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). First, we develop a new geography-based and time-varying instrument for export. This instrument exploits the transportation shock of the sharp increase (more than tripling) in the maximum size of container ships between 1995 and 2007. This shock has an asymmetric impact on different bilateral trade flows across countries. In particular, it raises exports relatively more towards countries that are more endowed with deep-water ports, as these are the only ones that can accommodate the new larger ships. We exploit this heterogeneity for identification, constructing the instrument for export in a gravity framework, in the spirit of Frankel and Romer (1999). Using WIOD data, we find that export 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 trade on income is crucially moderated by differences in the value added composition of exports. In particular, we find evidence of stronger export effects for countries that upgrade their positioning or improve their participation to GVCs more than others over time.

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1 Introduction

Assessing the causal impact of trade on growth is a relevant but notoriously difficult exercise, because of the endogeneity of trade. Countries whose income is higher for reasons that are not related to trade, in fact, may still engage in more trade. Since the seminal paper of Frankel and Romer (1999), the trade-growth relationship has been investigated through different instrumental variable strategies. 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 on different trade flows, depending on some geographic characteristics of country pairs (Feyrer, 2009; Pascali, 2017). However, none of the existing studies considers the increasing role of global value chains (GVCs). In fact, they exploit historical shocks for identification, 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. The implications of such phenomena for the trade-growth nexus have not been directly investigated so far. In this paper, we aim to shed light on this issue.

We make three contributions. First, we develop a new geography-based and time-varying instrument for trade encompassing the surge of GVCs. In order to do so, we exploit a recent transportation shock: the sharp increase in the maximum size of container ships, which has more than tripled between 1995 and 2007. The new larger ships available have been widely adopted, leading to a rapid growth in the average capacity of the world container ships fleet. This 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 can only enter such ports, which are unevenly distributed across countries. Exploiting this source of identification, we obtain a novel instrument for exports by estimating gravity equations, in the spirit of Frankel and Romer (1999), and in line with more recent studies by Pascali (2017) and Feyrer (2009).

Second, we use this new instrument to show that export has a positive effect on GDP per capita, both in levels (with an elasticity of about 0.35) and in growth terms. Evidence at the country and industry level suggests that this effect works through both the productivity and the capital deepening channels, as we detect a positive effect of export on both value added and capital per worker. 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. In particular, we find evidence of stronger export effects for those countries that upgrade their positioning or improve their participation to GVCs more than others over time.

Our analysis covers the 40 countries included in the 2013 Release of the World Input-Output Database (WIOD), which is our data source for export flows, as well as for value added and capital per worker at the industry level.[1] The countries in the WIOD sample jointly account for more than 85% of global trade (Timmer et al., 2015). Our analysis spans the period 1995-2007, which covers the rapid expansion of global value chains before the financial crisis. Key for our identification exercise, over the same period the maximum size of container ships has more than tripled, from about 5,000 to 15,500

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

TEU.[2] At the same time, the average capacity of the container ships fleet has also increased by 60% at the global level, moving from about 1,500 to around 2,400 TEU (UNCTAD). 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). Moreover, improvements in containerized trade have been pivotal for the expansion of global value chains, whose implications are investigated in our analysis (Bernhofen et al., 2016; Memedovic et al., 2008). This makes our identification strategy particularly suitable for the research question that we address.

As a result of the change in transportation technology, a restricted group of deep-water ports has become increasingly central for global trade, as these ports are the only ones that can accommodate the new larger ships. In our sample of countries, we have identified a total of 47 deep-water ports with a container terminal where all the new ships can operate. Their identification has not been trivial, due to lack of ready-to-use data sources. In particular, we had to collect information on water depth (and other characteristics) for more than 3,500 ports, by performing a detailed text analysis of 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 for each port.

Our identification strategy hinges on the fact that the same transportation shock has an asymmetric impact on different trade flows, depending on the uneven presence of deep-water ports across countries. In particular, we construct our instrument by predicting exports from gravity equations that include an interaction term between the time-varying maximum size of container ships available in the market, and the number of deep-water ports in each partner country. The basic intuition is that, as larger ships become available, countries start exporting relatively more towards partner countries

[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.

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. Indeed, 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 other channels as well, for instance by stimulating more domestic investment in infrastructures.

The number of deep-water ports in each country does not change over time in the sample, and thus is akin to a time-invariant geographic characteristic. Indeed, according to our port data, it is only after 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).[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. And yet, one could still worry that countries may invest in artificially creating DWPs when they expect higher growth in the countries they are importing from, thus leading to endogeneity. In any case, this is not happening over our period of analysis, for which the number of deep-water ports in each country is fixed and essentially driven by the geographic characteristics of the coast.

Another possible concern 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 projected, launched, and widely adopted in the shipping

[3]There is only one port in our sample of 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.

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– were driving technological change in transportation, one could worry about the endogeneity of the transportation shock in our analysis. For this reason, we *only* exploit variation across bilateral trade flows within each year for identification. 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, to industry characteristics, and to other features of country pairs such as bilateral distance.

More specifically, we construct our instrument by estimating gravity equations based on bilateral export flows at the industry level. We employ two different specifications for the gravity model. The first one is based on Frankel and Romer (1999) and includes the population of both exporting and importing countries, the standard dyadic controls (distance, contiguity and landlockedness), as well as fixed effects for exporting country, partner country, and years. As compared to Frankel and Romer (1999), this specification is augmented with the interaction between the maximum size of container ships operating in a given year, and the number of DWPs in the destination country (normalized by the length of the coastal line). This interaction term is itself also interacted with the other controls, e.g. distance. 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 trade, and less relevant for exports between contiguous countries. Indeed, Coşar and Demir (2017) find containerized trade to be more cost-effective at longer distances. Moreover, estimating the gravity equations at the industry level takes into account the fact that containerized trade might be more important in some industries than in others (Bernhofen et al., 2016).

In our second specification of the gravity model, we include exporter-year and importer-year fixed effects, so as to properly account for the multilateral resistance terms as in Anderson and van Wincoop (2003). This clearly entails dropping not only the population variables, but also the main interaction term between ship size and DWPs, which varies only by partner country and year. As a result, in this conservative approach our main source of identification is only exploited through the interactions with the dyadic controls: distance, contiguity, and landlockedness. All the results in the paper are robust to constructing the instrument based on this alternative specification.

Endowed with the industry-specific gravity estimates, we obtain the instrument for export by aggregating predicted exports either at the country level or at the country-industry level, depending on the equation to be estimated. First, at the country level, we regress GDP per capita over export, in (log) levels, finding a positive elasticity of about 0.35. At the same time, our predicted trade appears to be a powerful predictor of actual trade, with a positive and significant first-stage coefficient. This initial result is submitted to a number of robustness and sensitivity checks, dealing with the identification of DWPs, the specification of the gravity, as well as remaining endogeneity concerns.

