall effect of exports in column 4 –i.e., summing over domestic and foreign value, each multiplied by its own coefficient– we always obtain figures that are positive and statistically different from zero, even for the lowest predicted values.

Next, we focus on differences in the composition of the foreign value of exports (VS). As explained in Section 3.5, these differences are informative of the participation and positioning of countries within GVCs. As a proxy for participation, we consider the ratio between the foreign component of pure double counting (FDC) and the total foreign value of exports (VS). As a proxy for positioning, we take the ratio of foreign value added embodied in intermediates (FVA_INT) over VS (Wang et al., 2013). For each indicator, we compute the change at the country level over the whole sample period, from 1995 to 2007. We instrument such changes using variations in the corresponding ratios based on predicted trade flows, as obtained from the component-specific gravity estimations.

In columns 5 and 6 of Table 11 we interact VS with, respectively, the change in GVCs participation and the change in GVCs positioning.[19] In both cases the estimated coefficients on the interaction terms are positive and highly significant. These results point to a higher elasticity of income to exports for those countries witnessing an increase in participation or an upgrade in GVCs positioning over the sample. These interaction effects reduce the negative impact of VS on the trade elasticity of income. In particular, con-

[19]Notice that the linear terms of the changes in participation and positioning are subsumed by the country fixed effects.

sidering column 5, when computing the overall effect of VS on income at different levels of $\Delta Participation$ we find the effect to be negative and significant only up until the median change in participation, while it becomes statistically indistinguishable from zero above the median. Exactly the same finding is obtained in column 6, when considering the change in GVCs positioning. By and large, these results suggest that exporting foreign value generates stronger spillovers for the domestic economy in contexts where the growth in such exports is associated either with an upgrade in the positioning of a country in GVCs –from assembling to higher stages of the value chain– or with an increase in participation, thereby the country becomes more embedded and central in GVCs (Wang et al., 2013).

In Table 12 we perform the same analysis focusing on long differences. Column 1 replicates the baseline long-differences regression of column 2 in Table 7. In columns 2-4, we consider the 12-year differences in domestic and foreign value, first separately and then jointly. In columns 5 and 6, we interact the change in VS with the change in GVCs participation and positioning, respectively. The results are qualitatively unchanged with respect to the analysis in levels of Table 11. To provide a parallel with the previous discussion, the estimated overall effect of exports in column 4 is never negative. It is statistically insignificant only for Japan, otherwise it is always positive and significant. Perhaps not surprisingly, the strongest estimated effect of exports on growth is obtained for China, followed by the new Central and Eastern Members of the European Union, and by Mexico.

To summarize, our evidence suggests that the effect of exports on income is crucially moderated by the value added composition of gross trade flows, and by changes in countries' participation and positioning within GVCs. In particular, we find evidence that exporting foreign value does not necessarily reduce the impact of exports on growth, to the extent that higher exports of foreign value are related to increasing GVCs participation and upgraded GVCs positioning. To the best of our knowledge, this is the first empirical evidence on the moderating role of global value chains for the causal link between trade and growth.

Table 11: The role of GVCs - baseline

Dependent Variable: ln(GDP p.c.)	(1)	(2)	(3)	(4)	(5)	(6)
ln(Export)	0.321***					
	[0.029]					
ln(Domestic Value)		0.370***		0.489***	0.431***	0.487***
		[0.031]		[0.045]	[0.055]	[0.044]
ln(Foreign Value - VS)			0.217***	-0.108***	-0.220***	-0.046
			[0.024]	[0.027]	[0.039]	[0.032]
ln(VS) * Δ Participation					1.898***	
					[0.397]	
ln(VS) * Δ Positioning						0.794***
						[0.163]
Estimator	2SLS	2SLS	2SLS	2SLS	2SLS	2SLS
Country effects	yes	yes	yes	yes	yes	yes
Year effects	yes	yes	yes	yes	yes	yes
Obs.	507	507	507	507	507	507
R2	0.82	0.83	0.77	0.83	0.82	0.83
Kleibergen-Paap F-Statistic	569.5	577	647.4	298.5	32.5	30.2

Notes. The dependent variable is the logarithm of GDP per capita. ln(Export) is the logarithm of gross exports at the country level. ln(Domestic Value) is the sum of domestic value added (DVA), returned domestic value added (RDV), and the domestic part of pure double counting (PDC). ln(Foreign Value - VS) is the sum of foreign value added (FVA_INT + FVA_FIN) and the foreign part of pure double counting (FDC). Δ Participation is the change in the ratio between the foreign component of pure double counting (FDC) and the total foreign value of exports (VS), computed at the country level between 1995 and 2007. Δ Positioning is the change in the ratio between foreign value added embodied in intermediates (FVA_INT) and VS, computed at the country level between 1995 and 2007. All the regressions are estimated by 2SLS. Robust standard errors in brackets. ***, **, * indicate significance at the 1, 5 and 10% level, respectively.

5 Robustness

In this section, we provide a battery of robustness and sensitivity checks on the identification strategy. In Table 13, we focus on the baseline finding on the effect of exports on GDP per capita in the WIOD sample. All the reported coefficients refer to the gross exports explanatory variable. To ease comparisons, row 1 replicates the baseline estimate of column 2 in Table 6.