Second, using data both at the country and industry level, we show that export has a positive effect on both value added and capital per worker, pointing to growth effects over time. We then estimate growth specifications, where we regress the growth in GDP per capita over lagged export growth. We find positive and significant effects regardless of the number of years over which growth is assessed, from one to five. If anything, our results seem to suggest that the effect builds up over four years and stabilizes at five.

Next, in the second part of the paper, we focus on the role of global value chains. In particular, we explore whether differences in the value added composition of gross exports have any moderating effects on the identified relation between trade and income. To this purpose, we employ the methodology developed by Wang et al. (2013) for decomposing gross export flows.[4] This methodology allows for an exact decomposition of each bilateral export flow, at the industry level, into several value added components, the main ones being: domestic value added; foreign value added; returned domestic value added; and pure double counting.[5] In turn, the different components allow to compute indicators capturing the degree of participation and the positioning of countries within global value chains.

First, we investigate whether there is a lower elasticity between export and income when a country's export embodies a larger share of foreign value added, as the latter does not directly contribute to the GDP of the exporting country. We do this by augmenting our baseline regression of GDP per capita against export with a variable capturing the so-called vertical specialization share (VS share), i.e. the overall share of foreign value added embodied in gross exports (Hummels et al., 2001). Consistent with what one could expect, we do find some evidence of a lower trade elasticity for those countries witnessing a larger than average growth in the foreign share over the sample. However, for given change in VS share, we also find that the participation and the positioning of a country within global value chains plays an important role in moderating the effect of trade on income. In particular, there is an elasticity premium for countries that improve their participation or upgrade their positioning in GVCs more than others over time. We measure participation as the share of foreign value added accounted for by pure double counting, as suggested by Wang et al. (2013). Positioning is instead proxied in two ways: either through the share of foreign value added embodied in intermediate inputs (Wang et al., 2013), or through the *upstreamness* measure developed by Antràs and Chor (2013),

[4]We are very grateful to Zhi Wang, Shang-Jin Wei, and Kunfu Zhu for having shared their data on the exports' decomposition with us.

[5]See *infra* for a complete explanation.

which reflects distance of production from final consumption. Our results shed the first light on the role of global value chains in moderating the effect of trade on income. We regard this issue as being key for today's trade policy.

The remaining of the paper is organized as follows. Section 2 reviews the related literature. Section 3 presents the identification strategy. Section 4 describes the gravity estimations and the computation of the instrument. Section 5 presents the main results on trade and growth, while Section 6 discusses the role of global value chains. Finally, Section 7 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 characteristics 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).[6]

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, 2009, and Pascali,

[6] 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.

2017).[7] 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 differentiated impact on different countries, due to some exogenous geographic characteristics.

Specifically, Feyrer (2009) 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 surge of GVCs, whose expansion accelerated in the mid 90s. Moreover, they rely solely on gross exports data, which do not 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 (2009). However, we rely on a more recent shock to transportation technology, which is concomitant to the expansion of global value chains, and pivotal for their development. This allows us to investigate the role of GVCs in moderating the relationship between trade and growth.

Our work is related to the growing empirical literature on GVCs. From the methodological point of view, a number of contributions 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

[7] 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 a transportation shock.

Mancini, 2015; de Gortari, 2017). Other papers have developed indicators of participation and positioning of countries and industries within global value chains (Antràs et al., 2012; Fally, 2012; Antràs and Chor, 2013; Antràs and de Gortari, 2017; Antràs and Chor, 2018; Alfaro et al., 2018). We capitalize on these studies for assessing the implications of differences in the GVC-performance of countries on the causal link between trade and growth.

A number of papers have exploited the decomposition by Koopman et al. (2014) for studying the evolution of value-added exports over the recent financial crisis (e.g., Nagengast and Stehrer, 2015). Some recent studies focus on the role of GVCs with respect to the synchronization of business cycles across countries (Johnson, 2014b; Wang et al., 2017). Johnson and Noguera (2017) use data for the period 1970-2009 to show how the value added share of gross exports has been declining over time in manufacturing, as production processes were disintegrated across borders. Our paper contributes to this literature by investigating the role of global value chains in moderating the effect of exports on income.

3 Identification strategy

3.1 Container ships and deep-water ports

Containers started to be used for commerce in the US during the mid 1950s, in parallel with the introduction of container ships. This was a game changer for the transportation industry and for international trade. In fact, before containers, goods were only transported by breakbulk shipping, with limited possibilities for automation in cargo handling. As a result, a large part of the shipping time was spent in ports, waiting for ships to be loaded and unloaded. Containers improved dramatically the efficiency of sea-transportation, shortening the time spent into port facilities, and allowing for smoother connections with intermodal inland transport, with further reductions in overall shipping costs.

The international standardization of containers 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.[8] The diffusion of containerized trade had a large positive impact on international trade. In particular, Bernhofen et al. (2016) 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 years.

More recently, 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. Indeed, TEU stands for Twenty-foot Equivalent Unit, based on the volume of an internationally standardized container.[9] 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 adopted by market operators.

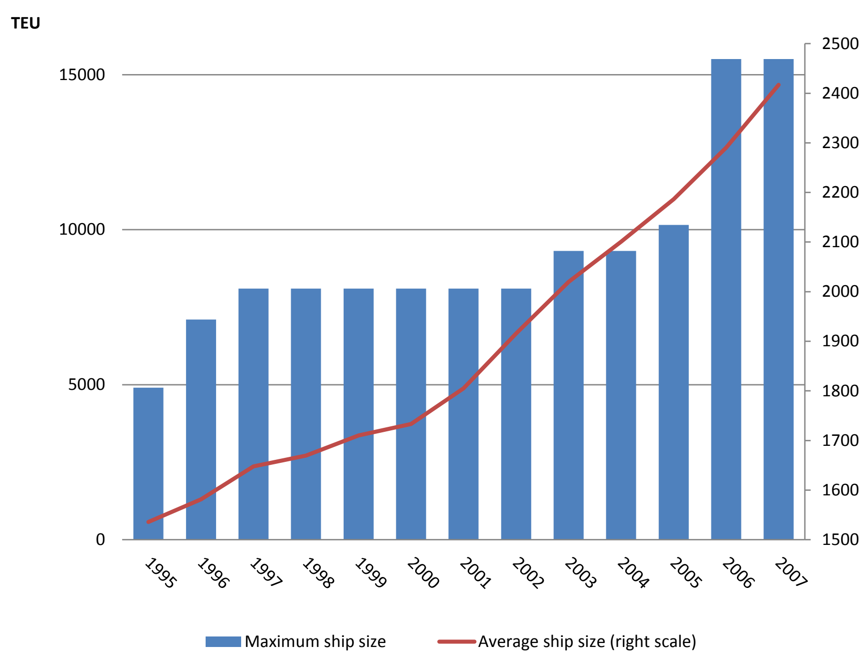
The introduction and the adoption of the new container ships were essentially related to the existence of economies of scale in shipping. To give an idea, according

[8]The remaining 35 countries were mostly developing economies, none of which appears in our sample.

[9]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.

to OECD estimates, an increase in capacity from 5,000 to 15,000 TEU reduces annual operation costs per TEU by almost 43%, from around 700$ to 400$ (OECD, 2015). As these 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 (1995-2007) also coincides with the rapid expansion of GVCs before the financial crisis.

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



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 trade flows, as driven by the uneven presence of deep-water ports across countries. The underlying idea is very simple: bigger ships have bigger 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 relatively more endowed with deep-water ports.

More specifically, before 1994, ports with at least 12.5 meters of depth could accommodate any container ships, as the "maximum draft" of container 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, as reported in Table 1, and the maximum draft has increased from 12 to 15.5 meters. 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 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.

[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.

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. Indeed, 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.

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

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. We have focused on the group of 3,528 ports that are located in the 40 countries covered by the WIOD dataset. For each of these ports, we have gathered information on: (1) whether or not they are commercial ports; (2) their water depth; and (3) 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 website of each individual port has been consulted.

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 trivial. 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 to identify a port as endowed with a container terminal, it is not enough to know that a 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 for each port.

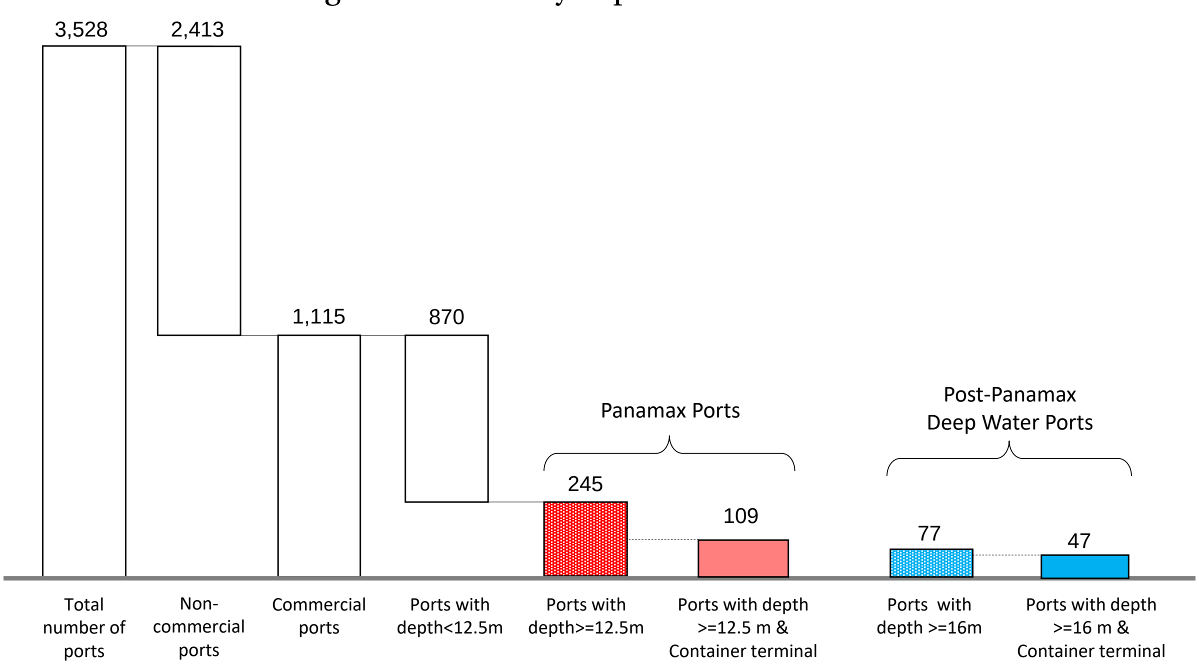
Figure 2 summarizes the information on ports in the WIOD countries over the sample period: 1995-2007. Out of a total of 3,528 ports, we first identify 1,115 commercial ports. Of these, 870 have water depth lower than 12.5 meters, which implies they could not even accommodate all the *Panamax* ships operating 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 ter-

[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.

minal, but with water depth between 12.5 and 16 meters, lose progressively relevance as bigger ships start operating. 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 expression 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.

Table 2 reports the distribution of the 47 DWPs with container terminal across the 40 WIOD countries: 19 countries have at least one; 16 countries have access to the sea but do not have any port in the group; 5 countries are landlocked. This heterogeneity is key for identification purposes. 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 deep-water ports is akin to a time-invariant geographic characteristic in our analysis.

Figure 2: Summary of ports in WIOD countries



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

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

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

3.2 Identification

Our main goal is estimating a regression of 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 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 (2009). 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 –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 the coastal line). This interaction term captures the basic intuition behind our identification strategy: the introduction of new larger ships reduces transportation costs and boosts trade 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: population, 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 be higher for longer-distance shipping (Coşar and Demir, 2017). On top of that, we also run separate gravity estimations for each industry, as 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. There are some possible concerns with the exclusion restriction underlying our

IV strategy. We discuss them in the remaining of this section.

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. Reassuringly, 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. However, the presence of DPWs in a country could also affect its GDP growth through channels other than trade, for instance by stimulating more domestic investment in general, especially in a time period where DWPs are becoming more relevant for the global economy. For these reasons, we employ *only* the number of deep-water ports in the partner countries where the domestic country is exporting, and we do not consider the ports located in the exporting country itself.

Still, one could worry that partner countries might invest in creating new deep-water ports, 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 only on the 47 deep-water ports that are operational throughout the time-period 1995-2007. As a matter of fact, 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)[12], and following the expansion of the Panama Canal locks, which started in 2009 and was completed in 2016.[13] 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.

There is only one port 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.

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 improvements, but also to positive expectations on the utilization of ship capacity in the future (Sys et al., 2008). These expectations, in turn, are related to encouraging forecasts on countries' trade growth, and relatedly GDP growth. As a matter of fact, international trade benefits from lower shipping costs thanks to larger container ships. Yet, at the same time, surging global trade is important for the exploitation of the economies of scale made possible by the same larger container ships. Hence the endogeneity concern.