We begin by changing the set of fixed effects included in the gravity specifications.

Table 12: The role of GVCs - long differences

Dependent Variable: Δ ln(GDP p.c.) 12 years	(1)	(2)	(3)	(4)	(5)	(6)
Δ ln(Export)	0.379***					
	[0.082]					
Δ ln(Domestic Value)		0.436***		0.642***	0.578***	0.590***
		[0.077]		[0.111]	[0.141]	[0.125]
Δ ln(Foreign Value - VS)			0.264***	-0.186**	-0.295***	-0.068
			[0.077]	[0.075]	[0.111]	[0.119]
Δ ln(VS) * Δ Participation					1.957**	
					[0.876]	
Δ ln(VS) * Δ Positioning						0.865**
						[0.431]
Estimator	2SLS	2SLS	2SLS	2SLS	2SLS	2SLS
Obs.	39	39	39	39	39	39
R2	0.46	0.52	0.28	0.56	0.47	0.56
Kleibergen-Paap F-Statistic	115.8	115.8	156.9	59.15	5.2	4.4

Notes. The dependent variable is the 12-year growth of GDP per capita, computed between 1995 and 2007. All the explanatory variables are also computed as 12-year growth rates, between 1995 and 2007. ln(Export) is the gross exports at the country level. ln(Domestic Value) is the sum of domestic value added (DVA), returned domestic value added (RDV), and the domestic part of pure double counting (PDC). ln(Foreign Value - VS) is the sum of foreign value added (FVA_INT + FVA_FIN) and the foreign part of pure double counting (FDC). Δ Participation is the change in the ratio between the foreign component of pure double counting (FDC) and the total foreign value of exports (VS), computed at the country level between 1995 and 2007. Δ Positioning is the change in the ratio between foreign value added embodied in intermediates (FVA_INT) and VS, computed at the country level between 1995 and 2007. All the regressions are estimated by 2SLS. Robust standard errors in brackets. ***, **, * indicate significance at the 1, 5 and 10% level, respectively.

Specifically, in row 2 we employ as instrumental variable the predicted exports obtained from the first specification of the gravity model (Eq. 1). This includes exporter, importer, and year fixed effects instead of exporter-year and importer-year effects, i.e., the multilateral resistance terms. In row 3, we include dummies for each pair of (exporter-importer) countries, along with the year dummies. The estimated elasticity of GDP to exports is essentially unchanged.

Next, we go back to the baseline specification of the gravity (including MRTs), to assess whether the normalization of the number of deep-water ports by the coast length has any bearing on our findings. To this purpose, in row 4 we employ the plain number of deep-water ports in partner countries, without dividing by the number of kilometers of coastline. Reassuringly, the estimated export elasticity is virtually unchanged. In row 5, we normalize the number of ports by the length of the coastline, as in the baseline regression, but we expand the set of DWPs from 47 to 51. In particular, we include the port of Manzanillo, in Mexico; Ambarli, in Turkey; Marsaxlokk, in Malta; and Sines, in Portugal. As discussed in Section 3.2, Manzanillo is the only port where water depth has increased above 16 meters over the sample years, due to dredging. In the other three cases, a container terminal was added after 2002 to ports that were already deeper than 16 meters. The inclusion of these four ports leaves the export elasticity unaffected.

One could be concerned that the presence of DWPs in the exporting country is key for our identification strategy. That is, a country's trade might not really be affected by the introduction of larger container ships unless it hosts DWPs within its own territory. In our baseline set-up of the gravity, we do not include the number of DWPs in the exporting country, as that could be endogenous to GDP per capita, by affecting income through channels other than trade. Yet, one could worry that this omission might lead to a suboptimal exploitation of the identification shock.

To address this concern, in row 6 we use as instrument the predicted exports from an augmented specification of the gravity, where we also take into account the number of DWPs in the exporting country. Specifically, on top of the interactions between $DWP_j * \ln MaxSize_t$ and the three dyadic variables, we also include interactions based on $DWP_i * \ln MaxSize_t$, where DWP_i is the number of deep-water ports in the exporting country. Along similar lines, in row 7 we consider the sum of the ports in the exporting and importing country, that is, $DWP_{ij} * \ln MaxSize_t$. In row 8 we interact $\ln MaxSize_t$ with a dummy taking value 1 if both the exporter and the importer host at least one deep-water port. The coefficient of exports is remarkably stable across specifications, suggesting that our conservative choice to leave out the potentially endogenous domestic ports has no significant implications for our findings. Still, to make sure that our results are not driven by exporting countries endowed with DWPs, in row 9 we replicate the baseline analysis of row 1, but keeping in the sample only the exporting countries that *do not* host any deep-water ports. Results are in line with the baseline evidence also in this case. This finding is consistent with the idea that the transportation shock, combined with the presence of DWPs in partner countries, may explain variation in export flows even for landlocked countries, as discussed in Section 3.4 when commenting on the gravity coefficients.