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

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

[13]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.

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 always show results based on instruments coming from 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 the multilateral resistance terms: exporter-year and importer-year fixed effects. 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. Our results are robust across the board, even if we exclude the estimated fixed effects from the computation of predicted exports, i.e. the instruments.

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 commonly thought to be largely 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 slightly different. Indeed, these two countries are characterized by large shipping and shipbuilding industries relative to their GDP. 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 income regressions include year and country fixed effects, which are meant to soak up any specific characteristics of countries, such as the ones just discussed.

4 Computation of the instrument

4.1 Gravity specifications and data

In order to compute the instrument, we estimate gravity equations based on export flows at the industry level. Data are sourced from the 2013 Release of the World Input Output Database (WIOD). The sample includes 40 countries that jointly account for more than 85% of global trade (Timmer et al., 2015). The full list is available 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 industries c03-c16 of Table A2. Nevertheless, we also present additional results based on total trade figures.

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

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

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. Data for all these variables are sourced from the CEPII database (Head et al., 2010). 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. Our approach is in line with the most recent studies by Pascali (2017) and Feyrer (2009), which also exploit the asymmetric implications of changes in transportation technology across different trade flows.

$DWP_j * \ln MaxSize_t$ 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. The intuition is that, as the maximum size of container ships grows over time, exports increase relatively more towards partner countries that are more endowed with deep-water ports where bigger ships can operate.

$Z_{ij,t}$ 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, for instance, on bilateral distance. In fact, it has been shown that containerized trade by sea is more cost-effective for long distance trade (Coşar and Demir, 2017), while it is intuitively less relevant for trade between contiguous countries. Moreover, it is important to notice that estimating the gravity equation separately for each industry, as we do, takes into account the fact that containerized trade –and thus the impact of container ships– might vary in relevance across different industries, due to their technological characteristics (Bernhofen et al., 2016).

Endowed with the industry-specific gravity estimates, 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:

$$Instrument_{i,t} = \sum_j \sum_z (\widehat{Export}_{ijz,t}). \tag{2}$$

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:

$$Instrument_{iz,t} = \sum_{j} (\widehat{Export}_{ijz,t}). \tag{3}$$

These two different aggregations are suggestive of the inherent 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. The versatile character of our IV strategy makes it suitable for the investigation of a variety of research questions in future work.

The second specification of the gravity is as follows:

$$\begin{aligned} \ln Export_{ijz,t} = \beta_{z0} + \beta_{z1} \ln Distance_{ij} + \beta_{z2} Contiguity_{ij} + \beta_{z3} Landlocked_{ij} \\ + W_{ij,t}\delta'_z + \alpha_{zi,t} + \alpha_{zj,t} + \epsilon_{ijz,t} \end{aligned} \tag{4}$$

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 the 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.

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. This is a very conservative choice. Yet, all the results in the paper are robust to using the instruments obtained from this alternative specification of the gravity. Notably, the effect of export on income is also robust to excluding the estimated MRTs from the computation of the instrument, as one could worry about their endogeneity with respect to GDP, despite the fact that the income regressions always include both country and year fixed effects.

4.2 Gravity results

Table 3 reports summary statistics on gravity estimates according to 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 bigger 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. 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 oil is not shipped through containers. All the industry-specific results are available in Table A3 of the Appendix. For ease of exposition, in the first row of Table 3 we report only the average and median estimated coefficients across industries, at columns 1 and 2, respectively.

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 coefficient in column 1 (1.86) implies that one extra deep-water port 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. If we take the average of $\ln MaxSize_t$, which is 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 impact 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.

It is important to consider that not all the exports attracted by deep-water ports are bound to stay within the countries hosting the ports. Part of these exports might be re-exported to other countries via sea or land transportation. To make a notable example,

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

the Netherlands –a relatively small country, with 1,914 Kms of coastline– hosts one of the most important entry points for European imports: the deep-water port of Rotterdam. A large share of imports arriving there does not have the Netherlands as a final destination market. For instance, lots of manufacturing goods are shipped from the US and Asia to Rotterdam and then transferred to other countries of Europe. According to estimates by the Central Statistical Office of the Netherlands, re-exports accounted for around 44% of total Dutch imports and exports in 2016. Even more tellingly, re-exports were responsible for 73% of the Dutch trade surplus with respect to other European countries (CBS, 2016).[14] This shows how, as larger container ships are introduced, and the importance of containerized trade increases, deep-water ports tend to become prominent hubs, through which more goods flow in and out of the hosting countries.

From the data point of view, suppose that an Italian company in Milan buys one container of goods from a Chinese supplier in Shanghai; the container is first transported by ship from the deep-water port of Shanghai to the one of Rotterdam, and then by truck to

[14]Full information is available at this link: https://www.cbs.nl/en-gb/news/2017/18/trade-surplus-excluding-re-exports-20-billion-lower

Milan. In the international trade statistics –and therefore in the WIOD data that we use– this transaction will generate two trade flows: one from China to the Netherlands, and a second one from the Netherlands to Italy. A phenomenon known as the "Rotterdam effect" in European trade statistics. This is a simple example of one important way through which the presence of DWPs can increase exports towards the hosting countries.

The fact that not all of the exports flowing through DWPs are absorbed by the national markets of the hosting countries is not problematic for our identification strategy. As a matter of fact, we are not investigating the effect of imports in the importing country. To the contrary, we study the effect of exports in the exporting country. We use the presence of deep-water ports, combined with the transportation shock, only as an exogenous source of variation in export flows across partner countries. As far as the instrument is concerned, it does not matter whether exported goods are going to be re-exported or not. Our identification strategy relies on the fact that: (1) the introduction of new larger container ships allows for economies of scale and thus reduces transportation costs; and (2) this increases trade in general, but especially towards partner countries that are more endowed with DWPs where larger container ships can operate, no matter if these partner countries are the final absorbers of traded goods or not.

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 ports with water depth of at least 16 meters, as presented in Table 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 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. 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 corroborates 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 results 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 exports of services. 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 only 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 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. Very plausibly, the positive interaction might be driven by landlocked countries exporting progressively more towards partner countries that are more endowed with deep-water ports. In fact, as the maximum size of container ships grows over time, these partners become more important as mediators for the exports of landlocked countries to the rest of the world. For example, in line with the previous discussion on the role played by Rotterdam, Austria –a landlocked country in the center of Europe– may start exporting more towards the Netherlands over time, to exploit the deep-water port of Rotterdam as a hub for its extra-EU exports. This type of dynamics would explain why the transportation shock, combined with the presence of DWPs, reduces the negative impact of landlockedness on trade.

5 Trade and income

5.1 Baseline results

To investigate the impact of export on income, in line with Feyrer (2009) we estimate 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 towards all the partner countries; while α_i and α_t are country and year fixed effects, respectively.

Table 4 reports the baseline estimates of Equation 5. Specifically, column 1 shows the OLS estimate, while columns 2 and 3 contain the 2SLS results. In column 2, the instrument is computed by aggregating the industry-level predicted exports from the first specification of the gravity model (Eq. 1), which does not include the country-year fixed effects, i.e., the multilateral resistance terms (MRTs). In column 3, we instead employ as instrument the predicted trade from the second specification of the gravity model (Eq. 4), which does include the country-year effects. In both cases, the first-stage coefficient on the instrument is positive and statistically different from zero, 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.

In terms of magnitudes, the IV coefficients suggest that a one percent increase in export leads to higher GDP per capita by around 0.32-0.35 percent. This effect is slightly lower than the one estimated by Feyrer (2009) over the period 1960-1995, i.e., 0.5. While comparing coefficients across different empirical studies is inherently problematic, a lower elasticity between trade and income between 1995 and 2007 might be consistent with the contemporaneous decrease in the domestic value added contribution to exports. This pattern has in fact been documented by recent studies as a result of the expansion of global value chains (see, for instance, Johnson and Noguera, 2017). We provide evidence consistent with this idea in the next section of the paper, where we investigate how differences in the value added composition of exports moderate the relation between trade and income.

The estimated elasticity between export and GDP per capita is somewhat higher in the IV estimates of columns 2 and 3 than in the OLS estimate of column 1. 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 estimates is related to measurement error. Indeed, 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).

5.2 Robustness

In Table 5, we submit our baseline findings to several robustness and sensitivity checks. We start by discussing the results in panel a), where we focus on IV regressions in which the instrument is obtained from the gravity without country-year fixed effects. All the reported coefficients refer to the export variable. To ease comparisons, row 1 replicates the baseline estimate of column 2 in Table 4.

First, we 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 2, when computing DWP_j we employ the plain number of deep-water ports in partner countries, without

Table 4: Income regressions: baseline

Dependent Variable: ln(GDP p.c.)	(1)	(2)	(3)
IV based on gravity:		Without MRTs	With MRTs
Export	0.270***	0.347***	0.321***
	[0.051]	[0.061]	[0.029]
Estimator	OLS	2SLS	2SLS
Country effects	yes	yes	yes
Year effects	yes	yes	yes
Obs.	507	507	507
R2	0.82	-	-
First-stage results			
Predicted trade flows from gravity	-	0.631***	0.592***
	-	[0.091]	[0.025]
Kleibergen-Paap F-Statistic	-	48.34	569.5

***, **, * = indicate significance at the 1, 5 and 10% level, respectively.

dividing by the number of kilometers of coastline. Reassuringly, the estimated export elasticity is virtually unchanged. In row 3, we do normalize the number of ports by the length of the coastline, as in the baseline regression, but we expand the set of deep-water ports 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, Manzanillo is the only port where water depth has increased above 16 meters over the sample, 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.

Next, one could be concerned that the presence of DWPs in the exporting country is key for our identification strategy. That is, countries may not really benefit from the introduction of larger container ships unless they host deep-water ports within their 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, e.g., higher investment in infrastructure. Yet, one could worry that this omission might lead to a suboptimal exploitation of the identification shock. In row 4, we then use as instrument the predicted trade 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 $DWP_j * \ln MaxSize_t$ and its interactions, we also include $DWP_i * \ln MaxSize_t$ plus interactions, where DWP_i is the number of deep-water ports in the exporting country. The coefficient of export is very close to the baseline, suggesting that our conservative choice to leave out the potentially endogenous domestic ports has no significant implications for the main finding. Still, to make sure that our results are not only driven by exporting countries endowed with DWPs, in row 5 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 4.2 when commenting on the gravity coefficients.

As already anticipated, a possible concern with our identification strategy is that the increase in the size of container ships over time is endogenous to GDP growth. Indeed, besides technical feasibility issues that are overcome from the engineering point of view, larger container ships are also introduced and adopted in the market in the expectation of rising trade volumes, which ensure adequate capacity utilization and thus the exploitation of economies of scale (Sys et al., 2008). 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– one could worry about the endogeneity of the transportation shock. 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 6 and 7 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. Specifically, in row 6 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 7, 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, they could have an impact on GDP in these countries via channels other than trade, thus raising endogeneity concerns. Both in row 6 and in row 7 our results are essentially unchanged as compared to the baseline evidence.

In row 8, we regress GDP per capita over total exports at the country level, thus including also trade in services, as well as in agriculture and mining. The elasticity of income to trade is somewhat higher in this case as compared to the baseline. This is suggestive of a further income-enhancing effect of non-manufacturing exports. We refrain from drawing stronger conclusions from this evidence given the nature of our identification strategy, which fits manufacturing better than other sectors.

Next, we perform two additional robustness checks on the gravity estimations. In particular, in row 9 the instrument is obtained by estimating the baseline gravity model with the two-step procedure developed by Helpman et al. (2008). This accounts for the

Table 5: Income regressions: robustness

Dependent Variable: GDP p.c.	Coeff.	Std. Err.	Obs.	KP F-Stat.
a) IV based on gravity without MRTs				
1) Baseline	0.347***	[0.061]	507	48.34
2) Plain number of DWPs	0.346***	[0.061]	507	48.34
3) Including 4 additional DWPs	0.347***	[0.062]	507	47.76
4) Including exporter DWPs	0.356***	[0.059]	507	49.01
5) Only countries with no domestic DWPs	0.382***	[0.018]	273	888.0
6) Excluding China	0.366***	[0.055]	494	57.34
7) Excluding Denmark and South Korea	0.353***	[0.060]	481	54.40
8) Considering total exports	0.559***	[0.112]	507	17.11
9) Helpman, Melitz, Rubinstein (2008)	0.312***	[0.063]	507	35.16
10) Gravity based on aggregate data	0.473***	[0.068]	507	72.19
b) IV based on gravity with MRTs				
11) Baseline	0.321***	[0.029]	507	569.5
12) Plain number of DWPs	0.316***	[0.029]	507	571.5
13) Including 4 additional DWPs	0.321***	[0.029]	507	568.5
14) Including exporter DWPs	0.321***	[0.029]	507	570.7
15) Only countries with no domestic DWPs	0.353***	[0.018]	273	1227
16) Excluding China	0.283***	[0.029]	494	580.5
17) Excluding Denmark and South Korea	0.317***	[0.030]	481	536.1
18) Considering total exports	0.361***	[0.031]	507	862.3
19) Helpman, Melitz, Rubinstein (2008)	0.196***	[0.026]	507	726.8
20) Gravity based on aggregate data	0.298***	[0.027]	507	781.2
21) Excluding fixed effects from IV computation	0.345***	[0.073]	507	16.39
22) PPML estimator	0.388***	[0.071]	507	31.21

***, **, * = indicate significance at the 1, 5 and 10% level, respectively.

presence of zero trade flows at the industry level, for some pairs of countries in some years. Specifically, we use common language as the variable entering the selection equation, as also suggested by Helpman et al. (2008). The export coefficient that we obtain is close to the baseline. Finally, to construct the instrument used in row 10 we estimate the gravity equation 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. In this case we obtain a slightly higher export elasticity. By and large, this body of evidence suggests that our baseline specification delivers a conservative estimate of the effect of trade on income.