Another possible concern with our identification strategy is that the increase in the size of container ships over time might be endogenous to GDP growth, to the extent that positive expectations about future trade growth are important for the change in transportation technology, and are at the same time related to GDP growth. For this reason, all our gravity estimations always include either country and year fixed effects or their interactions. In other words, for identification purposes we exploit the variation across bilateral trade flows within each year, as driven by the uneven presence of DWPs across partner countries and other bilateral features.

On top of that, in rows 10 and 11 we assess the sensitivity of our results to dropping from the analysis three countries for which this type of endogeneity concerns might be more relevant: China, Denmark, and South Korea. These countries are excluded not only from the income regressions but also from the gravity estimations. In particular, in the gravity we exclude the exports of each of the three countries towards all the partner countries, and also the exports of all the partner countries towards them. In row 10 we exclude China, whose rapid growth over the sample was key in fostering trade across the Europe-Asia route, free from the size constraints of the Panama canal. In that respect, the increase in the size of container ships could be endogenous to GDP growth in China. In row 11, we instead exclude Denmark and South Korea: two countries characterized by significantly large shipping and shipbuilding industries relative to their GDP. As improvements in transportation boost the performance of these industries, there could be an impact on GDP in these countries via channels other than trade, thus raising endogeneity concerns. Both in row 10 and in row 11 our results are essentially unchanged as compared to the baseline evidence.

In row 12, we regress GDP per capita over total exports at the country level, thus including also exports in non-manufacturing industries. The point estimate on the export elasticity is slightly higher, but not statistically distinguishable from the baseline estimate where we consider only manufacturing exports. We refrain from drawing any stronger conclusions from this evidence given the nature of our identification strategy, which fits manufacturing better than other sectors. In row 13, we consider as explanatory variable the total trade in manufacturing, that is, the sum of exports and imports. To instrument this variable, we take the sum of predicted export flows and predicted import flows from the gravity estimations. For exports, this just involves following the baseline approach as in row 1. For imports, we run the same gravity estimations as for exports, where the underlying intuition is that, as the size of container ships grows, countries start importing relatively more from partners that are endowed with more DWPs. The estimated elasticity of GDP per capita to total trade is very close to the one estimated for exports only. The latter has been the main focus of our analysis, since we have exploited the possibility of decomposing export flows in value added components to study the role of GVCs.

We proceed by performing some additional robustness checks on the gravity estimations. In particular, in row 14 the instrument is obtained from gravity estimates based on aggregate manufacturing exports from country to country. That is, we run only one estimation of the gravity equation, instead of 14 industry-specific estimations. The estimated export elasticity is close to the baseline.

In row 15 we exclude the estimated fixed effects from the computation of the instrumental variable. This is arguably the most conservative choice that we can make. In fact, the instrument now only reflects variation in export flows on top of exporter-

Table 13: Income regressions - robustness

Dependent Variable: ln(GDP p.c.)	Coeff.	Std. Err.	Obs.	KP F-Stat.
1) Baseline	0.321***	[0.029]	507	569.5
2) Gravity without MRTs	0.347***	[0.061]	507	48.34
3) Controlling for country-pair dummies	0.316***	[0.029]	507	639.2
4) Plain number of DWPs	0.316***	[0.029]	507	571.5
5) Including 4 additional DWPs	0.321***	[0.029]	507	568.5
6) Including exporter DWPs	0.321***	[0.029]	507	570.7
7) Sum of importer and exporter DWPs	0.322***	[0.029]	507	568.8
8) Dummy for country pairs with at least 1 DWP in both	0.324***	[0.029]	507	569.4
9) Only countries with no domestic DWPs	0.353***	[0.018]	273	1227
10) Excluding China	0.283***	[0.029]	494	580.5
11) Excluding Denmark and South Korea	0.317***	[0.030]	481	536.1
12) Considering total exports	0.361***	[0.031]	507	862.3
13) Considering total trade (exports + imports)	0.341***	[0.026]	507	283.5
14) Gravity based on aggregate data	0.298***	[0.027]	507	781.2
15) Excluding fixed effects from IV computation	0.345***	[0.073]	507	16.4
16) Using a time trend instead of Max Size	0.168*	[0.089]	507	5.4
17) PPML estimator	0.388***	[0.071]	507	31.2

Notes. The dependent variable is the logarithm of GDP per capita. Unless differently specified in the first column, the coefficients refer to the variable ln(Export), which is the logarithm of gross manufacturing exports at the country level. The regression in row 1 replicates the baseline result of column 2 in Table 6. All the other regressions provide robustness checks on that result, as detailed in each row. All regressions are IV. Robust standard errors in brackets. ***, **, * indicate significance at the 1, 5 and 10% level, respectively.

year and importer-year specific factors. Such residual variation is determined by the dyadic terms –distance, contiguity, landlocked– and, crucially, by their interactions with $DWP_j * \ln MaxSize_t$. Reassuringly, we still obtain a point estimate of the export coefficient that is very close to the baseline. If anything, it is actually slightly larger.

One could still wonder that our main interaction term, $DWP_j * \ln MaxSize_t$, is just capturing a generic time trend and not really any specific role of growing container ships. To address this concern, in row 16 we then interact DWP_j with a time trend instead of $\ln MaxSize_t$. As it can be seen, the F-statistics drops below 10, and the estimated coefficient on exports is much lower and imprecisely estimated, pointing to the key and distinctive role of the transportation shock for our results. As a final robustness check, on top of excluding the MRTs from the instrument, in row 17 we compute the instrumental variable based on the PPML gravity estimation proposed by Silva and Tenreyro (2006). This methodology addresses both zero trade flows and heteroskedasticity issues. If anything, the estimated elasticity of income to trade is again slightly higher than the baseline.

In Table 14 we take into account the potential role of underlying trends and unobserved contemporaneous shocks. We proceed by augmenting the baseline specification of column 2 in Table 6 with different sets of interactions, as explained in Section 3.2. In panel a) we allow for different trajectories across countries based on initial characteristics. Specifically, we interact the year dummies with either the initial value or the pre-sample growth of: GDP per capita, capital intensity, TFP, the ratio of imports to GDP, and the ratio of exports to GDP. The estimated coefficient on exports is always positive, highly significant, and close to the baseline estimate.

In panel b) we interact the year dummies with dummies denoting groups of countries displaying a similar performance over the sample. Specifically, we group countries based on the quartiles of the distributions of growth rates in the same variables considered for underlying trends. The idea is that countries displaying a similar performance in these observable outcomes might be facing similar unobserved shocks. In these regressions we identify the effect of exports only on the remaining variation within each group of countries and year. The results are again in line with the baseline analysis. Only in row 11 the estimated coefficient of exports is positive and significant but smaller than the baseline (0.094). However, that is the regression where we interact the year dummies with dummies capturing GDP per capita growth over the sample, which is clearly endogenous. Overall, our main results do not seem to be driven by any specific underlying trends or unobserved contemporaneous shocks.

Table 14: Income regressions - robustness

Dependent Variable: ln(GDP p.c.)	Coeff.	Std. Err.	Obs.	KP F-Stat.
a) Underlying trends based on pre-sample country characteristics				
1) Year dummies * initial GDP per capita (1995)	0.260***	[0.033]	507	280.1
2) Year dummies * pre-sample growth of GDP per capita (1990-1995)	0.262***	[0.026]	507	466.0
3) Year dummies * initial capital intensity (1995)	0.295***	[0.032]	507	344.9
4) Year dummies * pre-sample growth of capital intensity (1990-1995)	0.313***	[0.029]	507	559.6
5) Year dummies * initial TFP (1995)	0.251***	[0.033]	507	328.3
6) Year dummies * pre-sample growth of TFP (1990-1995)	0.267***	[0.024]	507	483.4
7) Year dummies * initial import/GDP (1995)	0.327***	[0.030]	507	540.3
8) Year dummies * pre-sample growth of import/GDP (1990-1995)	0.350***	[0.029]	507	588.9
9) Year dummies * initial export/GDP (1995)	0.328***	[0.030]	507	464.9
10) Year dummies * pre-sample growth of export/GDP (1990-1995)	0.319***	[0.028]	507	648.8
b) Contemporaneous shocks based on country performance in sample				
11) Year dummies * country group - GDP per capita growth (1995-2007)	0.094***	[0.028]	507	216.5
12) Year dummies * country group - capital intensity growth (1995-2007)	0.270***	[0.026]	507	470.4
13) Year dummies * country group - TFP growth (1995-2007)	0.282***	[0.027]	507	439.4
14) Year dummies * country group - import/GDP growth (1995-2007)	0.259***	[0.026]	507	441.7
15) Year dummies * country group - export/GDP growth (1995-2007)	0.379***	[0.032]	507	434.1

Notes. The dependent variable is the logarithm of GDP per capita. The coefficients refer to the variable ln(Export), which is the logarithm of gross manufacturing exports at the country level. In each row, the baseline specification of column 2 in Table 6 is augmented with interaction terms between the year dummies and the variables specified in the first column. All regressions are 2SLS. Robust standard errors in brackets. ***, **, * indicate significance at the 1, 5 and 10% level, respectively.

6 Conclusion

We have studied the effect of trade on growth in the age of global value chains. We have developed a new instrument for trade. This exploits a recent shock to transportation technology –the sharp increase in the size of container ships observed from the mid-1990s– which has had an asymmetric impact across bilateral trade flows depending on the ex-ante distribution of deep-water ports across countries. The new instrument has allowed us to investigate the effect of trade on income over a recent period characterized by a rapid expansion of GVCs. We have found that trade has a positive effect on GDP per capita, both in levels and in growth terms. Evidence at the country and industry level suggests that the effect works through both productivity improvements and capital deepening.

Our results shed the first light on the role of global value chains as moderators of the income effects of trade. In particular, we have shown that differences in the value added composition of exports have significant implications for the effect of exports on growth. Intuitively, the elasticity of income to exports decreases with the share of foreign value embodied in gross export flows. Yet, this is not the case when the growth of foreign value exports reflects a significant increase in participation or an upgrade in positioning within GVCs. In such contexts, exporting foreign value seems to generate stronger complementarities with respect to domestic activities, as driven by the enhanced involvement in global value chains.