In panel b) of Table 5, we focus on income regressions where the instrument is obtained by estimating gravity specifications which include country-year effects. This is a conservative choice from the identification point of view. In fact, as can be seen in Equation 4, the inclusion of the multilateral resistance terms entails dropping from the specification the main term capturing the role of the transportation shock: $DWP_j * \ln MaxSize_t$. For ease of exposition, row 11 replicates the baseline estimate, as in column 3 of Table 4. In rows 12-20, we then replicate exactly the same robustness checks of rows 2-10 of Table 5. Also in this case, results are robust across the board. In particular, the estimated coefficient on export remains always very close to the baseline estimate of row 11, with the only exception of row 19, where we get a somewhat lower export elasticity.

A possible concern with the instrument obtained from the gravity specification including the multilateral resistance terms is that these country-year fixed effects might be endogenous to income. Hence, their inclusion in the computation of predicted exports would invalidate the instrument. To deal with this concern, in row 21 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-year and partner-year specific factors. Such residual variation is determined by the bilateral controls –distance, contiguity, landlocked– and, crucially, by their interactions with $DWP_j * \ln MaxSize_t$. Reassuringly, in row 21 we still obtain an estimate of the export coefficient that is very close to the baseline. Moreover, while the F-statistic is unsurprisingly lower than the baseline, it is still comfortably high. This evidence can further assuage doubts on the validity of our identification strategy.

As a final robustness check, on top of excluding the MRTs from the instrument, in row 22 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.

5.3 Channels and growth

In Tables 6 and 7 we provide evidence on some of the mechanisms through which trade might affect income. Specifically, we focus on two traditional channels emphasized by earlier literature: labor productivity growth and capital deepening. The empirical specification is the same as for the income regressions (Equation 5). Labor productivity is proxied by value added per worker, while information on capital per worker is used to investigate capital deepening. Data on both 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 3, by aggregating predicted export flows separately for each industry in each country.

Table 6 reports our findings on labor productivity. Columns 1-3 refer to country-level regressions, while columns 4-6 contain the industry-level estimates, hence the increase in the number of observations. For each group of regressions: the first column contains the OLS estimates; the second column shows IV results based on gravity estimates excluding the multilateral resistance terms; while the IV regression in the third column employs the instrument from gravity estimates including MRTs. The estimated coefficient of export is almost always positive and statistically different from zero. This suggests that export has a positive effect on labor productivity, both at the industry level and on aggregate. This evidence is in line with a large literature that has shed light on the positive link between trade and productivity.

Table 7 presents the results on capital per worker. The structure of the table is the same as in Table 6. The coefficient of export is positive and significant in all the IV regressions, pointing to a positive effect of trade on capital deepening. Interestingly, the estimated elasticity of capital per worker to export is somewhat higher at the country level than at the industry level. This result is consistent with potential positive spillovers across industries. These are best captured when focusing on aggregate investment at the country level, where we also consider capital investment outside of manufacturing.

The identified positive effects of export on labor productivity and capital per worker are suggestive of growth effects induced by trade over time. To explore this issue further, in Table 8 we regress GDP per capita growth over lagged export growth, at the country level. We measure growth by computing log differences over different time intervals, from one to five years. Lags 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 results from three regressions: (1) OLS; (2) IV with instrument obtained from the gravity without multilateral resistance terms; (3) IV from the gravity including MRTs. The estimated coefficient of export growth is always positive and statistically different from zero. The estimated effect of trade on growth increases as we consider longer time periods, from one to four years, while it seems to stabilize at five.

Table 6: Channels: labor productivity

Dep. Variable: ln(VA per worker)	(1)	(2)	(3)	(4)	(5)	(6)
Level of analysis:	Country-level			Industry-level		
IV based on gravity:		Without MRTs	With MRTs		Without MRTs	With MRTs
Export	0.559***	0.260	0.567***	0.258***	0.443***	0.314***
	[0.194]	[0.271]	[0.116]	[0.044]	[0.047]	[0.027]
Estimator	OLS	2SLS	2SLS	OLS	2SLS	2SLS
Country effects	yes	yes	yes	no	no	no
Country-Industry effects	no	no	no	yes	yes	yes
Year effects	yes	yes	yes	yes	yes	yes
Obs.	507	507	507	7,032	7,032	7,032
R2	0.52	-	-	0.45	-	-
Kleibergen-Paap F-Statistic		56.02	565.2		707.7	1,536

***, **, * = indicate significance at the 1, 5 and 10% level, respectively.

Table 7: Channels: capital deepening

Dep. Variable: ln(Capital per worker)	(1)	(2)	(3)	(4)	(5)	(6)
Level of analysis:	Country-level			Industry-level		
IV based on gravity:		Without MRTs	With MRTs		Without MRTs	With MRTs
Gross exports	0.108*	0.311***	0.129***	0.032	0.095***	0.102***
	[0.062]	[0.076]	[0.037]	[0.035]	[0.028]	[0.023]
Estimator	OLS	2SLS	2SLS	OLS	2SLS	2SLS
Country effects	yes	yes	yes	no	no	no
Country-Industry effects	no	no	no	yes	yes	yes
Year effects	yes	yes	yes	yes	yes	yes
Obs.	507	507	507	7,032	7,032	7,032
R2	0.48	-	-	0.37	-	-
Kleibergen-Paap F-Statistic		56.02	565.2		707.7	1,536