Our results have important policy implications. First, they suggest that the positive effects of trade on growth remain relevant and are not necessarily weakened by the expansion of GVCs. Getting embedded in global value chains seems to be a powerful determinant of growth, even if it implies that a growing share of gross exports represents value added that has been produced in foreign countries. Moreover, exports have a positive effect on GDP growth even for countries that are not displaying substantial upgrades in positioning within GVCs over the sample, although climbing the value chain results in growth premia. Second, and relatedly, investing in physical infrastructures to facilitate trade seems to be key. Our results highlight the important role acquired by deep-water ports as main hubs for trade over the sample period. In light of our findings, the widespread investments observed in more recent years for the creation of new DWPs appear as a well-motivated and important step for trade facilitation and growth. We hope that our new data and empirical approach will nurture further research on the growth implications of global value chains, which we deem extremely important for trade policy.

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Appendix

Table A1: Wiod countries

Australia	Japan
Austria	Latvia
Belgium	Lithuania
Brazil	Luxembourg
Bulgaria	Malta
Canada	Mexico
China	Netherlands
Cyprus	Poland
Czech Republic	Portugal
Denmark	Romania
Estonia	Russia
Finland	Slovakia
France	Slovenia
Germany	South Korea
Greece	Spain
Hungary	Sweden
India	Taiwan
Indonesia	Turkey
Ireland	UK
Italy	USA

Notes. The table reports the list of countries included in the WIOD sample.

Table A2: WIOD industries

WIOD Code	Description	WIOD Code	Description
c01	Agriculture, Hunting, Forestry and Fishing	c19	Sale, Maint. and Repair of Motor V. Retail Sale of Fuel
c02	Mining and Quarrying	c20	Wholesale Trade and Commission Trade, Except of Motor V.
c03	Food, Beverages and Tobacco	c21	Retail Trade, Except of Motor Vehicles ; Repair of HH Goods
c04	Textiles and Textile Products	c22	Hotels and Restaurants
c05	Leather and Footwear	c23	Inland Transport
c06	Wood and Products of Wood and Cork	c24	Water Transport
c07	Pulp, Paper, Printing and Publishing	c25	Air Transport
c08	Coke, Refined Petroleum and Nuclear Fuel	c26	Other Supporting and Auxiliary Transport Activ.
c09	Chemicals and Chemical Products	c27	Post and Telecommunications
c10	Rubber and Plastics	c28	Financial Intermediation
c11	Other Non-Metallic Mineral	c29	Real Estate Activities
c12	Basic Metals and Fabricated Metal	c30	Renting of M&Eq and Other Business Activities
c13	Machinery, Nec	c31	Public Admin and Defence; Compulsory Social Sec.
c14	Electrical and Optical Equipment	c32	Education
c15	Transport Equipment	c33	Health and Social Work
c16	Manufacturing, Nec; Recycling	c34	Other Community, Social and Personal Services
c17	Electricity, Gas and Water Supply	c35	Private Households With Employed Persons
c18	Construction		

Notes. The table reports the list of industries included in the WIOD sample.

Table A3: Industry-level gravity - gross exports

Dependent Variable: ln(export)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Industry:	c03	c04	c05	c06	c07	c08	c09	c10	c11	c12	c13	c14	c15	c16
Partner DWPs * ln(MaxSize)	0.804	1.882***	2.967***	4.818***	1.421**	0.67	3.895***	1.679**	0.554	2.038***	1.341**	1.148	0.842	1.975**
	[0.678]	[0.730]	[0.897]	[0.806]	[0.695]	[1.182]	[0.641]	[0.673]	[0.749]	[0.665]	[0.628]	[0.727]	[0.918]	[0.778]
Distance	-1.763***	-1.602***	-1.651***	-1.838***	-1.912***	-2.309***	-1.533***	-1.656***	-1.646***	-1.750***	-1.381***	-1.327***	-1.564***	-1.425***
	[0.022]	[0.023]	[0.026]	[0.025]	[0.023]	[0.032]	[0.020]	[0.022]	[0.022]	[0.022]	[0.021]	[0.021]	[0.027]	[0.023]
Distance * Partner DWPs * ln(MaxSize)	0.007***	0.005***	0.005***	0.007***	0.006***	0.003***	0.005***	0.005***	0.007***	0.006***	0.004***	0.004***	0.003***	0.004***
	[0.000]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.000]	[0.001]	[0.000]	[0.000]	[0.000]	[0.000]	[0.001]	[0.001]
Contiguity	0.627***	0.261***	0.639***	0.587***	0.503***	0.749***	0.516***	0.603***	0.729***	0.414***	0.391***	0.385***	0.569***	0.635***
	[0.047]	[0.051]	[0.065]	[0.053]	[0.054]	[0.069]	[0.047]	[0.055]	[0.054]	[0.045]	[0.051]	[0.055]	[0.069]	[0.049]
Contiguity * Partner DWPs * ln(MaxSize)	0.004***	-0.004**	-0.004**	0.005**	0.000	-0.016***	-0.003*	-0.006***	-0.003***	-0.001	-0.004***	-0.003**	-0.005***	-0.007***
	[0.001]	[0.002]	[0.002]	[0.002]	[0.001]	[0.002]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.002]	[0.002]
Landlocked	-0.614***	-0.310***	-0.085	-0.667***	-0.022	-1.684***	-0.553***	0.145**	-0.141	-0.171***	-0.182***	0.084	-0.134	-0.105
	[0.091]	[0.090]	[0.098]	[0.112]	[0.083]	[0.117]	[0.084]	[0.073]	[0.086]	[0.064]	[0.069]	[0.078]	[0.108]	[0.065]
Landlocked * Partner DWPs * ln(MaxSize)	0.008***	-0.002	0.010***	0.003*	0.003***	-0.005***	-0.001	0.000	0.001	0.001	0.003***	0.007***	0.008***	0.000
	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.002]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.002]	[0.001]
Obs.	20,162	20,208	19,334	20,051	20,185	18,198	20,229	20,198	20,188	20,186	20,215	19,611	19,711	20,224
R2	0.81	0.79	0.79	0.81	0.81	0.74	0.82	0.83	0.82	0.84	0.85	0.83	0.82	0.83

Notes. The table reports estimates on selected coefficients from the industry-specific gravity regressions. These are estimated according to Equation 1, using gross exports as dependent variable. The column headers specify which industry is considered in each estimation. See Table A2 for the description of industries. Robust standard errors in brackets. ***, **, * indicate significance at the 1, 5 and 10% level, respectively.

Table A4: Industry-level gravity - DVA

Dependent Variable: ln(DVA)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Industry:	c03	c04	c05	c06	c07	c08	c09	c10	c11	c12	c13	c14	c15	c16
Partner DWPs * ln(MaxSize)	0.802	1.881***	2.944***	4.827***	1.422**	0.605	3.898***	1.681**	0.553	2.034***	1.334**	1.150	0.848	1.976**
	[0.678]	[0.727]	[0.895]	[0.804]	[0.695]	[1.179]	[0.643]	[0.672]	[0.749]	[0.665]	[0.627]	[0.719]	[0.917]	[0.777]
Distance	-1.762***	-1.594***	-1.647***	-1.831***	-1.906***	-2.302***	-1.524***	-1.648***	-1.641***	-1.740***	-1.376***	-1.319***	-1.558***	-1.422***
	[0.022]	[0.023]	[0.026]	[0.025]	[0.023]	[0.032]	[0.020]	[0.022]	[0.022]	[0.022]	[0.021]	[0.021]	[0.027]	[0.023]
Dist. * Part. DWPs * ln(MaxSize)	0.007***	0.005***	0.005***	0.007***	0.006***	0.003***	0.005***	0.005***	0.007***	0.007***	0.004***	0.004***	0.003***	0.004***
	[0.000]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.000]	[0.001]	[0.000]	[0.000]	[0.000]	[0.000]	[0.001]	[0.001]
Contiguity	0.623***	0.255***	0.639***	0.571***	0.489***	0.743***	0.501***	0.586***	0.719***	0.390***	0.383***	0.375***	0.557***	0.628***
	[0.047]	[0.051]	[0.065]	[0.053]	[0.054]	[0.068]	[0.047]	[0.055]	[0.054]	[0.045]	[0.051]	[0.054]	[0.069]	[0.049]
Cont. * Part. DWPs * ln(MaxSize)	0.004***	-0.004**	-0.004**	0.005**	-0.000	-0.016***	-0.003*	-0.006***	-0.003***	-0.001	-0.004***	-0.003*	-0.005***	-0.007***
	[0.001]	[0.002]	[0.002]	[0.002]	[0.001]	[0.002]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.002]	[0.002]
Landlocked	-0.614***	-0.315***	-0.087	-0.673***	-0.027	-1.685***	-0.561***	0.135*	-0.145*	-0.185***	-0.187***	0.077	-0.143	-0.108*
	[0.091]	[0.089]	[0.097]	[0.112]	[0.083]	[0.116]	[0.084]	[0.072]	[0.086]	[0.063]	[0.069]	[0.077]	[0.108]	[0.065]
Land. * Part. DWPs * ln(MaxSize)	0.008***	-0.001	0.010***	0.003**	0.004***	-0.005***	-0.001	0.000	0.001	0.001	0.003***	0.007***	0.008***	0.000
	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.002]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.002]	[0.001]
Obs.	20,162	20,208	19,334	20,051	20,185	18,198	20,229	20,198	20,188	20,186	20,215	19,611	19,711	20,224
R2	0.81	0.80	0.79	0.81	0.81	0.75	0.83	0.83	0.82	0.84	0.85	0.83	0.82	0.84

Notes. The table reports estimates on selected coefficients from the industry-specific gravity regressions. These are estimated according to Equation 1, using DVA as dependent variable. The column headers specify which industry is considered in each estimation. See Table A2 for the description of industries. Robust standard errors in brackets. ***, **, * indicate significance at the 1, 5 and 10% level, respectively.