***, **, * = indicate significance at the 1, 5 and 10% level, respectively.

Table 8: Growth regressions

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Dependent Variable:	GDP p.c. growth over 1 year			GDP p.c. growth over 2 years			GDP p.c. growth over 3 years			GDP p.c. growth over 4 years			GDP p.c. growth over 5 years		
IV based on gravity:		Without MRTs	With MRTs		Without MRTs	With MRTs		Without MRTs	With MRTs		Without MRTs	With MRTs		Without MRTs	With MRTs
Export growth over 1 year (lag)	0.069***	0.066***	0.088***												
	[0.013]	[0.019]	[0.019]												
Export growth over 2 years (lag)				0.103***	0.123***	0.129***									
				[0.017]	[0.023]	[0.022]									
Export growth over 3 years (lag)							0.142***	0.204***	0.173***						
							[0.024]	[0.036]	[0.032]						
Export growth over 4 years (lag)										0.174***	0.345***	0.213***			
										[0.039]	[0.083]	[0.053]			
Export growth over 5 years (lag)													0.175***	0.503*	0.200**
													[0.055]	[0.258]	[0.079]
Estimator	OLS	2SLS	2SLS	OLS	2SLS	2SLS	OLS	2SLS	2SLS	OLS	2SLS	2SLS	OLS	2SLS	2SLS
Country effects	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Year effects	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Obs.	429	429	429	351	351	351	273	273	273	195	195	195	117	117	117
R2	0.06	-	-	0.12	-	-	0.15	-	-	0.14	-	-	0.11	-	-
Kleibergen-Paap F-Statistic		266.5	298.1		262.1	484.6		133.7	355.3		28.58	210.2		4.887	108.3

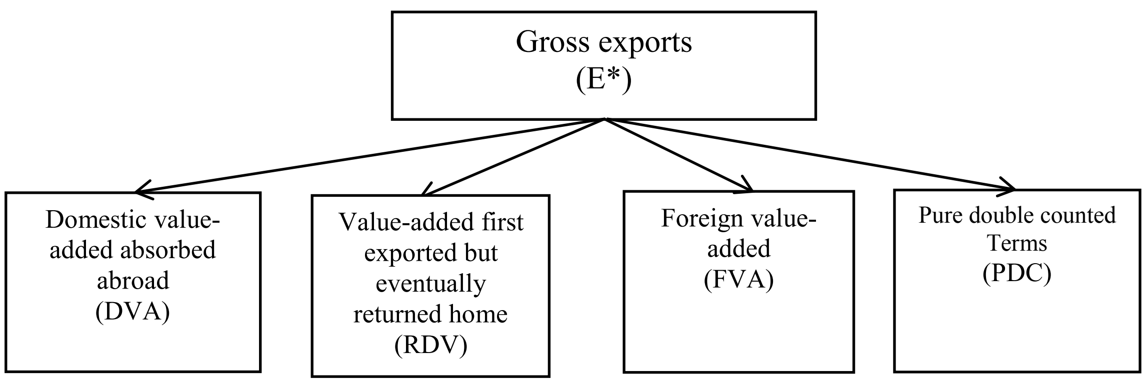
6 The role of global value chains

So far we have investigated the effect of exports on GDP per capita, in line with the received literature on trade and growth. 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 1995-2007, a time period characterized by a rapid expansion of global value chains. In this section, we go deeper by studying more explicitly how global value chains may have an impact the identified link between exports and income.

The expansion of global value chains has implied that production processes have become increasingly sliced across countries. As a result, when goods are produced in any country, they often embody value added that has been generated in other countries as well. From the export statistics point of view, global value chains raise three main issues. 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, for given export figures, countries may be different in the extent to which, and the modalities through which they operate within global value chains; more specifically, they may differ in terms of *participation* and *positioning* within GVCs. In what follows, we shed the first light on the implications of these phenomena for the effect of exports on income.

Our empirical strategy entails augmenting the baseline regression of GDP per capita over export, as outlined in Equation 5, with a set of interactions between the export variable and a number of dummies reflecting changes in countries' GVC-performance over the sample. To construct these dummies, we first need to decompose the gross export flows into their different value added components, which allow to infer information on the role that each country is playing in global value chains over time. To this purpose, we exploit the methodology recently 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 data. This feature derives from a "backward-linkage" modeling approach, which identifies, within a given 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 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.

Figure 3: Main value added components of exports



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, not necessarily in the partner country where the export flow is directed. 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, not necessarily from the partner country where the export flow is directed. It includes the export of intermediates that are processed abroad and return home, 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 domestic country and in foreign countries. To clarify how PDC works, imagine the following situation: country A produces and exports an intermediate input with 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. By the end of the day, 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 9 reports descriptive statistics on the four main components of gross exports, according to the decomposition methodology by Wang et al. (2013) as applied to the WIOD sample. 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 (e.g., Johnson and Noguera, 2017), and motivate further the analysis of this section.

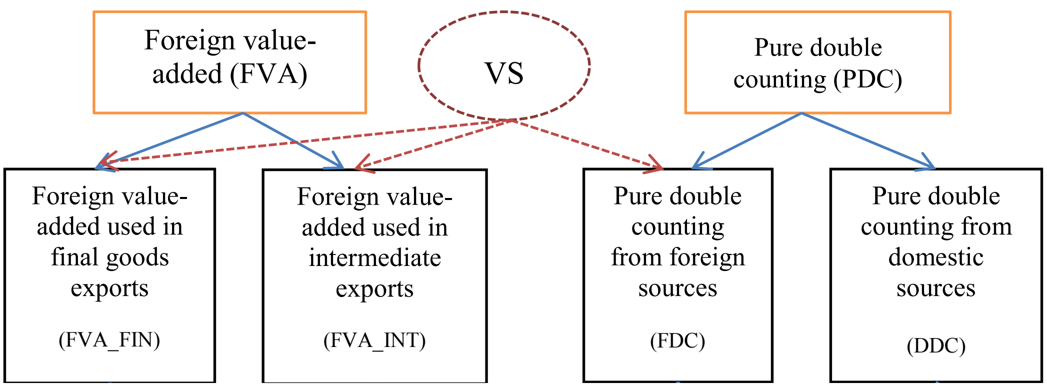
Each of the four main value added components identified by the Wang et al. (2013) methodology can be further decomposed into sub-components. For our purposes, it is important to consider the breakdown of foreign value added and pure double counting, as presented in Figure 4. In particular, FVA can be decomposed in two parts: foreign

Table 9: 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

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, plus PDC from foreign sources, constitutes the so-called "vertical specialization" share initially identified by Hummels et al. (2001). This captures the overall foreign value added embodied in export flows.