Table A5: Industry-level gravity - RDV

Dependent Variable: ln(RDV)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Industry:	c03	c04	c05	c06	c07	c08	c09	c10	c11	c12	c13	c14	c15	c16
Partner DWPs * ln(MaxSize)	-0.508	1.920**	3.142***	2.952***	0.730	-1.625	2.943***	0.562	-0.854	1.672**	-0.970	0.258	-0.289	0.680
	[0.898]	[0.954]	[1.150]	[0.925]	[0.845]	[1.241]	[0.801]	[0.829]	[0.878]	[0.823]	[0.788]	[0.896]	[1.041]	[0.919]
Distance	-2.789***	-2.734***	-2.686***	-2.894***	-2.971***	-3.201***	-2.550***	-2.674***	-2.656***	-2.819***	-2.359***	-2.262***	-2.458***	-2.495***
	[0.028]	[0.029]	[0.032]	[0.028]	[0.028]	[0.035]	[0.026]	[0.027]	[0.026]	[0.028]	[0.026]	[0.026]	[0.033]	[0.028]
Dist. * Part. DWPs * ln(MaxSize)	0.009***	0.007***	0.008***	0.009***	0.009***	0.005***	0.007***	0.007***	0.009***	0.009***	0.006***	0.005***	0.004***	0.007***
	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]
Contiguity	1.233***	0.533***	0.923***	1.064***	0.967***	1.111***	1.017***	1.012***	1.205***	0.772***	0.830***	0.772***	0.970***	1.062***
	[0.067]	[0.069]	[0.081]	[0.066]	[0.074]	[0.079]	[0.066]	[0.076]	[0.073]	[0.065]	[0.070]	[0.075]	[0.086]	[0.067]
Cont. * Part. DWPs * ln(MaxSize)	0.002	-0.010***	-0.008***	0.003	-0.000	-0.019***	-0.006***	-0.008***	-0.004**	-0.003	-0.007***	-0.006***	-0.004	-0.011***
	[0.002]	[0.002]	[0.003]	[0.003]	[0.002]	[0.003]	[0.002]	[0.002]	[0.002]	[0.002]	[0.002]	[0.002]	[0.003]	[0.002]
Landlocked	-0.854***	-0.348***	-0.524***	-0.638***	-0.181	-1.942***	-0.638***	0.099	-0.336***	-0.236***	-0.373***	0.066	-0.271**	-0.210**
	[0.119]	[0.114]	[0.132]	[0.117]	[0.112]	[0.141]	[0.102]	[0.099]	[0.110]	[0.091]	[0.095]	[0.096]	[0.129]	[0.090]
Land. * Part. DWPs * ln(MaxSize)	0.006***	-0.001	0.009***	0.004**	0.006***	-0.005***	-0.000	0.002*	0.005***	0.003***	0.005***	0.009***	0.010***	-0.000
	[0.001]	[0.001]	[0.002]	[0.002]	[0.001]	[0.002]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.002]	[0.002]	[0.001]
Obs.	19,765	20,118	18,709	19,879	20,153	18,095	20,207	20,163	20,163	20,165	20,177	19,584	19,633	20,159
R2	0.85	0.86	0.82	0.86	0.87	0.82	0.89	0.88	0.88	0.89	0.90	0.88	0.88	0.88

Notes. The table reports estimates on selected coefficients from the industry-specific gravity regressions. These are estimated according to Equation 1, using RDV as dependent variable. The column headers specify which industry is considered in each estimation. See Table A2 for the description of industries. Robust standard errors in brackets. ***, **, * indicate significance at the 1, 5 and 10% level, respectively.

Table A6: Industry-level gravity - FVA

Dependent Variable: ln(FVA)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Industry:	c03	c04	c05	c06	c07	c08	c09	c10	c11	c12	c13	c14	c15	c16
Partner DWPs * ln(MaxSize)	0.785	2.029***	2.836***	5.019***	1.464**	1.426	4.448***	1.990***	0.911	2.155***	1.535**	1.336*	1.056	2.122***
	[0.698]	[0.755]	[0.898]	[0.810]	[0.694]	[1.199]	[0.642]	[0.669]	[0.761]	[0.641]	[0.641]	[0.733]	[0.935]	[0.800]
Distance	-1.785***	-1.584***	-1.643***	-1.813***	-1.887***	-2.318***	-1.521***	-1.639***	-1.640***	-1.692***	-1.381***	-1.309***	-1.574***	-1.419***
	[0.022]	[0.023]	[0.027]	[0.025]	[0.023]	[0.032]	[0.020]	[0.022]	[0.023]	[0.022]	[0.021]	[0.022]	[0.028]	[0.023]
Dist. * Part. DWPs * ln(MaxSize)	0.007***	0.004***	0.005***	0.006***	0.006***	0.003***	0.005***	0.005***	0.006***	0.006***	0.004***	0.004***	0.003***	0.004***
	[0.000]	[0.001]	[0.001]	[0.001]	[0.000]	[0.001]	[0.000]	[0.001]	[0.000]	[0.000]	[0.000]	[0.000]	[0.001]	[0.001]
Contiguity	0.630***	0.304***	0.684***	0.584***	0.515***	0.776***	0.506***	0.606***	0.732***	0.415***	0.387***	0.396***	0.567***	0.643***
	[0.048]	[0.052]	[0.066]	[0.053]	[0.054]	[0.070]	[0.047]	[0.055]	[0.055]	[0.044]	[0.052]	[0.055]	[0.070]	[0.050]
Cont. * Part. DWPs * ln(MaxSize)	0.004***	-0.004***	-0.005***	0.005**	0.001	-0.016***	-0.002*	-0.007***	-0.004***	-0.002**	-0.004***	-0.002	-0.005***	-0.007***
	[0.001]	[0.002]	[0.002]	[0.002]	[0.001]	[0.002]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.002]	[0.002]
Landlocked	-0.559***	-0.278***	-0.047	-0.649***	0.020	-1.670***	-0.589***	0.150**	-0.131	-0.146**	-0.156**	0.122	-0.123	-0.067
	[0.094]	[0.088]	[0.105]	[0.112]	[0.084]	[0.118]	[0.086]	[0.073]	[0.087]	[0.061]	[0.069]	[0.079]	[0.110]	[0.069]
Land. * Part. DWPs * ln(MaxSize)	0.009***	-0.001	0.010***	0.003**	0.004***	-0.006***	-0.001	0.000	0.001	0.001*	0.003***	0.006***	0.008***	0.001
	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.002]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.002]	[0.001]
Obs.	20,162	20,208	19,334	20,051	20,185	18,182	20,229	20,198	20,188	20,186	20,215	19,611	19,711	20,224
R2	0.80	0.78	0.78	0.80	0.80	0.74	0.81	0.82	0.81	0.83	0.83	0.82	0.82	0.82

Notes. The table reports estimates on selected coefficients from the industry-specific gravity regressions. These are estimated according to Equation 1, using FVA as dependent variable. The column headers specify which industry is considered in each estimation. See Table A2 for the description of industries. Robust standard errors in brackets. ***, **, * indicate significance at the 1, 5 and 10% level, respectively.

Table A7: Industry-level gravity - PDC

Dependent Variable: ln(PDC)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Industry:	c03	c04	c05	c06	c07	c08	c09	c10	c11	c12	c13	c14	c15	c16
Partner DWPs * ln(MaxSize)	0.608	1.336*	3.083***	3.475***	1.196*	-0.887	3.539***	1.020	-0.500	2.155***	-0.678	0.612	0.444	0.971
	[0.757]	[0.812]	[1.034]	[0.793]	[0.711]	[1.208]	[0.684]	[0.685]	[0.739]	[0.711]	[0.651]	[0.752]	[0.883]	[0.786]
Distance	-1.769***	-1.710***	-1.700***	-1.921***	-1.999***	-2.280***	-1.560***	-1.720***	-1.705***	-1.863***	-1.409***	-1.388***	-1.569***	-1.549***
	[0.023]	[0.023]	[0.027]	[0.023]	[0.023]	[0.032]	[0.021]	[0.020]	[0.020]	[0.022]	[0.020]	[0.021]	[0.025]	[0.021]
Dist. * Part. DWPs * ln(MaxSize)	0.006***	0.005***	0.006***	0.006***	0.006***	0.003***	0.005***	0.005***	0.007***	0.007***	0.005***	0.003***	0.003***	0.005***
	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.000]	[0.001]	[0.000]	[0.000]	[0.000]	[0.001]	[0.001]	[0.001]
Contiguity	0.638***	0.190***	0.505***	0.603***	0.487***	0.693***	0.609***	0.587***	0.741***	0.406***	0.436***	0.394***	0.551***	0.630***
	[0.048]	[0.051]	[0.064]	[0.052]	[0.054]	[0.068]	[0.046]	[0.055]	[0.053]	[0.047]	[0.051]	[0.056]	[0.066]	[0.050]
Cont. * Part. DWPs * ln(MaxSize)	0.001	-0.007***	-0.002	0.003	-0.001	-0.015***	-0.004***	-0.007***	-0.003***	-0.002	-0.005***	-0.006***	-0.004**	-0.010***
	[0.001]	[0.002]	[0.002]	[0.002]	[0.001]	[0.002]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.002]	[0.002]
Landlocked	-0.635***	-0.163*	-0.333***	-0.490***	-0.096	-1.634***	-0.482***	0.196***	-0.182**	-0.138**	-0.242***	0.105	-0.178	-0.072
	[0.088]	[0.099]	[0.111]	[0.106]	[0.085]	[0.116]	[0.079]	[0.074]	[0.087]	[0.068]	[0.070]	[0.079]	[0.112]	[0.065]
Land. * Part. DWPs * ln(MaxSize)	0.004***	-0.004***	0.010***	0.002	0.004***	-0.006***	-0.002**	-0.001	0.002*	0.000	0.003***	0.006***	0.007***	-0.002*
	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.002]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]
Obs.	19,765	20,118	18,709	19,879	20,153	18,095	20,207	20,163	20,163	20,165	20,177	19,584	19,633	20,159
R2	0.77	0.77	0.74	0.80	0.80	0.73	0.82	0.82	0.82	0.82	0.85	0.83	0.83	0.83

Notes. The table reports estimates on selected coefficients from the industry-specific gravity regressions. These are estimated according to Equation 1, using PDC as dependent variable. The column headers specify which industry is considered in each estimation. See Table A2 for the description of industries. Robust standard errors in brackets. ***, **, * indicate significance at the 1, 5 and 10% level, respectively.