Figure 4: FVA, PDC, and VS



Source: Wang et al. (2013)

As anticipated above, to investigate the role of global value chains in moderating the identified link between trade and growth, we augment the income regressions with interactions between the export variable and a set of dummies capturing changes in the GVC-performance of countries over the sample. The first dummy we consider is equal to one for those countries that witness an increase in the vertical specialization share greater than the sample average over 1995-2007. Intuitively, one could in fact expect a lower trade elasticity of income in contexts where foreign value added acquires a more prominent role as a share of total exports. Indeed, this component of exports is not directly related to domestic activities that would contribute to GDP in the exporting country. However, exporting foreign value added might still be complementary to a whole range of domestic activities –from manufacturing to transportation and other services– which may not be reflected in domestic value added exports, but are certainly captured by GDP per capita.

The econometric results on the role of GVCs are presented in Table 10. Specifically, the table has two panels which contain, respectively: (a) IV regressions where the instrument is obtained from gravity estimations without the multilateral resistance terms; and (b) IV regressions using the instrument from the gravity model including MRTs. The interaction variables are instrumented by interacting the instrument for exports with the relevant dummies. For ease of exposition, the first column in each panel reports the baseline estimate of Equation 5, as presented in Table 4.

The second column includes the interaction between manufacturing exports and the dummy introduced above, which is equal to 1 for countries witnessing higher than the average growth in the vertical specialization share over the sample.[15] The estimated coefficient on the interaction term is negative in both cases, but statistically different from zero only in panel a). Overall, we find some evidence in favor of lower trade elasticity in those countries where the foreign contribution to exports grows the most, but this evidence is certainly not conclusive. The reason might lay in the complementarity between foreign value added exports and domestic activities. Moreover, for given vertical specialization share of exports, countries may also differ in their participation and positioning within global value chains. We consider these features in the remaining columns of Table 10.

[15]Notice that the linear term of the dummy is not included, as it is subsumed by the country fixed effects.

In column 3, we include a second interaction between export and a dummy taking value one for countries where participation to global value chains has increased more than the average over the sample. Participation is proxied by 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. For given VS share, an increasing weight of FDC in VS indicates the deepening of cross-country production sharing, with the exporting country getting more embedded in global value chains. The estimated interaction coefficient is positive and statistically significant in both panels. This evidence is suggestive of a trade elasticity premium for countries that increase their participation to GVCs more than others over time. In terms of magnitudes, this elasticity premium is far from negligible: about 0.9-0.10, which is around one third of the average effect of export of income (0.29-0.32).

In columns 4 and 5 we consider the role of positioning within global value chains. In both cases, we include an interaction term between export and a dummy equal to one for countries that have upgraded their positioning within GVCs more than the average over the sample. In column 4, we adopt as a proxy for positioning 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 might capture the fact that a country is upgrading its industries to start producing intermediates that are exported to other countries for final goods production. The estimated coefficient of the interaction term is positive and statistically significant in both estimations, pointing to a trade elasticity premium for countries that upgrade their positioning within GVCs more than others over time. The size of the interaction coefficient is very close to the one obtained when focusing on participation, in column 3.

Finally, in column 5 we employ a second proxy for positioning: the upstreamness measure developed by Antràs and Chor (2013), which captures distance of production from final use. Data on this measure are sourced from Miller and Temurshoev (2015), at the country-industry level. To retrieve a country-level measure, in line with Antràs and Chor (2018) we take a weighted average across industries, where the weights represent the share of each industry out of total manufacturing output. The dummy for increased upstreamness is equal to one for those countries where upstreamness increases more than the average between 1995 and 2007. When using this second measure, the coefficient on the interaction term is still positive and statistically different from zero in both estimations, while the magnitude is somewhat smaller than in column 4: around 0.05.

By and large, our evidence suggests that the effect of trade on income is crucially moderated by changes in countries' participation and positioning within global value chains. In particular, while we find only weak evidence of a smaller export elasticity of income for countries where the foreign value added share of exports increases relatively more over the sample, we do find robust evidence of significant export elasticity premia for countries increasing their participation, or upgrading their positioning within GVCs more than others over time. 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 income.

Table 10: The role of global value chains

Dependent Variable: ln(GDP p.c.)	(1)	(2)	(3)	(4)	(5)
a) IV based on gravity: Without MRTs					
Gross exports	0.347***	0.421***	0.321***	0.518***	0.427***
	[0.061]	[0.087]	[0.094]	[0.115]	[0.086]
Gross exports * Dummy high growth of VS share		-0.068**	-0.068**	-0.096**	-0.078**
		[0.032]	[0.034]	[0.039]	[0.032]
Gross exports * Dummy increased participation (FDC/VS)			0.100***		
			[0.021]		
Gross exports * Dummy upgraded positioning (FVA_INT/VS)				0.140***	
				[0.045]	
Gross exports * Dummy increased upstreamness					0.046**
					[0.022]
Country and Year effects	yes	yes	yes	yes	yes
Obs.	507	507	507	507	507
Kleibergen-Paap F-Statistic	48.34	15.85	9.273	5.218	9.392
b) IV based on gravity: With MRTs					
Gross exports	0.321***	0.343***	0.291***	0.323***	0.333***
	[0.029]	[0.038]	[0.043]	[0.039]	[0.038]
Gross exports * Dummy high growth of VS share		-0.028	-0.043*	-0.021	-0.031
		[0.027]	[0.025]	[0.027]	[0.026]
Gross exports * Dummy increased participation (FDC/VS)			0.090***		
			[0.022]		
Gross exports * Dummy upgraded positioning (FVA_INT/VS)				0.094***	
				[0.028]	
Gross exports * Dummy increased upstreamness					0.051**
					[0.022]
Country and Year effects	yes	yes	yes	yes	yes
Obs.	507	507	507	507	507
Kleibergen-Paap F-Statistic	569.5	241.7	163.1	167.6	137.2

7 Conclusion

This paper aims to contribute to our understanding of 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 trade flows depending on the distribution of deep-water ports across countries. The new instrument has allowed us to investigate the effect of export on income over a recent period, 1995-2007, which was characterized by a rapid expansion of global value chains. Using data from WIOD, we have found that export 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 have shown that the effect of export on income is significantly moderated by changes in the participation and positioning of countries in global value chains. In particular, the elasticity of GDP per capita to export is higher for countries that have increased their participation or upgraded their positioning in GVCs more than others over the sample. There is only weak evidence of a lower trade elasticity for countries where the share of foreign value added in total exports has increased more than the average. This is consistent with the existence of complementarities between foreign value exports and domestic activities. Our results shed the first light on the role of global value chains as moderators of the income effects of trade. We hope that our new data and empirical approach will nurture further research on this issue, whose implications are 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

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		

Table A3: Industry-level gravity estimations

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

***, **, * = indicate significance at the 1, 5 and 10% level, respectively.